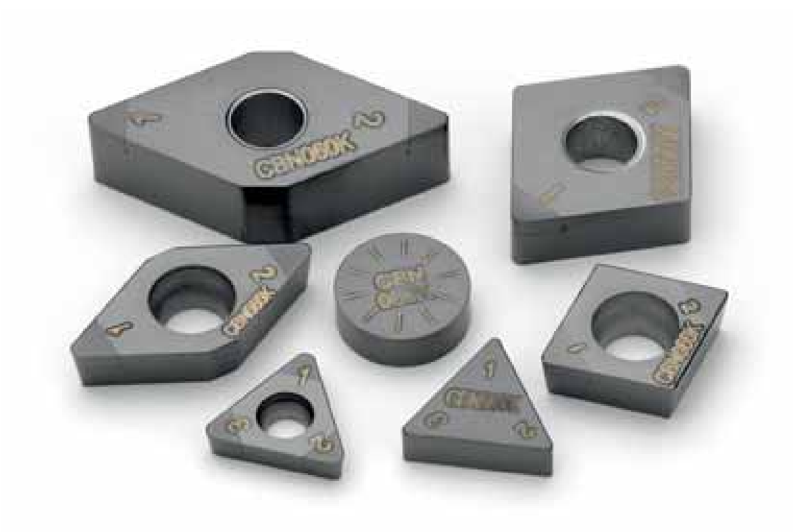
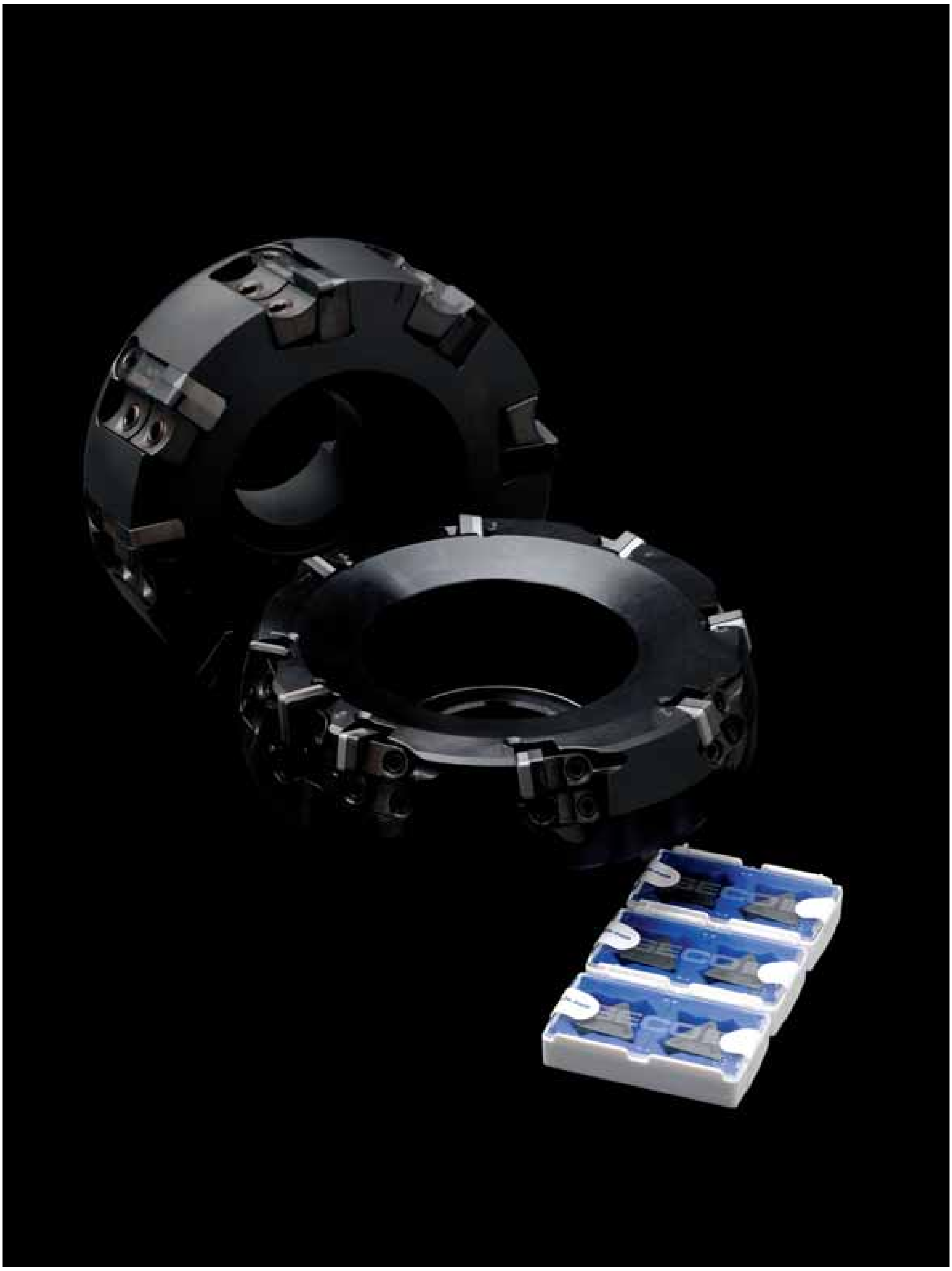


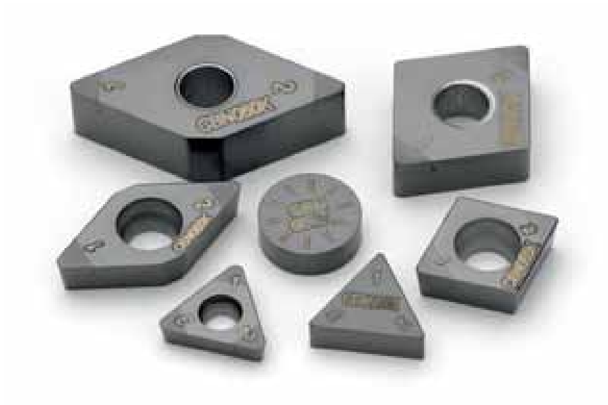
Contents

Contents

SECO



Introduction



Introduction	Page

Introduction

How to use the guide

The guide is divided into two sections 1) General information and 2) Material categories. The guide is intended to provide complete information for understanding and applying PCBN successfully.

General information

This section covers areas such as what is Secomax PCBN, where to use and not to use PCBN, machining technology, performance comparisons, general troubleshooting and other useful information. This leads to a basic understanding of PCBN by addressing the key issues relating to its use.

Material categories

This section approaches machining problems from a user perspective. Firstly by identifying the workpiece material, type of components etc, then providing in depth information on specific machining solutions and detailed operating windows.

What is PCBN?

Polycrystalline Cubic Boron Nitride (PCBN) is a purely man-made product. It is not found in any form in nature and its unique properties of high hardness (second only to diamond), its ability to retain its hardness at elevated temperatures as well as its inertness to iron, makes PCBN an ideal cutting tool material for machining hard and abrasive ferrous workpiece materials.

PCBN consists of selected cBN grains which have been bound together using a ceramic or metallic binder under ultra high pressure and high temperature to form a homogenous material. The binder in PCBN acts as a binder or "glue" to bond the hard cBN grains together.

What is Secomax?

Secomax is a range of high performance grades based on PCBN – Polycrystalline Cubic Boron Nitride. The current range of Secomax grades is CBN050C, CBN060K, CBN10, CBN100, CBN150, CBN160C, CBN200, CBN300, CBN300P, CBN350 and CBN400C. Secomax grades are formulated and specifically developed for machining hardened steel, pearlitic cast iron, hard iron and superalloys.

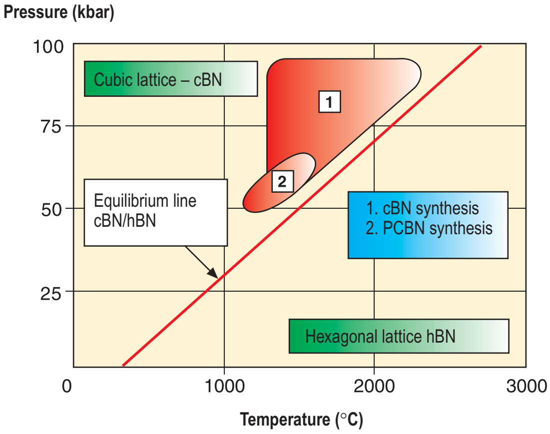
When machining these materials with Secomax, substantial reductions in production costs can be achieved. For example, machining times compared to grinding can be reduced by up to 90%. Secomax inserts can outperform ceramics by more than 30 times when machining pearlitic grey cast iron. Capable of high stock removal rates and environmental benefits, Secomax offers many advantages compared to grinding as well as ceramic and carbide tooling.

How is Secomax PCBN made?

The manufacturing of Secomax PCBN cutting tool materials is done in a 2 stage synthesis process using a hot isostatic press at ultra high pressures and temperatures.

The process begins by taking soft friable hexagonal boron nitride powder (hBN) and subjecting it to pressures in the region of 75 kbar and 1 700°C to produce finely sintered particles of cubic boron nitride (cBN). The cBN powders are then finely graded and mixed with a specific binder or catalyst which is used in preparing the precise formulations required to create the Secomax range of products. The powder mix is encapsulated and subjected to almost the same pressures and temperatures needed to produce the cBN grains. Computer monitoring and control ensures a consistent and repeatable feedstock material for the manufacture of Secomax inserts.

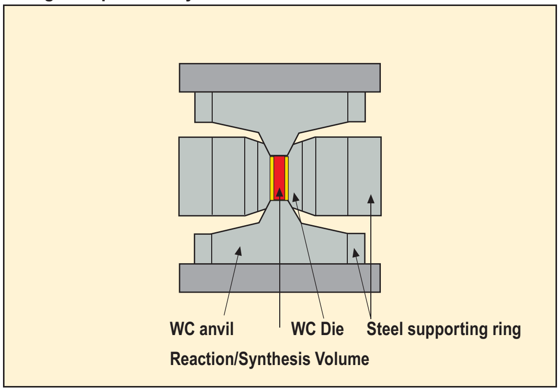
The result is a PCBN disc. The format can be solid PCBN or with a top layer of PCBN sintered onto a tungsten carbide substrate.



Manufacturing of Secomax cutting tool materials

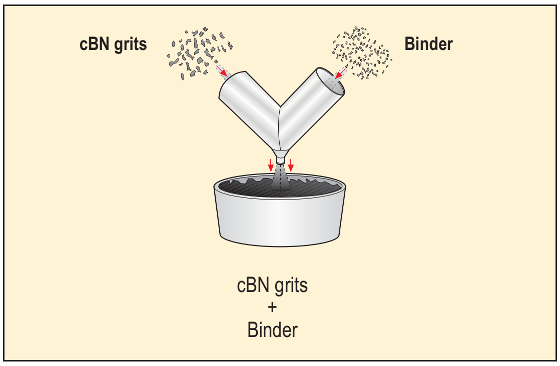
1. Hexagonal Boron Nitride – one of the softest materials known (hBN)

2. High pressure
High temperature synthesis

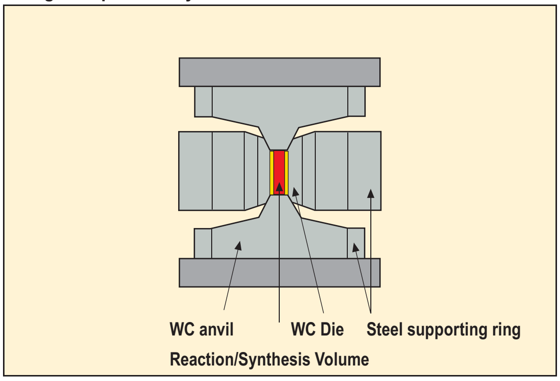


3. Cubic Boron Nitride grits – the second hardest material known (cBN grits)

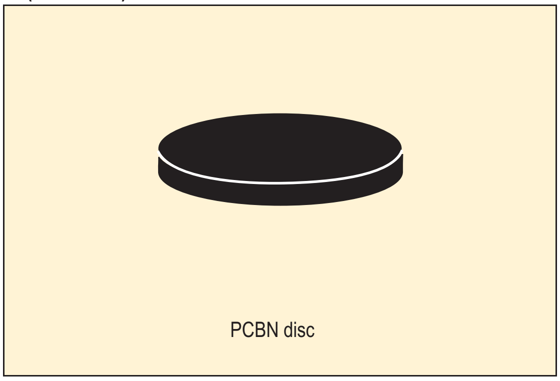
4. Admixing



5. High pressure
High temperature synthesis



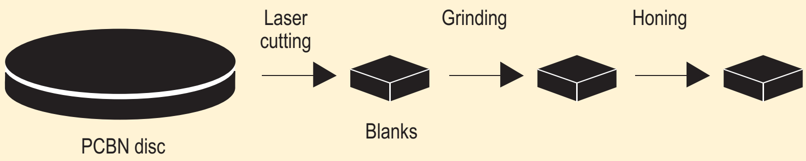
6. Polycrystalline Cubic Boron Nitride disc (PCBN disc)



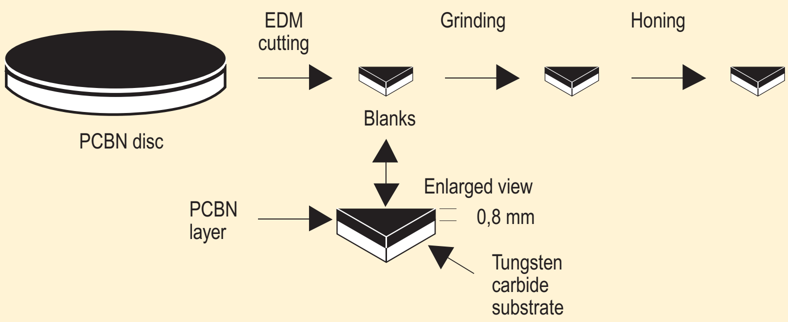
Manufacturing of Secomax cutting tools

Solid PCBN inserts and full-face (sintered layer) inserts are cut out directly from a PCBN disc and then finished by grinding on all faces. Secomax inserts with PCBN tips are made by brazing small PCBN segments into specially prepared pockets of ISO shaped inserts and then finish ground.

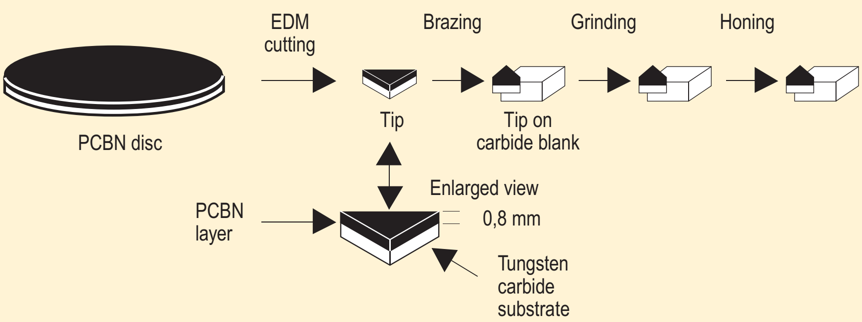
Solid inserts



Full-face (sintered layer) inserts



Brazed inserts



Secomax PCBN grades

Secomax is Seco's range of high performance grades based on PCBN – Polycrystalline Cubic Boron Nitride. The composition and properties are tailored to optimize performance in the targeted areas. The main variables are cBN content, grain size, binder type and format.

Product	cBN content approx. vol. %	Coating	Average grain size (μm)	Matrix – Binder	Format		
					Solid	Full-face (sintered layer)	Brazed
CBN050C	50	(Ti,Si)N	<1	TiCN ceramic	■	■	■
CBN060K	60	(Ti,Si,Al)N	1–2	TiCN + Superalloy	■		■
CBN10	50		2	TiC ceramic		■	■
CBN100	50		2	TiC ceramic	■		
CBN150	45		<1	TiCN ceramic		■	■
CBN160C	65	(Ti,Si)N	<1 (multi-modal)	TiCN ceramic		■	■
CBN200	85		2	Co-W-Al ceramic		■	■
	90		3–6	Al ceramic	■		
CBN300	90		22 (multi-modal)	Al ceramic	■		
CBN300P	90	(Ti,Al)N + TiN	22 (multi-modal)	Al ceramic	■		
CBN350	90		16 (multi-modal)	Al ceramic	■		
CBN400C	90	(Ti,Si)N	3–6	Al ceramic	■		

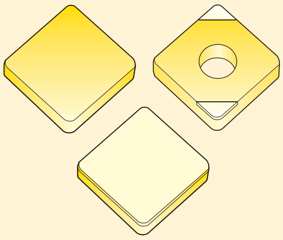
The change in composition also has an effect on the physical and mechanical properties and characteristics of the different PCBN grades.

A comparison of properties between different tool materials is shown below.

Product	Ceramic Si_3N_4	Ceramic Al_2O_3 + TICN (30% by Vol.)	WC K10	Typical PCD	Typical high cBN content PCBN	Typical low cBN content PCBN
Knoops hardness [GPa]	17,4	19,0	17,0	50,0	30,0	25,0
Fracture toughness [MPam 1/2]	6,1	5,6	10,5	8,8	6,0	4,0
Thermal conductivity [$Wm^{-1}K^{-1}$] (20°C)	30,0	32,0	100,0	540,0	160,0	38,0

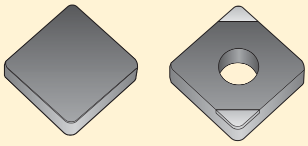
Low cBN content grades

CBN050C



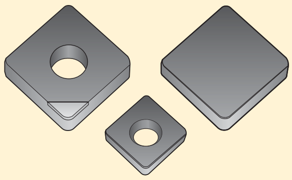
Solid, brazed tip or sintered layer
- For high speed light continuous to moderate interrupted cuts in hardened steel (a_p <0,5 mm).
- (Ti,Si)N PVD coating developed for high speed machining.

CBN060K



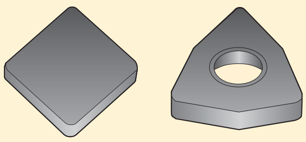
Solid or brazed tip
- For high speed light continuous to moderately interrupted cuts in hardened steel (a_p <0,5 mm).
- (Ti,Al,Si)N PVD coating developed for high speed machining.

CBN10



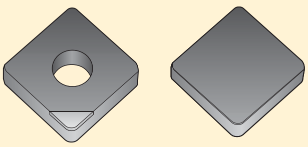
Brazed tip or sintered layer
- For light continuous to moderate interrupted cuts in hardened steel (a_p <0,5 mm).

CBN100



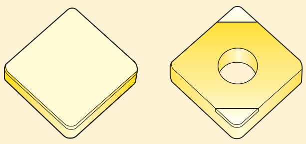
Solid insert
- For light continuous to moderate interrupted cuts in hardened steel (a_p <0,5 mm).

CBN150



Brazed tip or sintered layer
- Ideal for high surface requirements.
- Tough grade for interrupted cuts in hardened steel (a_p <0,5 mm).

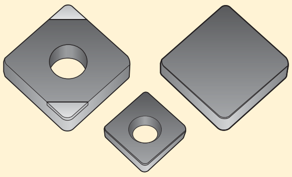
CBN160C



Brazed tip or sintered layer
- Tough grade for aggressive interrupted cuts in hardened steel (a_p<0,5 mm).
- (Ti,Si)N PVD coating developed for high speed machining.

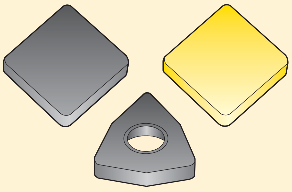
High cBN content grades

CBN200



Solid, brazed tip or sintered layer
- For medium rough machining of hardened steel (a_p = 0,5–1,0 mm).
- For finishing and roughing of pearlitic and white/chilled cast iron.
- For finishing of sintered iron.
- For roughing and finishing of powder metal (iron).

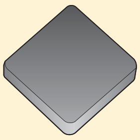
CBN300 CBN300P



Solid insert
- For roughing of hardened steel.
- For finishing and roughing of manganese steel.
- For finishing and roughing of pearlitic, chilled and white cast iron.

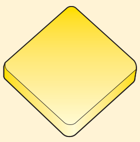
Coated (PVD)
(Ti,Al)N + TiN
- Equal or improved tool life.
- Easy to identify edge wear.
- Use same cutting data as for uncoated.

CBN350



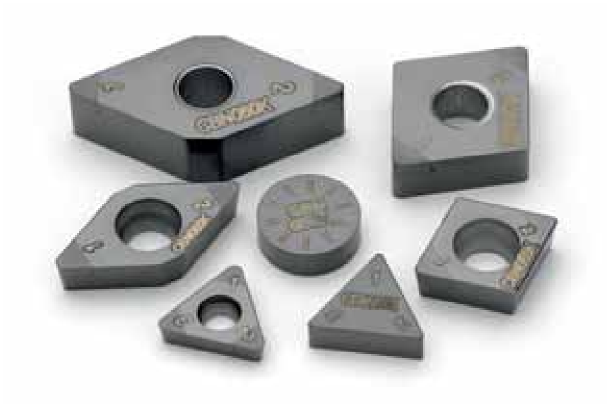
Solid insert
- Tougher than CBN300 resulting in reduced chipping and edge flaking in aggressive workpiece material.
- For roughing of hardened steel.
- For finishing and roughing of manganese steel.
- For finishing and roughing of chilled and white cast iron.

CBN400C



Solid insert
- Fine grain high cBN content grade, for machining of pearlitic grey cast iron.
- (Ti,Si)N PVD coating.

Workpiece materials



Workpiece materials	Page

Workpiece materials

Where to use PCBN

The range of materials where Secomax can be applied continues to expand, but the main material groups today are listed below. Some of these materials can not be interrupted cut with PCBN, only continuous cut, as shown in the list.

Hard materials

This group includes all low to medium carbon steels hardened to between 45 and 62 HRC. It also includes manganese steel, although it is a softer material.

Hard steels	Continuous machining	Interrupted machining
Case hardened steels	■	■
Bearing steels	■	■
Cold work tool steels	■	■
Hot work tool steels	■	■
Manganese steels	■	■
High tensile steels	■	■
High speed steels	■	
Martensitic stainless steels	■	■
Powder tool steels	■	

Hard irons	Continuous machining	Interrupted machining
Chilled irons	■	■
White irons	■	■
High chrome irons	■	■

Soft and abrasive materials

This group includes soft but very abrasive materials. Hardness levels are usually around 200 HB.

Soft irons	Continuous machining	Interrupted machining
Grey cast irons	■	■
Ductile irons	■	■
Compacted graphite irons	■	■

Ferrous powder materials

This group includes sintered powder metals. Hardness levels range from 20 to 60 HRC, but they are all very abrasive.

Sintered powder metals	Continuous machining	Interrupted machining
Powder Metallurgy (PM) alloys	■	■
Valve seat materials	■	■

Difficult to machine materials

This group includes other materials that can be successfully machined with PCBN inserts.

Others	Continuous machining	Interrupted machining
Hard facing alloys	■	■ (Not Cr-based)
Nickel based superalloys	■	
Tungsten carbides	■	

Workpiece materials

Where PCBN is difficult to apply

There are also a number of workpiece materials that, while not impossible to machine effectively with PCBN, can create their own set of problems. These are classified as difficult to machine and should be approached with caution.

Nitrided steel

Nitriding is a surface treatment applied to increase surface hardness and wear resistance. While turning with PCBN is an accepted process, milling the surface of nitrided steels is difficult due to the high incidence of edge chipping. It is recommended to use the toughest PCBN grade available at increased cutting speeds when machining.

Some D2 tool steels

While some D2 materials are very successfully machined with PCBN, other result in poor tool life due to subtle changes in the microstructure which occurs during heat treatment. If a difficult to machine D2 is encountered, double tempering after quenching during heat treatment will improve PCBN tool life.

Compacted graphite iron

Microstructure and material properties of compacted graphite iron fit between those of grey and nodular cast iron. The free ferrite will react with the PCBN chemically, and usually result in short tool life.

Austempered ductile iron

Austempered ductile iron is an alloyed heat treated nodular cast iron. Machining experiences are limited, and machining conditions continues to be evaluated.

Where not to use PCBN

Although the range of materials being economically machined using PCBN continues to expand, there are still a number of workpiece materials that are recognised as being uneconomical to machine. Amongst these are:

Soft steel

Tool life is short and WC tooling is a more cost effective solution.

Austenitic stainless steel

This is a soft stainless steel which sticks to the cutting edge causing catastrophic failure. Hard martensitic stainless steels are very effectively machined with PCBN.

Ferritic stainless steel

This is a soft stainless steel with a high ferrite content which causes chemical attack of the cutting edge resulting in short tool life.

Unhardened ferritic grey cast iron

The free ferrite in the workpiece material chemically attacks the PCBN resulting in short and uneconomic tool life.

Ferritic ductile (S.G.) iron

The free ferrite in the workpiece material chemically attacks the PCBN resulting in short and uneconomic tool life.

Chrome plate

The chrome plate is too hard to machine and results in cutting edge chipping. However, machining under the chrome plate to remove it is a successful PCBN application.

High speed steel HSS

The hard carbides in HSS make it impossible to interrupted cut, continuous cut (turning) is a successful PCBN application.

Cemented carbide

Although a successful turning application, cemented carbide is impossible to mill (interrupted cut) due to the inherent hardness of the material.

Workpiece materials

SECO

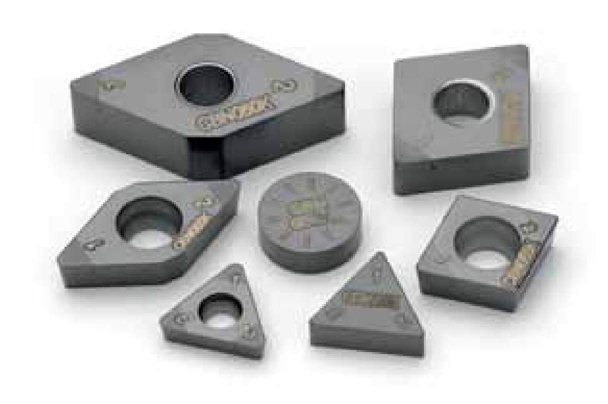
Grade selection overview

The following table shows a short summary of target areas for each of the Secomax PCBN grades:

Material group	Material	Operation	Grade(s)
Hard materials	Hard steels	Roughing	CBN200 / CBN300 / CBN350
		Finishing	CBN050C / CBN060K / CBN10/CBN100 / CBN150 / CBN160C
	Hard irons	Roughing	CBN300 / CBN350
		Finishing	CBN200 / CBN300 / CBN350
Soft and abrasive materials	Grey cast irons	Roughing	CBN200 / CBN300
		Finishing	CBN200 / CBN300 / CBN400C
Ferrous powder materials	PM alloys	Roughing	CBN200 / CBN300
		Finishing	CBN050C / CBN10/CBN100 / CBN160C / CBN200
	Valve seats	Roughing	
		Finishing	CBN200
Difficult to machine materials	Tungsten carbides	Roughing	CBN300
		Finishing	CBN300
	Superalloys	Roughing	
		Finishing	CBN10/CBN100
	Hard facing alloys	Roughing	CBN200 / CBN300 / CBN350
		Finishing	CBN050C / CBN060K / CBN10/CBN100 / CBN150 / CBN160C

For more information about machining recommendations for a specific workpiece material, see the material categories section.

Machinability and Process factors

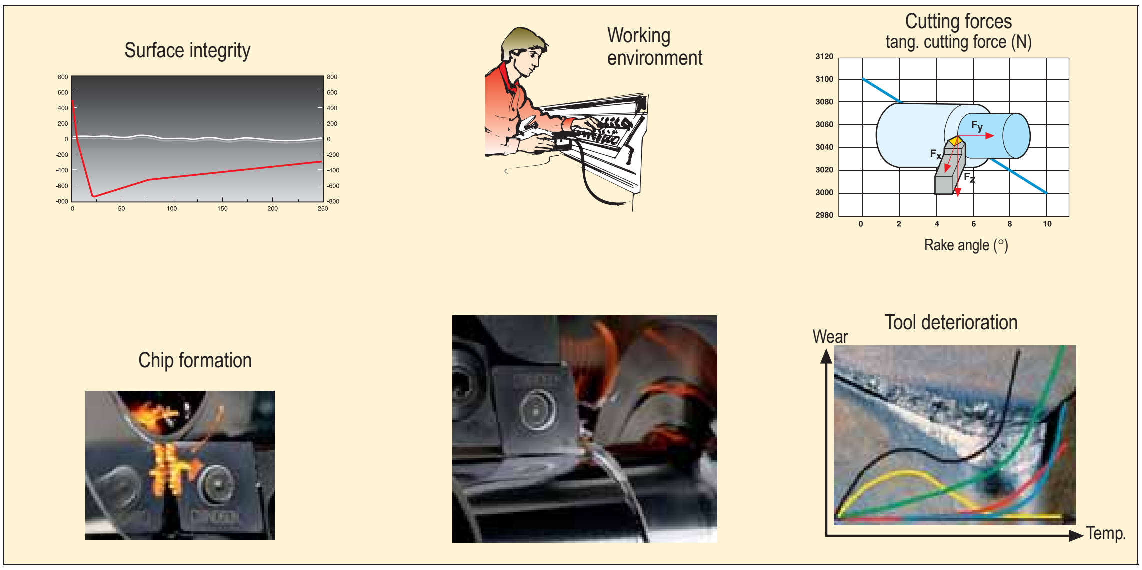


Machinability and Process factors	Page

Machinability and Process factors

Machinability

Machinability is the generic term describing the results or the output from a machining operation, and consists of chip formation, cutting forces and temperatures, surface integrity, tool deterioration and working environment.



Surface integrity

Surface integrity has become the generic term used to describe the properties and the condition of a machined workpiece regarding its surface and subsurface properties and includes:

- Surface topography (surface finish)
- Surface and subsurface material structure
- Surface and subsurface residual stresses

All of which will influence the surface function of the final product.

Topography

Included in the term topography are many parameters, the most commonly used are:

R_t = Maximum profile height
This is the distance from the highest peak to the lowest valley over a specified measuring distance

R_z = Average maximum profile height
This is the average distance from the 5 highest peaks to the five lowest valleys over a specified measuring distance

R_a = Average profile deviation from a mean value
This is an arithmetic mean value of the surface roughness over a specified measuring distance

R_p = Maximum peak height
This is the distance from the mean value to the highest peak over the specified measuring distance

R_v = Maximum valley depth
This is the distance from the mean value to the deepest valley over the specified measuring distance

For analysing the function of a surface, some additional parameters are used, for example:

R_{mr} = Material ratio (load bearing ratio)
This is a value of the load bearing capacity of a surface

R_{sk} = Skewness
This is a value of the symmetry of the profile about the mean line

R_{dq} = Average slope
This is a value of the average slope of the profile over a specified measuring distance

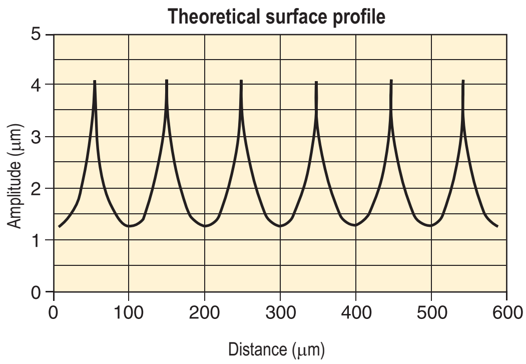
An ideal surface profile after machining is wave-formed, with the spacing depending on feed rate and the maximum profile height (wave height) depending on feed rate and insert nose radius according to the equation:

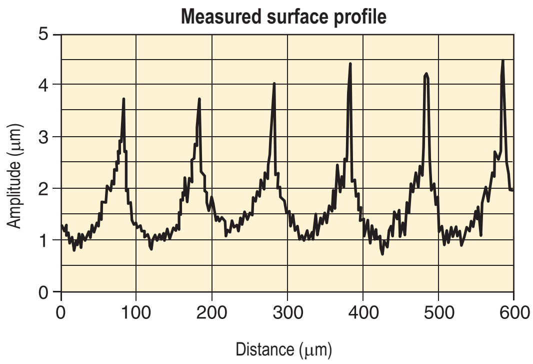
$$R_t = 125 \frac{f^2}{r_\varepsilon}$$

The Ra-value can be approximated as:

$$\frac{1}{6} R_z \leq R_a \leq \frac{1}{3} R_z$$

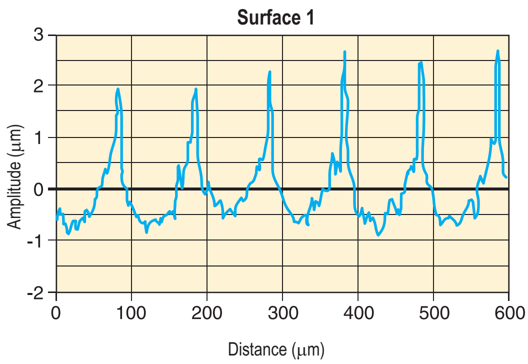
In practice, there will always be differences from the ideal surface depending on factors like tool wear, stiffness of workpiece, machine characteristics, vibrations etc. Also, at lower feed rates the R_a-equation trends to underestimate the R_a-value compared to measured values, while it overestimates the R_a-value at higher feed rates.

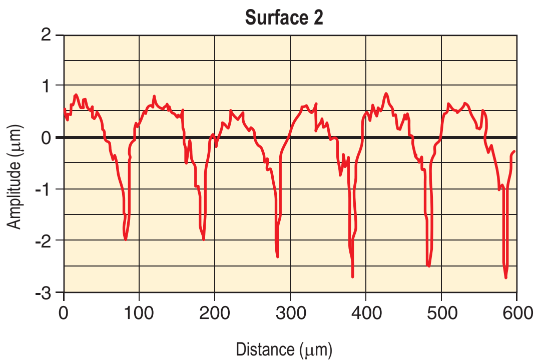




The average profile depth, R_a, is the most commonly used value, it is often specified on drawings and it is easily measured with surface roughness gauges after machining. The drawback is that it does not describe the surface very well.

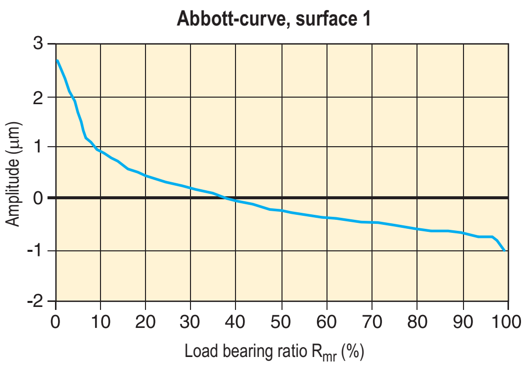
The blue curve (left) shows a profile with high peaks, and the red curve (right) shows a profile with deep valleys. The profiles are completely different, but when measured they have the same average profile height R_a.

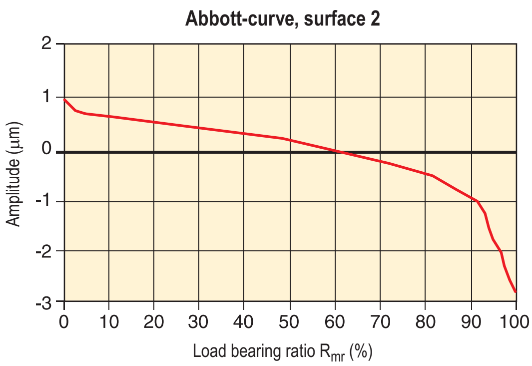




The load bearing ratio, R_{mr} , is a parameter that is becoming more and more used to describe the surface of a component. The load bearing ratio describes how much of a surface that is "bearing the load", and is measured at specific depths from a reference level, usually set at a 5% material ratio. As an example R_{mr} (-0,6) = 27% means that the material ratio at -0,6 µm below the reference level is 27%.

A measurement of the load bearing ratio would easily separate the profile with the high peaks from the profile with the deep valleys.





Material structure

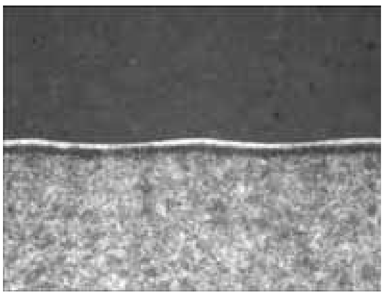
Changes to the surface and subsurface structure are known by various names, "white layer" regions, "grinding burn" and "heat affected zones" (HAZ) are just a few examples. Surface structural changes in workpieces generated by a material removal process is a highly important issue particularly in finishing processes of hardened steels and high performance materials that are generally dynamically loaded in an application, e.g. bearings, bearing surfaces, hydraulic components and gears.

In the heat affected zone, the generated heat has structurally changed the surface and sub-surface. The material undergoes a phase transformation when heated, and during subsequent cooling, a surface layer of rehardened material, consisting of untempered martensite is generated. This layer is called white layer, the name comes from the white appearance when studied under a microscope. The depth of the layer depends on the amount of heat generated.

If enough heat is generated, also the sub-surface will be affected. Beneath the layer of untempered martensite, a layer of over-tempered martensite will be found. This layer is called dark layer, since it is darker than the bulk material. In this layer, the temperature has not been high enough for a phase transformation, but high enough to soften the martensitic structure. Here, the hardness is lower than in the bulk material.

These changes to the workpiece surface and subsurface will occur in any mechanical or thermal machining process, such as grinding, EDM, turning or milling, when the generated temperature is too high.

The micrograph below shows the formation of a heat affected zone consisting of a white layer and a dark layer. These layers are only a few µm thick.



When machining with a new insert, no heat affected zone is formed; all the generated heat is removed with the chip and through the insert. With the development of flank wear, the contact area between the insert and workpiece is increased, and this leads to an increase in friction force and temperature. When the temperature is high enough, a heat affected zone is formed. With the development of flank wear, more heat is generated, and the thickness of the heat affected zone is increased.

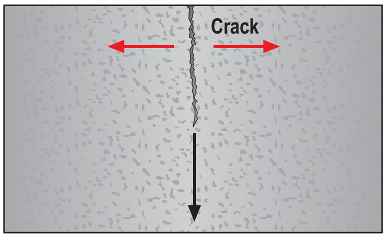
As in hard turning, the heat generated in grinding will cause a heat affected zone. Multiple grains are used in grinding to cut the material. When these grains wear, the heat generated will cause a heat affected zone, usually called grinding burn, and dressing of the grinding wheel has to be done regularly to avoid this. Flooding coolant is applied to reduce the effect of the temperature increase.

Machinability and Process factors

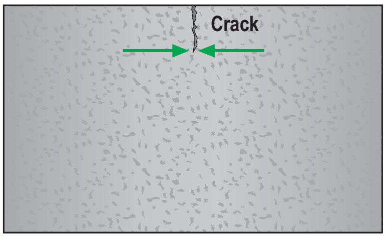
Residual stresses

One of the key aspects in machining hardened components is to maximise the service life of a specific component, hence the reason for hardening the component in the first place. Numerous independent investigations have shown that the component's fatigue properties can be positively affected by the surface changes generated by turning and milling with PCBN tooling. Under suitable conditions it is possible to induce compressive stresses into the workpiece subsurface using PCBN tooling. The increased level of compressive stresses below the surface, where normally the maximum load occurs, from hard turning or milling with PCBN is probably the main reason for the improved fatigue properties.

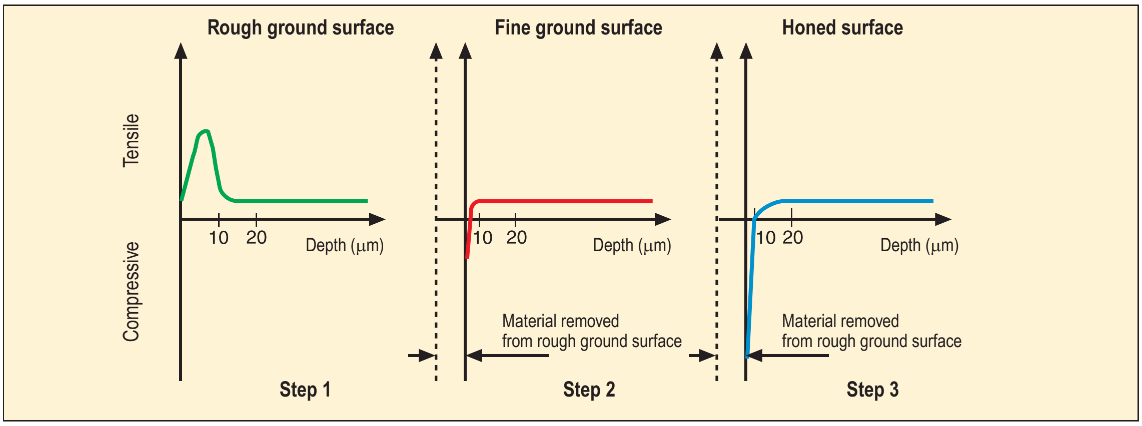
Tensile stresses



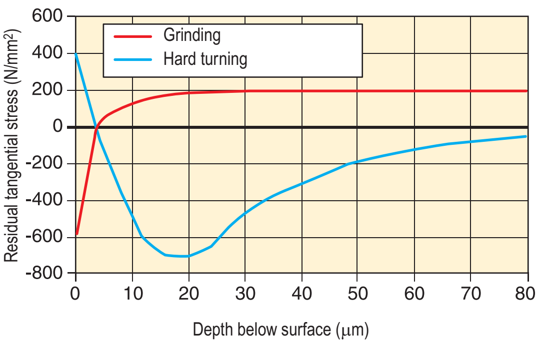
Compressive stresses

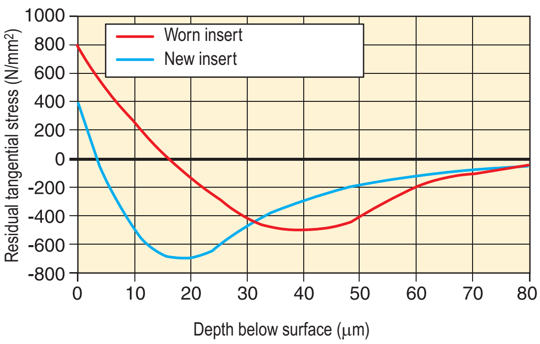


A stress profile of a rough ground surface shows a material completely in tension. Adding a fine grinding operation generates compression at the surface, but below the surface the material is still in tension. An additional honing operation only increases the compressive stresses at the surface.



A typical graph showing the residual stress versus depth below the surface for a hard turned workpiece clearly demonstrates the advantage hard turning offers as a manufacturing process. The initial layer is in tension, but the underlying material structure is in compression, this aids fatigue properties of the component by assisting in closing any surface defects that are present. As the insert wears, the tensile stresses at the surface as well as the depth of the tensile stresses increases.



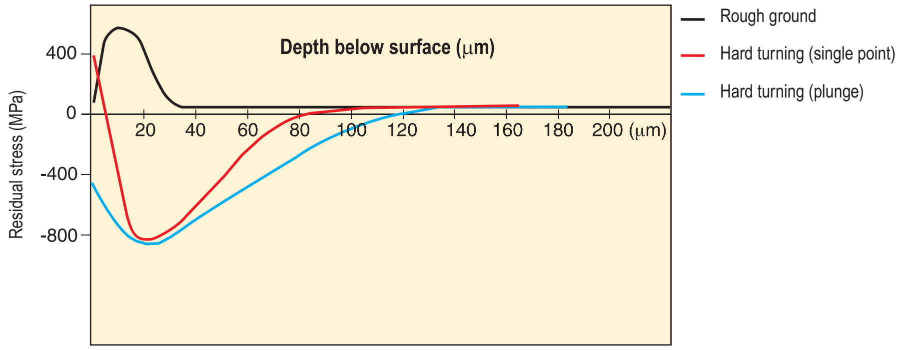


Machinability and Process factors

In an extremely complex subject this of course does not tell the complete story. A series of hard turning machining investigations have demonstrated that it is possible to affect the surface and subsurface residual stresses in hardened workpieces. Stresses can be affected by a number of individual parameter changes. For example, tool wear has a significant influence on the surface properties. Although there is no definitive cut off for flank wear, cutting edges used on highly critical surfaces should be changed when the flank wear exceeds 0,1 mm.

Equally it has been shown that by using the developed plunging process, it is possible to produce the complete surface in compression.

This improved understanding of the machining process will no doubt lead to future opportunities to tailor a component's surface structural characteristics to suit its application.



The table shows the effect from different machining parameters on surface and subsurface stresses.

Increased		Impact
Cutting speed	→	Increased compressive stresses (there is an upper limit).
Feed rate	→	Increased compressive stresses.
Corner radius	→	Decreased compressive stresses.
Edge rounding	→	Increased compressive stresses.
Edge chamfer angle	→	Increased compressive stresses.
Depth of cut	→	No effect.
Tool flank wear	→	Increased formation of white layer/HAZ and thereby increased tensile stresses at the surface. Increased compressive stresses in the subsurface.

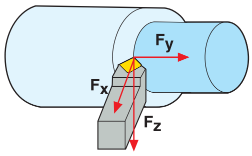
Working environment

The physical aspects include fumes, particles, coolant and noise which after long time exposure can create health problems as well as more direct physical damages like cuts, bruises and crushing injuries. Cutting media is often regarded as one of the more serious health hazards in the metal cutting industry, and it is common for operators today to use gloves to reduce the risk for allergies. PCBN's ability to run dry without any loss of performance is a large improvement to the working environment.

Cutting forces and temperatures

The total cutting force, F, acting on the insert can be devided into three ortogonal components:

- Tangential (vertical or z-direction)
- Axial (feed or y-direction)
- Radial (passive or x-direction)

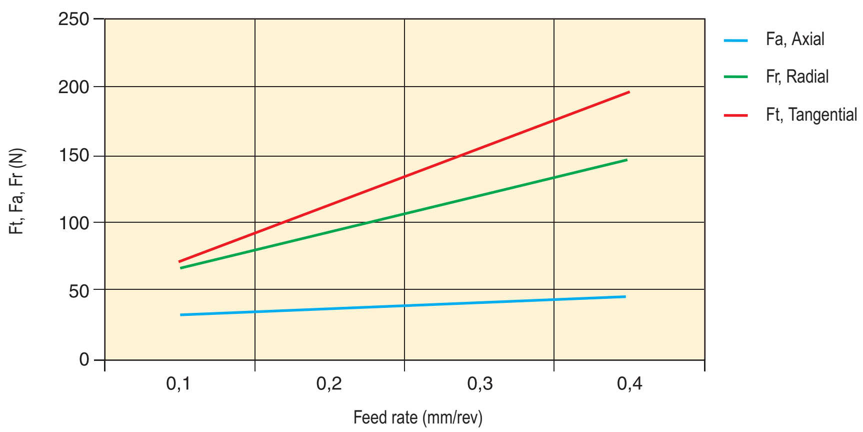


Compared to soft machining of a steel component, the cutting forces in hard turning are about doubled at the same cutting data. In grey cast iron, the cutting forces are about 70% compared to soft machining of a steel component.

High cutting forces also means higher specific cutting force, but since the depth of cut in a finish hard turning operation is only 0,1–0,2 mm, the cutting forces are rather low, typically in the range of 50–200 N. In roughing of hardened steel the forces are considerably higher, and can reach several thousand Newtons.

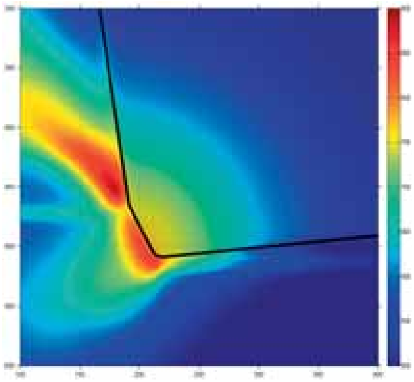
There is a linear relationship between cutting forces and both feed rate and depth of cut. The intersection of the force lines and the y-axis is the cutting force component on the flank face of the insert, and the slope depends on the cutting force components on the rake face. The figure shows the cutting forces as a function of feed rate when finish hard turning a case hardened material.

Cutting forces versus feed rate in finishing of hardened steel

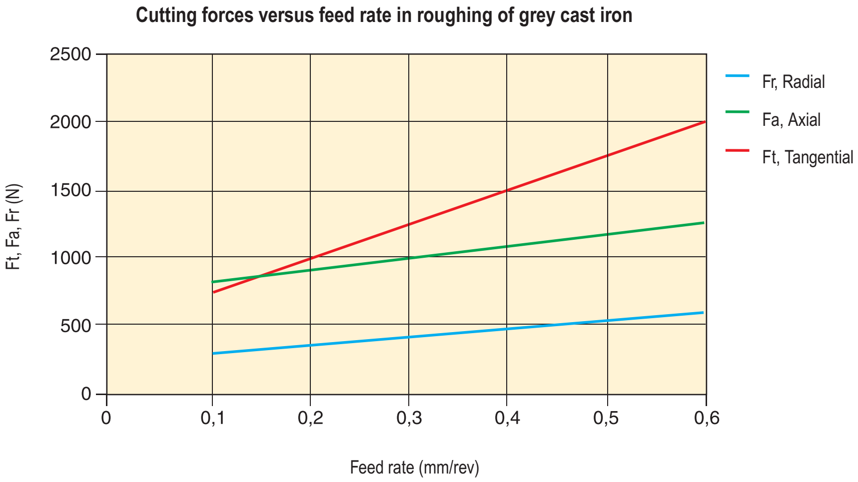


The effectiveness of PCBN in machining hardened steel and iron components in the hardness range of 45-65 HRC is due to the exploitation of PCBN's high hot hardness and chemical stability at elevated temperatures through the deliberate generation of heat in the cutting zone, which in turn softens the workpiece material. The self induced heat generated at the cutting zone is in the region of 700-800°C and is enough to reduce the hardness of the material in contact with the cutting tool. This heat induced soft cutting means that the PCBN is not in direct contact with the work-piece in its hardened state, thus giving PCBN with its high hardness and wear resistance greater tool life compared with other cutting tool materials.

Maximum temperature can often be found in the chamfer area, which is where the crater wear develops. The figure shows a simulation of temperatures in a typical hard turning operation. The chamfer can clearly be seen, and maximum temperature develops some way back from the edge line. The actual position will depend on, among others things, the feed rate.



In grey cast iron, both the cutting forces and the cutting temperatures are lower than in hard steel due to the lower specific cutting force. The figure below shows typical cutting forces when rough machining in grey cast iron.



Chip formation

Chip formation is usually not a problem when machining with PCBN. In grey cast iron, the chips are quite fine and there is no need for chip breaking. In finish turning of hardened steel, the chips come off the machine red hot, and as soon as they cool down, they break and are easily removed from the machining area. It should be possible to easily crumble chips from a hard turning operation in your hand. If they are not brittle, it is usually a sign of incorrect cutting data, with not enough heat generated in the cutting zone.

Tool deterioration

The same tool deterioration scenarios as on a carbide insert in soft machining can be seen on a PCBN insert. Tool deterioration can generally be divided in four groups:

Wear – A change in tool geometry through continuous loss of tool material

- Flank wear
- Crater wear
- Notch wear

Deformation – A change in tool geometry without loss of tool material

- Plastic deformation

Breakage – A sudden change in tool geometry with loss of tool material

- Breakage
- Flaking
- Chipping

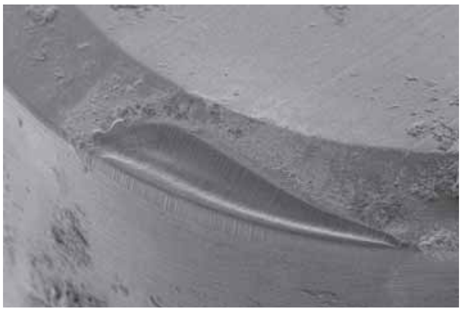
Chemical – Changes of the tool material

- Diffusion

When machining with PCBN, there are many interactions between the cutting edge and workpiece material, which affect the ultimate performance of the cutting edge. In the majority of PCBN machining processes, where tool life is stable, the cutting edge will wear by a combination of flank wear and crater wear. To optimise tool life, it is important to select machining parameters which will allow both these wear modes to progress evenly. The correct choice of machining parameters will vary according to the workpiece material being machined, the operation to be conducted and the grade of PCBN selected. Although feed rate and depth of cut play their part, the largest influence on the rate of development of both flank wear and crater wear when machining with PCBN is cutting speed. Increasing the cutting speed will increase crater wear, but reduce flank wear.

Reducing the cutting speed will result in the opposite (ie reduced crater wear and increased flank wear). Even when optimised machining parameters are selected, eventually either the flank wear or the crater wear will become too great and the cutting edge will break down by chipping or flaking. The choice of when the cutting edge has reached its ultimate tool life is the choice of the customer and is usually dictated by difficulties in keeping part dimensions or tolerances, exceeding surface roughness criteria or when the cutting edge will no longer cut efficiently.

Premature failure of the cutting edge is where the cutting edge has not been able to achieve its designed performance and can be the result of process instability, wrong grade or parameter selection or where something in the machining system is wrong. Sometimes premature failure is obvious, for example early chipping or flaking. Sometimes it can be more difficult to determine. An edge chip can be the result of excessive crater wear that has lead to a weakening of the cutting edge. In either of these situations, corrective action should be done by someone experienced in applying PCBN cutting tools.

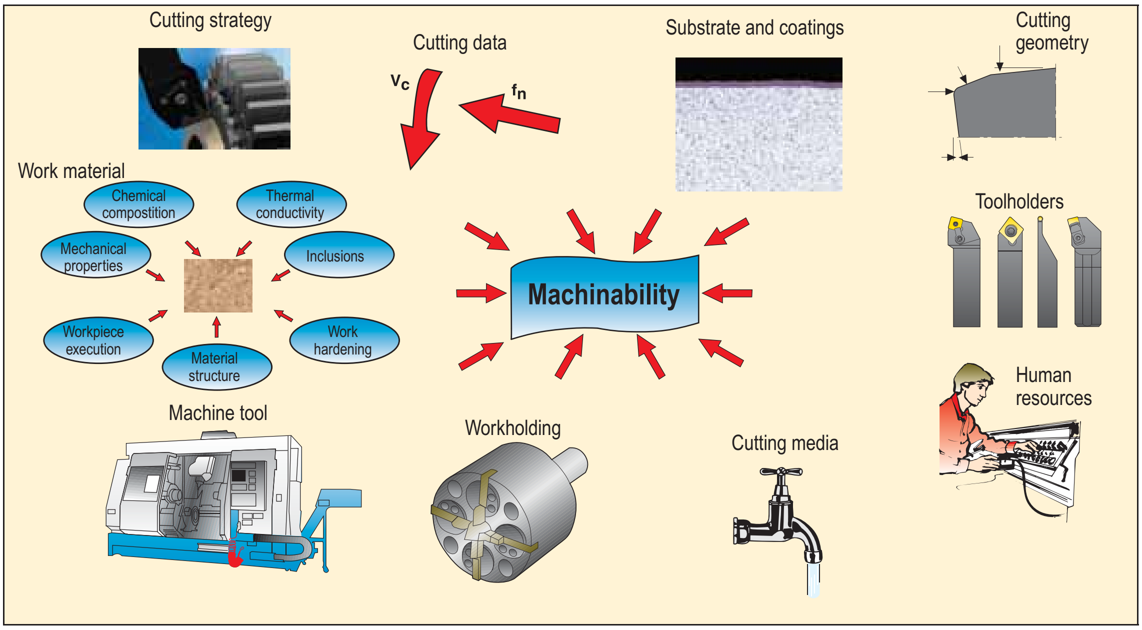


For more information on tool wear and remedies, see chapter Troubleshooting.

Machinability and Process factors

Process factors

The main factors that affect the machinability are; cutting data, cutting geometry, work material, machine tool, workholding, cutting media, substrate and coating, toolholders and milling cutters, human resources and cutting strategy. Sometimes a single factor, but more often a combination of many factors has a major influence on the machining result. Some of them, like cutting data, are easy to change and some of them, like the machine tool is more difficult to change.



Cutting strategy

Cutting strategy describes the metal removal method. It can be turning, milling, drilling etc, or a combination of two or more methods. In some cases the method can be changed, for example from conventional machining to plunging. See chapter machining methods.

Cutting data

The cutting data determines the metal removal rate:

- Cutting speed
- Feed rate
- Depth of cut

These parameters are the easiest to change in any PCBN machining optimisation, and they have a direct influence on the machining result.

Substrate and coating

A PCBN insert consists of a substrate and sometimes one or more layered coatings. The substrate in a PCBN insert is a mix of cBN grains and a ceramic or metallic binder. The volume of cBN present, cBN grain size and binder will determine the properties and performance of a PCBN insert. For more information about Seco's PCBN grades, see chapter Introduction.

For a long time PCBN inserts were uncoated, but coated inserts are now more and more common. PCBN has a high hot hardness and high abrasion resistance, but the coating works by sealing the surface and reducing friction in the interface between the insert, chip and workpiece. This will reduce the temperature, and consequently reduce tool wear.

A coating also helps in identifying tool wear. As PCBN insert is dark brown or black, and tool wear is often difficult to see. It is easier to see the wear if the insert is coated. The more visible tool wear will also reduce the risk of throwing away multi-tipped or solid inserts with one or more corners still unused. For more information about Seco's PCBN coatings, see chapter Insert Technologies.

Machinability and Process factors

Tool geometry

The term tool geometry includes macro and micro geometry of an insert in the toolholder.

Macro geometry

- Size and shape of the insert, nose radius, thickness, wiper geometry
- Point angle, relief angle
- Toolholder angles

Micro geometry

- Edge geometry
- Chip breaker geometry

The wide range of application areas where PCBN can be applied place quite different demands on the cutting insert. Consequently the need to optimise tool geometry to maximise tool performance is an important consideration. Because the workpiece materials machined with PCBN are generally difficult to machine, abrasive and/or hard, the operating window can be relatively small, hence the choice of tool geometry can be critical in the success or failure of an application.

Whilst PCBN is the second hardest material known to man it is relatively brittle compared to tungsten carbide. In many ways PCBN materials behave in a similar way to ceramics and likewise tool geometry and edge protection are fundamental to success.

For more information about selecting tool geometries and edge preparations, see chapter Insert Technology.

Toolholders and milling cutters

The toolholder is an important part of the machining setup. The anvil and pocket are often neglected, which can be problematic using a high precision, high performance cutting tool material such as PCBN. Make sure that there is no wear on the anvil and pocket, and that the pocket is clean when indexing the insert. Deformed pocket seats and worn out anvils will increase the risk for insert breakage, especially when using solid inserts.

Generally the same recommendations as when machining with carbide are applied in PCBN machining. Use as short overhangs and as large section toolholders as possible. Toolholders made of high density material have been very successful in PCBN machining, see chapter Tooling Technologies.

Human resources

All people involved in the machining operation, from programmer to operator and quality control, are important. Communication between departments regarding everything from tool paths to cutting data is vital for successful usage of PCBN.

Workpiece material

The main factors related to workpiece material that will affect the machining operation are:

- Composition
- Inclusions (from macro – larger than 0,50 mm to micro – smaller than 0,05 mm)
- Structure

For successful machining, it is important to know the specifics of the material, and select insert grades and cutting data accordingly. For more information about workpiece materials, see chapter Material Categories.

Cutting media

Cutting media, or more commonly coolant, is the general term for the liquid or gas used to assist in the machining operation, the most common being:

- Oils
- Emulsions
- Gases
- Air

Both oils and emulsions can be applied in different ways:

- High pressure
- Normal flooding
- MQL (Minimal Quantity Lubrication)

Emulsions applied through normal flooding are the most common in PCBN machining. High pressure is an interesting and closely studied area with a large potential, but still not very widely spread.

When using oil as a cutting media there is a risk for igniting the oil due to the high temperatures involved.

There are three main reasons for using cutting media:

- Cooling
- Lubrication
- Chip transportation

All three used to be vital for success in any metal cutting operation, and is still necessary in many operations, like grinding, drilling and tapping, but the development of new and more heat resistant grades has changed that. Today many turning and milling operations can be done dry. Cutting media is a good way of removing chips from the cutting zone, but designing the machine tool for PCBN machining, like vertical machine tools where chips is removed from the cutting zone by gravity, reduces the need for cutting media for chip removal. Lubrication in PCBN machining is most likely of minor importance.

Due to the physical properties of PCBN, it is well adapted to be an excellent player in the dry machining area. Besides the economical aspects that normally push for dry machining, this machining method can also be used to extend the tool life and create the right circumstances for a more predictable tool life. Investigations made have shown that in some applications it can be advantageous to remove the coolant from the application. In interrupted machining and when machining small parts where the time in cut per sequence is short, thermal shocks from high frequent heating up and cooling down, will contribute to a more frequent appearance of micro cracks at the cutting edge. These micro cracks will in time develop to cause frettering and chipping of the edge, and thereby reducing tool life and produce a less predictable process.

For recommendations on use of cutting media when machining with PCBN, see chapter Tooling Technologies.

Workholding

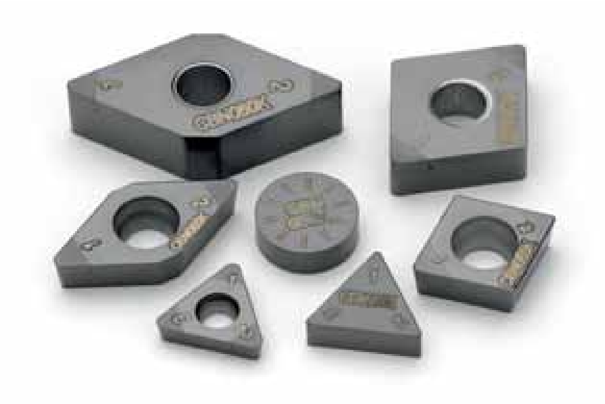
Workholding is an area where the tooling industry usually is not involved. However, rigid clamping of a part is important for avoiding part vibrations and reaching the required surface finishes. In milling, it is even more important to clamp the part correctly to minimise part vibrations that can destroy the surface finish, reduce the tool life and/or generate an unhealthy working environment with high noise levels.

Machine tool

The machine tool is normally something that is difficult to change. When PCBN hard turning started to grow, it was said that designated machine tools had to be used. This is not true today; a good standard machine tool has enough stability and accuracy for any normal PCBN machining operation. For applications where high accuracies are required, there are high precision machine tools.

In grey cast iron machining the tolerances are usually more open, the main issue is speed capabilities. Successful usage of PCBN requires high rpm spindles, since the cutting speed recommendations are from 1 000 m/min and up in turning, and even higher in milling.

Trends



Trends	Page

Trends

SECO

Machining trends

Machining trends have varied over time, and different industries have had different trends, depending on factors like factory size, type of machining, customer base, customer demands, business cycle etc. Though, there are a few main drivers for the manufacturing industry that will always be on top of the list. In today's world, the importance of environmental aspects has increased significantly.

- Reduced cost
- Increased speed
- Increased flexibility
- Environmental regulations

And to meet these requirements, the focus for development today is in the following areas:

- Increased cutting data
- Higher coolant pressures
- Dry machining
- New machine concepts
- Near net shape (NNS) forming
- PM materials
- Lighter and stronger materials

In the past the focus for the machining industry has been to increase speed and improve flexibility. This was a key driver to establish more advanced materials, such as PCBN, as viable cutting tool materials. In many cases today's machining techniques are now only possible because of the introduction of PCBN.

Today, the industry also demands more and more environmentally friendly machining solutions. This is being achieved by reducing energy costs, dry machining, chip recycling etc. Many of the advantages of PCBN are related to the term "green" manufacturing, like optional coolant and easier chip control and chip recycling.

New machine tool concepts are continuously being developed, with the ability for higher travel speeds, machines for complete machining in one setup, and machines where different disciplines are combined, e.g. hard turning and grinding.

Near net shape forming and the introduction of PM materials are closely related. The goal with near net shape is to reduce the amount of machining by forming the component as close as possible to final dimensions. A finish machining operation is then all that is needed. One way of forming the component is pressing and sintering of PM components from powders.

Energy consumption plays a vital role in today's society, and by developing stronger and lighter materials, the weight of the final component will be reduced, and thereby reducing the transportation cost. Stronger materials will also increase the safety of passengers in moving vehicles, like trains, aeroplanes and cars, in the case of an accident.

Material trends

The main material trends related to PCBN are summarized below:

Ductile and austempered ductile iron

Ductile irons have higher toughness than grey irons, and are widely used in the automotive industry.

Austempered ductile iron (ADI) has been rapidly adopted and exploited world wide for manufacturing of primarily automotive products. ADI exhibits remarkable properties, such as high toughness, relatively light weight, good heat conductivity and good vibration damping, as well as a high level of ductility, recyclability and wear resistance. These useful mechanical properties are arrived at via a unique process of heat treatment that provides designers with further manufacturing flexibility and effective cost reduction compared to comparative forged steel components.

Some resistance to these materials comes from the machining industry, who have got used to the superior performance and tool life of PCBN. Machining of both these materials with PCBN has been proven difficult due to the high content of free ferrite.

Compacted graphite iron

Compacted graphite iron has properties that are in between grey and ductile iron. They are harder, tougher and more abrasion resistant than grey cast iron and exhibit good damping and high thermal conductivity. They are also made to tighter compositional and structural specifications, resulting in a more homogenous material.

The drawback is the same as with ductile irons, PCBN cutting tool materials can not be used because of the higher free ferrite content, which leads to significantly reduced productivity.

Powder metal nickel based alloys replace cast nickel based alloys

With the need for further enhancements in properties demanded by the aerospace industry, materials like Inconel 718 will be replaced by new generations of powder metal based nickel based alloys. An example is the commercially available Udimet 720, which has significant material property advantages over Inconels. The Udimet 720 can be machined with PCBN at the same cutting data as Inconel 718.

Waspalloy in the aerospace industry

In combustion chambers and turbine casings Waspalloy is replacing Inconel 718 as the most common material. This material is more difficult to machine than Inconel 718, and success is not always possible with PCBN.

High chrome materials

The most common materials in this sector are white cast irons, often refered to as high chrome iron. White cast irons unlike chilled cast irons are through hardened and contain significant amounts of chromium to improve the materials wear resistant properties. 20 years ago common white cast irons were known as Ni-hard with a typical chromium content of 11%. In materials used in slurry pumps and rolls it is not uncommon to see chromium contents as high as 30%, making the materials more wear resistant, but also more difficult to machine. At these levels of chromium, PCBN is the only single point tooling solution available on the market.

Valve seat materials

Although valve seat materials are commonly referred to as sintered iron, current generations of materials are more likely to be a type of sintered steel rather than a sintered iron, due to the increasing demands on modern engines. For the majority of current petrol engines, low alloy steel valve seat materials are employed. For diesel engines, the higher fuel pressures mean that medium alloy steels are exclusively employed for their increased wear resistance. Occasionally high speed steel PM materials are also used. For the latest ethanol (E85) powered engines, high speed steel PM materials are the only choice. These PM HSS materials used in ethanol engines are extremely difficult to machine with anything other than PCBN, but even with PCBN tools, the tool life is comparatively short when compared with PM irons and steels.

High tensile steels

High tensile steels also known as ultra high strength steels (UHSS) are currently used in the production of aircraft landing gear. However, there is significant research being undertaken in the aerospace industry to look at replacing Inconel engine shafts with ultra high strength steels. In this area PCBN grades are already proven in both roughing and finishing applications. PCBN can be used for both roughing and finishing, for selection of PCBN grade and cutting data, see high tensile steel in the material categories section.

Titanium

Titanium is growing as an alternative material to high tensile steels in aircraft landing gear applications. Research is now focusing on PCD as the preferred tool material for machining of titanium.

Powder metals

The potential for PM technology is huge, as any component which is currently produced by casting, forging or machined from stock, could potentially be produced by PM techniques. Therefore, the use of PM materials in the industry is predicted to expand exponentially over the coming years. PCBN inserts, with it’s high abrasion resistance, will continue to be the best solution for machining of PM components.

Summary

Manufacturers look for comparable tool performance at similar machining conditions when machining these new materials. In many cases this is not possible due to the machining characteristics of these new generation materials. Often compromise conditions are implemented to either maximise tool life, through less aggressive cutting conditions, or reduce tool life at existing conditions.

Cutting tool materials therefore play a significant role in material development and the continued development of modified PCBN composite products will be required to meet the performance levels demanded by the manufacturing industry.

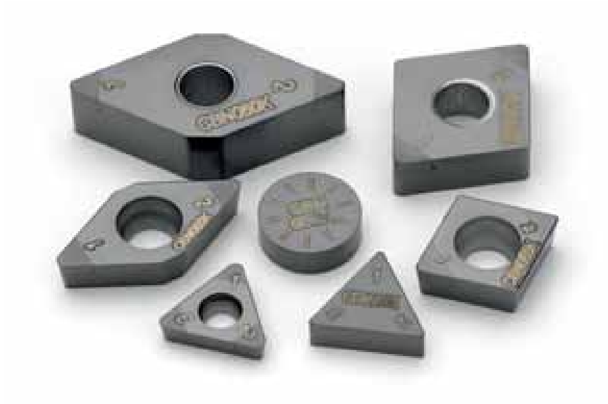
Machine tool trends

Machine tools are today not just lathes or milling machines. The development of machine tools follows the industry trends and requirements from customers regarding speed and flexibility. The machine tools are becoming more flexible, capable of complete machining in one setup by the addition of more axis, live tooling and subspindles.

A machine tool where two methods are combined in one, for example hard turning and grinding, is another way to increase flexibility and reduce manufacturing cost. The position accuracy is continuously improved, and machine tools today have higher travel speeds with maintained position accuracy than ever before.


CBN060K

Machining methods



Turning

The vast majority of heat treated components in the metal working industry are machined to their final geometrical form after hardening. During the last decade, turning of hardened components with PCBN tools has become increasingly common, and today it is an established alternative to grinding.

Turning is often termed conventional turning, where a single point is used to remove material compared to the multiple grains used in a grinding operation.

PCBN inserts for turning are available in the same geometries as carbide inserts, and in many cases the same toolholders can be used. For straight surfaces, wiper inserts are available in most shapes and sizes.

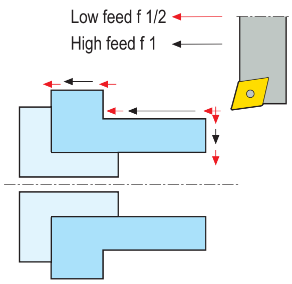
The main prerequisites that make it possible to use PCBN as a cutting tool material are heat and forces. The cutting forces produced in a machining operation generate a lot of heat that has a positive effect on the substrate toughness “a hot insert is also a tough insert”. The heat produced will soften the workpiece material and thereby create a reduction of the specific cutting force. The most critical situation for extremely hard tool material like PCBN is when the cutting edge is exposed to heavy load before a working temperature is reached. Entering a workpiece with an uneven diameter and/or face with a PCBN insert, means that the insert is exposed to mechanical interruptions before it has entered the working temperature, which can drastically reduce the lifetime of the cutting edge.

Some actions can be taken in order to prolong and secure the tool life when turning with PCBN.

Feed (f) alternation

PCBN is a hard and wear resistant tool material and needs heat to perform. Impact load at entry when the insert is cold can sometimes result in edge micro breakage. This can happen also at exits and when machining up to a shoulder. Often the feed selection is based on chip control, power limitations and surface demands. By using feed alternation the tool life can be drastically improved regarding both predictability and lifetime.

The idea is to reduce the feed rate when entering and/or exiting the workpiece in order to avoid heavy initial loads and interruptions before the cutting edge has entered a working temperature. When the corner radius is in full contact with the workpiece, maximum feed for the application and selected insert geometry can be applied. When turning against a shoulder it can be advantageous to reduce the feed in order to limit the impact from chip jamming and insert overload.

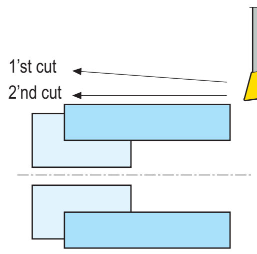


This method is especially important when using wiper inserts and high feed rates.

Machining methods

Depth of cut (a_p) alternation

In finish hard turning one or, depending on part heat treatment distortion, two cuts are necessary. If two cuts are necessary, one cut removes the black surface, and one cut sets the final dimensions and tolerances. The most common is to divide the total stock in two equal depth of cuts. This means that the depth of cut is relatively constant between first and second cut, and also between parts. The tool wear will be very localised, i.e the chip "grinds" on the same place on the insert for every part being machined. To spread the wear over a larger area, and prolong tool life, the depth of cut should be varied.

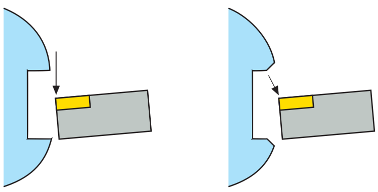


This method can increase tool life with as much as 30%.

Chamfered insert entries

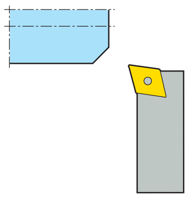
A PCBN insert needs heat to work properly, with a good balance between wear resistance and toughness. In interrupted machining, like machining over keyways or splines, the insert will continuously go in and out of cut. At insert entry, the full load on the insert is on the rake face. This causes an increased risk for overload in the tangential direction which can result in edge chipping. The use of chamfered inserts in interrupted machining is always recommended and will reduce the risk for edge breakage.

To reduce the risk for chipping and breakage even more, and thereby improve tool life, it is recommended to chamfer the parts features as well.



This method will significantly reduce the impact load, since there will be a gradual increase of the cutting forces, and the resultant force will be directed into the insert, instead of parallel to the insert.

Also when entering a continuous cut, it is recommended that the ends of gears and shafts etc. are chamfered.



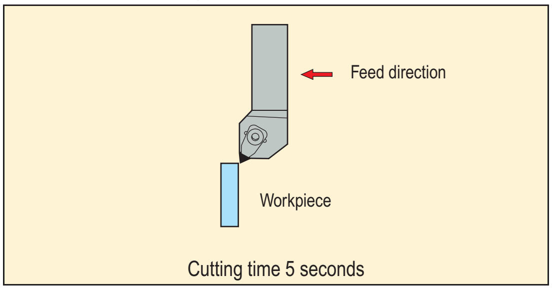
Machining methods

Plunging

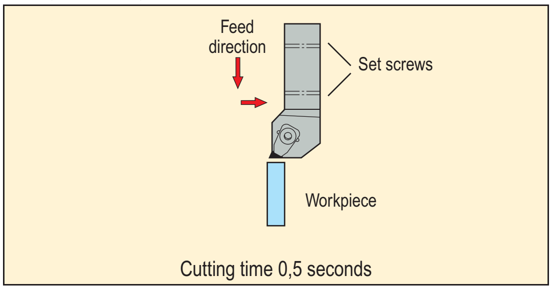
A breakthrough in hard turning was made with the introduction of plunge turning patented by Seco in 2001. The plunging process consists of hard turning with an orthogonal cut – made possible by the use of full-faced (sintered layer) or more cost effective solid inserts. To take advantage of the benefits of the plunging process, the cutting system must have good rigidity.

The two main advantages of plunging compared to conventional turning are the reduction in cutting time (up to 90%) and the improved surface integrity. With conventional turning, which generates a continuous spiral groove, the surface finish achieved is determined by a variety of factors, whereas with plunge turning the surface roughness is mainly dependent on the quality of the cutting edge. Experience has shown that the surface roughness achieved by plunging is usually better than with conventional hard turning. Sealing properties are equal to those of ground surfaces.

Conventional Turning



Plunge Turning



General cutting data recommendation for plunge turning is v_c = 200–400 m/min and f = 0,04 mm/rev, compared to v_c = 150 m/min and f = 0,15 mm/rev in conventional turning.

To avoid the cutting edge profile affecting surface finish, complete the operation with a small axial movement.

In addition to the introduction of the plunge turning method there are also designated toolholders. These toolholders have set screws which give the possibility to adjust the toolholder to an exact setting angle. The toolholders have a designation ending with – PL, and are available for inserts in sizes T..11 and T..16.

The residual stresses after plunging are compressive both in the tangential and axial direction, which are beneficial to the fatigue properties of the component. Ground workpieces show tensile residual stresses deep below the surface before changing into compressive residual stress at the surface.

With conventional hard turning, tool wear has an influence on the build up of white layer and tempered zone in the workpiece. With plunging, the white layer and tempered zone are in most cases eliminated. This is because plunging develops less flank wear on the tool edge, due to the shorter cutting time required. This generates lower cutting forces and less friction, resulting in less heat on the surface of the workpiece.

Overall, plunging has great potential for decreasing manufacturing costs, and the surface integrity of the workpiece is superior to conventional hard turned or ground parts.

Multi Directional Turning (MDT)

The Seco MDT system is a very flexible machining solution. The system can be used for turning, profiling, grooving, undercutting, parting-off as well as threading. This can be achieved using the same toolholder and inserts specifically designed for the task. MDT gives productivity close to conventional tools and allows great flexibility and offers the possibility to reduce the number of tool changes as well as tool inventory.

The main feature of the MDT system is the serrated contact surfaces between the insert and the toolholder. The clamping action produces a frictional force at the serrated contact surfaces, which is many times higher than in other systems. The rigidity improvement ensures at the same time maximum accuracy and high reliability.

The versatility and reliability of the MDT system yields good production economy, since the tool changes and related stoppages (machine down time) are fewer. For complex parts with many grooves and profiles, several conventional standard and special tools can be replaced with just one MDT tool, which also simplifies tool handling and stock keeping.

The standard PCBN inserts in shapes according to ISO standards are not always suitable for machining grooves. The shape of the component severely limits their use. In order to machine all surfaces, groove-turning inserts are needed. At the same time stability and accuracy in positioning are required. The patented serrations between holder and insert make Seco MDT the most rigid groove-turning system on the market.

The advantages of two high performing products are now available on one insert:

- The flexibility of Seco MDT and the advantages of PCBN.
- The serrations giving unmatched stability of Seco MDT and the superior edge quality of Secomax PCBN.
- The positioning accuracy of Seco MDT from the serrated bottom and the high performance of the Secomax PCBN grades.

A combination that is hard to beat – grinding quality and toolholder stability – PCBN and MDT – both from Seco.

Machining methods

Milling

Milling with PCBN is a very successful method providing a number of advantages over any other cutting tool material. As mentioned earlier in the technical guide, one of PCBN's principle advantages over other cutting tool materials is PCBN's high hardness at elevated temperatures.

As milling is an interrupted cutting operation, certain steps are required in order to keep heat focused in the cutting zone during cutting, thereby optimising the PCBN's performance:

- Never use coolant
- Increase the cutting speed
- Use conventional milling

Coolant and Milling

Coolant should never be used during milling operations. Using coolant during a milling operation would at the very least, drastically reduce PCBN's performance, or more likely result in thermal shocking of the insert, which invariably results in PCBN breakage. The theory behind this phenomenon is that during cutting, a large concentration of heat is generated at the cutting zone, some of which is dissipated through the PCBN insert. However, when out of cut, if the inserts are subject to coolant, the result is rapid cooling. The cycle of heating and cooling of the insert invariably leads to thermal shock breakage of the PCBN insert.

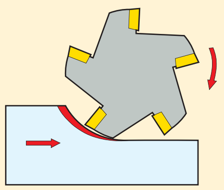
Coolant should **not** be used for any PCBN milling operation

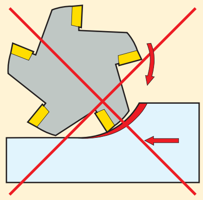
Cutting speed

Milling with PCBN is very dependent on heat generation in the cutting zone. During milling the cutting edge is out of cut for at least 50% of the time during each revolution of the cutter. To compensate for the time PCBN is out of cut during milling, cutting speeds are generally increased by as much as 50% compared to continuous turning recommendations. Milling with PCBN at the lower cutting speed advised for continuous turning will result in reduced tool life, as the cutting tool interruptions associated with milling results in reduced heat generation at the cutting zone.

Machining methods

Milling method – Chip formation





Conventional milling (Up cut milling)

- Feed direction opposite to cutter rotation direction
- Width of chip develops from thin to thick
- Increased friction and heat generation
- Optimised PCBN tool life

Recommended for PCBN

Climb milling (Down cut milling)

- Feed direction same as cutter rotation direction
- Width of chip develops from thick to thin
- Reduced friction and heat generation
- Reduced PCBN tool life

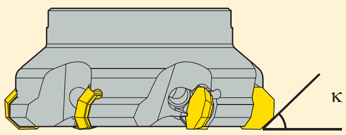
Not recommended for PCBN

Chip formation in PCBN machining is very important especially when machining hard steels and hard irons. It is important to mill using a technique that allows chip load to build up slowly. Therefore, conventional milling or up cut milling is always recommended when milling with PCBN. Again the reason is related to heat generation in the cutting zone. When the insert first comes into cut, it is cold and therefore, has an inefficient cutting action. As the insert moves further into cut, heat is generated and the cutting action becomes more efficient.

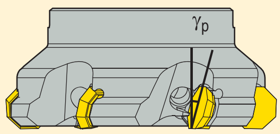
By applying conventional milling techniques, when the insert first comes into cut, chip load is small when the cutting zone is not up to an efficient working temperature. Chip load then increases as working temperature increases in the cutting zone. The result is an efficient cutting action that maximises tool life. This is in stark contrast to the adoption of climb milling or down cut milling with PCBN where tool life will be reduced. With climb milling maximum chip load is generated at the beginning of the cut when the cutting zone is below efficient working temperature.

Cutter geometry angles

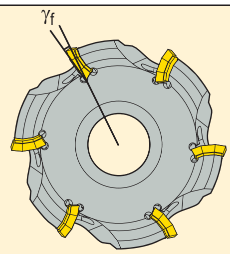
There are effectively three directional planes which are used to dictate the cutter geometry angles; these are the tool cutting edge angle and the radial and axial planes. The overall cutter geometry is achieved from a combination of these three angles.



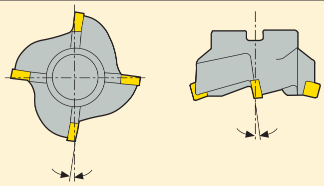
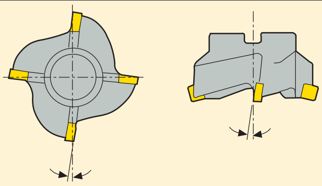
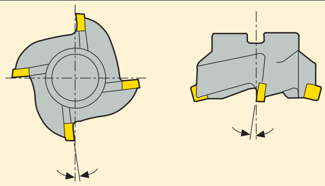
Tool cutting edge angle



Axial rake



Radial rake

 Radial angle neg Axial angle neg	 Radial angle neg Axial angle pos	 Radial angle pos Axial angle pos
Advantages: • Utilization of both sides of a solid PCBN insert • Strong cutting edge	**Advantages:** • Reduced cutting forces • Improved chip removal	**Advantages:** • Reduced cutting forces • Optimum chip removal
Disadvantages: • Increased cutting force	**Disadvantages:** • Only single side of an insert can be utilised • Reduced cutting edge strength	**Disadvantages:** • Only single side of an insert can be utilised • Reduced cutting edge strength

As shown, there are principally 3 basic cutter geometry combinations available. As a general rule, harder and more aggressive workpiece materials (e.g. chrome irons) require stronger insert geometries (γ_f negative and γ_p negative). On softer and more abrasive workpiece materials, more positive rake angles can be used.

Machining methods

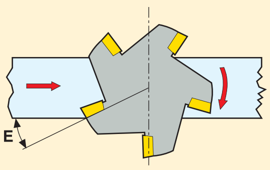
Insert entry angle

The angle at which the insert enters the cut is important to tool life. The insert entry angle (E) should always be as large as possible. This will reduce cutting forces and thereby increase tool life.

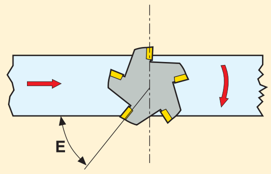
There are two options available to achieve a large insert entry angle:

- Use a cutter diameter that is close to the workpiece width
- Offset the cutter position relative to the workpiece

By selecting a cutter with a diameter slightly larger than the width of cut, the entry angle is kept at a high value. Generally for face milling, the cutter diameter should be 10–30% larger that the width of cut.

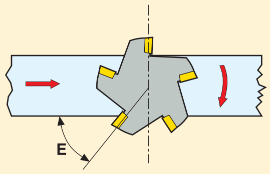


Not recommended for PCBN

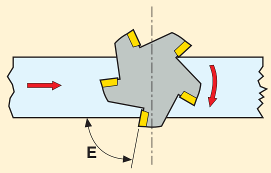


Recommended for PCBN

If the selected cutter diameter is much larger than the workpiece width, moving the cutter position off-centre relative to the workpiece center line will also result in an increased insert entry angle.



Not recommended for PCBN



Recommended for PCBN

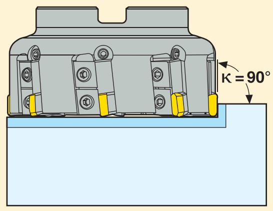
Cutting edge angle

The cutting edge angle (κ) of a milling cutter is the angle formed by the leading edge of the insert. Cutting forces, chip thickness and tool life are all affected by the cutting edge angle.

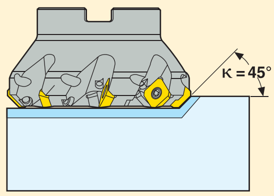
Decreasing the cutting edge angle, for example from 90° to 45°, reduces the chip thickness for any given feed rate. The chip thinning process occurs by spreading the same amount of workpiece material over a longer part of the cutting edge.

Decreasing the cutting edge angle allows the cutting edge to gradually enter and exit the workpiece. This helps reduce radial pressure, reduces the risk of breakout and reduces the load on a given point of the cutting edge, thereby increasing tool life. However, axial pressure is increased, which can cause deflection of the machined surface of a thin walled section part.

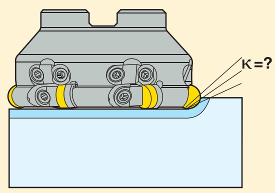
90° cutting edge angle
- Square shoulder requirements
- Poorly fixtured components
- Thin walled sections



45° cutting edge angle
- High productivity
- Reduced risk of vibration

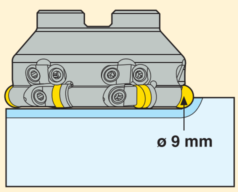


Round insert (multiple cutting edge angles)
- Strongest cutting edge
- Multiple cutting edges

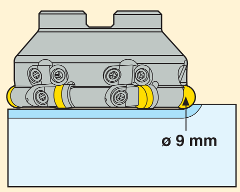


With round inserts, the cutting edge angle varies with depth of cut

For round inserts, the cutting edge angle is dependant on the depth of cut. As depth of cut is increased, the cutting edge angle also increases. This in turn will increase the chip load.



Depth of cut = 4,50 mm

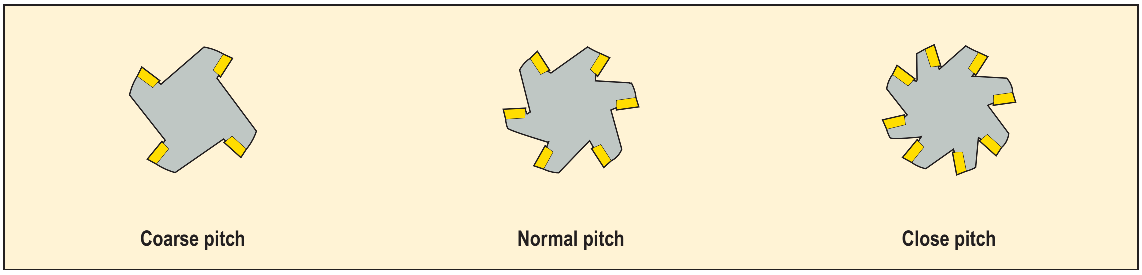


Depth of cut = 2,25 mm

Machining methods

Cutter pitch

The definition of pitch on a milling cutter is the distance between a specific point on one insert edge to the same point on the next insert edge. Milling cutters are classified as coarse, normal or close pitch.

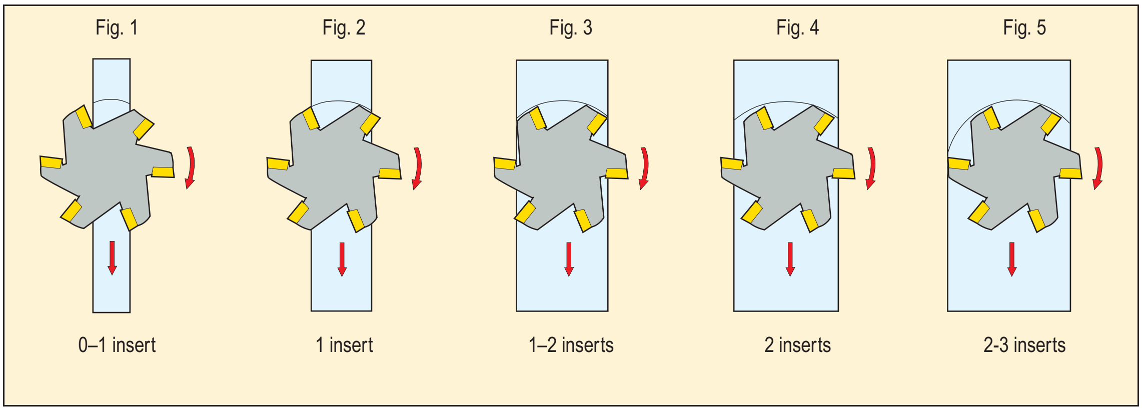


Generally coarse pitch cutters are used when stability and power are limited and when the chips are stringy and difficult to evacuate. However, as PCBN is designed for predominately hard or abrasive workpiece materials, the chips are generally short and brittle. This means chip evacuation is rarely a problem when using PCBN.

Number of inserts in cut

The number of cutting edges (inserts) in contact with the workpiece during the arc of cut is dictated by the cutter diameter in relation to the workpiece width and the chosen cutter pitch. Shown below are a number of scenarios for the number of inserts in contact with the workpiece. In figure 1, the relationship between the cutter diameter, the insert pitch and the width of the workpiece means that inserts in cut vary from none to one (i.e. the insert exits its cut before the next insert begins its cut). In this case the cutting force variation between out of cut and one insert in cut is very high.

The ideal number of cutting edges in contact during the arc of contact is two or more (fig. 4 and 5).



Summary

Points to consider when milling with PCBN:

- Do not use coolant
- Increase cutting speed compared to turning to compensate for the interruptions
- Apply conventional milling or up cut milling
- Use strongest insert geometry (round inserts where possible)
- Use chamfered and honed cutting edges

Machining methods

Turn-milling

A method not seen very often is turn-milling. In turn-milling a rotating tool is used, and at the same time the workpiece is also rotating. This allows for non-symmetrical parts to be machined in one setup, and reduces the need for multiple machining operations. Examples of components are cam-shafts and crankshafts.

One requirement is a lathe or a machining centre with at least 5 axis. The actual milling operation is done slightly off-centre relative to the workpiece, the programming is more complicated than in standard turning or milling, and tool paths usually have to be generated in a CAM program.

Turn-milling is a very efficient way of removing material, and workpiece deflection can sometimes be reduced compared to conventional turning when machining long and/or slender parts.

Drilling

Drills can be divided in three groups, depending on the application area:

- Solid drills
- Drills with replaceable crowns
- Indexable insert drills

Solid drills and drills with replaceable crowns made of PCBN or a combination of PCBN and carbide sintered together are still in the future. Rotating tools with brazed PCBN tips are available on the market today, but are mostly used to widen or improve existing holes. The price for these tools is usually very high, and it often involves rebrazing and regrinding to make them cost effective.

An interesting concept is to use Seco's range of indexable insert drills in combination with full-faced (sintered layer) PCBN inserts.

Speed is an issue when drilling, with the highest speed at the periphery and zero at the centre of the drill. Both periphery and centre insert can be PCBN inserts, or a combination of a PCBN insert at the periphery and a carbide insert in the centre can sometimes be optimal. Suitable applications for PCBN drilling include grey cast iron, hard irons as well as hardened steel components where the method opens up possibilities to reduce machining time or cut production steps.

This area is still under evaluation and development, but several projects have shown very promising results.

Machining methods

Lead-free machining

This is a method where the insert is moving tangentially to the workpiece surface where the contact point is moving along the edge. This method requires a machine equipped with a Y-axis, as well as the normal Z- and X-axis. The movement in Y-axis can be combined with a movement in Z-axis to machine surfaces wider than the insert.

The disadvantage is that a Y-axis is needed, which few conventional machines have. A further limitation is that only straight surfaces can be machined. Still, it is an alternative to conventional hard turning and there are several advantages with this method including improved surface finish with no spiral groove, reduced tool pressure compared to plunging, increased productivity through increased feed rates and very long tool life.

Lead-free machining is a similar method to plunging, but with the possibility to machine longer lengths of cuts.

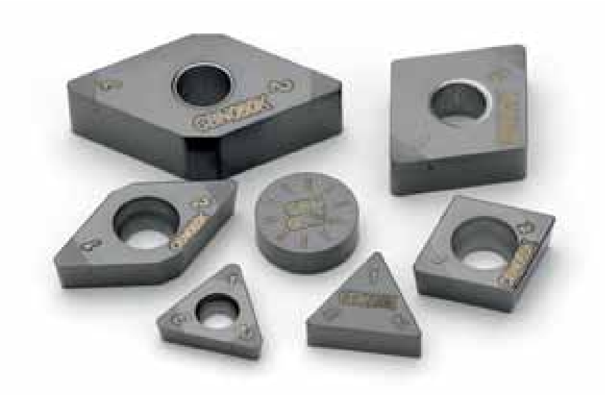
The method is not widely spread, but is under evaluation and development, and could potentially be very common in certain applications.

Threading

While the concept of PCBN threading has been around since the development of PCBN, recent developments pioneered by Seco have broadened the application areas and performance of PCBN in threading applications. Today both thread turning and milling techniques are being employed to machine a range of thread styles, including, Acme, Stub acme, ISO and Whitworth in both hard steels and irons.

Industrial sectors which have benefited significantly from these PCBN threading developments are the slurry pump and thread rolling industry. Advantages include replacing the slow thread grinding or annealing and WC threading techniques with PCBN which machines directly into the hardened material. The improvements include accurate and consistent thread profiles, consistent and predictable tool life and interchangeable inserts minimising consumables.

Insert technologies



Insert technologies

PCBN tool geometry

The tool geometry can be divided in macro and micro geometry.

Macro geometry

The macro geometry is usually determined based on strength, versatility and power requirements. The nose radius together with feed rate also decides the attainable surface roughness.

Corner radius:	6		1,6			1,2		0,8		0,4
Point angle:		90		80	80		60		55	35
Shape:	R	S		C	W		T		D	V

Strength ↔ Versatility/ Accessibility

← Risk for vibrations/ increased power requirements

Insert size

As a general rule, there is no need to select a larger insert than necessary. This is especially true when using solid inserts, since they have more edges and are often more cost effective than tipped products.

Insert shape/point angle

The insert shape should be selected based on the entering angle required vs requirements regarding accessibility and/or versatility. When using PCBN, the largest possible point angle should be selected for improved strength and economy.

Corner radius

The selection of size for the corner radius is of great importance. A rule of thumb, regarding the impact on the strength of the cutting edge is, one step in increased size of the corner radius is equivalent to one step in grade toughness. This fact makes it important to be critical when implementing hard and wear resistant cutting tool materials.

Toolholder angles

These angles are built into the toolholder, and include inclination angle, rake angle and entering angle.

Micro geometry

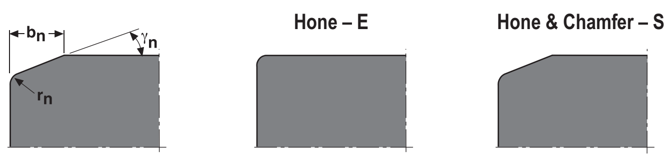
The micro geometry on a PCBN insert usually refers to the edge geometry, and there are two main edge geometries found:

Honed edges (E)

A small radius is applied to the edge

Chamfered and honed edges (S)

A chamfer is ground along the edge, and the edge is honed afterwards



The parameters used to describe the edge geometry are:

- Chamfer width, b_n
- Chamfer angle, γ_n
- Edge hone, r_n

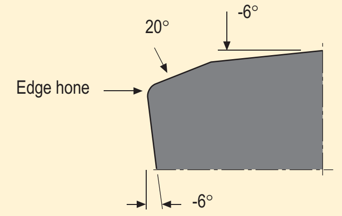
A typical PCBN insert has a chamfer angle of between 10° and 30°, and a chamfer width of between 0,05 and 0,25 mm. The edge hone can be from 0,015 to 0,050 mm.

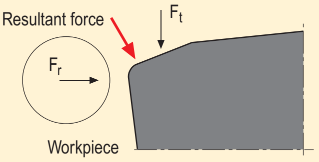
Insert technologies

General recommendations

When using PCBN it is generally preferred to use a negative top rake angle, this allows a large included angle at the tip, providing a strong edge. When machining hardened steels and irons this is usually not enough to be successful. The addition of a chamfer and an edge hone is necessary to provide the strongest possible edge. The precise size and angle of chamfer and hone depends on the application.

Ideally the resultant force between the tangential, axial and radial components should be directed into the body of the insert. The negative tool geometry in combination with the chamfer and hone achieves this. Where additional strength is required large nose radii inserts should also be used.





Radial and tangential forces should be balanced to provide best tool life

If the forces aren't balanced, chipping or flaking of the insert can occur. As an example, at tool entry or in interrupted cutting, all pressure is on top of the insert, which increases the risk for chipping. When the feed rate is too high, the feed force becomes dominant, and flaking might occur.

High tangential force and sharp edges result in edge breakage

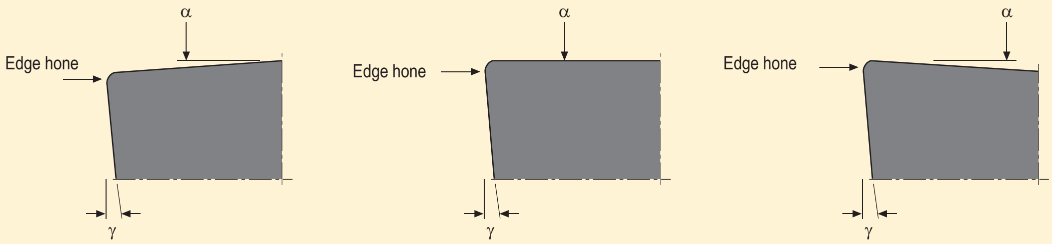
High radial forces and sharp edges result in edge flaking

Possible effects of unbalanced radial and tangential forces

There are standardised edge preparations available, and they are optimised for the general application, but there are always cases where a special edge preparation is needed.

Understanding of the fundamental theories behind the effect of edge geometry allows tool geometries to be changed for different workpiece materials. For example the finishing of pearlitic grey cast iron in terms of demands on the cutting edge is fairly forgiving, although extremely abrasive as the material hardness is low compared to hardened steels.

In this situation a range of tool configurations can be applied successfully (see below).



When understanding the characteristics of the workpiece material together with the required operation, the selection of optimal edge geometry becomes a logical choice.

Stable cutting edge geometries are always preferred:
- Chamfered cutting edges
- Negative cutting rake
- Large nose radius
- Small approach angles for roughing

Positive cutting edge geometry can be advantageous when:
- Finishing of small hardened bores without interruptions
- Finishing of unstable components without interruptions
- Finishing of grey cast iron

Solid PCBN inserts

The main advantages with solid PCBN inserts over tipped PCBN inserts are the number of usable edges per insert and that the full insert cutting edge is available. As on a conventional carbide insert, all corners on an insert can be used. The use of solid inserts cuts the cost per edge significantly compared to brazed tip inserts.

Roughing

Roughing operations are generally very demanding, the depth of cut can be as much as 5 mm or more, and a substantial amount of heat is generated. Most of the heat goes away with the chip, but some of it will go through the insert and out to the toolholder and machine tool.

A large depth of cut would require a large expensive tip, and the heat generated in these operations might soften a braze joint and result in tip loss. For these reasons, roughing operations are dominated by solid PCBN. Solid inserts for roughing are available in grades CBN200, CBN300, CBN350 and CBN400C.

Finishing

Seco is the first and only to offer solid grades in the low cBN content area, the solid CBN060K, CBN050C and CBN100 inserts are developed for application areas such as finishing of hardened steel, hard facing alloys, powdered metals and superalloys.

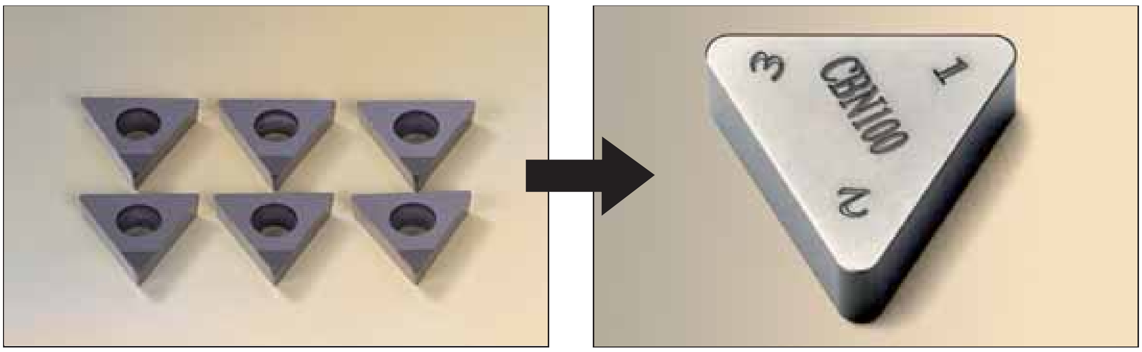
Plunging in hardened surfaces is possible by using the full cutting edge length available on a solid insert.

As mentioned the most important advantage of solid PCBN is having more cutting edges on one insert. This cuts the cost per edge significantly when compared with brazed single tipped and multi-tipped insert. In addition the solid PCBN's mono block format means that there is no braze joint, which can be beneficial when machining materials where large amounts of heat is generated, like Inconels.

While it is clear to see the economic and insert integrity advantages of solid PCBN, other advantages include reduced inventory and ease of handling of one multi-edged solid insert compared with several single or multi-tipped inserts required to achieve the same amount of work.

With Solid PCBN you can reduce the number of inserts and cut your costs at the same time!

The major advantage of Solid PCBN over tipped PCBN inserts is the number of cutting edges available. The figure shows a comparison of brazed single tipped and solid triangular PCBN inserts.



One solid triangular insert has the same number of cutting edges as six brazed single tipped inserts. While this advantage is reduced by the introduction of brazed multi-tipped inserts, their small tip size can be limiting in roughing applications. In addition the majority of brazed multi-tipped inserts consist of either PCBN tips on one face of the insert or PCBN tips on opposite sides of one corner. Further more when using a round button insert, the advantage of solid PCBN is 50% greater than that of the alternative, a single sided full-faced (sintered layer) PCBN insert.

PCBN High Feed (Wiper) inserts

The surface finish in a turning operation is affected by a great number of factors. Two of the most important factors are feed rate and the size of the corner radius. A relation commonly used in industry when choosing relevant cutting data regarding feed and surface finish, is that R_a roughly can be said to increase with the square of the feed rate and decrease with increased size of the corner radius. At least this was the case before the development of wiper geometries designed for high feed finishing, which is now gaining popularity in the metalworking industry. Wiper geometries changed this relationship with the capability to generate high surface finishes even at higher feed rates.

Seco High Feed (Wiper) inserts combine the high feed capability and high quality surface finish given by large round inserts and the low cutting forces and flexibility permitted by sharp pointed inserts. This can be achieved by the fact that the main part of the radial cutting force is generated by the main cutting edge. By transferring a small part of the round insert edges into the straight cutting edges of the pointed insert, an insert design adjusted for high feed machining producing superior surface finish is achieved.

General hints

- Use a High Feed (Wiper) insert to increase the feed without sacrificing surface finish, relative to conventional insert geometries.
- Use a High Feed (Wiper) insert to eliminate grinding operations. In many cases it is possible to obtain surface finishes and dimensional tolerances previously only possible with a final grinding operation.

Seco has three different types of wiper geometries designed for optimum performance in different applications:

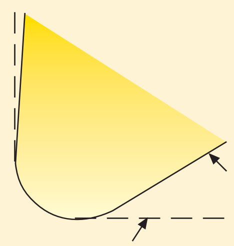
• Conventional wiper	-WZ
• Crossbill™ wiper	-L-WZ and -R-WZ
• Helix™ wiper	-WZN and -WZP

Conventional PCBN High Feed (Wiper) inserts

A conventional High Feed (Wiper) insert consists of a large radius added to the insert outside the nose radius. This wiper segment is added on both sides of the nose radius, allowing for turning left or right.

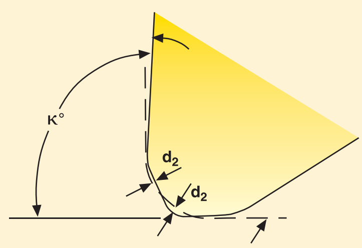
The Seco range of conventional High Feed (Wiper) products include all commonly used inserts shapes.

Standard insert



Standard insert-profile
(Nominal nose radius)

PCBN High Feed (Wiper) insert



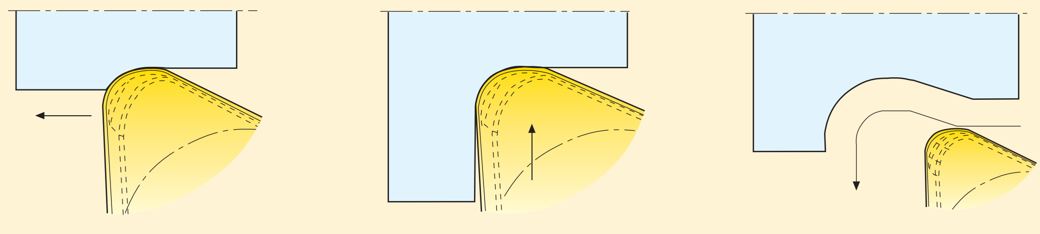
Standard insert-profile
(Nominal nose radius)

Seco Crossbill™ High Feed (Wiper) inserts

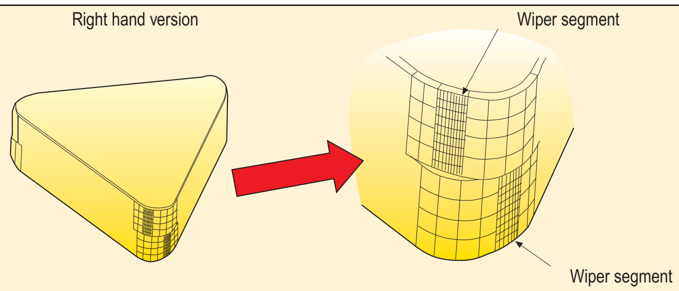
The advantages of wiper technology have been clearly defined on the previous page and the advantages of solid PCBN inserts are well documented. Until recently wiper designs on solid inserts limited their application to machine towards a shoulder or a face. This is due to the wiper design on one edge giving the reverse design on the other side of the corner radius. The introduction of the Crossbill™ wiper has addressed this issue.

The unique, patented, design of the wiper allows for the utilisation of handed wiper technology on all cutting edges on a solid insert. Available in both left and right handed designs, the Crossbill™ geometry insert offers great flexibility. The Crossbill™ wiper insert can axially turn with all the usual benefits of wiper technology all the way towards a shoulder/face. Due to the design of this wiper it is possible to machine a perfect radius with no deviation from a normal radius shape (see below).

Currently Crossbill™ geometry inserts are available as TNGX1103xxS inserts with a range of nose radii in either left or right hand format. It is designed to be used with a toolholder incorporating a 93° entering angle.

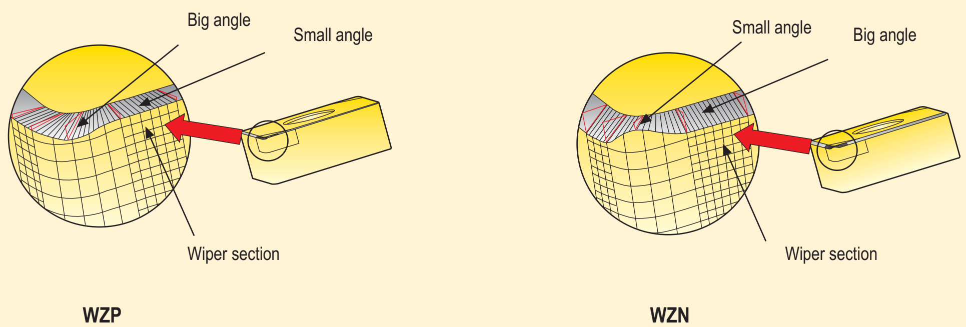


Axial turning (full wiper effect) | Facing (no wiper effect) | Copying (no deviation forming a radius)



Seco Helix™ High Feed (Wiper) inserts

Wiper technology is now an established method for decreasing cycle times and increasing productivity. However, the increased cutting forces associated with wiper inserts can sometimes create vibrations and chatter. The Helix design of wiper is a clever system of changing the angle of the chamfer at different intersections of the wiper area and nose radii. Available in two versions the helix wiper can manipulate cutting forces and crater wear development. In unstable setups the positive Helix geometry (WZP) allows you to enjoy all the high feed rate benefits of wiper technology in setups which in the past would have resulted in chatter. Where wiper inserts are currently used, the negative Helix geometry (WZN) can significantly increase tool life by moving the crater wear away from the cutting edge.



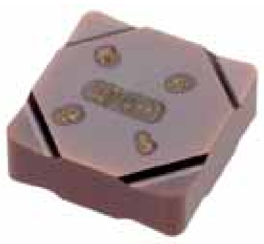
Currently Helix™ geometry inserts are available as CNGA120408S tipped inserts. It is designed to be used with a toolholder incorporating a 95° entering angle. The Helix wiper design can be added to any insert as a special.

PCBN chipbreaker inserts

Seco is the first company to offer a “chip breaker” geometry on solid PCBN inserts. The chip breaker offered in grade CBN400C increases the cutting edge rake angle as well as improves the chip flow over the insert. It is an ideal insert for use in finish machining of pearlitic grey cast iron, especially in boring operations where low cutting forces are required to reduce part distortion and out-of-roundness.

Pearlitic grey cast iron is a relatively soft material for PCBN to machine. However, it is also very abrasive, making CBN400C the most suitable cutting tool material for finishing. The abrasiveness and relatively low hardness of grey cast iron puts a high demand on the cutting edge of tool materials, the extreme wear resistance and hardness of CBN400C makes it possible to finish machine using chip breaker inserts to improve component quality.

Because of the way PCBN is manufactured it is neither practical nor economical to synthesise the material with built in chip breaker forms. By grinding it is now possible to manufacture a chip breaker edge into CBN400C inserts. This insert configuration combines the advantages of an increased rake angle cutting edge with the economics of a multi-cutting edged solid PCBN insert.



Due to the increased rake angle, chip breaker PCBN inserts should only be used for finish machining of grey cast iron.

The Secomax chip breaker increases the rake angle, thereby increasing the cutting edge rake angle. This leads to lower cutting forces and thus lower levels of transferred energy. The result is lower temperature levels in the cutting zone. Improvement in tool life has been realised through reduced crater wear. Reductions in both cutting temperature and load lead to a reduction in chemical attack of the cutting edge, thereby increasing tool life.

The main advantage is improved component accuracy due to lower cutting forces. In addition there is an improvement in surface finish due to the improved chip flow.

Tests carried out machining cylinder bores with CBN400C chip breaker inserts showed an increase in tool life of 50% compared with the equivalent negative rake insert geometry.

Currently chip breaker inserts are available as SNGF0903xxE inserts. The E-designation means only honed edges, with no chamfer.

Insert technologies

Coated PCBN inserts

Early development into the coating of PCBN inserts focused on worn cutting edge detection. PCBN by nature is dark grey/brown or black in colour, which could make worn cutting edges difficult to see with the naked eye. The problem is most acute with round button inserts, where the insert is indexed around its periphery, which can result in the possibility of machining with previously worn cutting edges, or discarding an insert before it has been fully used.

In 2002 Seco launched a new generation of PVD coating which in addition to give an easy detection of worn cutting edges, also gives improved tool life. This durable coating consists of a wear resistant (Ti, Al) N base coating with a TiN gold flash for wear scar identification. Total thickness of the coating is 2–4 µm and is available on CBN300. The letter ”P” after the product code denotes which products are available with this coating (e.g. CBN300P).

In 2006, together with the introduction of 2 new grades for machining hardened steel components, the C-coating was released. The new PVD coating improved coating technology significantly. The coating was developed specifically for PCBN and still offers great wear resistance and substrate bonding. The coating is available on CBN050, CBN160 and CBN400. The coating designation is the letter ”C” (e.g. CBN050C).


The latest generation of PVD coating from Seco has improved coating technology even more. It is introduced together with Seco’s latest grade for finishing of hardened steel components, CBN060K. The multi-layer coating coupled with optimisation of pre-treatments and PVD deposition techniques have resulted in a coating which gives unrivalled performance. The patented titanium aluminium silicon nitride (Ti,Al,Si)N based coating has shown improvements of 20% and more in finish hard turning when compared with the equivalent coated product. The patented coating is available on CBN060, the coating designation is the letter ”K” (e.g. CBN060K).

Seco’s PCBN coatings:

Designation	Composition	Available grades
P	(Ti,Al)N + TiN	CBN300P
C	(Ti,Si)N	CBN050C, CBN160C, CBN400C
K	(Ti,Al,Si)N	CBN060K

Benefits of Secomax coated PCBN Grades

- Improved tool life, particularly in finish machining applications
- Easy wear scar detection
- Improved resistance to chemical attack
- Reduced crater wear
- Improved insert fixturing
- Improved reliability
- No detrimental effect on surface finish

The use of uncoated inserts

Just as in tungsten carbide insert development, the coating has been an important factor in PCBN’s performance improvements. It has been clearly identified that coating a PCBN grade can significantly improve the tool life, especially in finishing operations. However, there is one area where current coating technology trends appears to be detrimental to a PCBN grade’s performance.

Where component surface finish criteria are particularly tight and critical, the addition of a coating to a PCBN grade appears to reduce the quality of surface finish achievable. Whilst the vast majority of surface finish requirements can be met with coated PCBN inserts, where component surface finish requirements are sensitive, uncoated PCBN has proven to be the best choice. Secomax CBN150 is a standard uncoated grade, which a sub micron grain structure and smooth flank wear characteristics, which make it the first choice for critical and consistent surface finish requirements. In fact Secomax CBN150 is the first and currently only grade to achieve a nanometer R_a surface finish value in published trials.

Solid PCBN inserts with pin lock hole

Seco offer CBN100 and CBN300 solid PCBN with a pin lock hole. The precision pin lock hole in solid PCBN gives additional insert security when clamping the insert. Solid PCBN can be used with M, P and D style toolholders. The pin lock hole in solid PCBN allows solid PCBN inserts to be used in existing pin lock toolholders found in industry. The D…-C toolholders are specifically developed for this insert format.

By adding pin lock holes to solid PCBN inserts, Seco have combined the advantages of multi-cutting edge solid inserts with the added insert mounting security of the pin lock insert clamping system.

For applications such as finishing of hardened steel, CBN100 with a pin lock hole is available in W and T style insert geometries, both styles are also available in combination with a wiper cutting edge. For applications such as grey cast iron, CBN300 with pin lock hole is available in D, S, V and W style insert geometries.

The Secomax range of solid PCBN inserts with a pin lock hole is the most comprehensive range on the market. In addition Seco is the only company to offer solid PCBN for finish machining and are also the first and only company to offer solid PCBN with a pin lock hole for finish machining of hardened steels.

Full-faced (sintered layer) inserts with c-lock hole

While the production of PCBN insert with a c-lock hole is not new, Seco has taken the format to its definitive stage. With developments in EDM hole making technology, the mass production of full-faced (sintered layer) PCBN inserts with a c-lock hole is now a reality.

This mass production capability has allowed for the development of an extensive cost effective range of inserts in C, S, and T style insert shapes. The full-faced (sintered layer) format eliminates the braze joint and any restrictions from tip size. The inserts are available as standard in grades CBN10 and CBN200 for both turning and milling. In addition to conventional turning, boring and milling, the full-faced (sintered layer) inserts offer a complete long edge, allowing for plunge turning to also be applied.

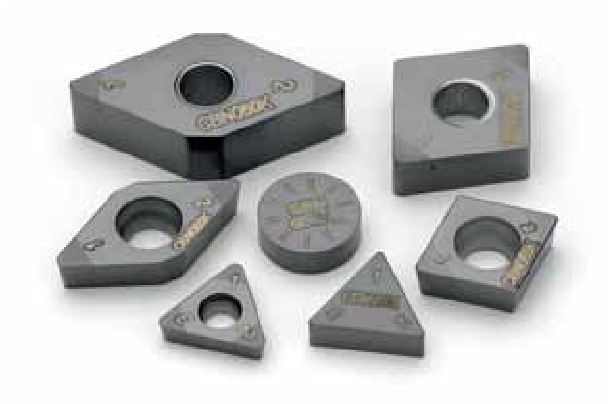
The main advantages are:

- Cost effective
- Secure locking
- Multiple cutting edges
- No tip segment to limit depth of cut
- No braze joint
- Long cutting edge availability for plunge turning

PCBN Cutting edge identification

Early PCBN inserts were normally supplied with a single tip of PCBN brazed onto a tungsten carbide substrate and there was no need to identify the cutting edge as the inserts were single-use. However, with the introduction and growth of multi-tipped, full-faced (sintered layer) and solid inserts, the majority of inserts today are multi-edge and therefore, multi-use. To support the use of these inserts, Seco supply all non round shaped inserts with a laser marked number adjacent to each cutting edge. This allows for the user to keep track of each cutting edge during operation and facilitates identifying which edges have been used and which have not, as well as relative performance of each cutting edge.

For round insert styles all inserts are laser marked into segments. This helps the user when indexing the round insert to the next position. This Seco feature is available on all round inserts, both coated and uncoated.



Tooling technologies

The use of coolant when machining with PCBN

The use of coolant in continuous cut machining operations in general does not have a significant effect on the rate at which the tool wear occurs. Tests have been carried out using a range of coolants, from simple oil emulsions to extreme pressure (EP-additives) coolants and synthetic oils. Test machining of a range of different workpiece materials shows no conclusive trend or benefit for either wet or dry machining as far as tool wear are concerned. The only exceptions are when machining tungsten carbide and Inconel with PCBN, where coolant is strongly recommended.

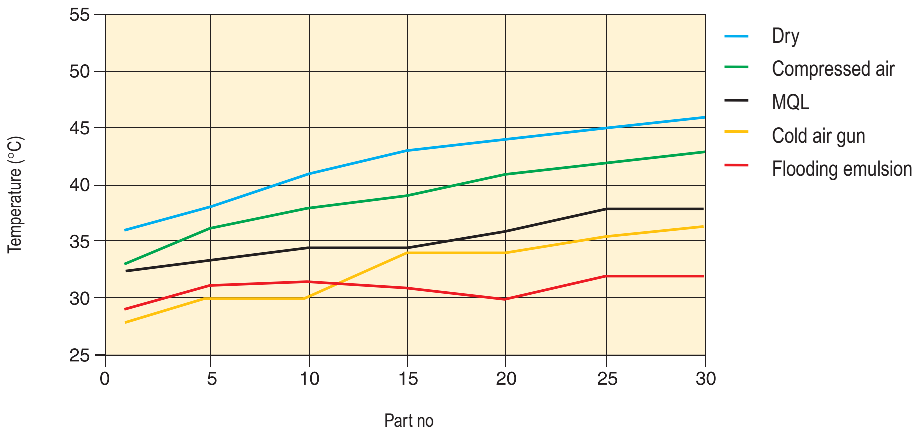
Even though coolant does no influence flank wear, coolant can be beneficial in controlling the temperatue in the machinng system, i.e cooling of the machine tool spindle, workholding, toolholder, and the component itself, as well as removing chips away from the cutting zone. The use of coolant can also be beneficial where crater wear is a problem.

The heat generated in a machining operation is removed through:

- The chip
- The insert
- The workpiece

Most heat goes away with the chip, usually about 70%. 15% goes into the machine, and another 15% goes into the workpiece. The heat that goes into the part will raise the part temperature, and increased tool wear will increase the amount of heat that goes into the part. An investigation made shows the temperature increase in machined parts after a finish hard turning operation when using different cutting media.

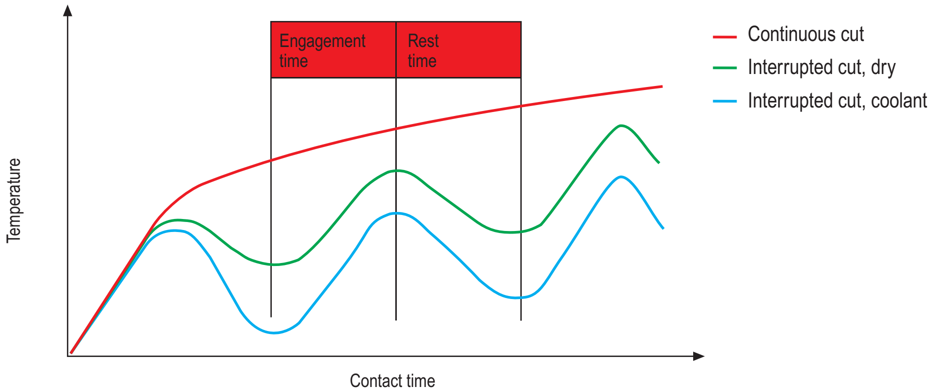
The parts are medium size, with a time-in-cut of 2 minutes/part.



The heat that goes into the workpiece will make it more difficult to control part dimensions and tolerances. The heat that goes into the tool will dissipate into the toolholder and out into the machine tool, again making it difficult to hold part dimensions and tolerances.

In interrupted machining (including milling), coolant must not be used. Using coolant during interrupted machining would at the very least, severely reduce PCBN's performance, or more likely result in thermal shocking of the insert, which invariable results in edge breakage of the PCBN insert.

The theory behind this phenomenon is that during cutting, a large concentration of heat is generated at the cutting zone, some of which is dissipated through the PCBN insert. However, when the cutting edge is out of cut, and the insert is subjected to coolant, the result is rapid cooling. The cycle of heating and cooling of the insert invariably leads to thermal shock breakage of the PCBN insert.



The figure shows the temperature development of the insert. In continuous turning, the temperature increases gradually and will reach a steady-state after a certain contact time, as shown with the red curve. In interrupted machining, the temperature will increase, and then decrease as the insert edge is out of cut, and increase again during machining of the second part, as shown by the green curve. If coolant is added, the temperature will decrease even more when the insert is out of cut, and then increase as the next part is being machined, as shown with the blue curve. The heating and cooling of the insert edge with the help of coolant will inevitably lead to thermal cracking of the insert edge.

In today's environmentally conscious world, the use and disposal of coolant is a real issue for the environment. In addition, the cost associated with using coolant (one study showed using coolant added 15% to a component's cost) has resulted in the drive to eliminate the use of coolants in the machining industry. PCBN with its dry machining capabilities is meeting and will continue to meet the trend of dry machining.

In interrupted machining and when machining small parts where the time in cut per sequence is short, thermal shocks from high frequency heating up and cooling down will contribute to a more frequent appearance of micro cracks at the cutting edge. These micro cracks will in time develop to cause frettering and chipping of the edge, and thereby reducing tool life and producing a less predictable process.

Jetstream Tooling™

Seco has developed Jetstream Tooling™, which is a revolutionary new solution to the age old problem of delivering coolant precisely to the cutting zone. Jetstream Tooling™ works by delivering a concentrated high pressure jet of coolant at high velocity straight to the optimum position close to the cutting edge. This jet of coolant lifts the chip away from the rake face, improving chip control and tool life enabling increased cutting data to be applied.

Jetstream Tooling™ is developed for machining with carbide tools, but can also be used in combination with PCBN inserts. The temperature at the edge needs to be high for PCBN to work efficiently, and the optimum wear modes on a PCBN insert is a balanced combination of flank wear and crater wear. If crater wear dominates, the speed has been too high, creating too high temperatures on the rake face. The use of Jetstream in combination with PCBN inserts will not reduce the edge temperature, but Jetstream can assist in decreasing the temperature on the rake face, allowing for higher speeds to be used.

When machining high temperature alloys as well as when roughing of hard steels with PCBN, the chips can sometimes be long and stringy. The concentrated high pressure jet can assist in breaking these chips, reducing the risk for chips getting tangled in or near the cutting zone, and instead fall down into the chip conveyor.

High density metal toolholders

As machining standards continue to increase, improvements can only be realised by looking at the complete machining system. From the cutting edge to toolholder, tool and workpiece clamping, through to machine spindle and machine bed, all these components have an effect on the quality and repeatability of the machining process.

In high precision and hard machining operations the requirements regarding surface quality and dimensional accuracy of the machined components are today critical issues, especially when converting from precision grinding to turning with PCBN tooling.

One important factor that has shown to have significant effect on the quality of turned components is the selection of the material used for the toolholder. Hard machining experiments using tungsten based high density material (DENSIMET, TRIAMET) in the toolholder, has proved to be beneficial in improving the surface quality and dimensional accuracy. Due to the properties of high density material with its good damping effect, the vibrations in the machining process are reduced. The reduced vibration will prolong the tool life of the PCBN insert and help to minimise tool life variation between cutting inserts.

High density metal toolholders are only available upon request as special tools

Comparisons between boring bars made from steel and Densimet show the effect the different materials have on hard turned surfaces in a boring operation. The stability of the boring bars were evaluated by machining bore lengths 3, 4 and 5 times the diameter of the boring bar. The effect of toolholder clamping was also measured by using a traditional six-bolt system and a hydraulic collet system. The test piece for the machining experiment was a bearing ring and the test was performed in a traditional CNC-lathe. The RNGN090300S style insert was selected for the test, in order to generate high radial forces.

Cutting data:
Cutting speed (v_c) 120 m/min
Feed rate (f) 0,20 mm/rev
D.O.C (a_p) 0,1 and 0,5 mm

Boring bar:
S40T-CRSNL 09,
Steel & High density material
Insert: RNGN090300S, CBN100

Coolant:
None

Workpiece:
Bearing ring made from 100Cr6 and the structure is bainitic with a hardness of 57-61 HRC

Results

Quite clearly using high-density material and a more rigid clamping system will improve the surface created in hard turning.

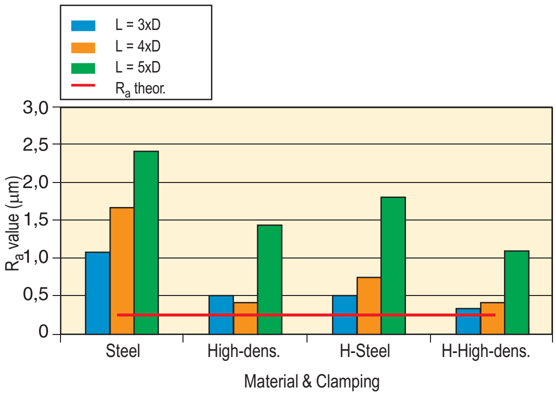
The practical tests show that only a combination with small length/diameter relationship, high-density material and a hydraulic clamping (H) makes it possible to reach the theoretical Ra value.

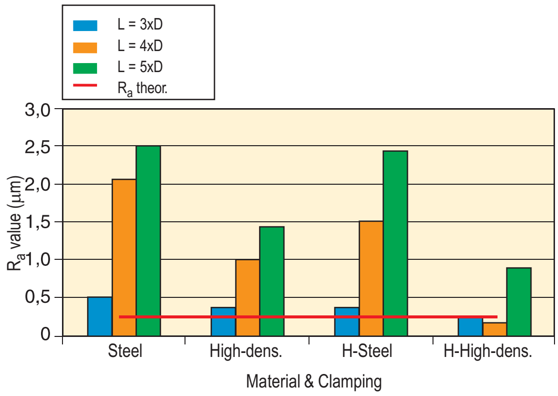
The theoretical value for Ra can be calculated as:

$$R_a, \text{theor} = \frac{f^2 \cdot 32}{r_\varepsilon} \ (\mu m)$$

The chosen cutting parameters of f 0,2 mm/rev and r_ε 4,5 mm will give a theoretical R_a value of 0,284 µm.

Surface finish produced with different toolholder materials and clamping methods at a depth of cut of 0,1 mm (left) and 0,5 mm (right).





SECO

Advantages with toolholders made from high density material

- Up to 50% increase in tool life
- Reduced variation in tool life
- Reduction of noise level
- No vibrations
- Excellent surface finish
- Increased tool life
- Improved capability

The table shows the properties of steel and a typical high density material, Densimet.

	Densimet	Steel
Young's modulus, GPa	320–340	206
Thermal expansion, 10^{-6}/K	6,0	11,5
Thermal conductivity, W/m/K	80	45
Density, g/cm^3	17	7,8
Hardness, HV	280–330	450
Tensile strength, MPa	700–950	1 450

Young's modulus is high	→	Low deflection
Thermal expansion is low	→	Improved tolerance
Thermal conductivity is high	→	Conduct heat from the toolholder, uniform temperature
Density is high + PM structure	→	Damping is high and vibrations will be reduced

Specials

Seco’s extensive range of standard inserts will cover almost all applications. The range is developed based on years of application experience, and continues to expand with new additions. However, there are cases where special tooling solutions either have to be used, or would improve the process significantly. Special tooling can be as easy as adding a wiper to a standard insert, or be as complicated as designing a completely new milling cutter system for a specific application in a transfer line. Often seen examples of special tooling are combination tools, which reduces tool change time, tool travel and idling.

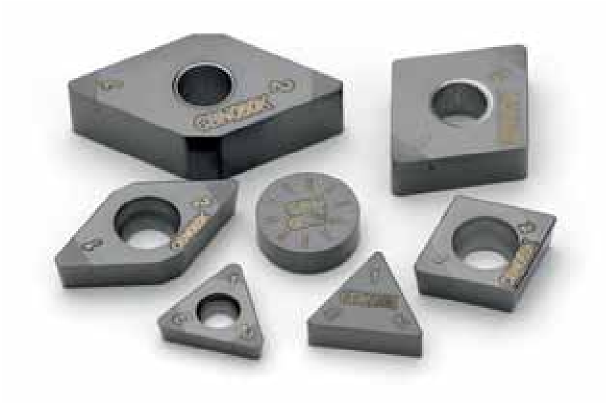
Seco has the ability to make inserts in almost any shape and size. Whether it is a different nose radius or a completely different shape, our custom design software or our specials department can handle the request.

A lot of specials can be found in the toolholder area. It is more and more common with combination toolholders, where several single toolholders are combined into one multi toolholder in order to reduce cycle time by reducing tool changes and tool travel. Machines are today made for complete machining in one setup, instead of multiple machines making one operation each, and part designs are getting more and more complicated. This development increases the need for special toolholders with improved reachability or where standard tooling has clearance issues, which have to be solved.

Although Seco’s range of milling cutters covers most standard applications, there are applications where a special design has to be applied. It can be a request for a closer pitch or where there are higher dimensional demands on angularity, flatness etc.


CBN060K

SECO



High productivity machining	Page

High productivity machining

General concept

With ever increasing demands from the industry for increased productivity, the term ”high productivity machining” is a concept which encompasses all aspects of the machining process. From the machining process itself, it covers the ability to machine at elevated speeds and feeds, and from a tooling supplier perspective, it covers the supply of a grade and the cutting edge profile/preparation necessary to achieve the desired increase in speeds, feeds and tool life which will reduce cycle time, reduce cost and increase productivity.

One way of increasing feed rate while maintaining surface finish is to use the wiper technology. Seco has taken a structured approach of combining grade and cutting edge wiper developments in order to give a product which allows the user to achieve increased cutting speeds and feed rates without compromising surface finish, tool life and accuracy.

High productivity machining can also mean to be open to changes to the machining method, in order to reduce machining time. Seco closely follows all developments in the area, and have for several years been working with plunging very successfully.

Obviously, there are factors working against ”high productivity machining” such as reduced tool life with an increase in cutting speed and loss of surface finish with increases in feed rate and these must be overcome in order to offer the benefits of high productivity machining.

Two industrial sectors where the demands for increased productivity are very strong are the automotive and bearing industries, where a lot of finish machining of hardened steels is carried out in a very competitive environment.

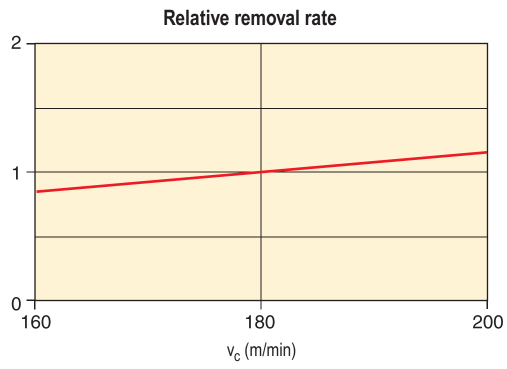
Cutting data

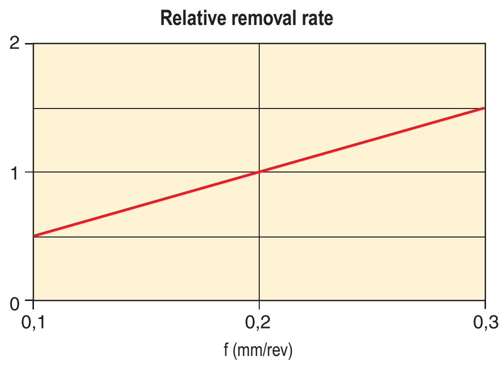
Metal removal rate is often used as a term to describe the amount of material being removed, and can be calculated as:

$$Q = f \cdot v_c \cdot a_p \ (cm^3/min)$$

Any increase in cutting data will increase the metal removal rate. The depth of cut is usually difficult to increase in a finish hard turning operation, which leaves speed and feed rate as the two remaining parameters. Increased cutting speed results in increased temperatures in the cutting zone, and will therefore increase tool wear and reduce tool life. The easiest way to increase the metal removal rate without affecting tool life too much is to increase the feed rate.

As a comparison, an increase in speed from 180 m/min to 200 m/min, which can be difficult to do with maintained tool life, will only increase the metal removal rate with 10%. An increase in feed rate from 0,2 mm/rev to 0,3 mm/rev will increase the metal removal rate with 50%.





The latest finish hard turning grades in the Secomax family, CBN050C / CBN160C / CBN060K, have been developed to run at cutting speeds as high as 250 m/min in finish machining of hardened steels. Having grades capable of running at high cutting speeds allows cycle times to be slightly reduced. However, while a high cutting speed grade covers one of the parameters responsible for productivity, the other, namely feed rate also needs to be addressed. In a finishing application, the feed rate is very often limited by the desired surface finish requirement.

High productivity machining

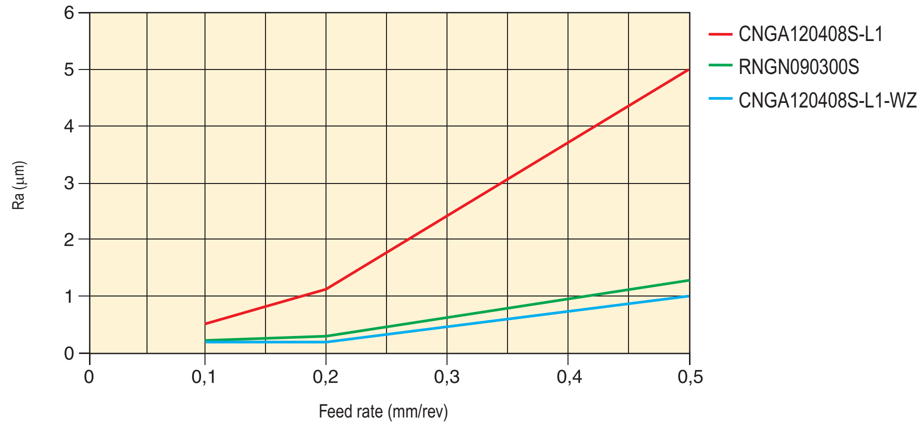
Wiper technology

When using a non wiper insert, the surface finish deteriorates rapidly with increased feed rate, and this is where the wiper technology can be successfully applied. The surface roughness in a turning operation is affected by several factors. Two of the most important are feed rate and size of the corner radius. A relation commonly used in the industry when choosing relevant cutting data regarding feed and surface finish is that R_a roughly can be said to increase with the square of the feed rate and decrease with increased size of the corner radius.

At least this was the case previous to the developed wiper geometries designed for high feed finishing, which is now gaining popularity in the metalworking industry. These wiper geometries change this relation by the capability to generate high surface finishes at relatively high feed rates. The feed rate can usually be increased up to 4 times while maintaining the same surface finish. The final result will always depend on the actual setup.

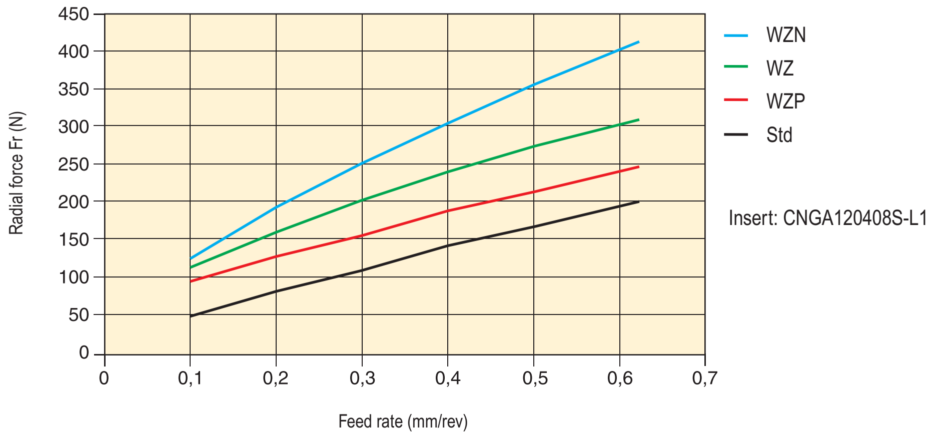
Seco can supply wiper geometries on most standard insert geometries, including specialized wiper geometries, like the Crossbill™ and Helix™ concepts.

Surface roughness



By adding a wiper, the contact length between the insert and workpiece is increased. This increase in contact length will increase the cutting forces acting on the insert, and this can cause vibrations in weak setups that will destroy the machined surface. If vibrations are a problem, Seco Helix wiper, the WZP, reduces cutting forces significantly compared to a standard wiper, allowing the feed rate to be kept at a high value, and maintaining the required surface finish.

Radial forces

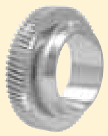


As in turning, wiper inserts are also available in milling. Seco's milling cutters designed specifically for PCBN are available for round, square or triangular inserts with standard nose radii. These cutters generate a very good surface finish, but they also have a special pocket position, where a wiper insert can be fitted that will improve the surface finish even more. Square and triangular inserts are also available with a wiper flat, for improved surface finish. Allowing for all positions in the cutter to work as wiper inserts.

High productivity machining

Plunging

The plunging method is a very cost effective way of machining components, where the machining time is reduced drastically. As an example, a gear wheel was ground on the taper OD, face and bore. By changing to PCBN turning, the cycle time was reduced from 31 seconds in grinding to 19 seconds with PCBN. This was further improved by applying plunging on the taper OD and face, and using wiper technology in the bore, which reduced the machining time to less than 5 seconds per component.

	**Operation**	**Grinding**	Time (sec)	**Turning**	Tme (sec)	**New methods**	Time (sec)
	Taper OD			Conventional	4,96	Plunging	0,04
	Face			Conventional	0,73	Plunging	0,04
	ID			Conventional	13,00	Wiper turning	4,33
	Total		31,00		18,69		4,41

Round inserts

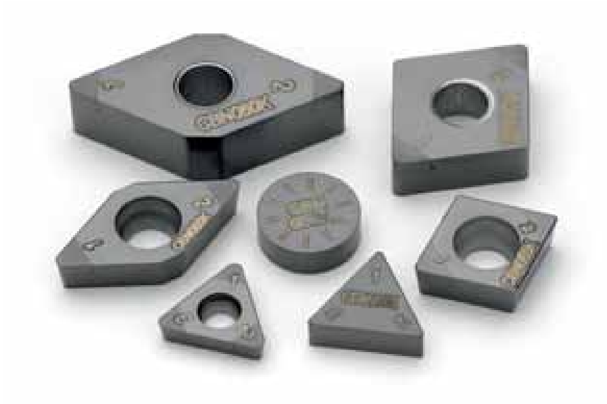
The large radius on round inserts allows for higher feed rates by acting as a type of wiper, and is an alternative to cornered High Feed (Wiper) inserts. An additional advantage of round inserts is the number of usable edges. Full-faced (sintered layer) or solid round inserts are indexed through rotating the insert around it's periphery, and offer more usable edges than any other insert shape.

Summary

By combining the high speed capabilities of CBN050C / CBN160C / CBN060K with the latest wiper technology, Seco offers unrivalled increases in cutting speed and feed rate. Alternative machining methods, like plunging, can drastically reduce machining times and increase productivity. The use of round inserts for finishing allows for increased feed rates without loosing surface finish. Round inserts also have the highest number of "corners" per insert.

These are all different ways Seco can offer the user significant improvements in productivity.

Advantages with PCBN



Advantages with PCBN

General

For years the machining of hard components was the domain of grinding. More recently other techniques such as PCBN, ceramic and electrical discharge machining (EDM) techniques have gained acceptance. However, PCBN machining is the only technique that offers the total flexibility of single point turning coupled with tolerances and surface finishes that are equal or better than after grinding. In addition PCBN offers cost and environmental benefits over grinding and the other machining techniques. These include process flexibility, where the use of CNC controls allows complex shapes to be machined with ease.

Reduced machining time (stock removal rates are generally higher), lower energy consumption, single point PCBN turning draws less power compared to multi-point grinding, optional use of coolant, coolant can add up to 15% to component costs (It is necessary when grinding but optional with PCBN machining) and finally ease of chip disposal, in grinding a slurry of coolant and fine metal is produced which is expensive to dispose of. With PCBN dry machining, chips can be easily disposed of or even recycled.

Rough turning of hard materials

PCBN was first used for roughing of hard materials, like abrasive hardened irons, and it was a very cost effective way of removing material compared to grinding. It also allowed components to be machined without tool change, which was a significant improvement when machining large components. Machining in these materials is almost completely done with PCBN today.

Turning of soft and abrasive materials

Later PCBN found its way into machining of soft and abrasive materials, namely grey cast iron. The significant increases in cutting data and tool life compared to carbide and ceramics quickly made PCBN an accepted and preferred tool material.

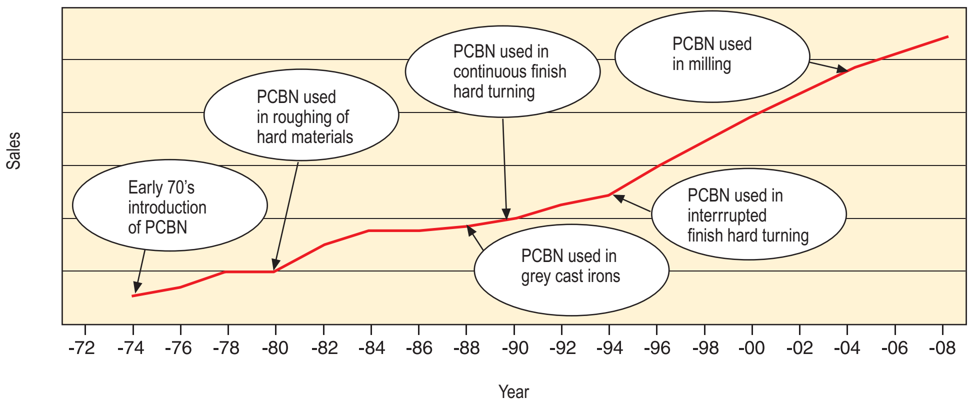
Continuous and interrupted finish hard turning

The major growth of PCBN started with hard turning replacing grinding of hardened steel components, and the advantages are well documented, and meet all the main trends through higher metal removal rate, a more flexible process and dry machining.

Successful interrupted machining proved to be difficult to achieve. The hardness of PCBN was the prerequisite for its growth, but that also meant that toughness was rather low. Extensive development increased the toughness of PCBN, and machining with PCBN can today compete with any other machining method in interrupted applications. Companies who were machining both continuous and interrupted and were reluctant to change could finally change to hard turning with maintained, or even improved component quality.

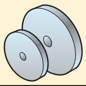
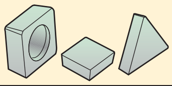
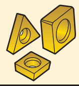
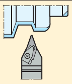
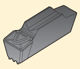
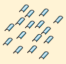
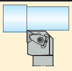
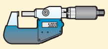
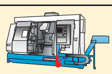
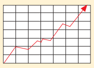
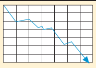
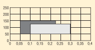
Milling

The latest area where PCBN has shown significant benefits is milling. Milling of grey cast iron with PCBN shows significant cost reductions through increased speed and tool lives compared to both carbides and ceramics. In milling of hard steels, the metal removal rates are much higher than in any grinding operation.



Advantages with PCBN

Advantages with PCBN in continuous machining

	Customer benefits with PCBN over:		
	Grinding 	Ceramics 	Tungsten carbide 
 **Process flexibility**	• The component profile is generated instead of formed • Programmable tool paths • Easy offset corrections		
 **Energy use**	• Reduced energy consumption, some studies show up to 20% reduction	• Reduced energy consumption	• Reduced energy consumption
 **Coolant – optional in continuous**	• Dry parts • Dry chips • No coolant cost, can be up to 15% of total manufacturing cost		
 **Tool inventory**	• Reduced tool inventory through programmable tool paths • Multi-purpose inserts, like MDT tools		
 **Metal removal rate**	• Faster metal removal rates • Reduced machining times	• Faster metal removal rates • Reduced machining times	• Faster metal removal rates • Reduced machining times
 **Chip control**	• Dry chips allows for easier and less costly recycling		• Dry chips allows for easier and less costly recycling
 **Surface finish**		• Improved surface finish through better edge quality	• Improved surface finish through better edge quality
 **Dimensional tolerance**		• Improved tolerances through better edge quality	• Improved dimensions and tolerances through less tool wear
 **Machine tool investment**	• Lathes and machining centers are less costly than grinding machines		
 **Edge toughness**		• Increased edge toughness • Increased process reliability	
 **Tool life**		• Increased tool life • Increased consistency	• Increased tool life
 **Idle/down time**		• Reduced idle time through less tool changes needed	• Reduced idle time through less tool changes needed
 **Working window**	• Larger working window	• Larger working window	• Much larger working window

Advantages with PCBN

Advantages with PCBN in interrupted machining (turning and milling)

	Customer benefits with PCBN over:		
	Grinding	**Ceramics**	**Tungsten carbide**
Process flexibility	• The component profile is generated instead of formed • Programmable tool paths • Easy offset corrections		
Energy use	• Reduced energy consumption, some studies show up to 20% reduction	• Reduced energy consumption	• Reduced energy consumption
Coolant – no coolant in interrupted	• Dry parts • Dry chips • No coolant cost, can be up to 15% of total manufacturing cost		
Tool inventory	• Reduced tool inventory through programmable tool paths • Multi-purpose inserts, like MDT tools		
Metal removal rate	• Faster metal removal rates • Reduced machining times	• Faster metal removal rates • Reduced machining times	• Faster metal removal rates • Reduced machining times
Chip control	• Dry chips allows for easier and less costly recycling		• Dry chips allows for easier and less costly recycling
Surface finish		• Improved surface finish through better edge quality	
Dimensional tolerance		• Improved tolerances through better edge quality	
Machine tool investment	• Lathes and machining centers are less costly than grinding machines		
Edge toughness		• Increased edge toughness • Increased process reliability	
Tool life		• Increased tool life • Increased consistency	• Increased tool life
Idle/down time		• Reduced idle time through less tool changes needed	• Reduced idle time through less tool changes needed
Working window	• Larger working window	• Larger working window	• Much larger working window

Advantages with PCBN

SECO

Performance comparisons

Below are a number of examples showing the advantages of PCBN over alternative machining methods. These examples demonstrate that PCBN offers advantages to mass producers as well as to the small batch producers.

PCBN versus grinding

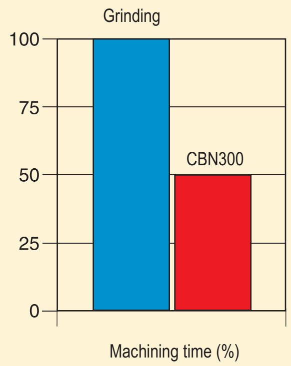
Machining: Slurry pumps

Workpiece

Component:	Slurry pump
Material:	Ni-Hard 2 (G-X260NiCr42)
Hardness:	52–58 HRC
Surface:	Rough

Conditions

Operation:	Facing and ID-Turning
Grade:	CBN300
Insert:	RNMN120300S
Cutting speed:	55–58 m/min
Feed rate:	0,25–0,40 mm/rev
Depth of cut:	0,5–3,0 mm
Coolant:	No



Result

Tool life:	180 minutes Machining time reduced with 50%

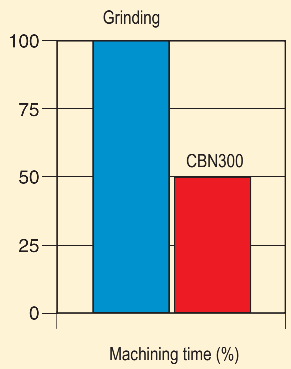
Machining: Pump impellers

Workpiece

Component:	Pump impeller
Material:	Ni-Hard
Hardness:	58–61 HRC
Surface:	Cast

Conditions

Operation:	Threading
Grade:	CBN300
Insert:	TNMN110304S
Cutting speed:	40 m/min
Thread pitch:	1,5 mm/rev
Infeed/pass:	0,1 mm
Coolant:	No



Result CBN300 Machining time 50% compared with grinding

Advantages with PCBN

SECO

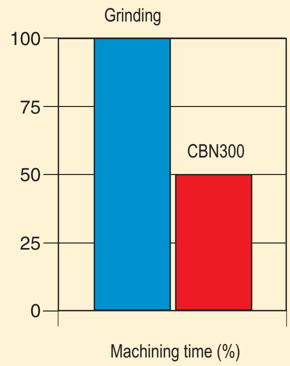
Machining: Working rolls

Workpiece

Component:	Working roll
Material:	Chilled cast iron
Hardness:	Hardened 78–88 shore C
Surface:	Rough

Conditions

Operation:	OD turning
Grade:	CBN300
Insert:	RNMN120300S
Cutting speed:	60 m/min
Feed rate:	0,6–0,8 mm/rev
Depth of cut:	2–4 mm
Coolant:	No



Result

Tool life:	100 minutes

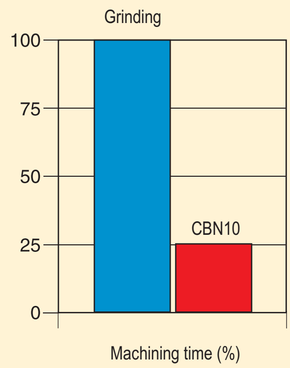
Machining: Turbine output clutches

Workpiece

Component:	Turbine output clutch gear
Material:	EN40B nitrided steel
Hardness:	60–62 HRC
Surface:	Pre-machined
Tolerance:	±0,02 mm

Conditions

Operation:	OD Finishing
Grade:	CBN10
Insert:	CNGA120408S-L0
Cutting speed:	200 m/min
Feed rate:	0,1 mm/rev
Depth of cut:	0,1 mm
Coolant:	No



Result CBN10 machining time = 15 minutes
Grinding time = 1 hour

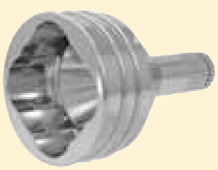
Machining: Constant velocity joints

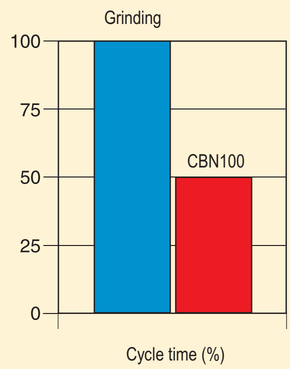
Workpiece

Component:	Constant velocity joint
Material:	Case hardened steel
Hardness:	60 HRC
Surface:	Forged

Conditions

Operation:	OD Turning
Grade:	CBN100
Insert:	TNGX110308S-WZ
Cutting speed:	180 m/min
Feed rate:	0,15 mm/rev
Depth of cut:	0,15 mm
Coolant:	No





Result CBN100 Wiper geometry improves productivity
Cycle time reduced by 40–50% compared with grinding

Advantages with PCBN

PCBN versus Tungsten carbide

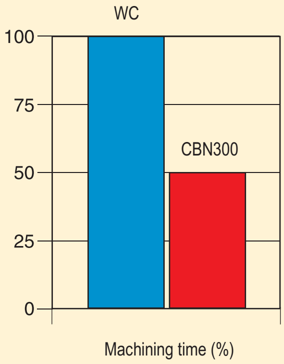
Machining: Crushing cones

Workpiece

Component: Crushing cone
Material: 12–20% Manganese steel
Hardness: 220–240 HBN
Surface: Rough casting

Conditions

Operation: Roughing, Finishing
Grade: CBN300/WC
Insert: RNMN120400S (WC = LNUX191940)
Cutting speed: 160–230 m/min (WC = 25–30 m/min)
Feed rate: 0,3–0,5 mm/rev (WC = 0,8–1,0 mm/rev)
Depth of cut: 2,5 mm
Coolant: No



Result CBN300 machining time half of that achieved with WC

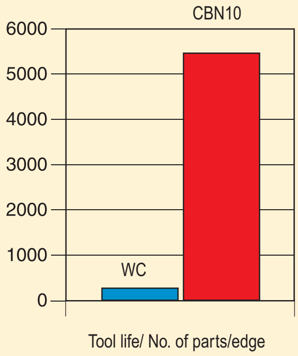
Machining: Sintered iron valve seats

Workpiece

Component: Valve seat
Material: Sintered Iron
Surface: Pre-machined

Conditions

Operation: Finishing
Grade: CBN10
Insert: CCMW060208E-L0
Cutting speed: 140 m/min
Feed rate: 0,1 mm/rev
Depth of cut: 0,3 mm
Coolant: Yes



Result

Tool life: CBN10 = 5 500 parts/edge
Carbide = 300 parts/edge

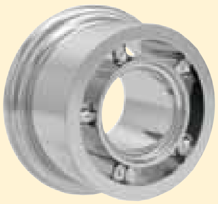
Machining: Inconel 718

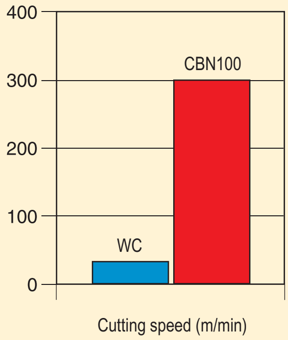
Workpiece

Component: Jet interduct
Material: Inconel 718
Hardness: 43 HRC
Surface: Cast

Conditions

Operation: Semi-finishing
Grade: CBN100
Insert: TNGN110308E25
Cutting speed: 300 m/min
Feed rate: 0,1 mm/rev
Depth of cut: 0,2 mm
Coolant: Yes





Result

Tool life: CBN100 = 12 minutes
WC = 34 seconds

Advantages with PCBN

Machining: Engine blocks

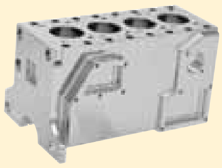
Workpiece

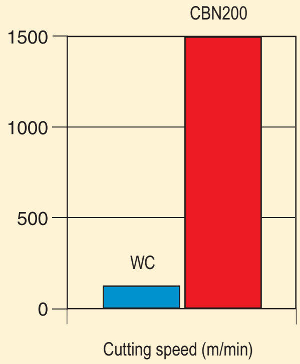
Component:	Engine block
Material:	GG25 (Pearlitic)
Hardness:	230 HBN
Surface:	Pre-machined

Conditions

Operation:	Face milling
Grade:	CBN200/WC
Insert:	SNMN090312S
Cutting speed:	1 500 m/min (WC = 150 m/min)
Feed rate:	0,15 mm/tooth (WC = 0,2 mm/tooth)
Depth of cut:	5 mm
Coolant:	No

Result 10 x greater cutting speed with CBN200
2 x greater feed speed with CBN200





Advantages with PCBN

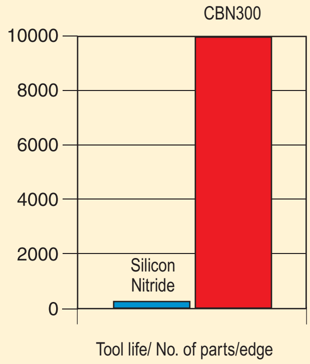
PCBN versus Ceramic

Machining: Cast iron brake discs

Workpiece
Component: Brake disc
Material: GG25 (Pearlitic)
Hardness: 230 HBN
Surface: Rough

Conditions
Operation: Roughing, disc plane side
Grade: CBN300/ Silicon nitride
Insert: CNMN120412S
Cutting speed: 1 100–850 m/min
(Silicon nitride 800–650 m/min)
Feed rate: 0,65 mm/rev
Depth of cut: 1–3 mm
Coolant: No

Result
Tool life: CBN300 = 10 000 parts/edge
Silicon nitride = 200 parts/edge

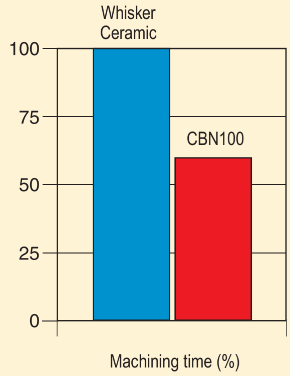


Machining: Inconel 718 combustion chamber bore

Workpiece
Component: Jet engine combustion chamber
Material: Inconel 718 forged blank
Hardness: 35 HRC
Surface: Pre-machined

Conditions
Operation: Semi-finishing
Grade: CBN100
Insert: TNGN110308E25
Cutting speed: 350 m/min
Feed rate: 0,25 mm/rev
Depth of cut: 0,5 mm
Coolant: Yes

Result CBN100 machining time = 6 minutes
Whisker Ceramic machining time = 10 minutes

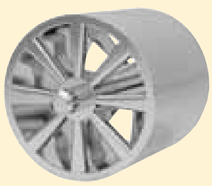


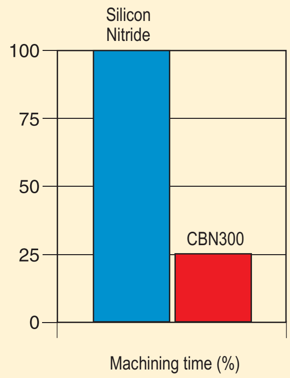
Machining: Yankie rolls

Workpiece
Component: Yankie roll
Material: GG40 Grey Cast Iron
Hardness: 225 HBN
Surface: Pre-machined

Conditions
Operation: Turning
Grade: CBN300
Insert: RNMN120300S
Cutting speed: 900 m/min
Feed rate: 1,0 mm/rev
Depth of cut: 0,5 mm
Coolant: No

Result CBN300 reduced machining time by 75% compared to silicon nitride





Advantages with PCBN

Seco PCA, Productivity and Cost Analysis

Today's manufacturing companies are facing ever increasing demands to increase throughput, improve productivity and increase profitability. One solution to meet these demands is to reduce costs and improve lead times.

Seco's extensive experience within the global metal cutting environment has lead to the development of a system that enables measurement, control and management of manufacturing processes.

The system is called PCA (Productivity and Cost Analysis). By using PCA, Seco takes a wider view of your manufacturing methods, focusing not only on the cost of tooling, but at the total cost of production. Using PCA, Seco can evaluate a single machine tool process or the complete path a workpiece takes through the manufacturing plant. The PCA software provides a comprehensive report with both process information such as tooling and cutting data, and cost information such as cost per part, output per hour, tool consumption and investment cost.

The following is a summary of a PCBN milling PCA.

Operation overview

Customer:	Company AB
Machine:	Horizontal machining centre
Workpiece:	Transmission case
Material:	Grey cast iron, GG30
Hardness:	220 HB
Operation:	Finish face milling
Production:	76 000 parts/year

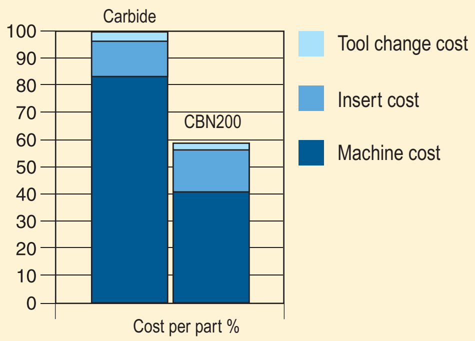
	PCBN	Carbide
Tools and cutting data		
Grade:	CBN200	Competitor Carbide
Insert:	SNMN090308S	
Holder/Cutter:	R220.74-8200-09-12	∅200 mm
No. of inserts:	12	16
Edges per insert:	8	6
Cutting speed:	1 463 m/min	152 m/min
Feed rate:	0,09 mm/tooth	0,28 mm/tooth
Feed speed:	2 514 mm/min	1 079 mm/min
Depth of cut:	0,25 mm	0,25 mm
Coolant:	No	No
Tool life criteria		
R_a:	<0,80 µm	<0,80 µm
Flatness:	<0,04 mm	<0,04 mm
Results		
Time-in-cut:	1,38 min/part	2,80 min/part
Metal removal rate (MRR):	33 cm³/min	16 cm³/min
Tool life:	828 min	560 min
Output per hour:	42 parts	20 parts
Tool wear type:	Flank wear	Chipping

Cost comparisons per part (%)

Machine cost:	50% vs carbide
Insert cost:	125% vs carbide
Tool change cost:	25% vs carbide
Total cost:	**57% vs carbide**

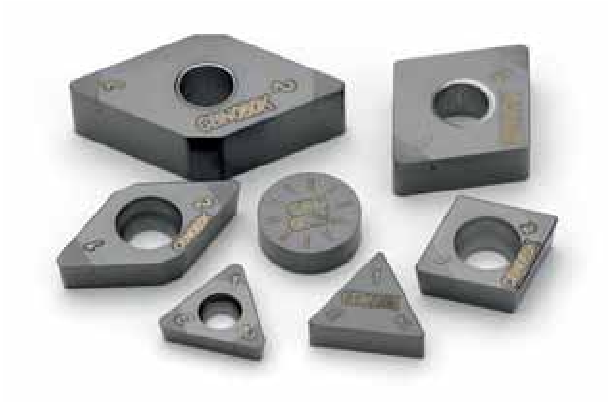
Comments: The main goals of surface roughness and flatness were achieved. Actual values R_a = 0,25 µm and flatness 0,013 mm.

The insert cost per part is higher, but through faster metal removal rate and longer tool life, the total manufacturing cost per part is significantly reduced.



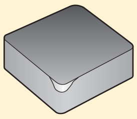
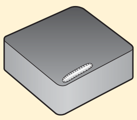
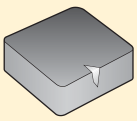
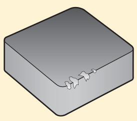
Useful information

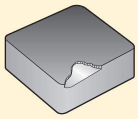
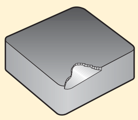
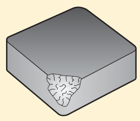
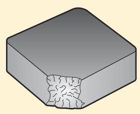
SECO



Troubleshooting

Cutting tool wear mechanisms are dependent on factors such as workpiece material, PCBN grade, machining parameters and conditions. There are however, certain actions that can be taken in order to minimise the effects of different types of wear modes and thereby improve tool life.

Excessive flank wear 	• Increase cutting speed • Increase feed rate • Increase depth of cut • Check cutting tool centre height • Check the ferrite content
Excessive crater wear 	• Reduce cutting speed • Reduce feed rate • Reduce chamfer angle • Use E edge condition • Use coated insert • Use coolant (continuous cut only)
Notch wear 	• Increase cutting speed • Reduce feed rate • Increase insert approach angle (preferably round inserts) • Vary the depth of cut • Use inserts with chamfered cutting edges
Edge chipping 	• Use inserts with a chamfered and honed cutting edge • Increase system rigidity • For interrupted cuts, chamfer the tool entry/exit slots and holes • Vary cutting speed to eliminate vibration

Rake face flaking (continuous cut) 	• Increase cutting speed • Reduce feed rate • Use chamfered and honed cutting edges • Check cutting tool centre height • Reduce insert approach angle
Rake face flaking (interrupted cut) 	• Do not use coolant • Use chamfered and honed cutting edges • Reduce feed rate • Increase cutting speed • Check cutting tool centre height • Reduce insert approach angle
Catastrophic edge breakage 	• Reduce depth of cut (reduce insert load) • Reduce cutting speed • Increase nose radius (ideally use round insert) • Use chamfered and honed inserts • Check cutting tool centre height
Insert breakage (solid PCBN) 	• Check insert seating and insert are clean • Check insert anvil has good support • Do not use worn anvils • Do not use worn clamps • Check cutting tool centre height

Note: The above assumes that correct machining parameters have been chosen.

House keeping – Solid PCBN

House keeping is a generic term for "best practices" for maximising the tool life of a PCBN insert. The major advantage of solid PCBN is multiple cutting edges, however, because solid PCBN does not have a WC backing to add support, extra care is required in order to eliminate the risk of premature failure by insert breakage. Below are some simple suggestions which can dramatically reduce that risk.

- Check that the anvil is not damaged. A worn or damaged anvil can lead to an unsupported insert increasing the risk of breakage during clamping or machining.
- Make sure the insert is pushed all the way back into the insert pocket. Extra insert overhang means the cutting edge is unsupported increasing the risk of breakage. In addition, lack of pocket support increases the risk of insert movement.
- Avoid using worn clamps and use toolholders designed for PCBN which have a large contact area between clamp and insert.
- Clean the top and bottom insert faces every time when indexing an insert. Rubbing with silicon carbide paper (emery cloth) will remove debris which often builds up during use, affecting insert flatness and therefore, support.
- Keep cutter and workpiece overhang to a minimum to avoid vibrations.
- Do not stop the machine in cut as this creates a high risk of breakage.

Remember, the time and cost of following the above recommendations is considerably lower than the cost of a replacement insert.

Useful information

SECO

Hardness values – Comparative table

Vickers	Brinell		Rockwell		Scleroscope	UTS
HV 10	HB 500	HB 3000	HRB	HRC	Shore C	R_m (N/mm^2)
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
–	–	–	–	–	–	–
70	53	–	0	–	–	–
80	61	–	20	–	–	–
90	72	–	39	–	–	–
100	82	–	50	–	–	–
110	95	108	60	–	–	–
120	107	121	68	–	–	–
130	114	130	72	–	–	–
140	122	140	76	–	–	–
150	129	148	80	–	–	–
160	135	157	82	3	24	525
170	140	163	84	5	25	550
180	148	172	87	7	27	580
190	156	182	90	9	28	615

Vickers	Brinell		Rockwell		Scleroscope	UTS
HV 10	HB 500	HB 3000	HRB	HRC	Shore C	R_m (N/mm^2)
200	161	193	92,0	11,0	30	655
210	162	201	93,0	13,0	31	675
220	172	208	95,0	16,0	32	700
230	179	215	96,0	19,0	33	730
240	185	224	97,0	21,0	35	760
250	200	237	99,0	22,0	36	800
260	–	248	101,0	24,0	37	835
270	–	257	102,0	26,0	38	860
280	–	265	103,5	28,0	40	895
290	–	275	104,5	29,0	41	930
300	–	284	105,0	30,0	42	960
310	–	293	106,0	31,0	43	995
320	–	303	107,0	32,0	45	1 020
330	–	313	108,0	33,0	46	1 060
340	–	322	109,0	34,5	47	1 090
350	–	332	109,5	35,5	48	1 120
360	–	341	110,5	37,0	50	1 155
370	–	351	111,0	38,0	51	1 185
380	–	360	111,0	39,0	52	1 210
390	–	370	112,0	40,0	54	1 240
400	–	379	112,0	41,0	55	1 270
410	–	389	113,0	42,0	56	1 310
420	–	398	113,0	43,0	57	1 340
430	–	405	114,0	44,0	58	1 370
440	–	415	115,0	45,0	60	1 400

Vickers	Brinell		Rockwell		Scleroscope	UTS
HV 10	HB 500	HB 3000	HRB	HRC	Shore C	R_m (N/mm^2)
450	–	424	115	45,0	61,0	1 440
460	–	433	115	46,0	62,0	1 470
470	–	442	116	47,0	63,0	1 490
480	–	451	116	48,0	64,0	1 510
490	–	460	117	49,0	65,0	1 540
500	–	470	117	49,0	66,0	1 570
510	–	479	117	50,0	67,0	1 595
520	–	488	118	51,0	68,0	1 620
530	–	498	118	52,0	68,0	1 650
540	–	508	118	52,0	69,0	1 680
550	–	517	119	52,5	70,0	1 720
560	–	527	119	53,0	71,0	1 760
570	–	536	119	54,0	72,0	1 800
580	–	546	119	54,0	72,5	1 840
590	–	555	120	55,0	73,0	1 870
600	–	565	–	55,5	74,0	1 900
610	–	574	–	56,0	75,0	1 935
620	–	583	–	57,0	75,5	1 960
630	–	592	–	57,0	76,0	1 990
640	–	602	–	58,0	77,0	2 030
650	–	612	–	58,0	78,0	2 060
660	–	621	–	58,0	79,0	2 090
670	–	630	–	59,0	79,0	2 120
680	–	640	–	59,0	90,0	2 150
690	–	649	–	60,0	81,0	2 190

Vickers	Brinell		Rockwell		Scleroscope	UTS
HV 10	HB 500	HB 3000	HRB	HRC	Shore C	R_m (N/mm^2)
700	–	657	–	60,0	82,0	2 215
710	–	663	–	60,0	82,5	2 235
720	–	670	–	61,0	83,0	2 260
730	–	677	–	61,5	83,5	2 295
740	–	684	–	62,0	84,5	2 330
750	–	691	–	62,0	85,0	2 360
760	–	698	–	62,5	86,0	2 400
770	–	703	–	63,0	86,5	2 430
780	–	710	–	63,5	87,0	2 460
790	–	717	–	64,0	87,5	2 490
800	–	722	–	64,0	88,0	2 520
810	–	727	–	64,5	88,5	2 550
820	–	732	–	65,0	89,5	2 580
830	–	738	–	65,0	90,5	2 620
840	–	–	–	65,0	91,0	2 655
850	–	–	–	65,5	91,5	2 690
860	–	–	–	66,0	91,5	2 730
870	–	–	–	66,0	92,0	2 770
880	–	–	–	66,5	93,0	2 800
890	–	–	–	66,5	94,0	2 830
900	–	–	–	67,0	95,0	2 860
910	–	–	–	67,5	95,5	2 890
920	–	–	–	67,5	96,0	2 930
930	–	–	–	68,0	96,5	2 970
940	–	–	–	68 ,0	97,0	3 000

R_m = Ultimate tensile strength
HV = Vickers hardness
HB = Brinell hardness
HRB = Rockwell hardness, B-scale
HRC = Rockwell hardness, C-scale
Shore C = Shore hardness

Useful information

SECO

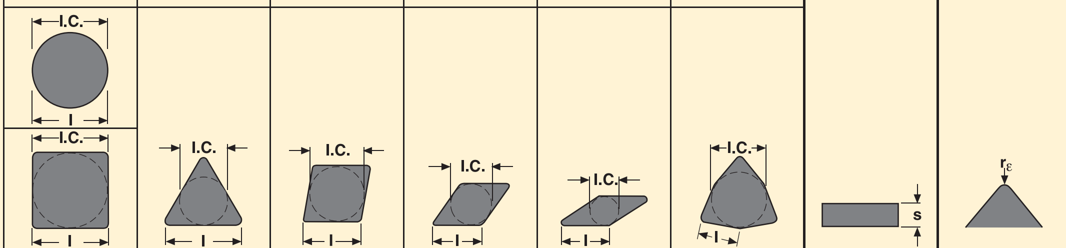
ANSI to ISO conversions

The following are conversion factors for ANSI and ISO units.

- **Dimensions**
  - 1 inch = 25,4 mm
  - 1 mm = 0.0393 inch
- **Tolerances**
  - 0.0001 inch = 1/10000 inch = 2,54 µm
  - 10 µm = 0.000393 inch = 3.93/10000 inch
- **Surface finishes**
  - 1 µm = 39.3 µin
  - 1 µin = 0,0254 µm
- **Pressures and stresses**
  - 1 bar = 0,1 MPa = 14.5 psi = 0,1 N/mm^2
  - 1 MPa = 145 psi = 1 N/mm2 = 10 bar
  - 1 psi = 0,0069 N/mm^2 = 0,069 bar = 0,0069 MPa
  - 1 N/mm^2 = 10 bar = 1 MPa = 145 psi
  - 1 ksi = 1000 psi
- **Torques**
  - 1 Nm = 0.738 ft-lbs = 8.851 in-lbs
  - 1 ft-lbs = 12 in-lbs = 1,355 Nm
  - 1 in-lbs = 0,112 Nm = 0.083 ft-lbs
- **Speeds**
  - 1 sfm = 0,3048 m/min
  - 1 m/min = 3.28 sfm
- **Feed rates**
  - 0,1 mm/rev = 0.00393 in/rev
  - 0.010 in/rev = 0,254 mm/rev

ANSI to ISO insert nomenclature conversions

The following table explains the ANSI and ISO insert nomenclature.



	1. Shape and size												2. Thickness		3. Radius	
	Round and square (R, S)		Triangle (T)		Rhomboid (C, D, V)						Trigon (W)					
					80°		55°		35°							
Ø	l	I.C.	l	I.C.	l	I.C.	l	I.C.	l	I.C.	l	I.C.	s	s	r_ε	r_ε
	ISO	ANSI	ISO	ANSI	ISO	ANSI	ISO	ANSI	ISO	ANSI	ISO	ANSI	ISO	ANSI	ISO	ANSI
5/32	03	1.2 (5)	06	1.2 (5)	03	1.2 (5)	04	1.2 (5)	–	–	–	–	01	1	00*	–
3/16	04	1.5 (6)	08	1.5 (6)	04	1.5 (6)	05	1.5 (6)	08	1.5 (6)	–	–	T1	1.2	M0**	–
7/32	05	1.8 (7)	09	1.8 (7)	05	1.8 (7)	06	1.8 (7)	09	1.8 (7)	03	1.8 (7)	02	1.5	01	0
1/4	06	2	11	2	06	2	07	2	11	2	04	2	03	2	02	0.5
5/16	07	2.5	13	2.5	08	2.5	09	2.5	13	2.5	05	2.5	T3	2.5	04	1
3/8	09	3	16	3	09	3	11	3	16	3	06	3	04	3	08	2
1/2	12	4	22	4	12	4	15	4	22	4	08	4	05	3.5	12	3
5/8	15	5	27	5	16	5	19	5	27	5	10	5	06	4	16	4
3/4	19	6	33	6	19	6	23	6	33	6	13	6	07	5	24	6
1	25	8	44	8	25	8	31	8	44	8	17	8	09	6	32	8
1 1/4	31	10	54	10	32	10	38	10	54	10	22	10	12	8	40	10

*Round inserts, inch size, no ANSI equivalent
**Round inserts, metric size, no ANSI equivalent

Examples:

ISO: RNMN120400
ANSI: RNMN43

ISO: TNMN220408
ANSI: TNMN432

ISO: DNMN150612
ANSI: DNMN443

ISO: CCGW09T308
ANSI: CCGW32.52

Useful information

SECO

Nomenclature and formulae in turning

RPM

$$n = \frac{v_c \cdot 1000}{\pi \cdot D_c} \quad \text{(rev/min)}$$

Cutting speed

$$v_c = \frac{n \cdot \pi \cdot D_c}{1000} \quad \text{(m/min)}$$

Metal removal rate

$$Q = v_c \cdot f \cdot a_p \quad \text{(cm}^3\text{/min)}$$

Power demand

$$P_c = \frac{v_c \cdot f \cdot a_p \cdot k_c}{60\,000\,000 \cdot \eta} \quad \text{(kW)}$$

$$k_c = \frac{1 - 0{,}01 \cdot \gamma_0}{h^{mc}} \cdot k_{c1.1} \quad \text{(N/mm}^2\text{)}$$

$$h = f \cdot \sin \kappa$$

Surface finish

$$\frac{1}{6} R_z \le R_a \le \frac{1}{3} R_z \quad (\mu\text{m})$$

$$R_t = \frac{f^2 \cdot 125}{r_\varepsilon} \quad (\mu\text{m})$$

a_p	= Depth of cut	(mm)
D_c	= Workpiece diameter	(mm)
f	= Feed/revolution	(mm/rev)
R_a	= Average profile depth	(μm)
v_c	= Cutting speed	(m/min)
r_ε	= Nose radius	(mm)
Q	= Metal removal rate	(cm³/min)
R_t	= Theoretical profile depth	(μm)
k_c, $k_{c1.1}$	= Specific cutting force*	(N/mm²)
η	= Efficiency	
P_c	= Power	(kW)
κ	= Setting angle	
h	= Chip thickness	(mm)
mc	= Exponent*	
γ_o	= Cutting rake angle	

Nomenclature and formulae in milling

RPM

$$n = \frac{v_c \cdot 1000}{\pi \cdot D_c} \quad \text{(rev/min)}$$

Cutting speed

$$v_c = \frac{n \cdot \pi \cdot D_c}{1000} \quad \text{(m/min)}$$

Feed speed

$$v_f = n \cdot z_n \cdot f_z \quad \text{(mm/min)}$$

Feed per tooth

$$f_z = \frac{v_f}{n \cdot z_n} \quad \text{(mm/tooth)}$$

Feed per revolution

$$f = z_n \cdot f_z \quad \text{(mm/rev)}$$

Metal removal rate

$$Q = \frac{a_e \cdot a_p \cdot v_f}{1000} \quad \text{(cm}^3\text{/min)}$$

Cutting speed and RPM for copying

$$v_c = \frac{n \cdot \pi \cdot D_w}{1000} \quad \text{(m/min)}$$

$$n = \frac{v_c \cdot 1000}{\pi \cdot D_w} \quad \text{(RPM)}$$

$$D_w = 2 \cdot \sqrt{a_p\,(D_c - a_p)} \quad \text{(mm)}$$

a_e	= Width of cut mm/radial depth of cut	(mm)
D_c	= Cutter diameter	(mm)
f_z	= Feed per tooth	(mm/tooth)
n	= RPM	(rev/min)
v_f	= Feed speed	(mm/min)
z_n	= Number of teeth	
D_w	= Mean diameter	(mm)

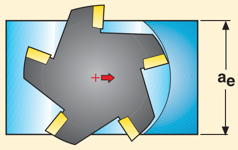
*For more detailed information see the Machining Navigator, Turning and Milling.

Power requirement in milling

Calculating the power demand

$$P_c = \frac{a_p \cdot a_e \cdot v_f}{60\ 000\ 000 \cdot \eta} \cdot k_c$$

P_c	= Power	(kW)
a_p	= Depth of cut	(mm)
a_e	= Width of cut	(mm)
v_f	= Feed speed	(mm/min)
η	= Efficiency	
k_c	= Cutting force per mm^2	



Calculating average chip thickness (h_m) and specific cutting force (k_c)

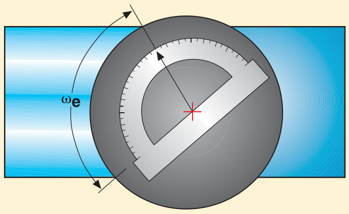
$$h_m = \frac{360 \cdot f_z \cdot a_e}{\pi \cdot D_c \cdot \omega_e} \cdot \sin\kappa$$

h_m	=	Average chip thickness	(mm)
f_z	=	Feed per tooth	(mm/tooth)
D_c	=	Cutter diameter	(mm)
ω_e	=	Engagement angle	
κ	=	Cutting edge angle	

$$k_c = \frac{1-0{,}01 \cdot \gamma_0}{h_m^{\ mc}} \cdot k_{c1.1}$$

γ_0	=	Effective rake angle (Rake angle of cutter + rake angle of insert)	
mc	=	Exponent*	
$k_{c1.1}$	=	Cutting force for 1 mm chip thickness*	(N/mm^2)

Engagement angle



Cutter position: Centre

Engagement a_e/D_c	Engagement angle ω_e
75%	97°
100%	180°

Cutter position: Off centre

Engagement a_e/D_c	Engagement angle ω_e
5%	26°
10%	37°
25%	60°

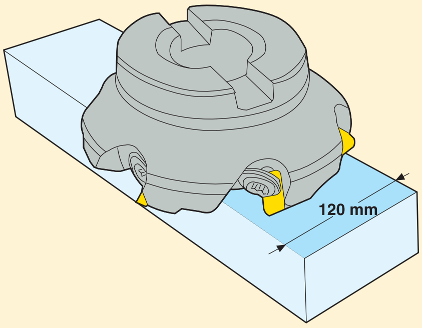
*For more detailed information see the Machining Navigator, Turning and Milling.

Power requirement example – Milling

Example

Calculate power demand for a face milling cutter:
R220.53-8160-12-10C
equipped with insert type:
SEEX1204AETN-MD13-LF, CBN200

Material group	= 12
Depth of cut a_p	= 0,5 mm
Width of cut a_e	= 120 mm
Cutter position	= centre
Feed per tooth f_z	= 0,15 mm/tooth
Cutting speed v_c	= 1 500 m/min



Step 1 calculate RPM and feed speed

See formula on page 84

No of teeth z = 10

Feed speed $v_f = 10 \cdot 0{,}15 \cdot 2\,984 = 4\,476$ mm/min

$$\text{Rev/min } n = \frac{1500 \cdot 1000}{\pi \cdot 160} = 2984 \text{ rpm}$$

Step 2 calculate average chip thickness, h_m

See formula on page 85

Cutting edge angle $\kappa = 45°$

$a_e/D = 120/160 = 75\%$ engagement angle $\omega_e = 97°$

$$\text{Average chip thickness } h_m = \frac{360 \cdot 0{,}15 \cdot 120}{\pi \cdot 160 \cdot 97} \cdot \sin 45° = 0{,}094 \text{ mm}$$

Step 3 calculate specific cutting force, k_c

Effective rake angle $\gamma_o = 10° + (-20°) = -10°$

$kc_{1.1}$-value = 1 500 N/mm²
mc-exponent = 0,25

$$\text{Specific cutting force } k_c = \frac{1 - 0{,}01 \cdot (-10)}{0{,}094^{0{,}25}} \cdot 1500 = 2128 \text{ N/mm}^2$$

Step 4 calculate power, P_c

See formula on page 85

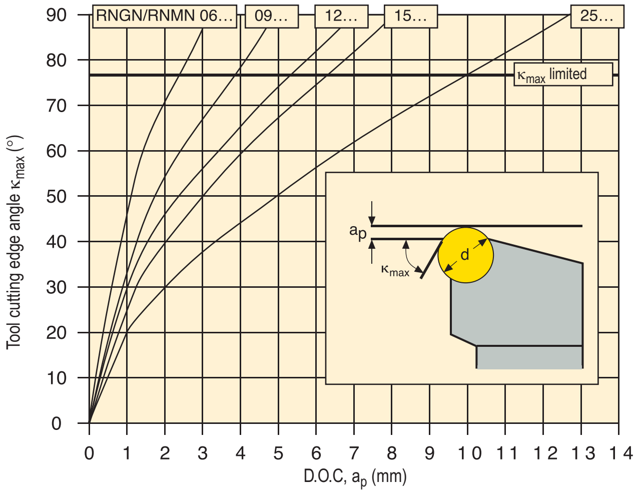
Efficiency $\eta = 80\%$

$$\text{Power } P_c = \frac{0{,}5 \cdot 120 \cdot 4476}{60\,000\,000 \cdot 0{,}80} \cdot 2128 = 11{,}9 \text{ kW}$$

Useful information

Maximum depth of cut recommendations

Round inserts



The setting angle is limited to 75° resulting in maximum depth of cut (a_p).

D.O.C. a_p (mm)	Number of usable cutting edges/side at 80% utilization		
	R...06	R...09	R...12
0,10	20	24	–
0,15	16	20	23
0,20	14	17	20
0,25	12	15	18
0,30	11	14	16
0,40	10	12	14
0,50	8	10	12
0,80	7	8	10
1,00	6	7	9
1,20	5	7	8
1,50	5	6	7
1,80	4	5	6
2,00	4	5	6
2,50	3	4	5
3,00	3	4	5
3,50	–	4	4
4,00	–	3	4
4,50	–	–	4
5,00	–	–	3

Type	Grade	Max. D.O.C. a_p (mm)
L0	CBN10 CBN200	0,3 0,5
L1	CBN050C CBN060K CBN10 CBN150 CBN160C CBN200	0,5 0,5 0,5 0,5 0,5 1,0
L2	CBN10	0,5
LF	CBN050C CBN060K CBN10 CBN150 CBN160C CBN200	0,5 0,5 0,5 0,5 0,5 30% of cutting edge length
Solid	CBN050C CBN060K CBN100 CBN300 CBN350 CBN400C	0,5 0,5 0,5 30% of cutting edge length 30% of cutting edge length 30% of cutting edge length

Useful information

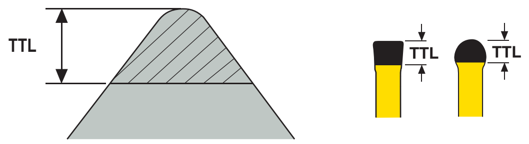
SECO

True tip length (TTL) in mm per nose radius (r_ε) and tip type

Insert shape	Nose angle	r_ε = 0,4 mm			r_ε = 0,8 mm			r_ε = 1,2 mm	
		L0	L1	L2	L0	L1	L2	L0	L1
C	80°	1,4	2,7	–	1,2	2,4	–	1,6	2,2
D	55°	2,1	3,2	–	1,6	2,7	–	1,2	2,2
S	90°	–	–	–	1,1	2,2	–	–	–
T	60°	1,7	2,6	–	1,3	2,2	–	0,9	1,8
V	35°	2,7	–	5,1	1,7	–	4,2	–	–

MDT size	..-LF	..M0-LF
LC..1303..	2,2	2,4
LC..1304..	2,2	2,4

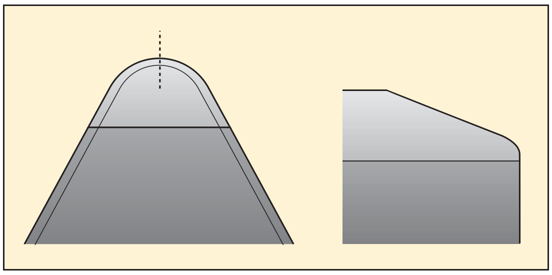
MDT size	..-LF	..M0-LF
LC..1603..	2,5	2,5
LC..1604..	2,5	3,1
LC..1605..	2,8	3,1
LC..1606..	3,2	3,7



Geometry recommendations

Strong cutting edge geometries are always preferred:
- Negative cutting geometry
- Chamfered cutting edge
- Large nose radius

Sharp positive cutting edge geometry can be advantageous when:
- Finishing of small hardened bores without interruptions
- Finishing of unstable components without interruptions
- Finishing of pearlitic grey cast iron



Standard edge preparation

E = Honed
E25 = Extra honed, intended for Nickel-based superalloys
S = Chamfered and honed
S25 = Chamfered and extra honed intended for PM material

WZ = High Feed (Wiper) geometry
WZP = High Feed (Wiper) geometry Positive
WZN = High Feed (Wiper) geometry Negative

Standard chamfer size and angle

Solid CBN inserts

CBN050C = 0,15 mm x 25°
CBN060K = 0,15 mm x 25°
CBN100 = 0,10 mm x 20°
CBN200 = 0,20 mm x 20°
CBN300 = 0,20 mm x 20°
CBN350 = 0,20 mm x 20°
CBN400C = 0,20 mm x 20°
S-04015 CBN300 = 0,40 mm x 15°
S-15020 CBN300 = 1,50 mm x 20°

Brazed CBN inserts CBN10, CBN200

L0 = 0,10 mm x 20°
L1 = 0,20 mm x 20° (L1-WZ = 0,10 mm x 20°)
L2 = 0,20 mm x 20°
LF = 0,20 mm x 20°
LF-MDT = 0,10 mm x 25°

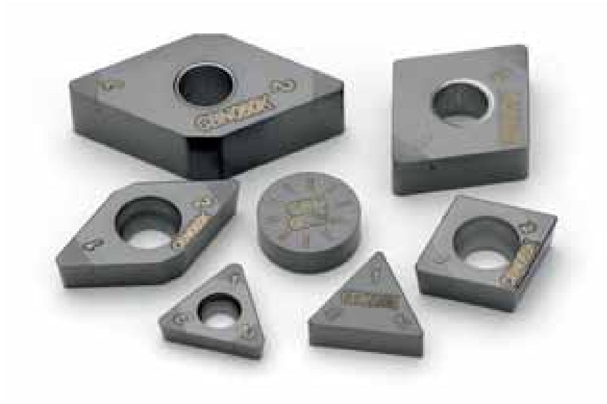
CBN150

L0 = 0,15 mm x 25°
(positive C-lock inserts, 0,10 mm x 20°)
L1 = 0,15 mm x 25°
LF = 0,15 mm x 25°

CBN050C, CBN160C, CBN060K

L1 = 0,15 mm x 25°
LF = 0,15 mm x 25°

Insert code keys

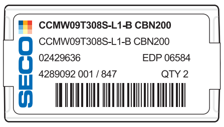


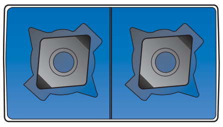
Insert code keys

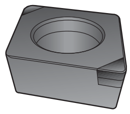
Insert code keys – Turning

SECO

Insert/Metric series, Extract from ISO 1832-2004

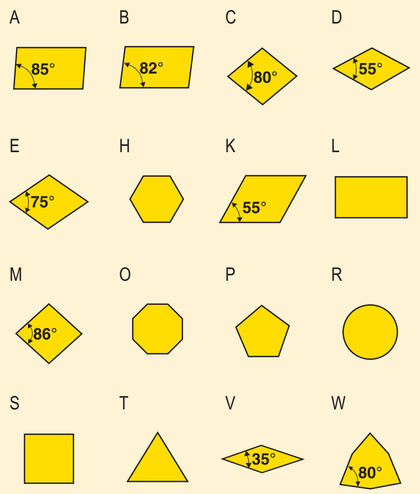




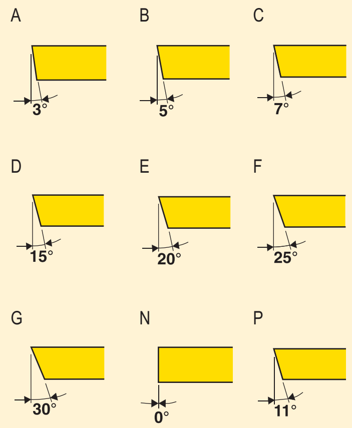


C	C	M	W	09	T3	08	S	-		-		-	L1	-		-	B
1	2	3	4	5	6	7	8		9		10		11		12		13

1. Insert shape



2. Normal clearance



O = Special

3. Tolerances

Tol.-class	Tolerance ± mm s	Tolerance ± mm d	3,175*	3,969	4,064	4,760	6,350	9,525	12,700	15,875	19,050	25,400	31,750	38,100
A	0,025	0,025	•			•	•	•	•	•	•	•	•	•
C	0,025	0,025	•	•	•	•	•	•	•	•	•	•	•	•
E	0,025	0,025	•			•	•	•	•	•	•	•	•	•
F	0,025	0,013	•			•	•	•	•	•	•	•	•	•
G	0,130	0,025	•			•	•	•	•	•	•	•	•	•
H	0,025	0,013	•			•	•	•	•	•	•	•	•	•
J	0,025	0,050	•			•	•	•						
	0,025	0,080							•					
	0,025	0,100								•	•			
	0,025	0,130										•		
	0,025	0,150											•	•
K	0,025	0,050	•			•	•	•						
	0,025	0,080							•					
	0,025	0,100								•	•			
	0,025	0,130										•		
	0,025	0,150											•	•
M	0,130	0,050	•			•	•	•						
	0,130	0,080							•					
	0,130	0,100								•	•			
	0,130	0,130										•		
	0,130	0,150											•	•
U	0,130	0,080	•			•	•	•						
	0,130	0,130							•					
	0,130	0,180								•	•			
	0,130	0,250										•	•	•

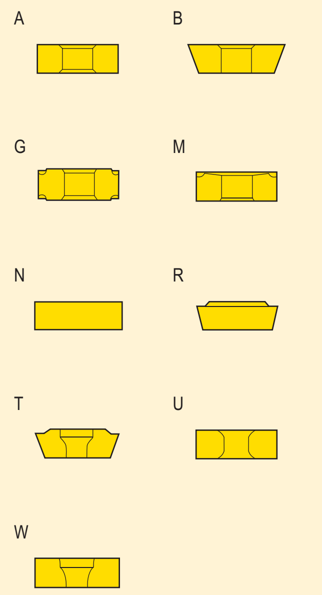
*not ISO

Insert code keys – Turning

SECO

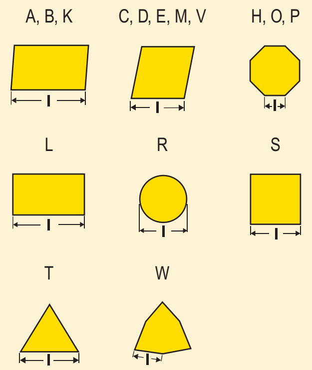
Inserts

4. Fixing and/or chipbreaker

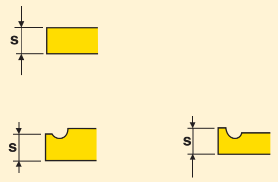


X = Special

5. Cutting edge length



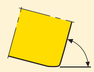
6. Thickness



01 = 1,59 mm
T1 = 1,98 mm
02 = 2,38 mm
03 = 3,18 mm
T3 = 3,97 mm

04 = 4,76 mm
05 = 5,56 mm
06 = 6,35 mm
07 = 7,94 mm
08 = 8,00 mm
09 = 9,52 mm

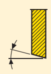
7. Corner configuration



1st letter

A = 45°
D = 60°
E = 75°
F = 85°
P = 90°

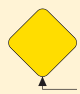
Z = Special



2nd letter

A = 3°
B = 5°
C = 7°
D = 15°
E = 20°
F = 25°
G = 30°
N = 0°
P = 11°

Z = Special

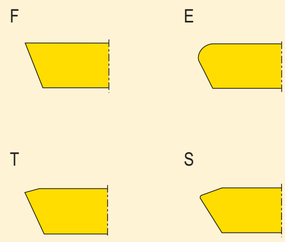


nose radius

M0* = round inserts
00 = sharp
01 = 0,1 mm
02 = 0,2 mm
04 = 0,4 mm
08 = 0,8 mm
12 = 1,2 mm
etc

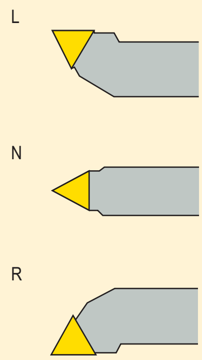
*Metric version

8. Cutting edge condition



Not mandatory information

9. Cutting direction



Not mandatory information

10. Internal designation

e.g. chipbreaker designation
F = Finishing
M = Medium
R = Roughing

e.g. edge designation
e.g. 01020=0,1 mm x 20°

11. Manufacturers option

Tip sizes:
L0
L1
L2
LF = full-face insert (sintered layer)

Not mandatory information

12. Internal designation

Turning
e.g. chipbreaker designation
F = Finishing
M = Medium
R = Roughing
WZ = Wiper (PCBN)
etc.

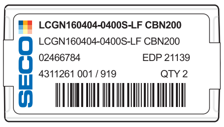
Not mandatory information

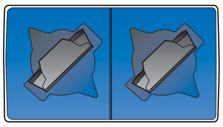
13. No. of tips

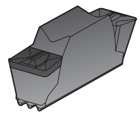
B = 2
C = 3
D = 4

Insert code keys – Turning

MDT Insert/Metric series







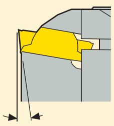
L	C	G	N	16	04	04	-		0400	S	-	LF
1	2	3	4	5	6	7		8	9	10		11

1. Shape

L

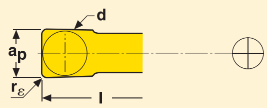
Rectangular

2. Front clearance angle



C = 7°

3. Tolerances



Tol. class	Tolerance ± mm				For insert width a_p mm				
	a_p	d	r_ε	l	3	4	5	6	8
G	0,025	0,025	0,025	0,040	•	•	•	•	•
M	0,050	0,050	0,050	0,080	•	•	•	•	•

4. Insert type

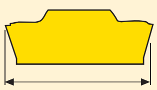
N

Single ended
without chipbreaker

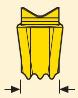
A

Double ended
without chipbreaker

5. Insert gauge length

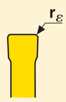


6. Insert gauge width



Seat size

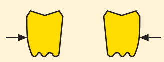
7. Corner radius



M0,00 = round
04 = 0,4 mm
08 = 0,8 mm

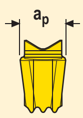
-A/G55 =
thread profile
-A/G60 =
thread profile
etc

8. Side clearance radius



L R

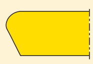
9. Insert width

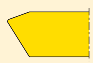


0300 = 3,0 mm
0400 = 4,0 mm
0500 = 5,0 mm
etc

10. Cutting edge condition

E S





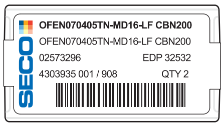
11. Insert type code

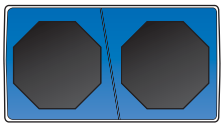
LF = full-face insert (sintered layer)

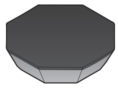
Insert code keys – Milling

Insert/Metric series, Extract from ISO 1832-2004

Dimensions refer to theoretical measurements. Nominal dimensions and tolerances on Seco inserts may differ from the table below. Actual tolerances for each insert type are shown in the insert section in the catalogue.

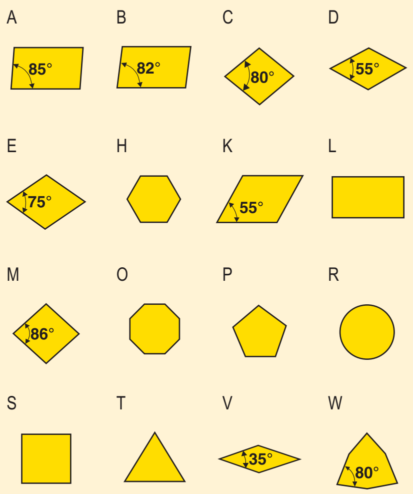




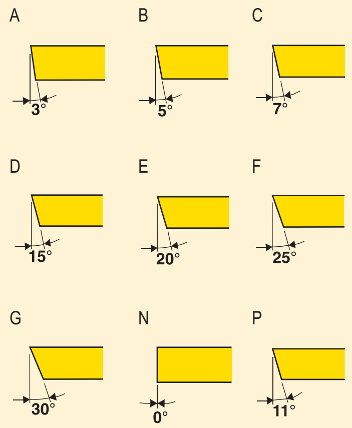


O	F	E	N	07	04	05	T	N	-	MD16	-	LF
1	2	3	4	5	6	7	8	9		10		11

1. Insert shape



2. Normal clearance



O = Special

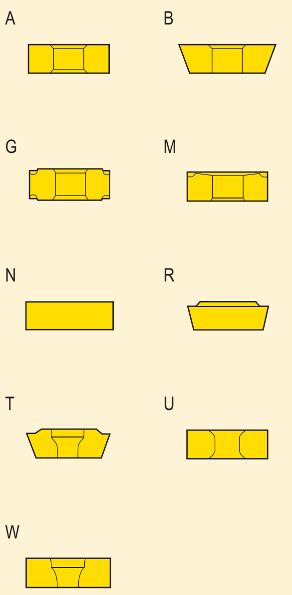
3. Tolerances

Tol.-class	Tolerance ± mm m	s	d	For d, dimension mm 3,175*	3,969	4,064	4,760	6,350	9,525	12,700	15,875	19,050	25,400	31,750	38,100
A	0,005	0,025	0,025	•			•	•	•	•	•	•	•	•	•
C	0,013	0,025	0,025	•	•	•	•	•	•	•	•	•	•	•	•
E	0,025	0,025	0,025	•			•	•	•	•	•	•	•	•	•
F	0,005	0,025	0,013	•			•	•	•	•	•	•	•	•	•
G	0,025	0,130	0,025	•			•	•	•	•	•	•	•	•	•
H	0,013	0,025	0,013	•			•	•	•	•	•	•	•	•	•
J	0,005	0,025	0,050	•			•	•	•						
	0,005	0,025	0,080							•					
	0,005	0,025	0,100								•	•			
	0,005	0,025	0,130										•		
	0,005	0,025	0,150											•	•
K	0,013	0,025	0,050	•			•	•	•						
	0,013	0,025	0,080							•					
	0,013	0,025	0,100								•	•			
	0,013	0,025	0,130										•		
	0,013	0,025	0,150											•	•
M	0,080	0,130	0,050	•			•	•	•						
	0,130	0,130	0,080							•					
	0,150	0,130	0,100								•	•			
	0,180	0,130	0,130										•		
	0,200	0,130	0,150											•	•
U	0,130	0,130	0,080	•			•	•	•						
	0,200	0,130	0,130							•					
	0,270	0,130	0,180								•	•			
	0,380	0,130	0,250										•	•	•

*not ISO

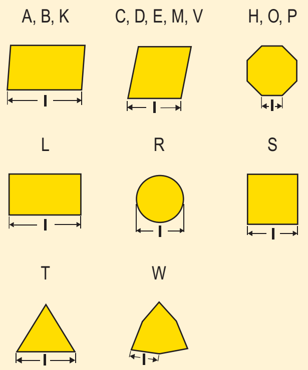
Inserts

4. Fixing and/or chipbreaker

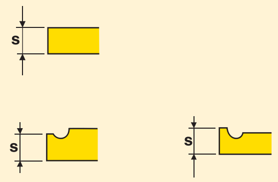


X = Special

5. Cutting edge length



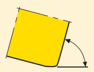
6. Thickness



01 = 1,59 mm
T1 = 1,98 mm
02 = 2,38 mm
03 = 3,18 mm
T3 = 3,97 mm

04 = 4,76 mm
05 = 5,56 mm
06 = 6,35 mm
07 = 7,94 mm
08 = 8,00 mm
09 = 9,52 mm

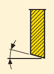
7. Corner configuration



1st letter

A = 45°
D = 60°
E = 75°
F = 85°
P = 90°

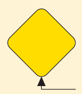
Z = Special



2nd letter

A = 3°
B = 5°
C = 7°
D = 15°
E = 20°
F = 25°
G = 30°
N = 0°
P = 11°

Z = Special

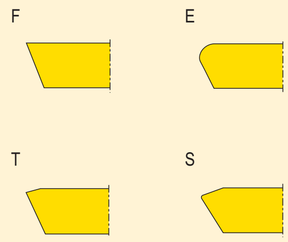


nose radius

M0* = round inserts
00 = sharp
01 = 0,1 mm
02 = 0,2 mm
04 = 0,4 mm
08 = 0,8 mm
12 = 1,2 mm
etc

*Metric version

8. Cutting edge condition

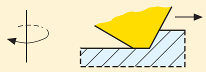


W = High feed insert

Not mandatory information

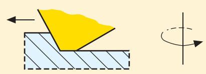
9. Direction of cutting

R



Right-rotated

L



Left-rotated

N

Neutral
(R- and L-rotated)

10. Internal designation

e.g. chipbreaker designation
F = Finishing
M = Medium
R = Roughing

11. Manufacturers option

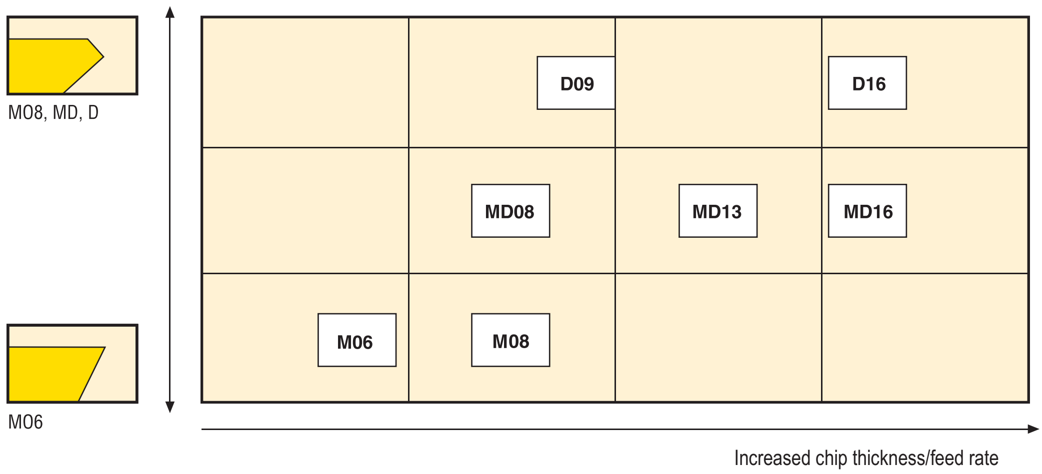
Tip sizes:
L0
L1
L2
LF = full-face insert (sintered layer)

Not mandatory information

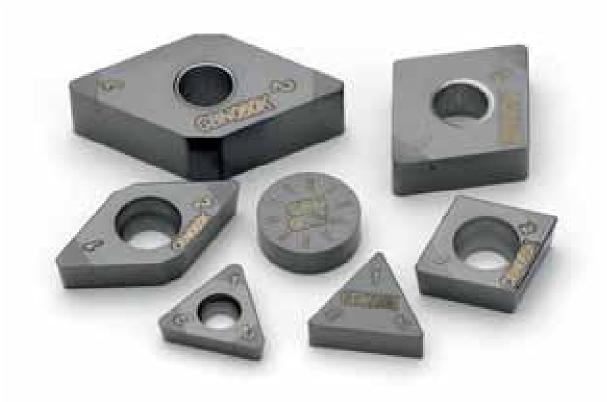
Insert code keys – Milling

Designation system

The Seco designation system for milling inserts has been developed to provide the user with better guidance concerning the fields of application for the various insert geometries.



Toolholders and Milling cutters



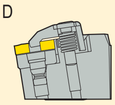
Toolholders and Milling cutters | **Page**

Turning toolholders

External

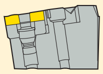
Insert clamping

D



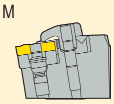
Clamp/inserts with centre hole

P



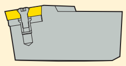
Pin/Wedge or lever

M



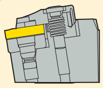
Pin/Clamp

S



Screw

C

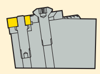


Clamp

Internal

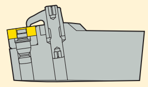
Insert clamping

P



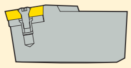
Pin/Wedge or lever

M



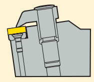
Pin/Clamp

S



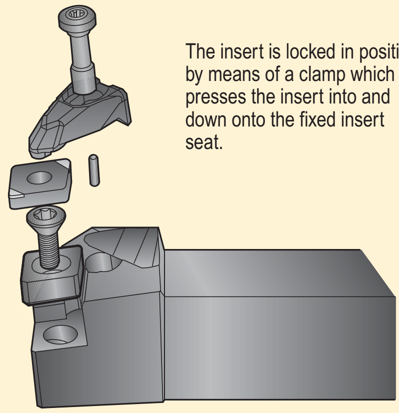
Screw

C



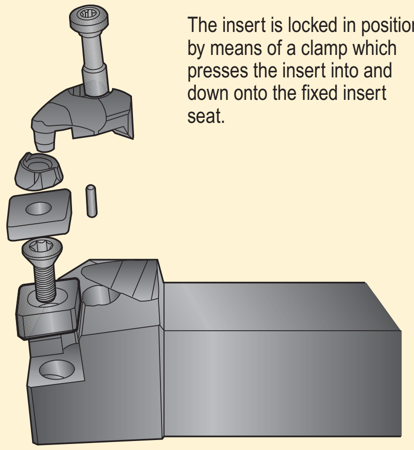
Clamp

D Toolholder
First choice for general machining, external
- For negative inserts with hole
- Robust, stable locking arrangement



The insert is locked in position by means of a clamp which presses the insert into and down onto the fixed insert seat.

D....-C Toolholder
- For negative solid inserts with hole
- With pin and carbide pressure pad

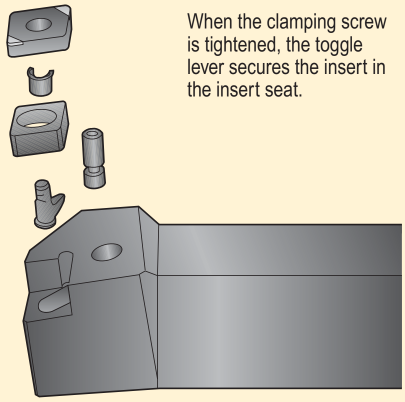


The insert is locked in position by means of a clamp which presses the insert into and down onto the fixed insert seat.

Toolholders and Milling cutters

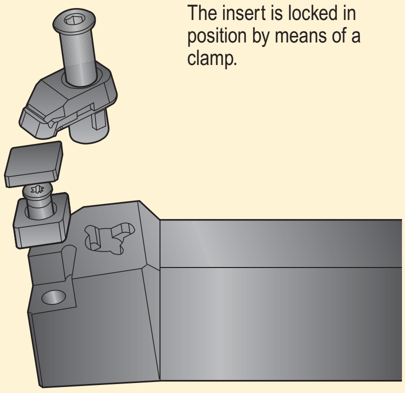
SECO

P Toolholder
A complement to the D toolholder, external
- For negative inserts with hole
- No clamp on the top, facilitates free chip flow



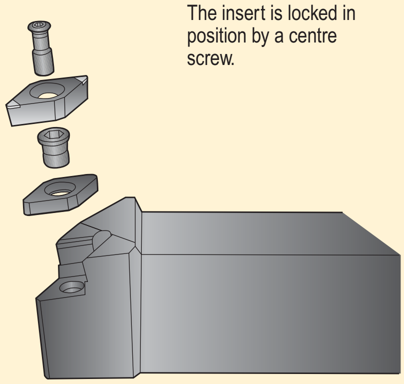
When the clamping screw is tightened, the toggle lever secures the insert in the insert seat.

C Toolholder
Designed mainly for Seco PCBN inserts without hole
- For negative inserts
- With carbide pressure pad



The insert is locked in position by means of a clamp.

S Toolholder
For external and internal turning with positive inserts
- Available as stocked item



The insert is locked in position by a centre screw.

Toolholders and Milling cutters

Selection of toolholders

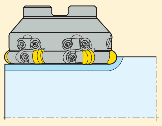
The following are recommendations on selecting the right toolholder depending on type of insert:

Type of inserts	First choice	Second choice
Tipped insert with cylindrical hole	D-style	M-style
Tipped insert with c-lock hole	S-style	
Full-faced (sintered layer) insert	C-style	
Full-faced (sintered layer) insert with cylindrical hole	D....-C-style	M-style
Full-faced (sintered layer) insert with c-lock hole	S-style	
Solid insert	C-style	
Solid insert with cylindrical hole	D....-C-style	M-style

Toolholders and Milling cutters

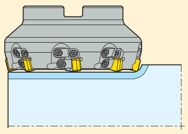
Face milling cutters

217/220.70-06/09



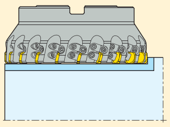
- Face milling cutter for roughing with high speed in cast iron materials
- Fixed pocket (06 size) or adjustable pocket seat (09 size), normal pitch
- Insert types RN..060300 or RN..09/SNEX12
- Insert size 06 or 09 mm

220.74-09



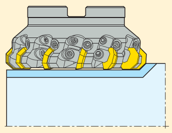
- Face milling cutter for finishing and roughing with high speed in cast iron materials
- Adjustable pocket seat, normal pitch
- Insert types SN..09/SNEX12
- Insert size 09 mm

220.30-12ST



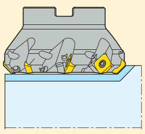
- Face milling cutter for finishing in cast iron materials
- Adjustable pocket seat, arbor or CAP mounting, super close pitch
- Insert types SEEX1203AFTN
- Insert size 12 mm

Octomill-07 220.43-07



- Versatile face milling cutter which can be used for many types of operations, in all materials
- Fixed pockets and cassettes, normal, coarse and close pitch
- Insert types OFE.070405
- Insert size 07 mm

QuattroMill-09/12 R217/220.53



- General purpose light cutting face milling cutter for mixed production in all materials
- Fixed pockets and cassettes, normal, coarse and close pitch
- Insert types SE.X09T3/1204
- Insert size 09/12 mm

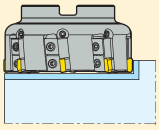
Toolholders and Milling cutters

SECO

Square shoulder cutters

R220.68-T11C/T16C

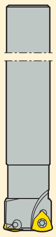
κ = 90°



- Cassette version – for triangular inserts
- Insert type TNGN1103/TNGN1604
- Insert size 11 or 16 mm

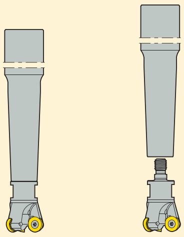
Copy milling

R217.21



- Cutter with 120° setting angle
- Insert type 218.19-100

R217/220.29-04/05



- Cutter with round positive inserts
- Inserts type RDHW08/10

SECO

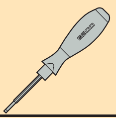
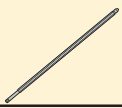
Clamp torque setting

The amount of clamping pressure applied to the insert during clamping is very important. While it must be adequate to hold the insert securely in position during machining, too much clamping pressure can result in stress cracking the insert. The following is a guide to recommended torque settings.

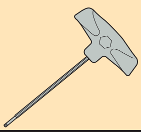
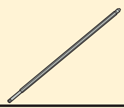
			Carbide backed	Solid	
Turning toolholder	Insert	Clamp/ screw	Max (Nm)	Low cBN = <65% Max (Nm)	High cBN = >65% Max (Nm)
C style	R06, S06, T11	CC17P-06	6,0	2,0	6,0
	C09, R09, S09, T16	CC17P-09	6,0	2,0	6,0
	C12, R12, S12	CC17P	6,0	–	6,0
	D11, V16	CC20P	6,0	–	6,0
S style	C06, D07, S06, T11, V11	C02506-T07P	0,9	0,9	0,9
	C09, D11, S09	C04008-T15P	3,5	3,5	3,5
	D11	C03510-T15P	3,0	3,0	3,0
D style	T16, W06	CD09-S09	2,0	2,0	2,0
	C12, D15, S12, W08	CD12-S12	3,5	3,5	3,5
	V16	CD19-V16	5,0	5,0	5,0
D....-C style	D11, W06	CC09P-D11	2,0	–	2,0
	V13	CC08P-V13	2,0	–	2,0
	S12, W08	CC12P-S12	3,5	–	3,5

			Carbide backed	Solid	
Miling cutter type	Insert	Screw	Max (Nm)	Low cBN ~50% (Nm)	High cBN >65% (Nm)
R220.70-06	R06	LD4012-T09P	1,5	1,5	1,5
R220.70-09	R09	LD06018T-T15P	3,5	3,0	3,5
R220.74-09	S09	LD06018T-T15P	3,5	3,0	3,5
R220.68-T11, T16	T11, T16	LD8020-T25P	6,0	–	6,0
R220.30	SE1203	LD8020-T25P	6,0	–	6,0
R220.43	OFEN07	C05013-T20P	6,0	–	6,0
R220.53-09	SE09T3	C03008-T09P	2,0	–	2,0
R220.53-12	SE1204	C04011-T15P	3,5	–	3,5
R220.29-04	R08	C05013-T20P	1,2	–	1,2
R220.29-05	R10	C05013-T20P	2,0	–	2,0
R217.21	218.19	C03508-T15P	1,2	–	1,2

Dynamomentic keys

Dynamomentic key* 	Replaceable blade 	Torque Plus size	Torque value
T00-06P05	T00-06P	T06P	0,5 Nm
T00-07P05	T00-07P	T07P	0,5 Nm
T00-07P09	T00-07P	T07P	0,9 Nm
T00-08P12	T00-08P	T08P	1,2 Nm
T00-09P09	T00-09P	T09P	0,9 Nm
T00-09P12	T00-09P	T09P	1,2 Nm
T00-09P20	T00-09P	T09P	2,0 Nm
T00-10P20	T00-10P	T10P	2,0 Nm
T00-10P30	T00-10P	T10P	3,0 Nm
T00-15P20	T00-15P	T15P	2,0 Nm
T00-15P30	T00-15P	T15P	3,0 Nm
T00-15P35	T00-15P	T15P	3,5 Nm
T00-15P50	T00-15P	T15P	5,0 Nm
T00-20P35	T00-20P	T20P	3,5 Nm
T00-20P50	T00-20P	T20P	5,0 Nm

*Including blade

Dynamomentic key* 	Replaceable blade 	Torque Plus size	Torque value
T00T-15P50	T00T-15P	T15P	5,0 Nm
T00T-20P50	T00T-20P	T20P	5,0 Nm
T00T-20P60	T00T-20P	T20P	6,0 Nm
T00T-20P80	T00T-20P	T20P	8,0 Nm
T00T-25P50	T00T-25P	T25P	5,0 Nm
T00T-25P60	T00T-25P	T25P	6,0 Nm
T00T-25P80	T00T-25P	T25P	8,0 Nm
T00T-30P80	T00T-30P	T30P	8,0 Nm

*Including blade

SECO

Pocket accuracy

The following are pocket accuracy specifications for fixed pocket cutters, and suggested tolerances for adjustable cassette style cutters.

- **Fixed pocket cutters**
  - Radially (fixed) max 30 µm
  - Axially (fixed) max 20 µm
- **Cassette cutters**
  - Radially (fixed) max 30 µm
  - Axially (adjustable) set within 10 µm

The wiper insert should be set 0,04–0,10 mm above the other inserts depending on workpiece material. The lower value for hard steels and the higher value for grey cast irons.

Milling cutter setting

Seco milling cutters essentially employ two methods for mounting the inserts. A cutter pocket solution where the insert is mounted directly in the cutter body or a cassette/cartridge system where the insert is mounted into a carrier which in turn is mounted to the cutter body.

All cassettes/cartridges and the majority of our cutter pocket cutters offer axial insert height adjustment.

Minimal axial run-out gives the following benefits:

- Improved surface finish. Depending on the material, surface finishes better than 2 µm R_a can be achieved.
- Improved tool life. All inserts have the same depth of cut which means all experience the same cutting load.
- Improved flatness.
- Reduced risk of insert chipping. Minimal axial run out means all inserts have the same workload.
- Reduced vibration.

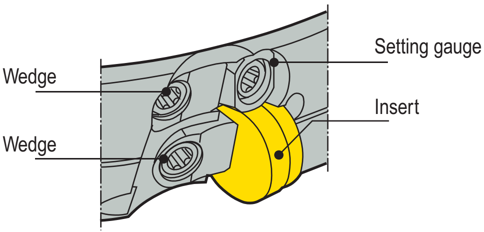
To get the full benefit of an adjustable pocket cutter, following the correct setting procedure is paramount.

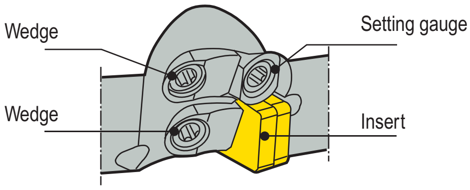
For fine adjustment of the inserts axial (Z axis) run out, a dedicated pre-setter is the most reliable and accurate method to employ. These are available in contact and non-contact form. The contact form uses some method of contact arm which is linked to an analogue of digital measuring device, usually a DTI (dial test indicator) or microcator. The more sophisticated non-contact presetters use optical (shadow graphs), camera or lasers and are often linked to computers which assist in the adjustment routine. A somewhat outdated but still effective method is to use a DTI (dial test indicator) or microcator, a suitable cutter toolholder block and a stable Diabase (stone) table.

All that is required is an accurate way to identify and measure the height difference between each insert when the cutter is rotated.

Toolholders and Milling cutters

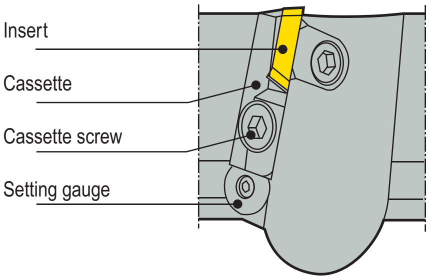
Setting of adjustable cutters – R220.70, R220.74





- Load all inserts in the required pockets. Tighten (clamp) each insert to the required torque insert setting (see page 103). Make sure all clamping/ adjustment screws are tight. If not all pockets are filled with inserts, then remove the adjustable components from the unused pockets to eliminate the risk of them coming loose during machining.
- Measure the axial run-out for each insert and record the results.
- Identify the insert or inserts which gave the largest axial dimension (most protruding) and set this measurement as the reference point. Adjust up the remaining inserts which are set below the same reference point.
- To adjust the insert pockets, first loosen the insert. Adjust the insert height by turning the setting gauge clockwise to move the insert up and away from the pocket and, if required, anti-clockwise to move the insert down or towards the pocket. Do not loosen the clamping element (wedge) during this procedure unless the required insert movement is in excess of 5 µm.
- An adjustment between the two marks on the scale on the adjustment key gives 5 µm axial adjustment (when changing direction of adjustment, care must be taken to eliminate backlash).
- Tighten (clamp) the inserts to the required torque setting and measure the axial run out again. Repeat procedure until run out is to the desired tolerance.
- For cutters with a wiper insert pocket, the wiper insert should be adjusted to be 40–100 µm above the other inserts.

Setting of adjustable cassette style cutters – R220.68, R220.30, R220.43, R220.53



- Load all inserts in the required pockets. Tighten (clamp) each insert to the required insert torque setting (see page 103 for torque setting recommendations). Set the adjustment wedges to their bottom position in the cutter and lightly clamp the cassette/ cartridge into its seat as shown in above. If not all pockets are filled with inserts, then remove the cassette/cartridges and adjustable components from the unused pockets to eliminate the risk of them coming loose in machining.
- Measure the axial run-out for each insert and record the results.
- Identify the insert or inserts which gave the largest axial dimension (most protruding) and set this measurement as the reference point. Adjust up the remaining inserts which are set below the same reference measurement by adjusting the cassette/cartridge.
- To adjust the cassette/cartridge use the required allen key and raise the cassette/cartridge to the desired height by turning the setting gauge screw at the base of the cassette/cartridge clockwise. Re-measure the axial run-out again and make any further adjustments necessary.
- Tighten the cassette/cartridge wedge screw and make a final axial dimension check.
- While fixed pocket cutters do not offer the same level of accuracy as adjustable pocket cutters, all Seco fixed pocket are designed with a maximum axial run-out of as little as 20 µm.


CBN060K

Material categories – Case hardened steels (55–62 HRC)

Case hardened steels (55–62 HRC)

Material introduction

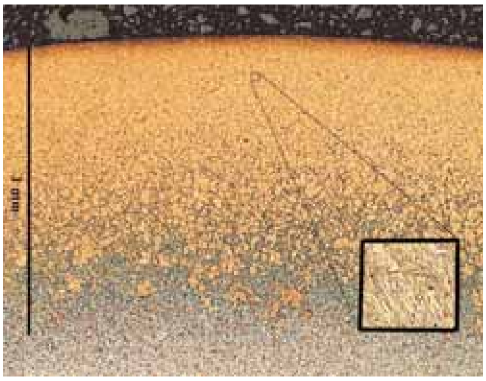
Common to all case hardened steels is the relatively low carbon content, which rarely exceeds 0,20%. This gives a soft-core material and if the case hardened part is exposed to high pressure the core might yield and the brittle surface would then be damaged. A higher content of carbon would lead to the effect of increased strength and reduced toughness of the core material.

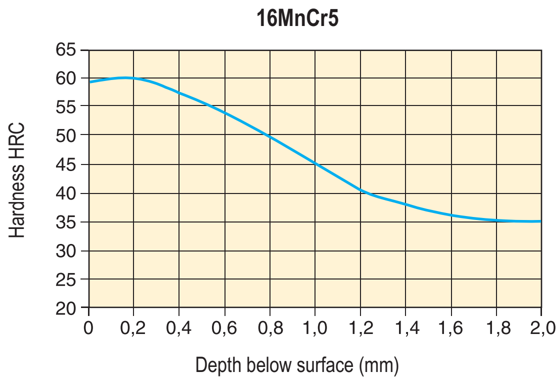
Alloying elements such as manganese, chromium, nickel and sometimes also molybdenum are used to improve the mechanical properties of the core material i.e. increasing both strength and toughness.

After shaping by soft machining the components are carburised (The carbon content is raised to <1.0% to a depth of <2.0 mm from the surface). The component is then hardened (quenched and tempered) to a surface hardness of about 60 HRC. The core material remains in a tough condition while the microstructure of the surface layer becomes martensitic or sometimes bainitic. Transformation of the microstructure into martensite or bainite at heat treatment leads to some deformation of the component and, therefore, it has to be finished after hardening.

Case hardened steel is used for its hard and wear resistant surface combined with a tough core able to endure alternate stresses on components like gear wheels, gear shafts, joints and bushes.

Typical case hardened steel microstructure and hardness profile





Examples of representative case hardening steels

Designation					Average composition (wt%)						
SAE	DIN	AFNOR	BS	SS	C	Si	Mn	S	Cr	Mo	Ni
1016	CK15	XC18	080M15	1370	0,15	0,30	0,75	–	–	–	–
8620	21 NiCrMo2	–	805M20	2506	0,21	<0,40	0,80	0,02	0,55	0,20	0,55
5115	16 MnCr5	16MC5	(527M20)	2511	0,16	<0,40	1,15	0,02	0,95	0,10	1,10
–	St52-3	20M5	150M19	2172	0,20	0,55	1,60	–	–	–	–
–	C45E	–	–	1672	0,47	0,25	0,60	–	–	–	–
–	25 CrMoS4	–	–	2225	0,26	0,25	0,62	0,03	1,05	0,20	–
–	42 CrMoS4	–	–	2244	0,42	0,25	0,75	0,03	1,05	0,20	–
4340	34 CrNiMo6	–	817M40	2541	0,34	0,40	0,65	0,03	1,50	0,23	1,50

Material categories – Case hardened steels (55–62 HRC)

Examples of typical case hardened steel components

- Gears
- Shafts
- Bearings
- Nozzles
- Bushes
- Clutch sleeves
- Constant velocity (CV) joints

Cutting tool grade selection

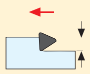
Roughing or finishing

In the machining of case hardened steels roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

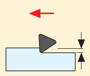
Preferred grade – Roughing (Depth of cut >0,5 mm)



D.O.C. 0,5–4,0 mm (Roughing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	N/A	N/A
	Milling	N/A	N/A

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)



D.O.C. <0,5 mm (Finishing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	**CBN060K** / CBN050C / CBN10/CBN100 / CBN150	**CBN160C** / CBN150
	Milling	N/A	**CBN200** / CBN160C
	Plunging	**CBN050C** / CBN160C / CBN10/CBN100 / CBN150	**CBN150** / CBN160C
	Threading	**CBN10/CBN100** / CBN150	N/A
	Grooving	**CBN10/CBN100** / CBN150	**CBN150** / CBN160C

Bold = First choice

Comment

Generally the machining of case hardened steel is classified as a finishing operation. For case hardened steels, it is unlikely that a roughing operation would be required as the case depth is typically not thicker than 0,5 mm.

Material categories – Case hardened steels (55–62 HRC)

SECO

Machining below the case

There may be occasions when there is a requirement to remove the entire hardened layer. If the hardened layer is more than 0,5 mm deep, then this would be identified as a roughing operation. If removal of the hardened layer is required then caution should be taken, as machining the soft core with PCBN will result in reduced tool life. For removing the case hardened layer low cBN content grades are recommended.

When machining beneath the case where the material is softer, the heat generated in the cutting zone will be lower and to reach the optimum cutting zone temperature, the cutting speed often have to be increased.

The temperature in the chips will also be lower, and instead of coming off red hot and easy to crumble, they will be much more tough and stringy. Inserts with “chip breakers” can improve chip breaking, or at least deflect the chip away from the newly cut area, and also curl the chip into tighter bundles.

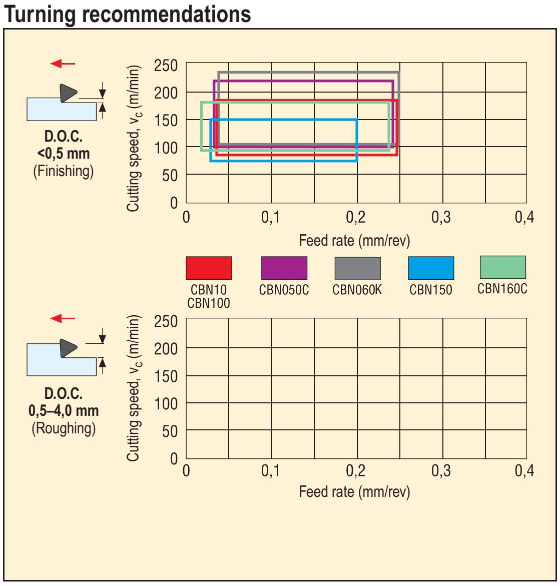
Material categories – Case hardened steels (55–62 HRC)

Parameter guide – Recommended machining conditions

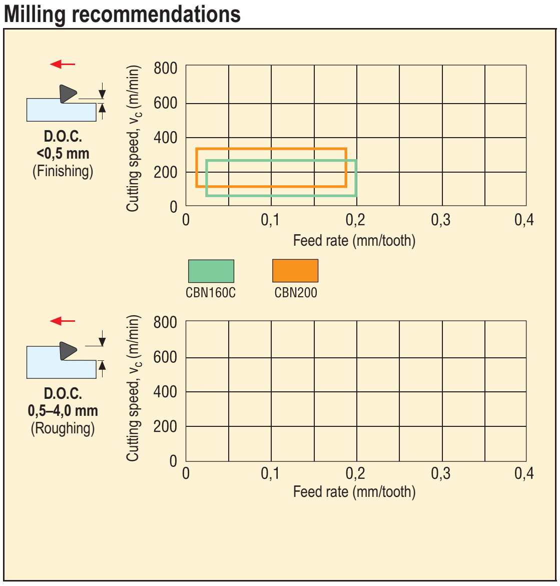
Case hardened steels (55–62 HRC)

The following charts show the recommended cutting data for case hardened steel applications.

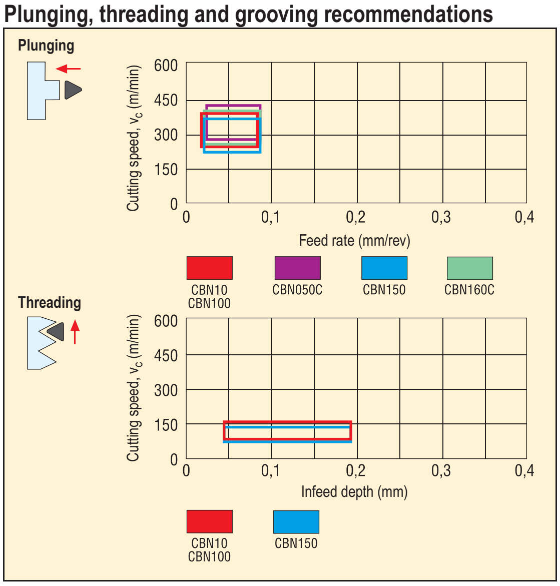
Turning recommendations

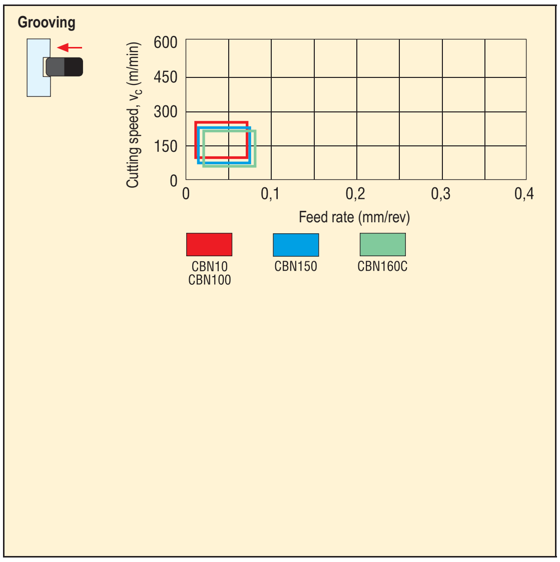


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Case hardened steels are not generally rough machined, and therefore data is not shown.

Material categories – Case hardened steels (55–62 HRC)

Tool geometry and edge preparation

Finishing machining
The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of case hardened steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

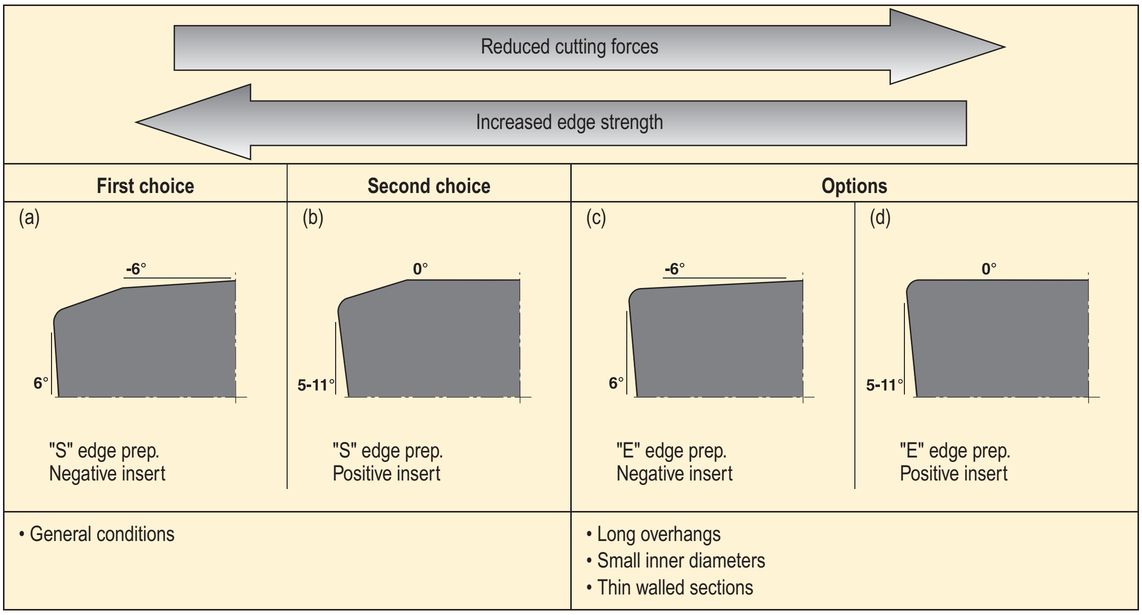
When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

Rough machining
Roughing is usually not done in case hardened steels.

Heavy interruptions and milling
In these operations, a negative rake angle combined with a chamfered and honed cutting edge (a) should always be used.



Troubleshooting for case hardened steels

In general case hardened steel is easily machined with excellent tool life. With case hardened steels it is important to make sure that machining is taking place in the hard case zone. Machining into the soft core will reduce PCBN performance. If machining through the case is necessary, then reduction in tool life should be taken into account.

For general troubleshooting recommendations, see page 80.

Material categories – Case hardened steels (55–62 HRC)

SECO

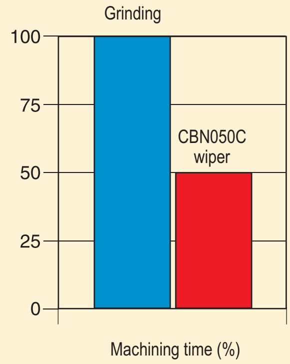
Application examples

Machining: Gear shafts

Workpiece
Component: Gear shaft
Material: Case hardened steel
Hardness: 58 HRC
Surface: Pre-machined

Conditions
Operation: OD turning
Grade: CBN050C
Insert: TNGX110304S-01525-WZ
Holder:
Cutting speed: 200 m/min
Feed rate: 0,30 mm/rev
Depth of cut: 0,10 mm
Coolant: No

Result
Machining time: Cycle time reduced by 50% compared to grinding
Machined in one setup

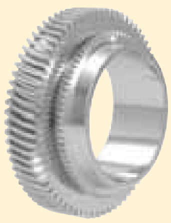


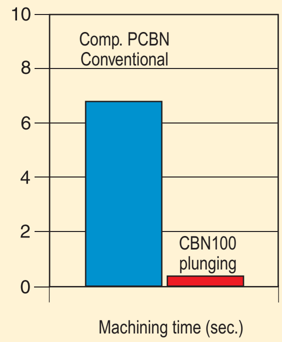
Machining: Syncromesh gears

Workpiece
Component: Syncromesh gear
Material: Case hardened steel
Hardness: 60 HRC
Surface: Pre-machined

Conditions
Operation: Plunging of OD taper
Grade: CBN100
Insert: TNGN110304E
Holder:
Cutting speed: 200 m/min
Feed rate: 0,04 mm/rev
Depth of cut: 0,15 mm
Coolant: No

Result
Machining time: CBN100 plunging time = 0,18 seconds
Competitor conventional turning = 6,9 seconds



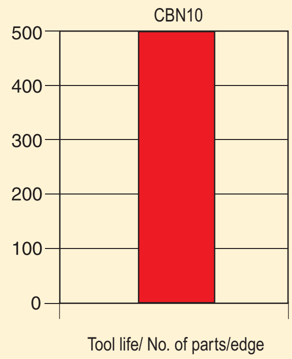


Machining: Clutch sleeves

Workpiece
Component: Clutch sleeve
Material: Case hardened steel
Hardness: 58 HRC
Surface: Pre-machined

Conditions
Operation: Plunging of two inner faces + the inner diameter
Grade: CBN10
Insert: LCGN3008 (special)
Holder:
Cutting speed: 160 m/min
Feed rate: 0,04 mm/rev
Depth of cut: 0,05–0,10 mm
Coolant: No

Result
Tool life: ~ 500 parts/edge



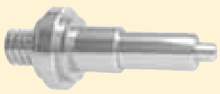
Material categories – Case hardened steels (55–62 HRC)

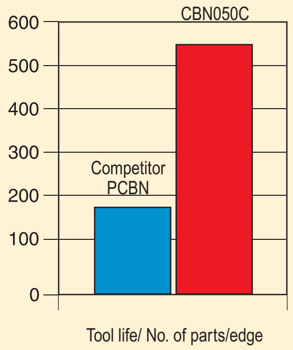
Machining: Shafts

Workpiece
Component: Shaft
Material: Case hardened steel
Hardness: 60 HRC
Surface: Black

Conditions
Operation: OD turning
Grade: CBN050C
Insert: DNGA150404S-01525-L1-B
Holder:
Cutting speed: 200 m/min
Feed rate: 0,04 mm/rev
Depth of cut: 0,12 mm
Coolant: No

Result
Tool life: CBN050C = 550 parts/edge
Competitor PCBN = 182 parts/edge



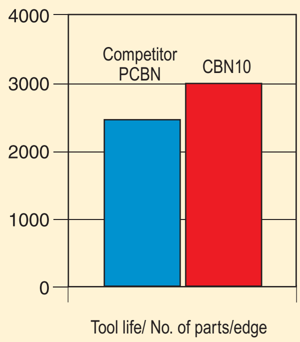


Machining: Rocker arms

Workpiece
Component: Rocker arm
Material: Case hardened steel (8620)
Hardness: 58–62 HRC
Surface: Forged

Conditions
Operation: ID turning
Grade: CBN10
Insert: TCGN060108S-01020-LF
Holder:
Cutting speed: 120 m/min
Feed rate: 0,10 mm/rev
Depth of cut: 0,15 mm
Coolant: No

Result
Tool life: CBN10 = 3 000 parts/edge
Competitor PCBN = 2 500 parts/edge

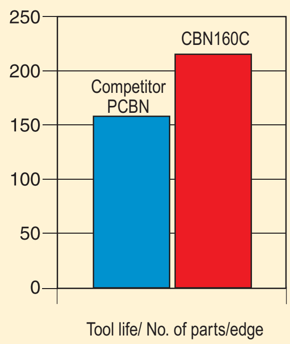


Machining: Ring gears

Workpiece
Component: Ring gear
Material: Case hardened steel (DIN16MnCr5)
Hardness: 58–62 HRC
Surface: Pre-machined

Conditions
Operation: Facing and ID turning
Grade: CBN160C
Insert: CNGA120412S-01525-L1-B
Holder:
Cutting speed: 95 m/min and 160 m/min
Feed rate: 0,25 mm/rev and 0,28 mm/rev
Depth of cut: 0,20 mm
Coolant: No

Result
Tool life: CBN160C = 220 parts/edge
Competitor = 130–200 parts/edge



Material categories – Case hardened steels (55–62 HRC)

SECO

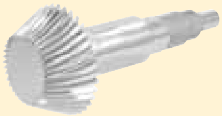
Machining: Pinion gears

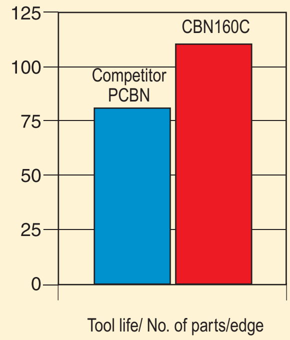
Workpiece

Component:	Pinion gear
Material:	Case hardened steel (DIN16MnCrS5)
Hardness:	58–62 HRC
Surface:	Pre-machined

Conditions

Operation:	Facing, interrupted
Grade:	CBN160C
Insert:	DNGA150608S-01525-L1-B
Holder:	
Cutting speed:	140 m/min
Feed rate:	0,14 mm/rev
Depth of cut:	0,30 mm/0,15 mm/0,01 mm (3 cuts)
Coolant:	No





Result

Tool life:	CBN160C = 110 parts/edge Competitor PCBN = 80 parts/edge

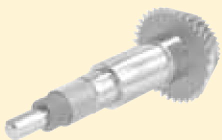
Machining: Pinion gears

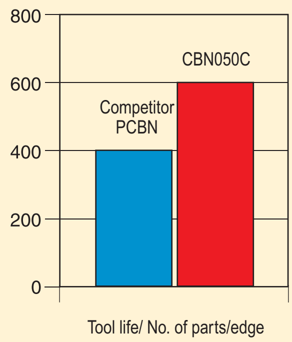
Workpiece

Component:	Pinion gear
Material:	Case hardened steel (DIN16MnCrS5)
Hardness:	60–62 HRC
Surface:	Pre-machined

Conditions

Operation:	OD turning
Grade:	CBN050C
Insert:	WNGA080412S-01525-L1-WZ-C
Holder:	
Cutting speed:	130 m/min
Feed rate:	0,20 mm/rev
Depth of cut:	0,15 mm
Coolant:	No





Result

Tool life:	CBN050C = 600 parts/edge Competitor PCBN = 400 parts/edge
Tool life criteria:	R_a max 0,8 µm

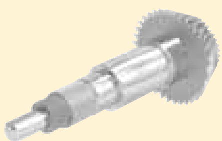
Machining: Pinion gears

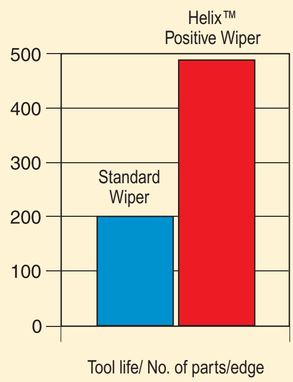
Workpiece

Component:	Pinion gear
Material:	Case hardened steel
Hardness:	55–60 HRC
Surface:	Pre-machined

Conditions

Operation:	OD turning
Grade:	CBN050C
Insert:	CNGA120408S-L1-WZP-B
Holder:	
Cutting speed:	200 m/min
Feed rate:	0,20 mm/rev
Depth of cut:	0,15 mm
Coolant:	Yes





Result

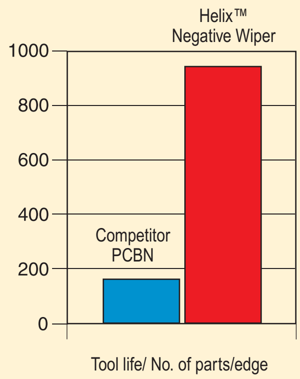
Tool life:	Standard wiper = 200 parts/edge Helix™ positive Wiper = 490 parts/edge

Material categories – Case hardened steels (55–62 HRC)

Machining: Clutch cylinders

Workpiece
Component: Clutch cylinder
Material: Case hardened steel (DIN16MnCr5)
Hardness: 60 HRC
Surface: Pre-machined

Conditions
Operation: OD turning and facing
Grade: CBN050C
Insert: DNGA150612S-L1-WZN-B
Holder:
Cutting speed: 160 m/min
Feed rate: 0,25 mm/rev
Depth of cut: 0,15 mm
Coolant: No

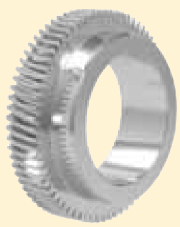


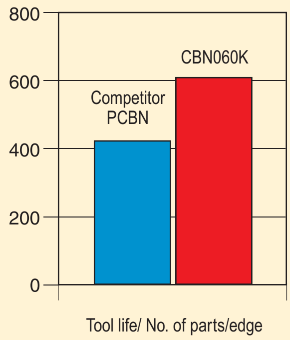
Result
Tool life: 5 times longer tool life compared to competitor

Machining: Gear wheels

Workpiece
Component: Gear wheel
Material: Case hardened steel
Hardness: 58–62 HRC
Surface: Black

Conditions
Operation: ID turning
Grade: CBN060K
Insert: CNGA120408S-01525-L1-WZ-B
Holder:
Cutting speed: 160 m/min
Feed rate: 0,30 mm/rev
Depth of cut: 0,15 mm
Coolant: No



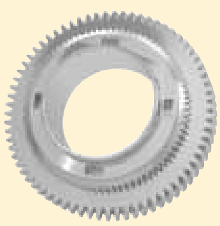


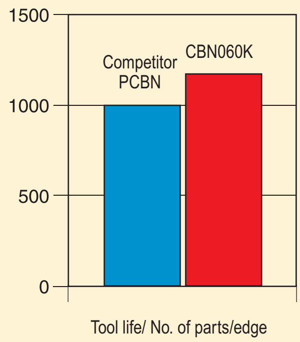
Result
Tool life: CBN060K = 607 parts/edge
Competitor PCBN = 425 parts/edge

Machining: Gear wheels

Workpiece
Component: Gear wheel
Material: Case hardened steel (DIN16MnCr5)
Hardness: 60 HRC
Surface: Black

Conditions
Operation: ID turning
Grade: CBN060K
Insert: TNGX110308S-01525-WZ
Holder:
Cutting speed: 180 m/min
Feed rate: 0,38 mm/rev
Depth of cut: 0,03 mm
Coolant: No





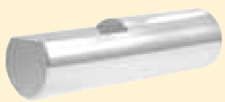
Result
Tool life: CBN060K = 1 200 parts/edge
Competitor PCBN = 1 000 parts/edge

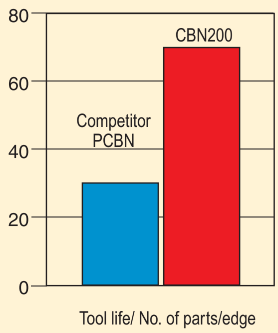
Material categories – Case hardened steels (55–62 HRC)

Machining: Machine shafts

Workpiece
Component: Shaft
Material: Case hardened steel
Hardness: 58–62 HRC
Surface: Pre-machined

Conditions
Operation: Face milling
Grade: CBN200
Insert: RNGN060300S-LF
Cutter: R217.70-2525.3-06-4
Cutting speed: 300 m/min
Feed rate: 0,10 mm/tooth = 1 527 mm/min
Depth of cut: 0,10 mm
Coolant: No



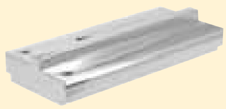


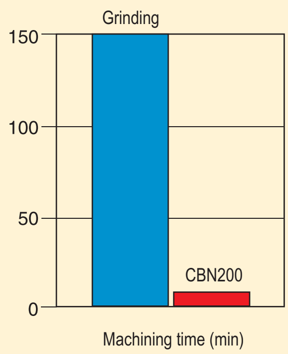
Result
Tool life: CBN200 = 70 parts/edge
Competitor PCBN = 30 parts/edge

Machining: Machine tool guides

Workpiece
Component: Machine tool guide
Material: Case hardened steel (C45)
Hardness: 60 HRC
Surface: Pre-machined

Conditions
Operation: Face milling
Grade: CBN200
Insert: SNEN0903ENS-M08
Cutter: R220.74-0063-09-6
Cutting speed: 280 m/min
Feed rate: 0,13 mm/tooth = 1 102 mm/min
Depth of cut: 0,30 mm + 0,20 mm (2 passes)
Coolant: No



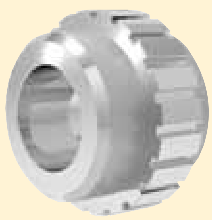


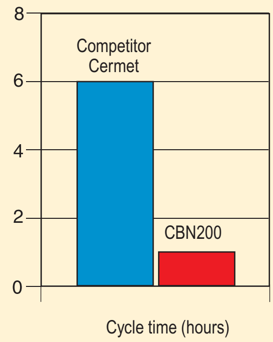
Result
Tool life: CBN200 = 40 minutes/edge
Grinding = 150 minutes machining time
CBN200 = 8 minutes machining time

Machining: Inducers

Workpiece
Component: Inducer
Material: Case hardened steel (8620)
Hardness: 55–57 HRC
Surface: Pre-machined

Conditions
Operation: Face milling of pads
Grade: CBN200
Insert: SNEN0903ENS-M08
Cutter: R220.74-0080-09-6
Cutting speed: 285 m/min
Feed rate: 0,075 mm/tooth = 511 mm/min
Depth of cut: 0,500 mm
Coolant: No





Result
Tool life: CBN200 = 8 hours machining time/edge
Cycle time reduced from 6 hours with cermet to one hour with PCBN

Material categories – Bearing steels (58–62 HRC)

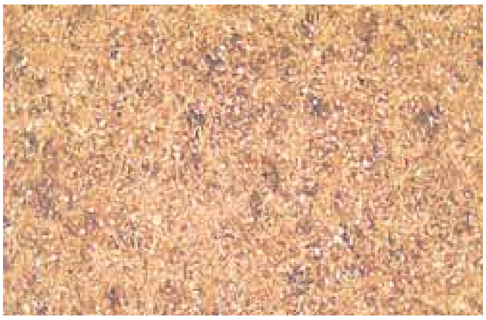
Bearing steels (58–62 HRC)

Material introduction

Bearing steels are slightly hyper eutectic with a carbon content of about 1%. The chromium content determines the hardness penetration properties. Characteristics for this type of steel are purity and a fine grain structure. Quenching gives a high surface hardness of >60 HRC. The microstructure is martensitic with embedded carbides.

The main requirements in bearing applications are resistance to alternating load and resistance to contact fatigue. This type of steel is also used for a variety of inexpensive small tools like taps and threading dies. The steel is then hardened and tempered to a bainitic microstructure with a hardness of about 60 HRC.

Typical bearing steel microstructure



Examples of representative bearing steels

Designation					Average composition (wt%)				
SAE	DIN	AFNOR	BS	SS	C	Cr	Mn	Mo	Si
52100	100Cr6	100C6	EN 31	2258	1,00	1,50	0,35	–	0,20
–	100Cr6Mo7	100CD7	–	–	1,00	1,50	0,70	0,30	0,20
50100	S 2-10-1-8	100C2	–	–	1,00	0,50	0,35	–	0,20

Comment

Bearing steels have high requirements on cleanliness, hardenability, wear resistance and fatigue strength. The cleanliness means low amounts of impurities; the most critical being oxygen, titanium and sulphur, which all reduce the fatigue properties of the final component.

Material categories – Bearing steels (58–62 HRC)

Examples of typical bearing steel components

- Bearing housings
- Roller bearings
- Fuel injector nozzles
- Ball bearings
- Hub units

Cutting tool grade selection

Roughing or finishing

In the machining of bearing steels roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C 0,5–4,0 mm (Roughing)	Turning	**CBN350** / CBN300 / CBN200	**CBN200** / CBN350
	Milling	N/A	**CBN200** / CBN350

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	Turning	**CBN10/CBN100** / CBN050C	**CBN150** / CBN160C
	Milling	N/A	**CBN200** / CBN150
	Plunging	**CBN10/CBN100** / CBN150	**CBN150**
	Threading	**CBN10/CBN100** / CBN150	N/A
	Grooving	**CBN10/CBN100** / CBN150	N/A

Bold = First choice

Comment

Both roughing and finishing of bearing steels are established operations. Due to the abrasiveness of the material, wear resistant grades should be used.

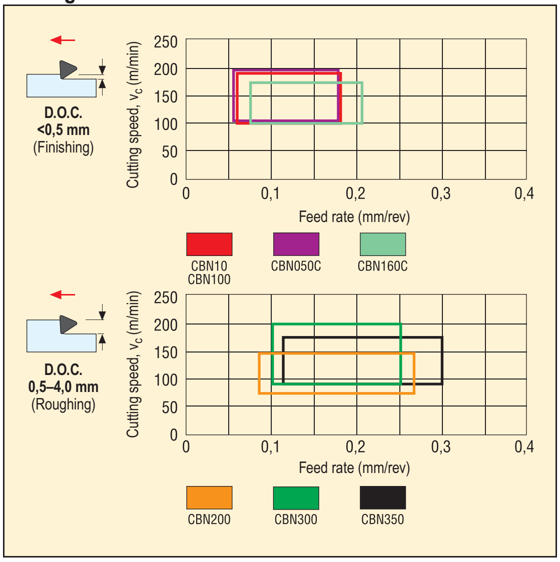
Material categories – Bearing steels (58–62 HRC)

Parameter guide – Recommended machining conditions

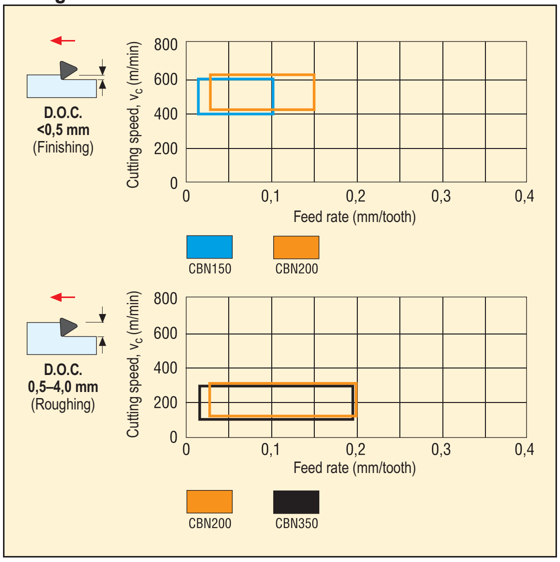
Bearing steels (58–62 HRC)

The following charts show the recommended cutting data for bearing steel applications.

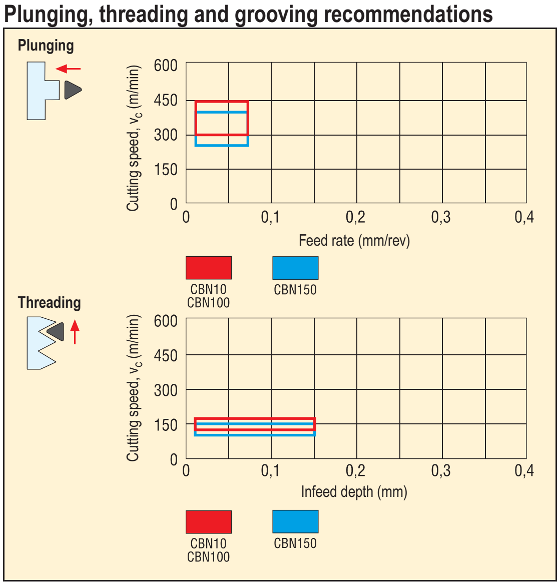
Turning recommendations

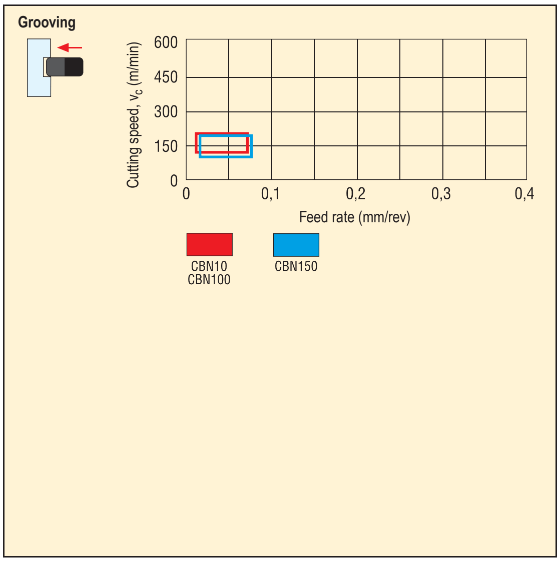


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Bearing steels (58–62 HRC)

SECO

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of bearing steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

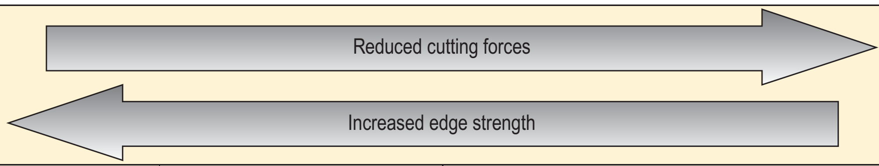
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

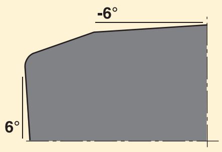
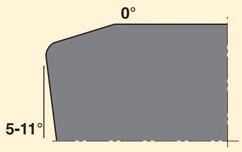
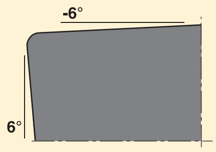
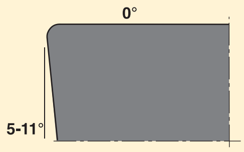
Rough machining

The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a), and provides a good balance between optimum edge stability and minimised cutting forces.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for bearing steels

Basic machining of bearing steels in the hardened condition is easily achieved using PCBN. Because of the wear characteristics of bearings steels they are generally more difficult to machine than, for example, 60 HRC case hardened steels.

Due to the high abrasion resistance characteristics of these materials crater wear can be the most dominant wear mode. To reduce crater wear cutting speeds should be reduced.

In roughing operations notching can occur if feed rates are too high. In this situation it is recommended to use a larger nose radius if it is not possible to reduce the feed rate.

Interrupted machining can cause premature failure of the cutting edge. In general it is recommended to increase the cutting speed and reduce the feed rate to improve tool performance. There are however some circumstances where tool life can be improved by reducing cutting speeds down to 80 m/min, for example in finishing operations where there are severe interruptions.

Surface integrity and residual stresses are important particularly on dynamically loaded surfaces. The machined surface can be affected by tool wear, on critical components tool wear should be monitored closely. For more detailed information on surface integrity see chapter Process factors and Machinability.

For general troubleshooting recommendations, see page 80.

Material categories – Bearing steels (58–62 HRC)

Application examples

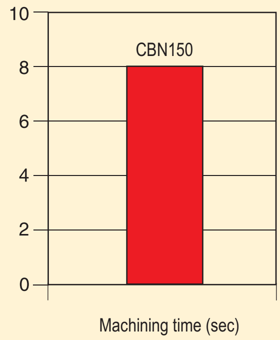
Machining: Bearing rings

Workpiece

Component:	Bearing ring
Material:	100Cr6 bearing steel
Hardness:	60 HRC
Surface:	Forged

Conditions

Operation:	Plunging
Grade:	CBN150
Insert:	TNGN160304E-LF
Holder:	
Cutting speed:	450 m/min
Feed rate:	0,04 mm/rev
Depth of cut:	0,80 mm
Coolant:	No



Result

Machining time:	Machining time 8 seconds for both end journals

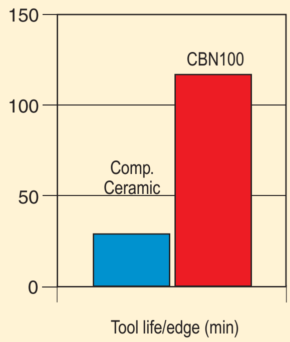
Machining: Bearing rings

Workpiece

Component:	Industrial ring
Material:	100Cr6 bearing steel
Hardness:	58–62 HRC
Surface:	Forged

Conditions

Operation:	OD and ID turning
Grade:	CBN100
Insert:	RNGN090300S-01020
Holder:	
Cutting speed:	140 m/min
Feed rate:	0,50 mm/rev
Depth of cut:	0,50 mm
Coolant:	No



Result

Tool life:	CBN100 = 120 minutes/edge Competitor Ceramic = 30 minutes/edge

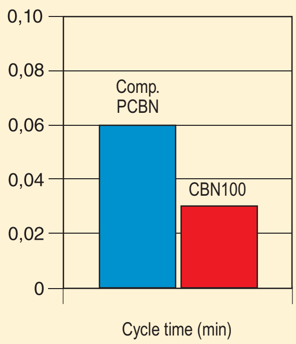
Machining: Bearing rings

Workpiece

Component:	Industrial ring
Material:	100Cr6 bearing steel
Hardness:	60 HRC
Surface:	Forged

Conditions

Operation:	Plunging
Grade:	CBN100
Insert:	TNGN110308S-01020
Holder:	Capto C5
Cutting speed:	200 m/min
Feed rate:	0,04 mm/rev
Depth of cut:	0,30 mm
Coolant:	Yes



Result

Cycle time:	CBN100 = 0,03 minutes/part Competitor PCBN = 0,06 minutes/part

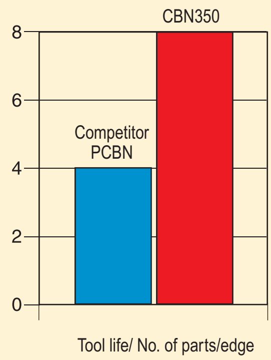
Material categories – Bearing steels (58–62 HRC)

Machining: Large rings

Workpiece
Component: Large ring
Material: 100Cr6 bearing steel
Hardness: 58 HRC
Surface: Black

Conditions
Operation: Rough turning
Grade: CBN350
Insert: RNMN120400S-04015
Holder:
Cutting speed: 120 m/min
Feed rate: 0,60 mm/rev
Depth of cut: 1,00 mm
Coolant: No

Result
Tool life: CBN350 = 8 parts/edge
Competitor PCBN = 4 parts/edge
Increased consistency and reliability

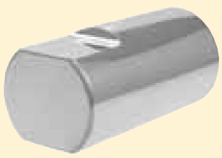


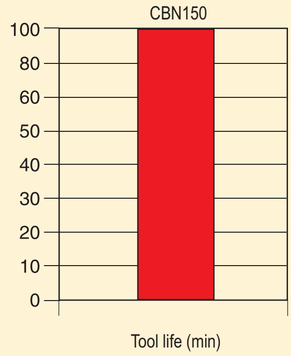
Machining: Facets on a shaft

Workpiece
Component: Shaft
Material: 100Cr6 bearing steel
Hardness: 50 HRC
Surface: Pre-machined

Conditions
Operation: Face milling
Grade: CBN150
Insert: RNGN060300S-01020-LF
Cutter: R217.70-2020.3-06-3
Cutting speed: 180 m/min
Feed rate: 0,10 mm/tooth = 860 mm/min
Depth of cut: 0,50 mm
Coolant: No

Result
Tool life: CBN150 = 100 minutes/edge



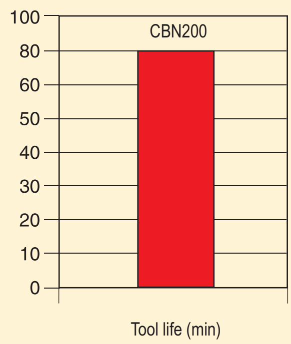


Machining: Bearing rings

Workpiece
Component: Ball bearing ring
Material: 100Cr6 bearing steel
Hardness: 58 HRC
Surface: Black

Conditions
Operation: Face milling
Grade: CBN200
Insert: SNEN0903ENS-M08
Cutter: R220.74-0125-09-8
Cutting speed: 300 m/min
Feed rate: 0,15 mm/tooth = 916 mm/min
Depth of cut: 0,70 mm
Coolant: No

Result
Tool life: CBN200 = 80 minutes/edge



Material categories – Cold work tool steels (45–65 HRC)

Cold work tool steels (45–65 HRC)

Material introduction

Cold work tool steels exhibit the properties of good machinability, dimensional stability on heat treatment, high wear resistance, enough toughness and compressive strength. These properties are achieved by alloying the steel with one or several of the elements manganese, chromium, nickel, molybdenum, tungsten and vanadium. By heat treatment the microstructure of the steel is transformed into martensite with embedded carbides.

Cold work tool steels are highly abrasive and the embedded carbides lead to increased crater wear on cutting tools. Typical tools manufactured from this type of steel are cold extrusion tools, stamping tools, dies, punches and tools for the manufacture of screws, nuts, bolts and balls. Working hardness is usually between 55–64 HRC.

Typical cold work tool steel microstructure

Examples of representative cold work tool steels

Designation					Average composition (wt%)									
SAE	DIN	AFNOR	BS	SS	C	Mn	Si	Cr	Ni	Mo	V	Co	W
L3	115 CrV3	–	–	(2140)	0,93	1,20	0,30	0,50	–	–	0,10	–	0,50
D3	X210 Cr 12	Z 200 C12	BD 3	2312	2,15	0,60	0,60	12,20	0,30	–	1,00	–	1,00
A2	X100CrMoV51	Z 100 CDV5	BA 2	2260	1,00	0,60	0,20	5,20	–	1,10	0,20	–	–
S2	45WCrV7	55 WC20	BS 2	2710	0,49	0,30	0,90	1,20	–	0,25	0,15	–	2,30
D2	X155CrMoV 12 1	Z 160 CDV12	BD 2	2310	1,50	0,60	0,60	12,00	0,30	1,00	1,10	1,00	–
S7	–	–	–	–	0,50	0,50	0,60	3,25	–	1,55	0,25	–	–

Material categories – Cold work tool steels (45–65 HRC)

SECO

Examples of typical cold work tool steel components

Most components in cold work tool steel are for the mould and die industry.

- Extrusion tools
- Tool and dies
- Punches
- Crushing rolls
- Stamping dies

Cutting tool grade selection

Roughing or finishing

When machining cold work tool steels, roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	**Turning**	**CBN300** / CBN350 / CBN200	**CBN200** / CBN350
	Milling	N/A	**CBN200** / CBN350

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	**Turning**	**CBN060K** / CBN050C / CBN10/CBN100	**CBN160C** / CBN150
	Milling	N/A	**CBN200** / CBN150
	Plunging	**CBN060K** / CBN050C / CBN10/CBN100	**CBN150** / CBN160C
	Threading	**CBN10/CBN100** / CBN150	N/A
	Grooving	**CBN10/CBN100** / CBN150	**CBN150** / CBN160C

Bold = First choice

Comment

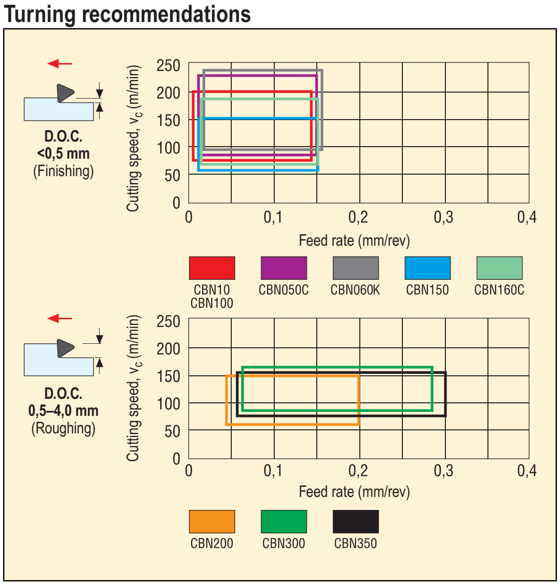
Cold work tool steels are difficult to machine, they are wear resistant and a lot of heat is generated during machining. Several of the alloying elements in cold work tool steels generate hard and abrasive carbides. Selected PCBN grades have to be both abrasion resistant and tough. Cutting speeds have to be kept lower than for case hardened steels.

Parameter guide – Recommended machining conditions

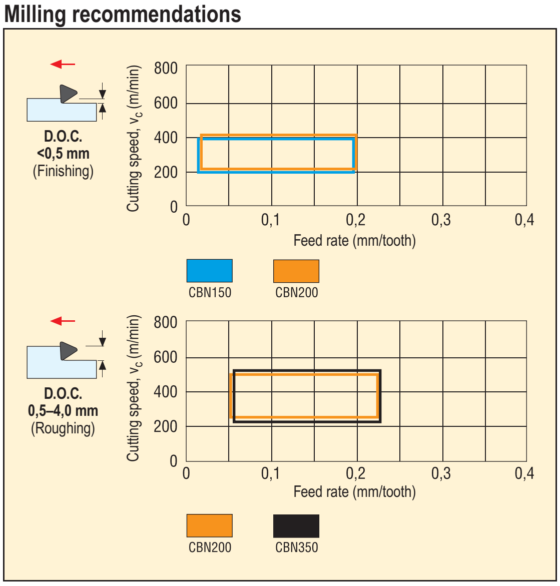
Cold work tool steels (45–65 HRC)

The following charts show the recommended cutting data for cold work tool steel applications.

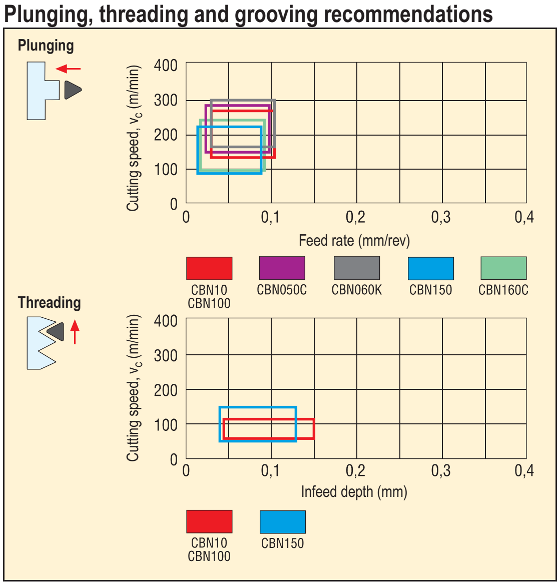
Turning recommendations

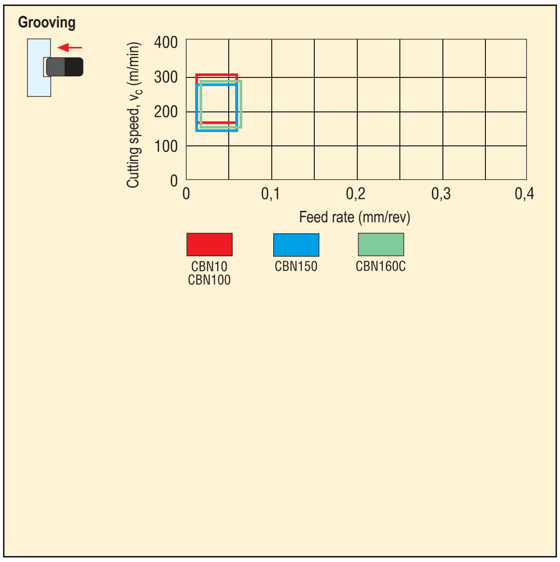


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Cold work tool steels (45–65 HRC)

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for any finishing of cold work tool steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

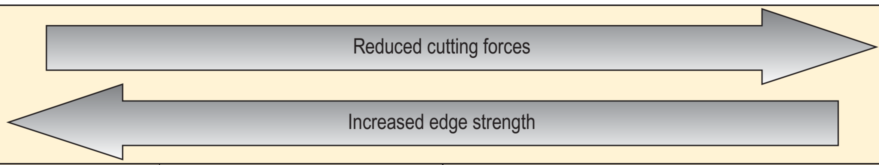
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

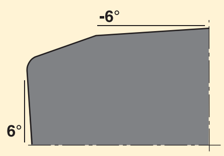
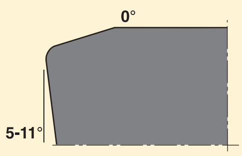
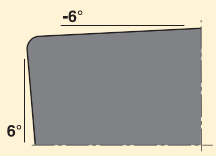
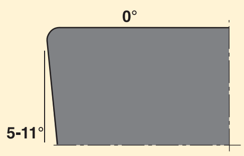
Rough machining

The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a). This provides a balance between optimum edge stability and minimised cutting forces.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for cold work tool steels

In general cold work tool steels are easily machined in the hardened condition, tool performance can be affected by the heat treatment procedure, a double tempering after quenching can improve workpiece machinability. Cold work tool steels can also vary in abrasiveness, for example the SKD11 is more abrasive than a D3 tool steel although the composition is very similar. In this type of material tool wear can be dominated by crater wear and cutting speeds should be reduced accordingly.

Tool steels like D2 can be difficult to machine, particularly in interrupted cutting operations. Success is not always possible.

For general troubleshooting recommendations, see page 80.

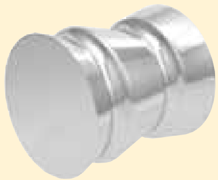
Material categories – Cold work tool steels (45–65 HRC)

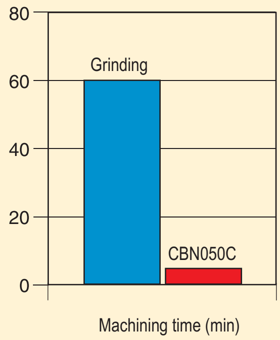
Application examples

Machining: Profiling rolls

Workpiece
Component: Profiling roll
Material: D3 tool steel
Hardness: 60 HRC
Surface: Pre-machined

Conditions
Operation: Facing
Grade: CBN050C
Insert: VNGA160408S-01525-L1-B
Holder:
Cutting speed: 150 m/min
Feed rate: 0,15 mm/rev
Depth of cut: 0,10 mm
Coolant: No



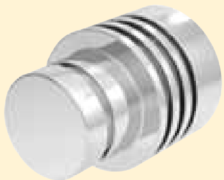


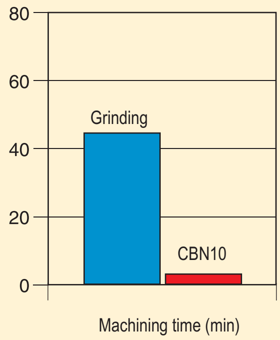
Result
Machining time: Machining time reduced with 85% compared to grinding
Reduced stock inventory

Machining: Form rolls

Workpiece
Component: Form roll
Material: D3 tool steel
Hardness: 60 HRC
Surface: Pre-machined

Conditions
Operation: Grooving
Grade: CBN10
Insert: LCGN160404-0400S-LF
Holder:
Cutting speed: 150 m/min
Feed rate: 0,01 mm/rev
Depth of groove: 5,00 mm
Coolant: No



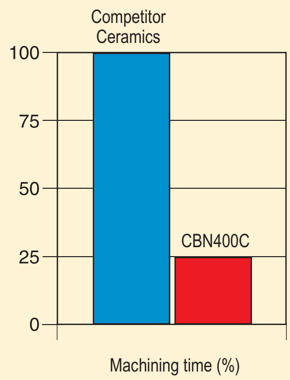


Result
Machining time: Machining time reduced with 90% compared to grinding
Reduced stock inventory

Machining: Rolls

Workpiece
Component: Roll
Material: D2 Cold work tool steel
Hardness: 62 HRC
Surface: Rough

Conditions
Operation: Rough turning
Grade: CBN400C
Insert: RNMN090300S
Holder:
Cutting speed: 126 m/min
Feed rate: 0,10 mm/rev
Depth of cut: 1,50 mm
Coolant: No



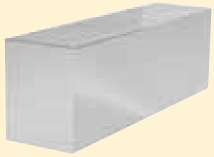
Result
Machining time: Machining time reduced with 75% compared to ceramics

Material categories – Cold work tool steels (45–65 HRC)

Machining: Tool steel blocks

Workpiece

Component:	Tool steel block
Material:	D3 tool steel
Hardness:	60–62 HRC
Surface:	Pre-machined



Conditions

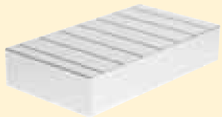
Operation:	Fly-cut milling
Grade:	CBN100
Insert:	RNGN090300S-01020
Cutter:	R220.70-0125-09-8
Cutting speed:	200 m/min
Feed rate:	0,10 mm/tooth = 407 mm/min
Depth of cut:	0,30 mm
Coolant:	No

Result Excellent surface finish

Machining: Moulds

Workpiece

Component:	Mould
Material:	Cold work tool steel (X210Cr12)
Hardness:	58 HRC
Surface:	Pre-machined



Conditions

Operation:	Milling
Grade:	CBN200
Insert:	RDHW0803M0S-01030-LF
Cutter:	R217.29-1225.RE-04.4A
Cutting speed:	457 m/min
Feed rate:	0,35 mm/tooth = 8 146 mm/min
Depth of cut:	0,50 mm
Coolant:	No

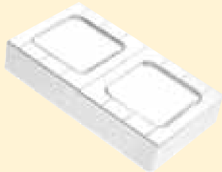
Result

Machining time: Reduced machining time
High stock removal rate compared to grinding

Machining: Moulds

Workpiece

Component:	Mould
Material:	Cold work tool steel (X210Cr12)
Hardness:	58 HRC
Surface:	Pre-machined



Conditions

Operation:	Milling
Grade:	CBN200
Insert:	218.19-100T-MD08-LF
Cutter:	R217.21-1225.RE-R100.3A
Cutting speed:	457 m/min
Feed rate:	0,35 mm/tooth = 8 146 mm/min
Depth of cut:	0,30 mm
Coolant:	No

Result

Machining time: Reduced machining time
High stock removal rate compared to grinding

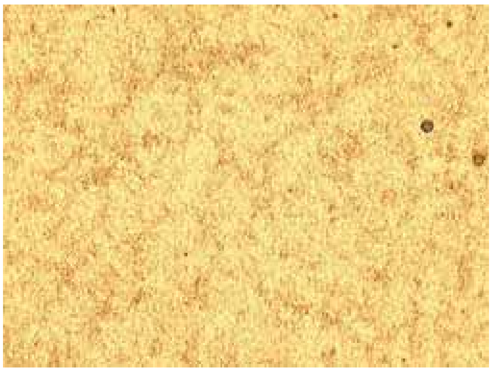
Material categories – Hot work tool steels (45–58 HRC)

Hot work tool steels (45–58 HRC)

Material introduction

Hot work tool steels are used to manufacture tools for the chipless forming of metal by hot moulding. Typical properties for these types of steels are high hot tensile strength, high hot toughness, high wear resistance, high resistance to thermal shocks and high retention to tempering. These properties are obtained by balancing some of the alloying elements silicon, manganese, chromium, nickel, molybdenum, tungsten, vanadium and cobalt while taking the carbon content into consideration. Vanadium, cobalt or nickel is used to improve the properties obtained by other alloying elements. Many of the alloying elements are carbide formers and as a consequence the machining of these steels will lead to edge chipping and crater wear.

Typical quenched and tempered H13 steel microstructure



Examples of representative hot work tool steels

Designation					Average composition (wt%)								
SAE	DIN	AFNOR	BS	SS	C	Mn	Si	Cr	Ni	Mo	V	Cu	W
H10	X32 CrMoV 3 3	32 DCV 28	BH 10	–	0,40	0,50	1,0	3,3	0,3	2,50	0,50	0,25	–
H11	X38 CrMoV 5 1	Z 38 CWDV 5	BH 11	–	0,38	0,35	1,0	5,2	0,3	1,35	0,45	0,25	–
H12	X37 CrMoV 5 1	Z 35 CWDV 5	BH 12	–	0,35	0,35	1,0	5,2	0,3	1,50	0,50	0,25	1,35
H13	X40 CrMoV 5 1	Z 40 CDV 5	BH 13	2242	0,38	0,35	1,0	5,2	0,3	1,40	1,00	–	–

Material categories – Hot work tool steels (45–58 HRC)

SECO

Examples of typical hot work tool steel components

Most components made of hot work tool steel are tools for pressure die casting, metal extrusion, drop forging and the manufacturing of tubes.

- Extrusion dies
- Tool and dies
- Punches
- Drop forging dies

Cutting tool grade selection

Roughing or finishing

When machining hot work tool steels, roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness; wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	Turning	**CBN300** / CBN350 / CBN200	**CBN200** / CBN350
	Milling	N/A	**CBN200** / CBN350

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C <0,5 mm (Finishing)	Turning	**CBN060K** / CBN050C / CBN10/CBN100	**CBN160C** / CBN150
	Milling	N/A	**CBN200** / CBN150
	Plunging	**CBN060K** / CBN050C / CBN10/CBN100	**CBN150** / CBN160C
	Threading	**CBN10/CBN100** / CBN150	N/A
	Grooving	**CBN10/CBN100** / CBN150	**CBN150** / CBN160C

Bold = First choice

Comment

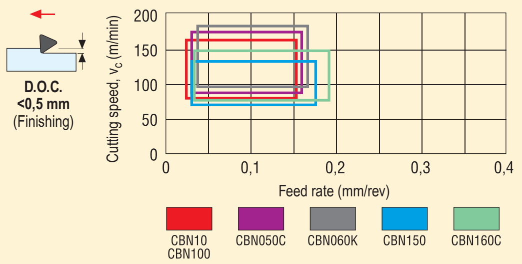
Hot work tool steels are difficult to machine, they are wear resistant and a lot of heat is generated during machining. All alloying elements in hot work tool steels generate hard and abrasive carbides. Selected PCBN grades have to be both abrasion resistant and tough. Cutting speeds have to be kept lower than for case hardening steels.

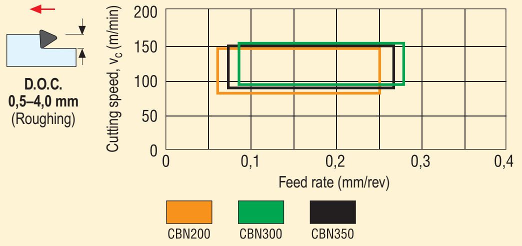
Parameter guide – Recommended machining conditions

Hot work tool steels (45–58 HRC)

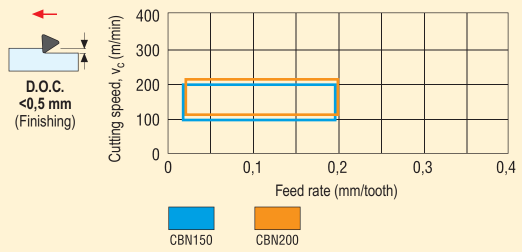
The following charts show the recommended cutting data for hot work tool steel applications.

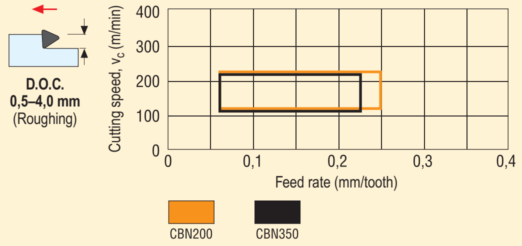
Turning recommendations



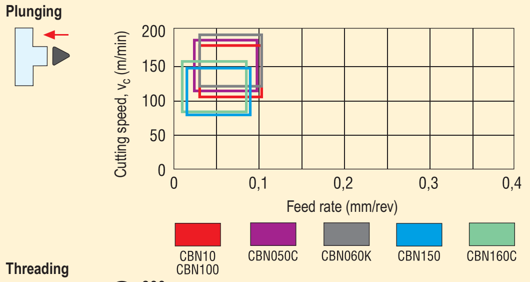


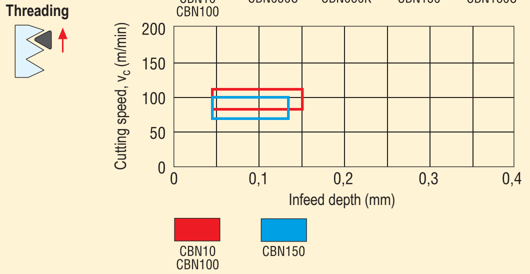
Milling recommendations

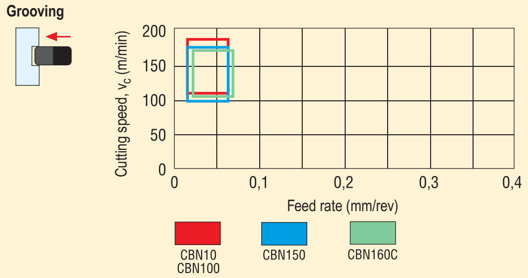




Plunging, threading and grooving recommendations







Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Hot work tool steels (45–58 HRC)

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of hot work tool steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

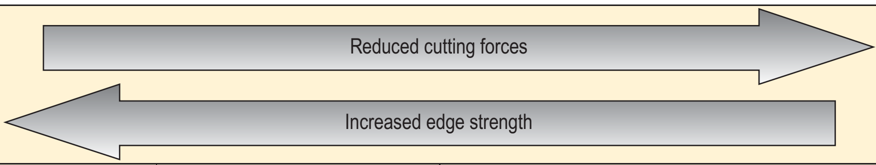
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

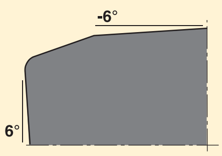
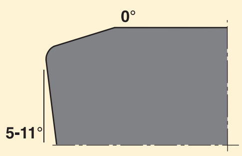
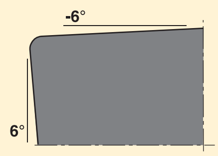
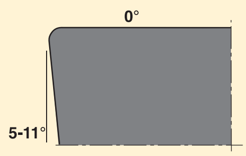
Rough machining

The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a). This provides a good balance between optimum edge stability and minimised cutting forces.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for hot work tool steels

In general hot work tool steels are not as easy to machine as cold work tool steel. The hard carbides present in the material have a detrimental effect on tool life especially when milling. However, when compared to other cutting tool materials, PCBN more often than not, gives the best performance.

Tool performance can be affected by the heat treatment procedure; a double tempering after hardening can improve workpiece machinability. Nitride heat treatment can reduce performance, if machining through the nitrided skin is necessary. In this type of material tool wear can be dominated by crater wear and cutting speeds should be reduced accordingly.

For general troubleshooting recommendations, see page 80.

Material categories – Hot work tool steels (45–58 HRC)

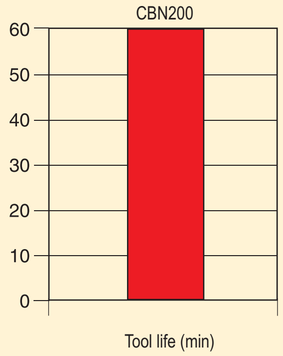
Application examples

Machining: Shearing knives

Workpiece
Component: Wood shearing knife
Material: H13 Hot work tool steel
Hardness: 56 HRC
Surface: Black

Conditions
Operation: Face milling
Grade: CBN200
Insert: RNMN090300S-02020-LF
Cutter: R220.70-8200-09-12
Cutting speed: 150 m/min
Feed rate: 0,20 mm/tooth = 571 mm/min
Depth of cut: 0,50 mm
Coolant: No

Result
Tool life: 60 minutes/edge

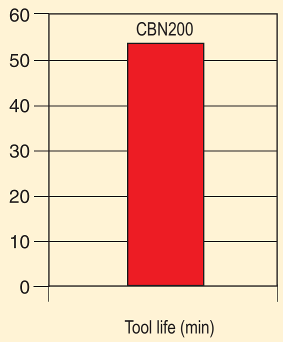


Machining: Moulds

Workpiece
Component: Mould
Material: Hot work tool steel (Z38CDV5)
Hardness: 52 HRC
Surface: Pre-machined

Conditions
Operation: Copy milling
Grade: CBN200
Insert: RDHW0803M0S-01030-LF
Cutter: R217.29-1225.RE-04.4A
Cutting speed: 220 m/min
Feed rate: 0,20 mm/tooth = 2 240 mm/min
Depth of cut: 0,50 mm
Coolant: No

Result
Tool life: 54 minutes machining time/edge. High stock removal rate compared to grinding




CBN050C

Material categories – High manganese steels

High manganese steels (12–20%) (200–400 HBN)

Material introduction

The original austenitic manganese steel, containing about 1 % C and 12 % Mn, was invented by Sir Robert A. Hadfield in 1882 and was one of the first high-alloy steels. In the case of high manganese steel, austenite is the desired structure after heat treatment and quenching in water. Austenite is very ductile but, when austenitic manganese steel is deformed under high impact loads (in applications like rock crushing) it work hardens severely.

The work hardening means it becomes very hard and resistant to wear and abrasion. Many variations of the original austenitic manganese steel have been developed by different companies. Usually they involve combinations of carbon and manganese, with additional alloys such as chromium, nickel, molybdenum, vanadium and titanium.

Typical 18% manganese steel microstructure

Examples of representative high manganese steels

	ASTM 128A/128M grade	Average composition (wt%)							
		C	Mn	Mo	Cr	Ni	Si	P	S
Hadfield	A, B	1,0–1,3	11–14	–	–	–	<1,0	0,03	0,01
Molybdenum alloyed	E, F	0,7–1,3	11–14	1,0–2,0	–	–	<1,0	0,03	0,01
Chromium alloyed	C	1,0–1,3	11–14	–	1,5–2,5	–	<1,0	0,03	0,01
Nickel alloyed	D	0,7–1,3	11–14	–	–	3,0–4,0	<1,0	0,03	0,01
High Manganese	–	–	18–30	–	–	–	<1,0	0,03	0,01

Material categories – High manganese steels

Examples of typical high manganese steel components

- Crushing cones
- Railway components
- Deflector plates
- Sieves
- Mineral processing equipment

Cutting tool grade selection

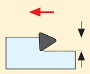
Roughing or finishing

In the machining of high manganese steels roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation. As far as grade selection is concerned the machining of manganese steels requires high cBN content grades for both roughing and finishing operations.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

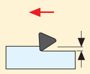
Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. **<0,5 mm** (finishing)	Turning	**CBN350** / CBN300	**CBN350** / CBN200
	Milling	N/A	**CBN200** / CBN350

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm	Turning	**CBN350** / CBN300	**CBN350** / CBN200
	Milling	N/A	**CBN200** / CBN350
	Plunging	**CBN350** / CBN300	**CBN350** / CBN300
	Threading	N/A	N/A
	Grooving	**CBN200**	**CBN200**

Bold = First choice

Comment

The material is extremely abrasive, and both roughing and finishing are done with high cBN-content grades.

Material categories – High manganese steels

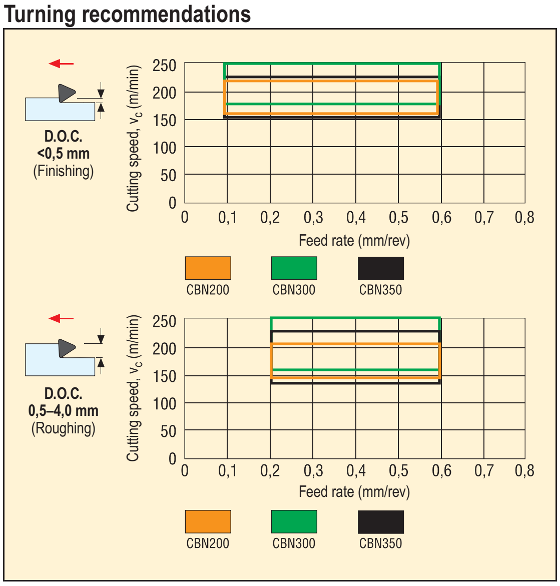
SECO

Parameter guide – Recommended machining conditions

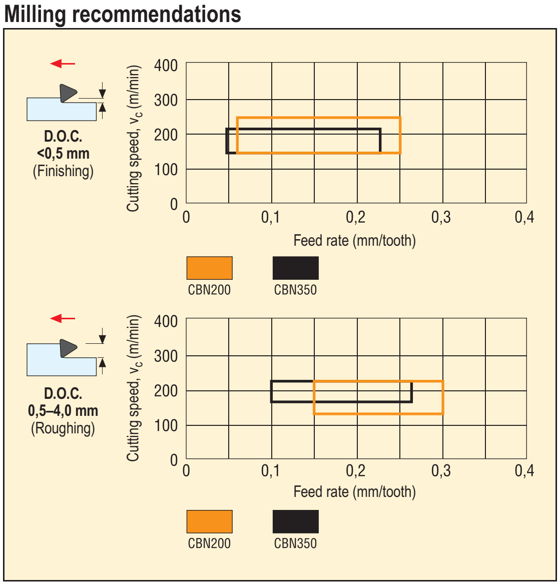
High manganese steels (12–20%)

The following charts show the recommended cutting data for high manganese steel applications.

Turning recommendations

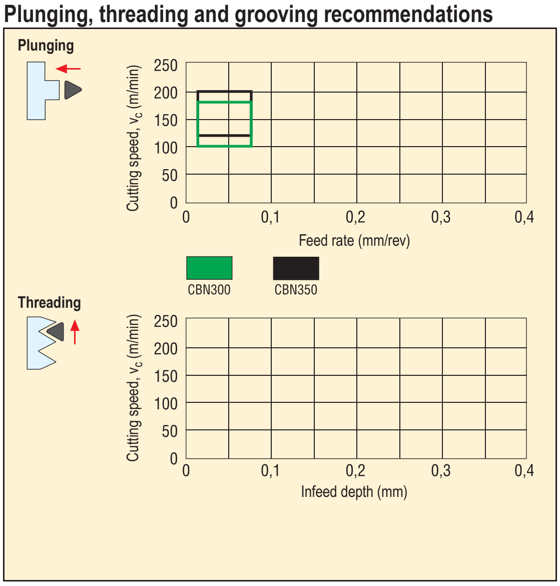


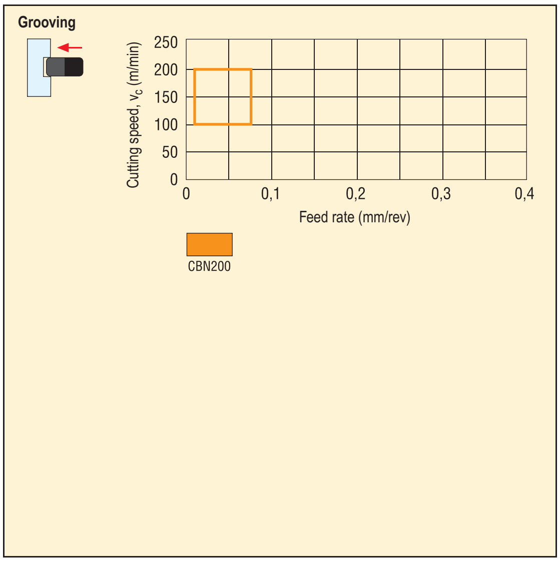
Milling recommendations



For rough milling, the depth of cut is limited to maximum 2 mm.

Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – High manganese steels

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of high manganese steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

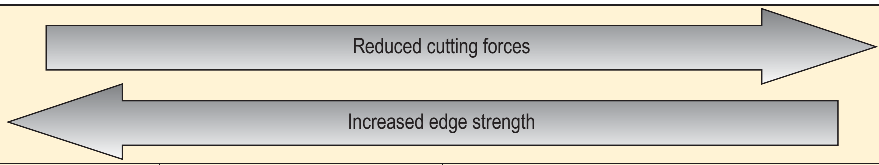
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

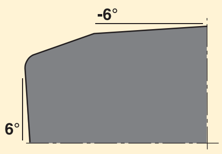
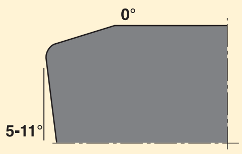
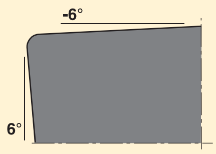
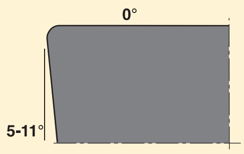
Rough machining

The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a), and provides a good balance between optimum edge stability and minimised cutting forces.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for high manganese steels

High manganese steels have a tendency to work harden, it is therefore important to ensure the cutting action remains efficient if maximum tool life is to be achieved. Always machine beneath the skin of the component, tool wear will be accelerated by trying to machine the actual skin. Tool life will be reduced by using too low feed rates, notching can occur by increasing the feed rate too much. Coated inserts have proven beneficial to increasing tool performance.

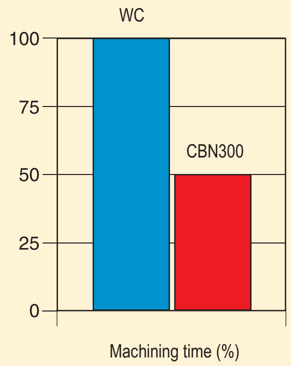
For general troubleshooting recommendations, see page 80.

Material categories – High manganese steels

Application examples

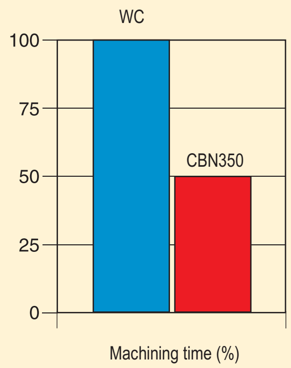
Machining: Crushing cones

Workpiece	
Component:	Crushing cone
Material:	Manganese steel (12–20% Mn)
Hardness:	220–240 HB
Surface:	Rough cast
Conditions	
Operation:	ID turning
Grade:	CBN300 (WC)
Insert:	RNMN120400S
Holder:	
Cutting speed:	160–230 m/min (25–30 m/min)
Feed rate:	0,3–0,5 mm/rev (0,8–1,0 mm/rev)
Depth of cut:	2,5 mm
Coolant:	No
Result	
Machining time:	Machining time reduced with 50% compared to WC



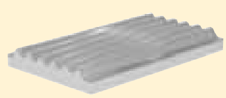
Machining: Crushing cones

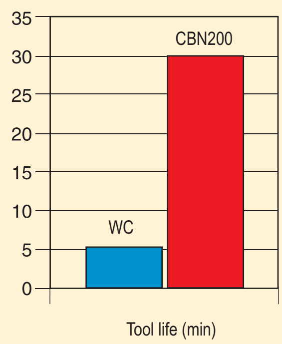
Workpiece	
Component:	Crushing cone
Material:	Manganese steel (12–20% Mn)
Hardness:	220–240 HB
Surface:	Rough cast
Conditions	
Operation:	ID turning
Grade:	CBN350 (WC)
Insert:	RNMN120400S-04015
Holder:	
Cutting speed:	200 m/min (30 m/min)
Feed rate:	Rough: 0,45 mm/rev Finish: 0,60 mm/rev
Depth of cut:	2,5–4,0 mm
Coolant:	No
Result	
Tool life:	CBN350 = 62 minutes Machining time reduced with 50%



Machining: Crushing plates

Workpiece	
Component:	Jaw crushing plate
Material:	Manganese steel
Hardness:	220–240 HB
Surface:	Rough cast
Conditions	
Operation:	Milling
Grade:	CBN200 (WC)
Insert:	RNGN090300S
Cutter:	R220.70-0100-09-8
Cutting speed:	200 m/min
Feed rate:	0,15 mm/tooth = 763 mm/min
Depth of cut:	2,00 mm
Coolant:	No
Result	
Tool life:	Carbide = 5,2 min tool life CBN200 = 30 min tool life Machining time reduced significantly





Material categories – High tensile steels (45–56 HRC)

High tensile steels (45–56 HRC)

Material introduction

High tensile steels are heat treatable low alloy steels containing alloys such as nickel, chromium and molybdenum. They are known for their toughness and capability of obtaining high tensile strength in the heat treated condition while retaining good fatigue strength and adequate ductility. In addition high tensile steels offer excellent corrosion resistance. Many high strength steels are variations of SAE/AISI 4340 and have typical yield strengths in the region of 1200 MPa.

High tensile steel materials such as A300M and more recently AerMet 100 are applied for aerospace forgings such as landing gear components, rocket cases and air frame fittings where they are machined from forged in order to optimise the materials properties in these high stress areas.

Typical high tensile steel microstructure

Examples of representative high tensile steels

Designation					Average composition (wt%)						
SAE	DIN	AFNOR	BS	SS	C	Cr	Ni	Mo	Si	Mn	Co
4340	34CrNiMo6	–	817 M 40	2541	0,38	0,69	1,99	0,19	0,22	0,66	0,02
4330	–	–	–	–	0,25	0,50	1,25	0,40	<0,80	<0,80	–
Aermet 100	–	–	–	–	0,23	3,00	11,10	1,20	–	–	13,40
A300M	–	–	–	–	0,42	0,80	1,80	0,40	1,65	0,75	–

Material categories – High tensile steels (45–56 HRC)

SECO

Examples of typical high tensile steel components

- Aerospace parts
- Undercarriage struts
- Jet engine mounting
- Helicopter camshaft gears

Cutting tool grade selection

Roughing or finishing

In the machining of high tensile steels roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	Turning	**CBN300** / CBN200	**CBN200** / CBN300
	Milling	N/A	**CBN200** / CBN300

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	Turning	**CBN10/CBN100** / CBN050C	**CBN150** / CBN160C
	Milling	N/A	**CBN160C** / CBN200
	Plunging	**CBN10/CBN100** / CBN050C	N/A
	Threading	**CBN10/CBN100** / CBN050C	N/A
	Grooving	**CBN10/CBN100**	N/A

Bold = First choice

Comment

The hardness and alloying content makes these grades difficult to machine, the generated temperature is high, and crater is the dominant wear mode. Cutting speeds have to be kept relatively low.

Material categories – High tensile steels (45–56 HRC)

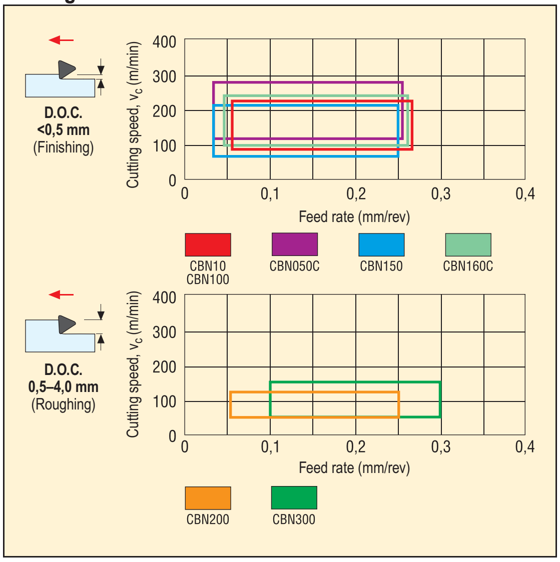
SECO

Parameter guide – Recommended machining conditions

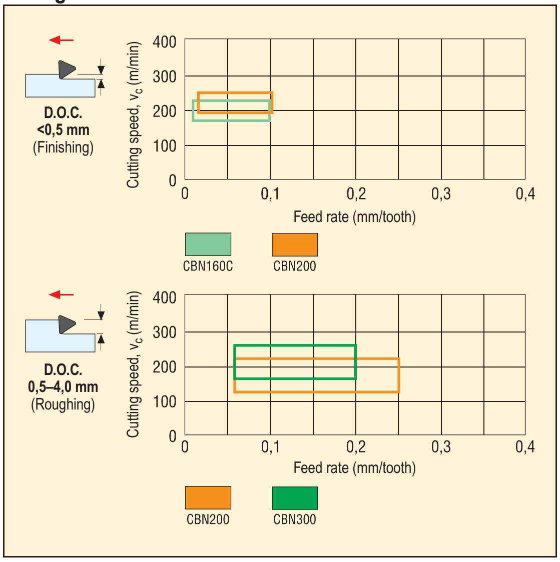
High tensile steels (45–56 HRC)

The following charts show the recommended cutting data for high tensile steel applications.

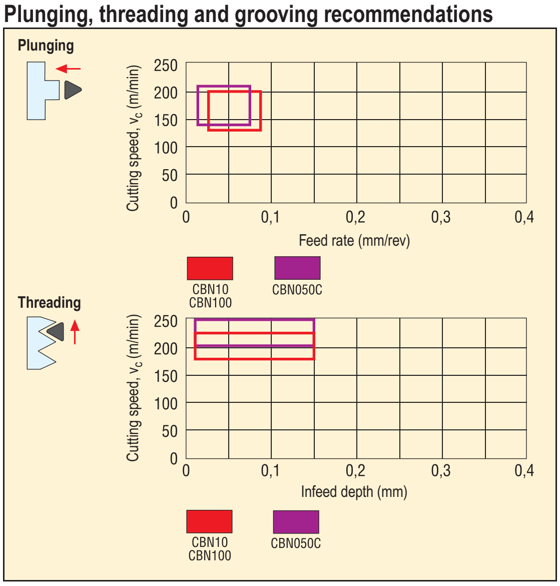
Turning recommendations

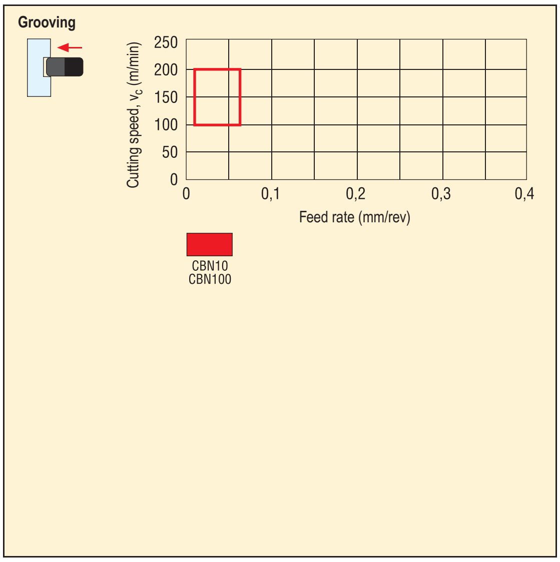


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – High tensile steels (45–56 HRC)

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of high tensile steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

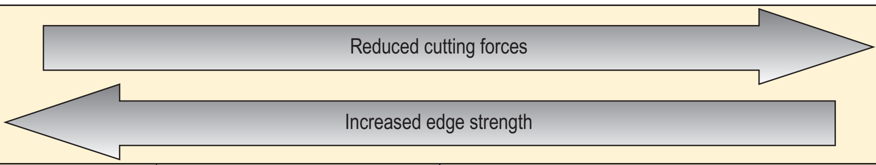
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

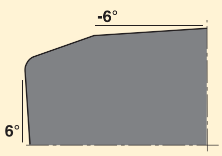
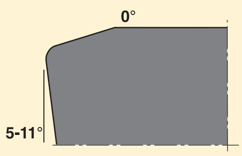
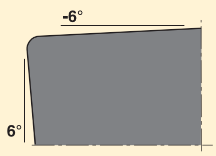
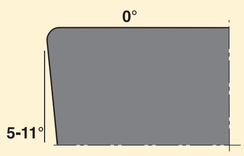
Rough machining

The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a), and provides a balance between optimum edge stability and minimised cutting forces.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for high tensile steels

In general high tensile steel is easily machined in the hardened condition, traditional methods use low cutting speeds, sharp positive tool geometries to prevent surface abuse and carbon depletion. Machining high tensile strength steels with PCBN is extremely efficient and surface etching has shown no signs of carbon depletion, using negative tool geometry, increased cutting speeds and chamfered cutting edges.

For general troubleshooting recommendations, see page 80.

Material categories – High tensile steels (45–56 HRC)

Application examples

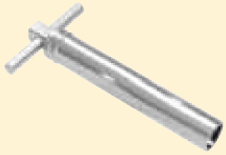
Machining: Landing gear pistons

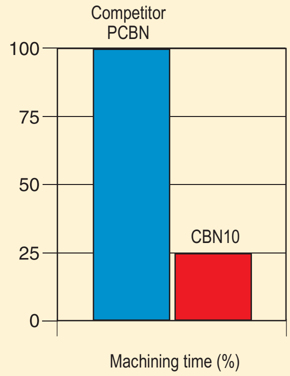
Workpiece

Component:	Landing gear piston
Material:	High tensile steel (300M)
Hardness:	54–56 HRC
Surface:	Forged

Conditions

Operation:	ID turning
Grade:	CBN10
Insert:	CNGA120408S-L1-WZ-B
Holder:	
Cutting speed:	92 m/min (limited)
Feed rate:	0,36 mm/rev
Depth of cut:	0,23 mm
Coolant:	No





Result

Machining time:	Machining time reduced with 75% compared to competitor non-wiper
Tool life criteria:	R_a max 0,81 µm

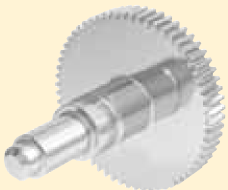
Machining: Free wheel camshaft gears

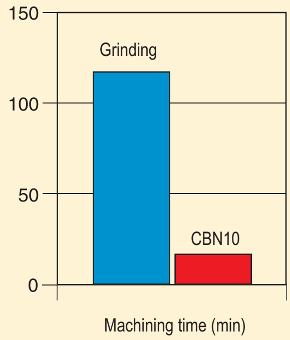
Workpiece

Component:	Free wheel camshaft gear
Material:	High tensile steel (4330M)
Hardness:	48–54 HRC
Surface:	Forged

Conditions

Operation:	OD turning
Grade:	CBN10
Insert:	TNGA160408S-L0-C
Holder:	
Cutting speed:	90 m/min
Feed rate:	0,03 mm/rev
Depth of cut:	0,05–0,10 mm
Coolant:	No





Result

Machining time:	CBN10 = 15 minutes/part (0% reject) Grinding = 120 minutes/part (30% reject)

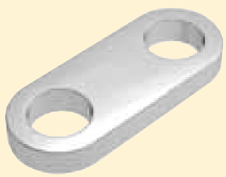
Machining: Jet engine mounting brackets

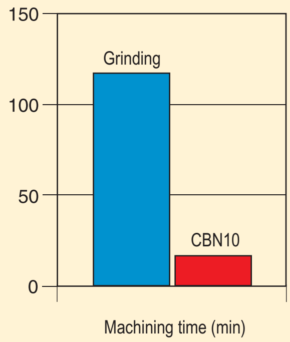
Workpiece

Component:	Jet engine mounting bracket
Material:	High tensile steel (4330M)
Hardness:	50 HRC
Surface:	Forged

Conditions

Operation:	Boring
Grade:	CBN10
Insert:	CCMW09T308E-L0-B
Holder:	
Cutting speed:	155 m/min
Feed rate:	0,15 mm/rev
Depth of cut:	0,04 mm
Coolant:	No





Result

Machining time:	CBN10 = 15 minutes/part Grinding = 120 minutes/part
Tool life criteria:	Tolerance ± 15 µm


CBN400C

Material categories – High speed steels (58–66 HRC)

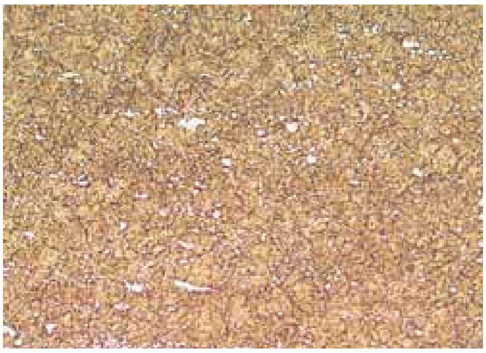
High speed steels (58–66 HRC)

Material introduction

High speed steel (HSS) is mainly used to produce metal cutting tools such as milling cutters, drills, taps, and threading dies. The properties for this type of steel are high strength, high hardness, high retention to tempering, good wear resistance and high edge sharpness. Alloying elements are chromium, molybdenum, tungsten, vanadium and cobalt.

Hardening at a temperature of 1 250–1 280ºC gives a martensitic matrix with a high proportion of embedded fairly large mixed carbides. After a double tempering at 550–580°C, the working hardness of 64–66 HRC is reached.

Typical high speed steel microstructure



Examples of representative high speed steels

Designation					Average composition (wt%)					
SAE	DIN	AFNOR	BS	SS	C	Cr	Mo	V	Co	W
T1	S 18-0-1	Z80 WCV 18-4-1	BT1	–	0,75	4,0	18,0	1,00	–	–
M35	S 6-5-2-5	Z85 WDKCV 6-5-2-5	BM35	2723	0,93	4,2	5,0	2,70	4,8	6,4
M2	S 5-5-2	Z85 WDCV 6-5-2	BM2	2722	0,85	4,0	5,0	2,00	–	6,0
M42	S 2-10-1-8	Z110 DKCWV 2-9-1-8	BM42	–	1,05	3,9	9,5	1,15	8,0	1,5
T4	S 18-1-2-5	Z80 WKCV 19-5-4-1	BT4	–	0,75	4,0	18,0	1,00	5,0	–

Material categories – High speed steels (58–66 HRC)

Examples of typical high speed steel components

- Tool and dies
- Thread rolling dies
- Pressure rolls
- High temperature bearings

Cutting tool grade selection

Roughing or finishing

In the machining of high speed tool steel roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	**Turning**	**CBN200** / CBN300	N/A
	Milling	N/A	N/A

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	**Turning**	**CBN10/CBN100** / CBN200 / CBN150	N/A
	Milling	N/A	N/A
	Plunging	**CBN200** / CBN10/CBN100 / CBN150	N/A
	Threading	**CBN200** / CBN150	N/A
	Grooving	**CBN200** / CBN10/CBN100	N/A

Bold = First choice

Comment

High speed steels are very hard and abrasive. Due to the high hardness, interrupted machining is not possible.

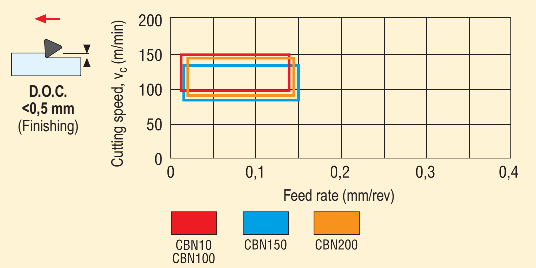
Material categories – High speed steels (58–66 HRC)

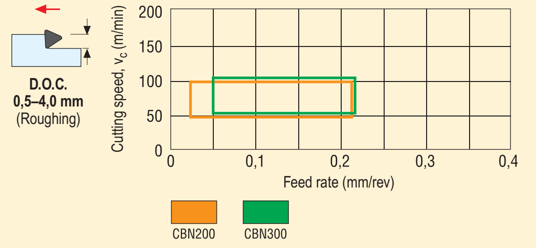
Parameter guide – Recommended machining conditions

High speed steels (58–66 HRC)

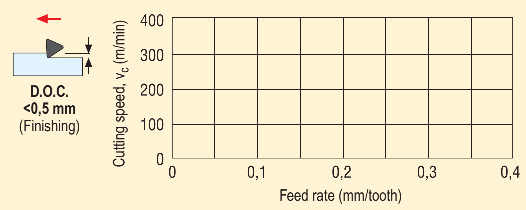
The following charts show the recommended cutting data for high speed steel applications.

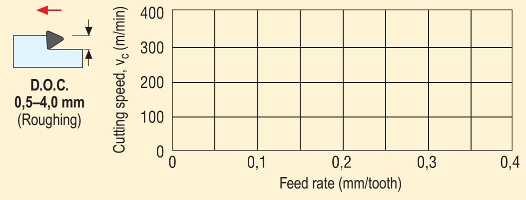
Turning recommendations



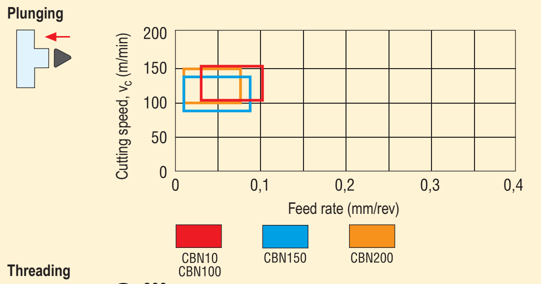


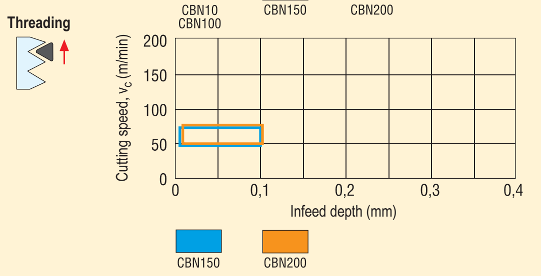
Milling recommendations

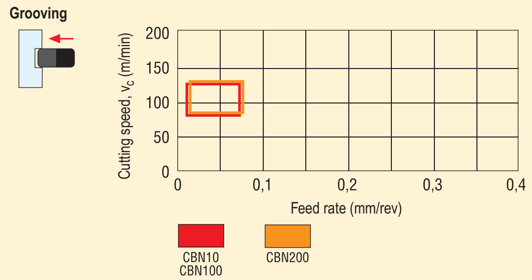




Plunging, threading and grooving recommendations







Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of high speed steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

Rough machining

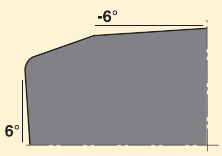
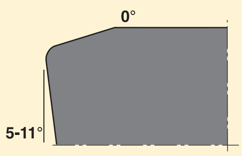
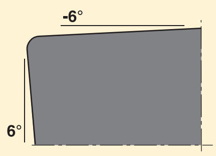
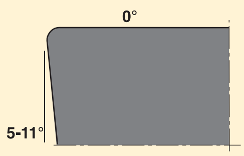
The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a). This provides a good balance between optimum edge stability and minimised cutting forces.

Heavy interruptions and milling

These operations are not possible with PCBN in high speed steels.

Reduced cutting forces →

← Increased edge strength

First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for high speed steels

Machining of high speed steels in the hardened condition is generally more difficult compared to other hardened workpiece materials. This is because of the characteristic properties high speed steels exhibit. In general this means the working window for successful machining with PCBN is smaller compared to other hardened steels.

When machining HSS, high temperatures are generated at the cutting edge. This is caused by the high hardness and the high strength of the material. To reduce the temperature a suitable coolant should be used.

Due to the high abrasion resistance and toughness characteristics of these materials the most dominant wear modes are cratering or notching. Crater wear can be reduced by lowering the cutting speed and notching by reducing the feed rate.

Interrupted cut machining is not possible with PCBN on HSS materials, tool life being extremely short and failure is due to edge chipping. In operations such as the removal of worn thread rolling die forms, it is absolutely necessary to increase the depth of cut to ensure the cut is continuous. The direction of the feed should also be with the thread to prevent notching.

Surface integrity and residual stresses are important particularly on dynamically loaded surfaces such as pressure rolls. The machined surface can be affected by tool wear, on critical components tool wear should be monitored closely.

For general troubleshooting recommendations, see page 80.

Material categories – High speed steels (58–66 HRC)

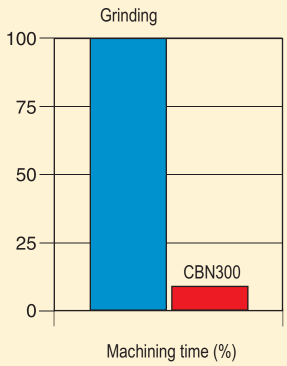
Application examples

Machining: Rolling dies

Workpiece
Component: Rolling die
Material: M2 high speed steel
Hardness: 62–64 HRC
Surface: Worn threads

Conditions
Operation: OD turning
Grade: CBN300
Insert: RNMN120300S
Holder:
Cutting speed: 95 m/min
Feed rate: 0,10 mm/rev
Depth of cut: 2,50–4,00 mm
Coolant: No

Result
Tool life: CBN300= 640 rolls/insert
Machining time reduced with 90% compared to grinding

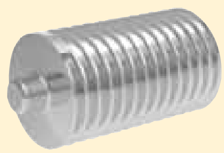


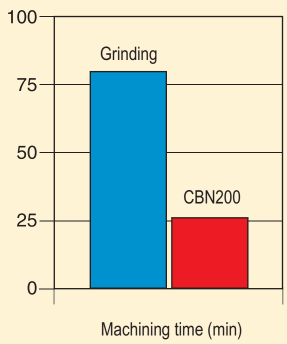
Machining: Thread rolling dies

Workpiece
Component: Thread rolling die
Material: M42 high speed steel
Hardness: 64 HRC
Surface: Worn threads

Conditions
Operation: Removing worn threads
Grade: CBN200
Insert: RNGN120400S-02020-LF
Holder:
Cutting speed: 50 m/min
Feed rate: 0,02 mm/rev
Depth of cut: 1,00 mm
Coolant: No

Result
Machining time: 26 minutes/part
Grinding 80 minutes/part



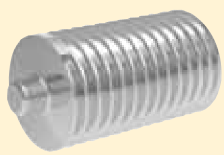


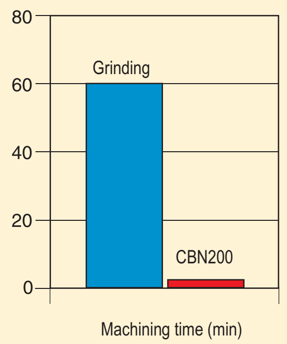
Machining: Thread rolling dies

Workpiece
Component: Thread rolling die
Material: M42 high speed steel
Hardness: 64 HRC
Surface: Pre-machined

Conditions
Operation: Thread turning, ISO thread
Grade: CBN200
Insert: TCGW110204S-01020-LF
Holder:
Cutting speed: 60 m/min
Feed rate: 2,117 mm/rev
Depth of cut: 0,055 mm x 25 passes = 1,375 mm
Coolant: No

Result
Machining time: CBN200 = 6 minutes/part
Grinding = 60 minutes/part
Machining time reduced by 90% compared to grinding






CBN
060K

Martensitic stainless steels (45–60 HRC)

Material introduction

The stainless steels have properties which normally are not available within the alloy systems of the ferrous alloys group. Systematically and historically they are placed between ultra high strength steels and tool steels. The stainless steels were developed because other ferrous alloys did not exhibit enough corrosion resistance or oxidation resistance in the environment where they were used.

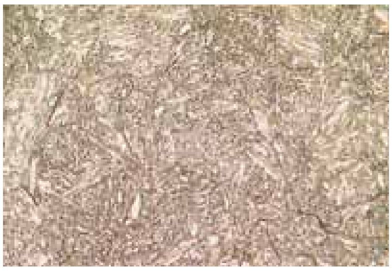
More than 75 years ago, it was discovered that a minimum of 12% chromium gives corrosion and oxidation resistance to steel. The subsequent development resulted in several subcategories of stainless steels, namely the ferritic, austenitic, martensitic and precipitation-hardenable grades.

The ferritic and the martensitic grades are closely related because they have only iron, carbon and chromium as the constituents. In some cases there can be small amounts of supplementary alloying elements. The ferritic grades cannot be strengthened by heat treatment.

The martensitic grades were developed in order to provide a group of stainless alloys, which would be corrosion resistant and hardenable by heat treatment. This is accomplished by adding carbon to the binary iron-chromium system, which gives an alloy which responds to a quench cycle. A disadvantage is that those steels are not as corrosion resistant as the ferritic or austenitic grades. Strengths up to 2 860 N/mm^2 are achievable with martensitic grades.

The machining of ferritic and austenitic stainless steels is not economically viable with PCBN.

Typical martensitic stainless steel microstructure



Examples of representative martensitic stainless steels

Designation					Average composition (wt%)				
SAE	DIN	AFNOR	BS	SS	C	Cr	Ni	Mo	S
403	1.4006	Z 6C13	403S17	2302	0,12	13,0	<1,0	–	–
410	1.4006	Z 6C13	410S21	2302	–	–	–	–	–
416	1.4006	Z 12CF13	416S21	2380	0,12	13,0	<1,0	<0,6	0,25
420	1.4021	Z 20C13	420S37	2303	0,20	13,0	<1,0	–	–
420F	1.4028	Z 30C13	420S45	2304	0,30	13,0	<1,0	–	–
431	1.4057	Z 15CNi1602	431S29	2321	0,18	16,5	2,0	–	–

Material categories – Martensitic stainless steels (45–60 HRC)

Examples of typical martensitic stainless steel components

- Ball screws
- Mould and die inserts
- Extrusion tools

Cutting tool grade selection

Roughing or finishing

In the machining of martensitic stainless steels roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	**Turning**	**CBN300** / CBN350	**CBN350** / CBN200
	Milling	N/A	**CBN200** / CBN350

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	**Turning**	**CBN10/CBN100** / CBN150	**CBN160C** / CBN150
	Milling	N/A	**CBN200** / CBN160C
	Plunging	**CBN10/CBN100** / CBN050C	N/A
	Threading	**CBN160C** / CBN150	N/A
	Grooving	**CBN10/CBN100**	N/A

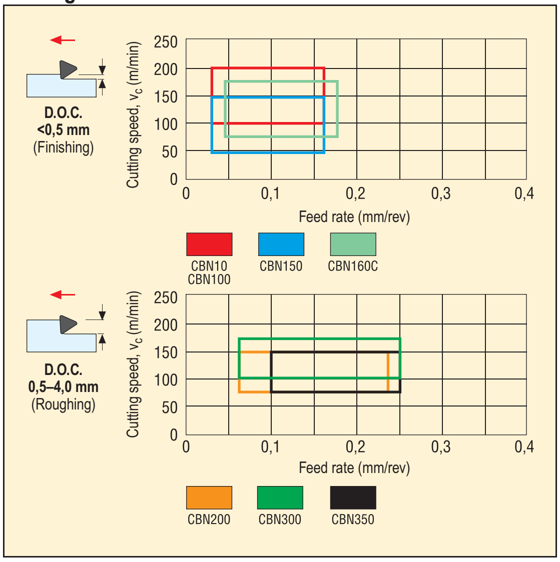
Bold = First choice

Parameter guide – Recommended machining conditions

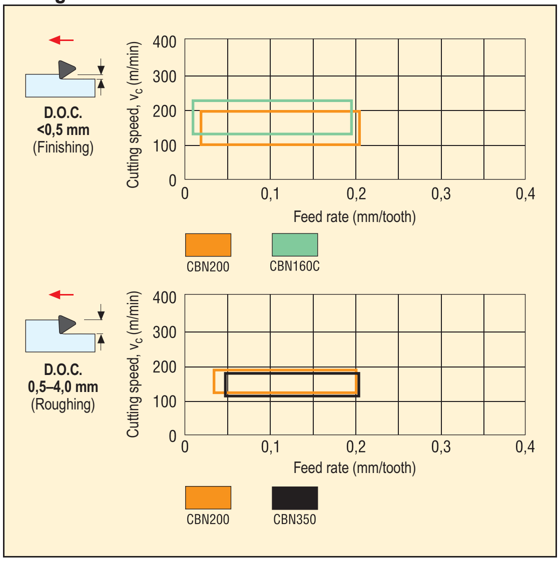
Martensitic stainless steels (45–60 HRC)

The following charts show the recommended cutting data for martensitic stainless steel applications.

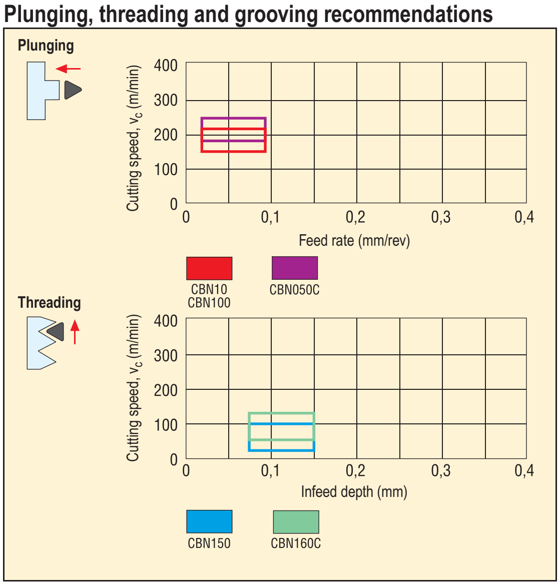
Turning recommendations

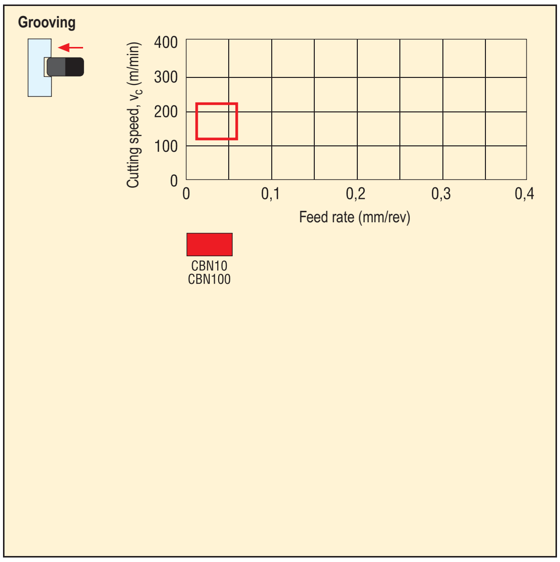


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Martensitic stainless steels (45–60 HRC)

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of martensitic stainless steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

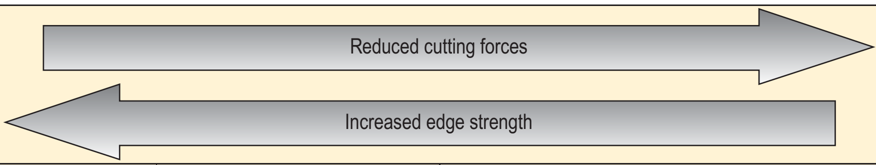
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

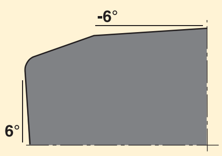
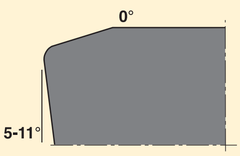
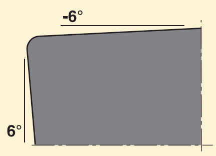
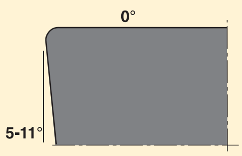
Rough machining

The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a), and provides a balance between optimum edge stability and minimised cutting forces.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for martensitic stainless steels

In general martensitic stainless steel is easily machined in the hardened state, but tool performance can be affected by the heat treatment procedure, a double tempering after hardening can improve workpiece machinability.

For general troubleshooting recommendations, see page 80.

Material categories – Martensitic stainless steels (45–60 HRC)

Application examples

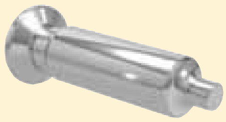
Machining: Punches

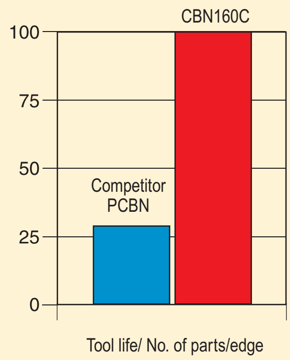
Workpiece

Component:	Punch
Material:	Stainless steel
Hardness:	57–59 HRC
Surface:	Smooth

Conditions

Operation:	OD turning
Grade:	CBN160C
Insert:	DNGA150608S-01525-L1-B
Holder:	
Cutting speed:	100 m/min
Feed rate:	0,15 mm/rev
Depth of cut:	0,50 mm
Coolant:	Yes





Result

Tool life:	CBN160C = 100 parts/edge Competitor PCBN = 30 parts/edge


CBN050C

Material categories – White cast irons (Chrome iron)

White cast irons (50-58 HRC)

Material introduction

When a grey cast iron component is cooled very rapidly from the melt, a white cast iron surface is formed. These materials are known as chilled cast irons. They exhibit a soft grey cast iron core with a hard white iron skin. Chilled cast iron castings are produced by adjusting the carbon content of the grey cast iron so that the normal cooling rate at the surface is fast enough to produce white cast iron. Consequently the slower cooling rate below the surface, maintains the grey cast iron core. The depth of the chill decreases and the hardness of the chilled zone increases when elevating the carbon content.

Chromium is also used to control the chill depth. Because of the formation of chromium carbide, chromium is typically used in an amount of between 1-4% in chilled irons. Chromium is added to increase hardness and improve abrasion resistance. It also stabilises the carbides and suppresses the formation of graphite in heavy sections. Fast cooling of the surface prevents the formation of graphite and pearlite. If the elements such as nickel, chromium or molybdenum are added, much of the austenite transforms to martensite instead of pearlite.

White cast irons also known as high chrome irons exhibit essentially the same microstructure as the hard chilled surface of chilled cast iron. However, unlike chilled cast irons with their soft grey cast iron core, white cast irons are through hardened. White cast irons also generally contain more chromium, which in some cases can be as much as 30%.

White cast irons get their name from the formation of martensite which, while accounting for the material's overall hardness, is also white when viewed under a metallurgical microscope.

Typical white cast iron microstructure

Examples of representative white cast irons

Designation						Average composition (wt%)						
	SAE A532	BS 4844	DIN 1695	EN 12513	SS	C	Cr	Ni	Mo	Si	Mn	Cu
Nickel-Chromium												
Ni-Hard 1	CL 1 A	2B	G-X330NiCr42	GJN-HV550	0513-00	2,8–3,6	1,0–4,0	3,3–5,0	1,0	0,8	2,0	–
Ni-Hard 2	CL 1 B	2A	G-X260NiCr42	GJN-HV520	0512-00	2,4–3,0	1,0–4,0	3,3–5,0	1,0	0,8	2,0	–
Ni-Hard 3	CL 1 C	–	–	–	–	2,5–3,7	1,0–2,5	4,0	1,0	0,8	2,0	–
Ni-Hard 4	CL 1 D	2C, 2D, 2E	G-X300CrNiSi952	GJN-HV600	0457-00	2,7–3,6	7,0–11,0	5,0–7,0	1,5	2,0	2,0	–
Chromium-Molybdenum												
–	CL II A	3F, 3G	–	GJN-HV600 (XCr11)	–	2,0–3,3	11,0–14,0	2,5	3,0	1,5	2,0	1,2
–	CL II B	3A, 3B	G-X300CrMo153	GJN-HV600 (XCr14)	–	2,0–3,3	14,0–18,0	2,5	3,0	1,5	2,0	1,2
–	CL II D	3C	G-X260CrMoNi2021	GJN-HV600 (XCr18)	–	2,0–3,3	18,0–23,0	2,5	3,0	2,2	2,0	1,2
–	CL III A	3D, 3E	G-X300CrMo271	GJN-HV600 (XCr23)	0466-00	2,0–3,3	23,0–30,0	2,5	3,0	1,5	2,0	1,2

Material categories – White cast irons (Chrome iron)

Examples of typical white cast iron components

- Crushing cones and crushing bodies
- Mineral processing
- Mining equipment
- Steel rolls
- Paper rolls
- Rod rolls
- Impellers

Cutting tool grade selection

Roughing or finishing

When machining white cast irons, roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation. As far as grade selection is concerned the machining of chilled cast irons requires high cBN content grades for both roughing and finishing operations.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance, and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	Turning	**CBN350** / CBN200	**CBN350** / CBN200
	Milling	N/A	**CBN200** / CBN350

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	Turning	**CBN350** / CBN200	**CBN350** / CBN200
	Milling	N/A	**CBN200** / CBN350
	Plunging	**CBN200** / CBN350	**CBN200** / CBN350
	Threading	**CBN200** / CBN350	N/A
	Grooving	**CBN200**	**CBN200**

Bold = First choice

Comment

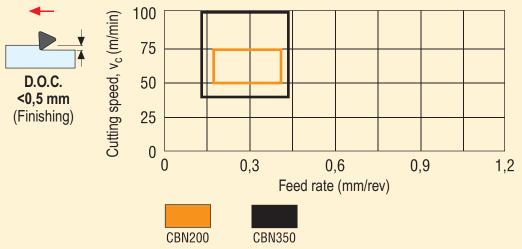
These materials are difficult to machine, and require a very hard and tough insert grade. Sand inclusions, blow holes and uneven depth of cut due to out-of-roundness and out-of-flatness from the casting process add to the severity. Very tough grades have to be used both for roughing and finishing.

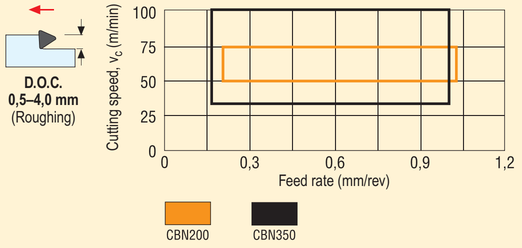
Parameter guide – Recommended machining conditions

White cast irons (50-58 HRC)

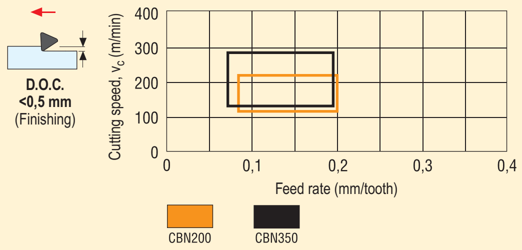
The following charts show the recommended cutting data for white cast iron applications.

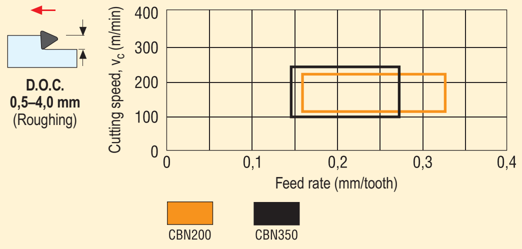
Turning recommendations



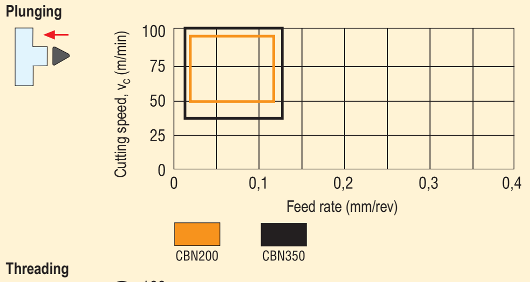


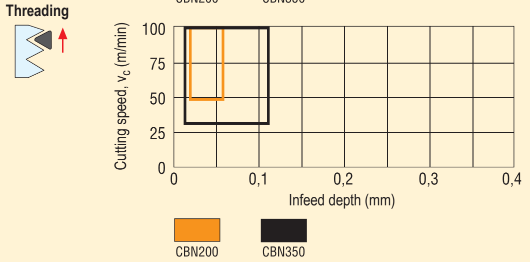
Milling recommendations

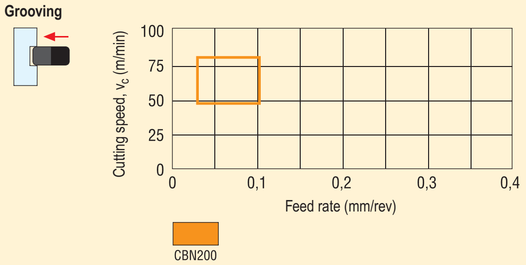




Plunging, threading and grooving recommendations







Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – White cast irons (Chrome iron)

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for any roughing or finishing of white cast iron components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

In threading it is necessary to use a zero top rake insert in order to keep the correct profile.

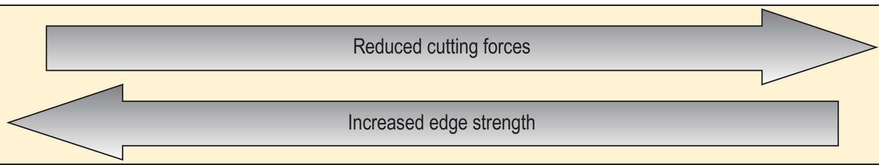
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

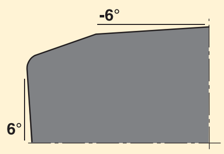
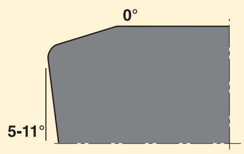
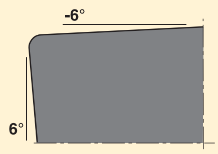
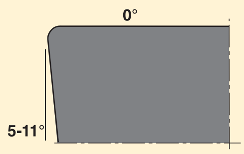
Rough machining

Rough machining of white cast iron requires chamfered and honed cutting edges. The material is hard, abrasive and contains impurities such as sand from the casting process. These and the larger depth of cut mean much more pressure on the cutting edge. Chamfering of the insert strengthens the PCBN cutting edge and thereby ensuring consistent and maximum tool life.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used. A larger chamfer width will increase edge toughness and reduce the risk of flaking and chipping.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for white cast irons

White cast irons are hard and aggressive materials and, therefore, require the strongest possible cutting edge. Chamfered and honed edges are essential. Where possible, the strongest edge geometry should be employed, preferably round inserts or square inserts with the largest possible nose radius. If machining a rough cast component, it is important to machine under the cast skin and not within it. The cast skin is rough, hard and often has sand inclusions. Machining within the cast skin will reduce tool life.

If it is possible to eliminate interrupted cutting, for example by increasing the depth of cut on an out of round component, tool life will be greatly increased. The tool life of PCBN is much higher in continuous machining operations compared with interrupted cutting operations.

For general troubleshooting recommendations, see page 80.

Material categories – White cast irons (Chrome iron)

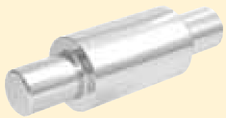
Application examples

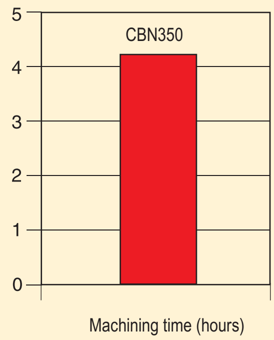
Machining: Mill rolls

Workpiece
Component: Mill roll
Material: H-IC-R80-N
Hardness: 80 Shore C
Surface: Rough

Conditions
Operation: OD turning
Grade: CBN350
Insert: RNMN250600S-15020
Holder:
Cutting speed: 45 m/min
Feed rate: 0,45 mm/rev
Depth of cut: 6,00 mm
Coolant: No

Result
Machining time: 4 hours 15 minutes



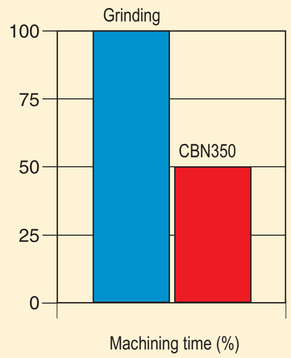


Machining: Slurry pumps

Workpiece
Component: Slurry pump
Material: Ni-hard 2 (G-X260NiCr42)
Hardness: 52–58 HRC
Surface: Cast, rough

Conditions
Operation: Facing and ID turning
Grade: CBN350
Insert: RNMN120300S
Holder:
Cutting speed: 55–80 m/min
Feed rate: 0,25–0,40 mm/rev
Depth of cut: 0,50–3,00 mm
Coolant: No

Result
Tool life: CBN350 = 180 minutes/edge
Machining time 50% compared to grinding

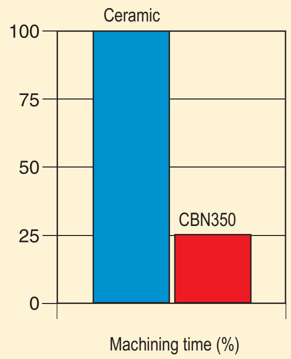


Machining: Impellers

Workpiece
Component: Impeller
Material: White cast iron (SS0466)
Hardness: 60 HRC
Surface: Cast, rough

Conditions
Operation: Facing, interrupted
Grade: CBN350 (Whisker ceramic)
Insert: RNMN120300S
Holder:
Cutting speed: 160 m/min (63–118 m/min)
Feed rate: 0,35 mm/rev (0,15 mm/rev)
Depth of cut: 0,50–1,00 mm
Coolant: No

Result
Tool life: CBN350 = 20 parts/edge, 360 parts/insert
Ceramic = 3 parts/edge, 24 parts/insert
Machining time reduced with 75%



Material categories – White cast irons (Chrome iron)

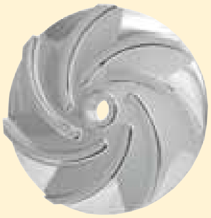
Machining: Impellers

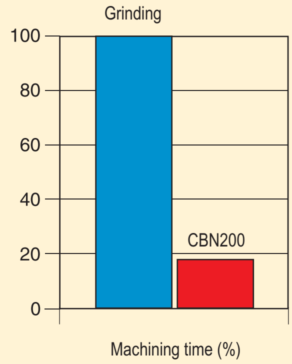
Workpiece

Component:	Impeller
Material:	White cast iron
Hardness:	60 HRC
Surface:	Cast, rough

Conditions

Operation:	Finish boring, diameter 15 H7
Grade:	CBN200
Insert:	TCMW110208S-02020-L1-C
Holder:	
Cutting speed:	200 m/min
Feed rate:	0,1 mm/rev
Depth of cut:	First cut 0,2–0,3 mm, second cut 0,1 mm
Coolant:	No





Result

Machining time: Reduced machining time with more than 80% compared to grinding face and bore

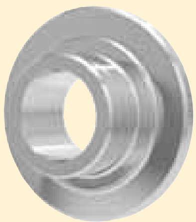
Machining: Pump throat bushes

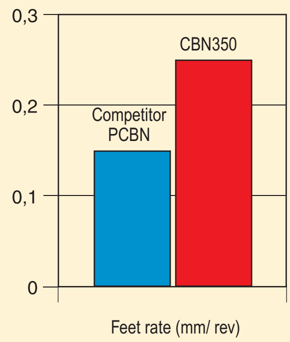
Workpiece

Component:	Slurry pump
Material:	Chrome iron (25% Cr)
Hardness:	600 HB
Surface:	Cast, rough

Conditions

Operation:	Facing and OD-turning
Grade:	CBN350
Insert:	RNMN120300S
Holder:	
Cutting speed:	80 m/min
Feed rate:	0,25 mm/rev
Depth of cut:	3,50 mm
Coolant:	No





Result Increased feed rate compared to competitor PCBN

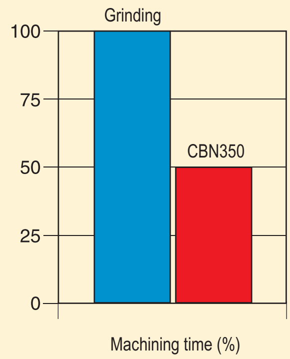
Machining: Working rolls

Workpiece

Component:	Working rolls
Material:	Chilled cast iron
Hardness:	78–88 Shore C
Surface:	Cast, rough

Conditions

Operation:	OD-turning
Grade:	CBN350
Insert:	RNMN120300S
Holder:	
Cutting speed:	60 m/min
Feed rate:	0,6–0,8 mm/rev
Depth of cut:	2–4 mm
Coolant:	No



Result

Tool life: CBN350 = 100 minutes/edge
Machining time reduced with 50%

Material categories – White cast irons (Chrome iron)

Machining: Pump houses

Workpiece

Component:	Pump house
Material:	Chrome iron
Hardness:	53 HRC
Surface:	Pre-machined

Conditions

Operation:	1 inch ACME threading
Grade:	CBN200
Insert:	Special
Holder:	Special
Cutting speed:	61 m/min
Feed rate:	25,4 mm/rev
Depth of cut:	0,127 mm (67 cuts)
Coolant:	

Result

Cycle time:	Cycle time reduced from days when grinding to hours with PCBN

Machining: Pump impellers

Workpiece

Component:	Pump impeller
Material:	Chrome iron
Hardness:	53 HRC
Surface:	Pre-machined

Conditions

Operation:	3 inch BSW threading
Grade:	CBN200
Insert:	DCGW11T304S-01020-L1-B
Holder:	Special
Cutting speed:	150 m/min
Feed rate:	1 200 mm/min
Depth of cut:	First cut 2,2 mm, second cut 1,7 mm
Coolant:	

Result

Cycle time:	Cycle time 15 minutes 41 seconds

Machining: Pump impellers

Workpiece

Component:	Pump impeller
Material:	Chrome iron
Hardness:	53 HRC
Surface:	Cast, rough

Conditions

Operation:	Face milling
Grade:	CBN200
Insert:	OFEN070405TN-MD16-LF
Cutter:	R220.43-0100-07W
Cutting speed:	200 m/min
Feed rate:	0,07 mm/tooth = 300 mm/min
Depth of cut:	3,00 mm
Coolant:	No

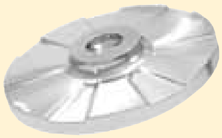
Result

Cycle time:	Cycle time 2 minutes 13 seconds

Machining: Slurry pump housings

Workpiece
Component: Slurry pump housing
Material: White cast iron
Hardness: 60 HRC
Surface: Cast, rough

Conditions
Operation: Finish milling
Grade: CBN200
Insert: RNGN060300S-02020-LF
Cutter: R217.70-2525.3-06-4
Cutting speed: 200 m/min
Feed rate: 0,10 mm/tooth = 1 018 mm/min
Depth of cut: 0,25 mm
Coolant: No

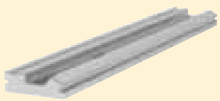


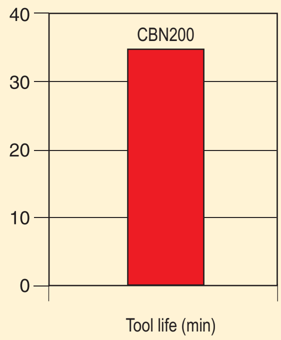
Result
Tool life: Excellent tool life

Machining: Machine beds

Workpiece
Component: Machine bed
Material: Chilled cast iron
Hardness: 53 HRC
Surface: Pre-machined

Conditions
Operation: Face milling
Grade: CBN200
Insert: SNGN090308S
Cutter: R220.74-0125-09-8
Cutting speed: 180 m/min
Feed rate: 0,27 mm/tooth = 989 mm/min
Depth of cut: 0,50 mm
Coolant: No



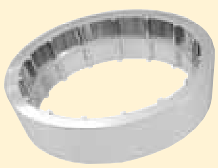


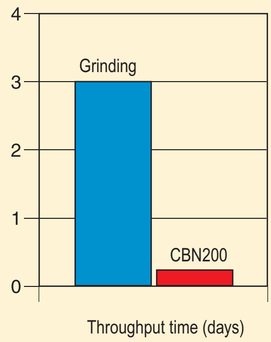
Result
Tool life: 35 minutes/edge
CBN200 replaced grinding with significant reduction in machining time and cost

Machining: Barrel liners

Workpiece
Component: Barrel liner
Material: Chrome iron (26% Cr)
Hardness: 58 HRC
Surface: Forged

Conditions
Operation: Milling
Grade: CBN200
Insert: 218.19-100T-MD08-LF
Cutter: R217.21-1225.RE-R100.3A
Cutting speed: 454 m/min
Feed rate: 0,45 mm/tooth
Depth of cut: 0,12 mm
Coolant: No





Result
Tool life: CBN200 = 30 minutes/edge
High stock removal and reduced machining time compared to grinding

Material categories – Austempered ductile irons

Experiences machining ADI material with PCBN are limited, machining conditions and tool selection continues to be evaluated and improved.

Austempered ductile irons (ADI) (270-550HBN)

Material introduction

Austempered Ductile Iron (ADI) is an alloyed heat-treated ductile cast iron. The ductile cast iron is subjected to a unique isothermal heat treatment called "Austempering". In contrast to conventional "as cast" irons, ADI gains its mechanical properties by the heat treatment process and not by a specific alloy combination. Thus the only condition for obtaining a desirable ADI component is a good quality ductile iron material. The ADI requires a consistent ductile iron with a predictable chemical analysis, a reasonably consistent pearlite to ferrite ratio and a commercially accepted level of graphite nodularity and count. The typical microstructure of ADI consists of bainite and graphite nodules.

The ADI material exhibits remarkable properties, such as high toughness, relatively light in weight, good heat conductivity and good vibration damping as well as a high level of ductility and wear resistance. These useful mechanical properties are attributed to the material via a unique process of heat treatment that also provides designers with further manufacturing flexibility and effective cost reduction compared to comparative forged steel components.

Typical austempered ductile iron microstructure with nodules

Examples of representative standard ADI grades ASTM 897-90 (ASTM 897M-90)

ADI grade	Tensile strength MPa(1)	Yield strength MPa	Elongation	Impact energy joules(2)	Typical hardness HBN
850/550/10	850	550	10	100	269–321
1050/700/7	1050	700	7	80	302–321
1200/850/4	1200	850	4	60	341–344
1400/1100/1	1400	1100	1	35	388–447
1600/1300/–	1600	1300	N/A	N/A	444–555

(1) Minimum values, (2) Un-notched charpy bars tested at 22° ±4° C (72° ±7° F)

Material categories – Austempered ductile irons

Examples of typical austempered ductile iron components

- Gears
- Torsion bars
- Locomotive axle components
- Locomotive wheels
- Wheel hubs

Cutting tool grade selection

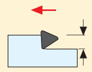
Roughing or finishing

When machining ADI materials, roughing or finishing is defined by the depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

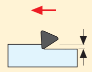
Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	**Turning**	**CBN200** / CBN300	**CBN200** / CBN300
	Milling	N/A	**CBN200** / CBN300

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	**Turning**	**CBN10/CBN100** / CBN160C	**CBN160C** / CBN150
	Milling	N/A	**CBN200** / CBN150
	Plunging	**CBN10/CBN100** / CBN050C	N/A
	Threading	N/A	N/A
	Grooving	**CBN10/CBN100**	N/A

Bold = First choice

Comment

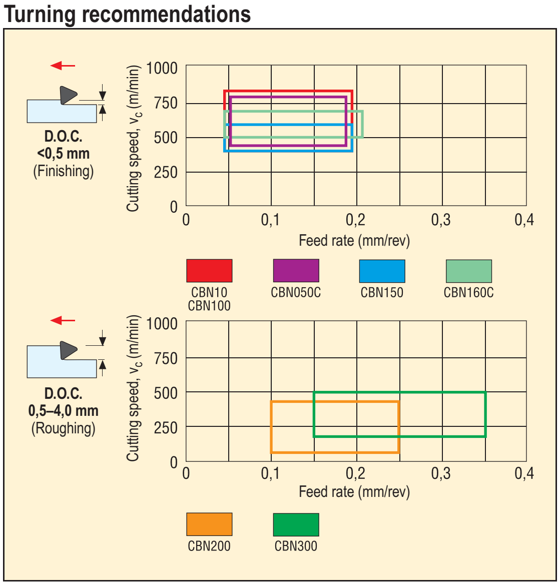
Although part of the iron family, Austempered Ductile Irons machine like hard steels. Therefore, grade selection is very dependent on the operation. Finishing operations should be carried out with low cBN content grades and roughing with high cBN content grades.

Parameter guide – Recommended machining conditions

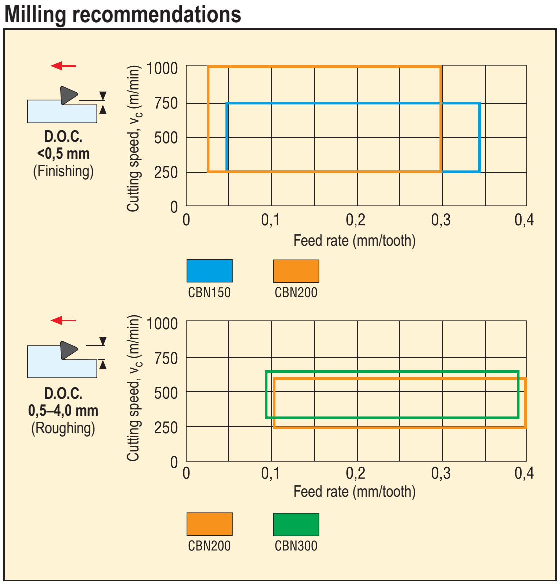
Austempered ductile irons

The following charts show the recommended cutting data for austempered ductile iron applications.

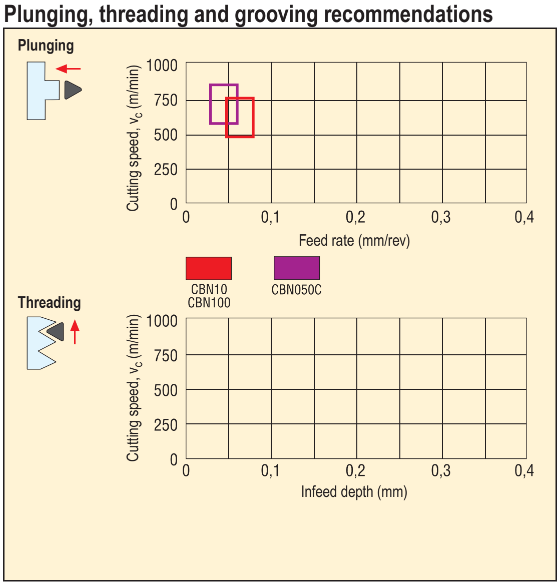
Turning recommendations

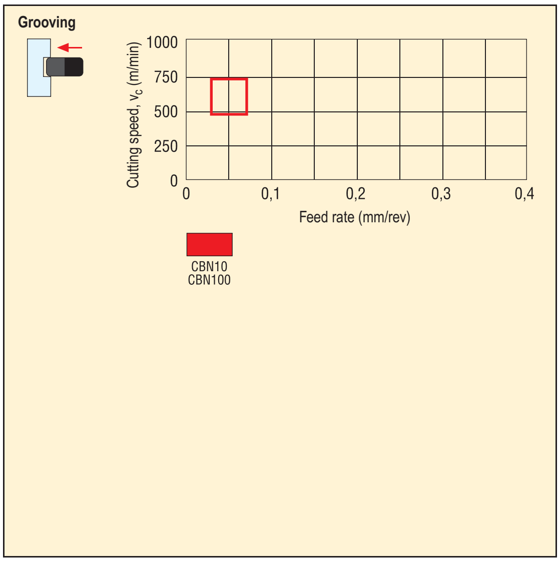


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Austempered ductile irons

Tool geometry and edge preparation

Finishing machining
The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of austempered ductile iron components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

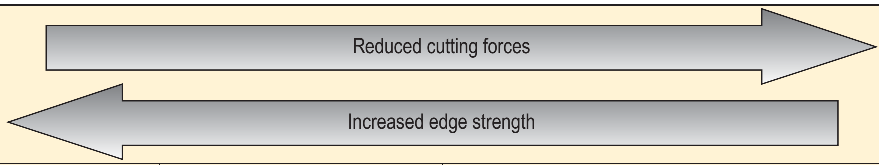
When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

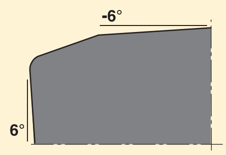
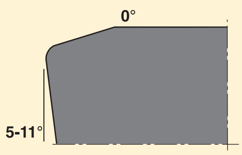
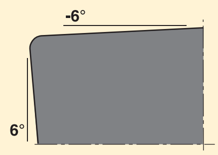
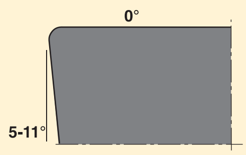
In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further decrease tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

Rough machining
Rough machining of austempered ductile iron requires chamfered and honed cutting edges (a). The skin of the austempered ductile iron can be rough, hard and contain impurities such as sand from the casting process. These and the larger depth of cut mean much more pressure on the cutting edge. Chamfering of the insert strengthens the PCBN cutting edge and thereby ensuring consistent and maximum tool life.

Heavy interruptions and milling
In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for austempered ductile irons

For general troubleshooting recommendations, see page 80.

Material categories – Austempered ductile irons

Application examples

Machining: Test pieces

Workpiece

Component:	Test piece
Material:	ADI, grade 3
Hardness:	388 HBN
Surface:	Cast (smooth)

Conditions

Operation:	Facing, interrupted
Grade:	CBN100
Insert:	RNGN090300S-01020
Holder:	
Cutting speed:	700 m/min
Feed rate:	0,1 mm/rev
Depth of cut:	0,5 mm
Coolant:	No

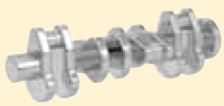
Result

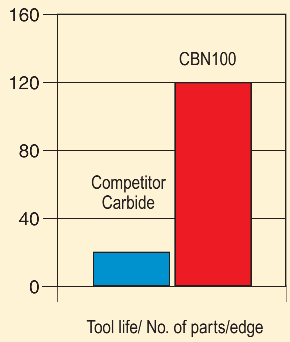
Tool life:	Excellent tool life and productivitiy

Machining: Crank shafts

Workpiece

Component:	Crank shaft
Material:	ADI
Hardness:	
Surface:	Cast (smooth)





Conditions

Operation:	OD turning of journals
Grade:	CBN100
Insert:	TNGX110308S-01020-L-WZ
Holder:	
Cutting speed:	240 m/min
Feed rate:	0,13 mm/rev
Depth of cut:	0,15 mm
Coolant:	No

Result

Tool life:	CBN100 = 120 parts/edge Carbide = 20 parts/edge Higher metal removal rate


CBN060K

Material categories – Grey cast irons

Grey cast irons (~240 HBN)

Material introduction

Cast iron that solidifies with separation of graphite is called grey cast iron due to the fact that fracture surfaces appear grey because of the exposed free graphite. Grey cast iron is also known in the Far East as Ferrum Casting (FC). A typical structure is shown below. Within the grey iron area there are a number of standardised grades. The nomenclature of these grades can be different from country to country. In every case the standard is based on strength and hardness, which is related to the microstructure of the matrix. This in turn is related to the chemical composition. However, knowledge of the composition does not necessarily infer knowledge of the microstructure or mechanical properties. To be able to make an estimate it is important to know the impurity levels in different sections of the component, cooling rate and heat treatment.

In all grey cast iron grades free graphite is present in the form of flakes of various size and distribution. Fast cooling yields a grey iron with too much cementite. Up to one or two percent cementite is present in all grey irons. Slow cooling of a grey iron with a high content of carbon and silicon will result in a matrix with a high content of free ferrite and large flakes of graphite. In the table below, the microstructure is described for a cast sample rod with a diameter of 30 mm. The sample rod has been allowed to cool in its mould to a temperature below 500° C.

Typical grey cast iron microstructure with graphite flakes in a pearlitic matrix

Examples of representative grey cast irons

SS	DIN1691	ASTM A48-76	CE %	C %	Si %	Mn %	P %	S %	Micro structure	Rm (MPa)	HBN
0100	GG00	–	4,3–4,7	3,5–3,8	2,8–2,2	0,4–0,8	–	–	–	–	–
0110	GG10	20B	4,3–4,7	3,5–3,8	2,8–2,2	0,4–0,8	<0,50	<0,15	Ferritic/Pearlitic	100	100–180
0115	GG15	25B	4,1–4,5	3,4–3,7	2,6–2,0	0,5–0,8	<0,50	<0,15	Ferritic/Pearlitic	150–250	130–190
0120	GG20	30B	3,9–4,2	3,3–3,6	2,1–1,8	0,6–0,8	<0,35	<0,15	Ferritic/Pearlitic	200–300	160–210
0125	GG25	35B/40B	3,7–4,0	3,2–3,5	2,1–1,5	0,6–0,8	<0,25	<0,15	Pearlitic	250–350	180–230
0130	GG30	45B	3,5–3,7	3,1–3,3	1,8–1,3	0,7–0,9	<0,15	<0,10	Pearlitic	300–400	200–250
0135	GG35	50B	3,3–3,5	3,0–3,2	1,5–1,1	0,8–1,0	<0,10	<0,10	Pearlitic	350–450	220–260
0140	GG40	60B	–	–	–	–	–	–	Pearlitic	400–500	–

Carbon Equivalent CE = $C\% + \frac{Si\%}{4} + \frac{P\%}{2}$

The strength and hardness of the grey iron can be improved by adding Mn, Cr, Ni, V or Cu.

From a machinability point of view the microstructure, which is almost synonymous with the hardness, is totally dominant. It is quantity, size and distribution of the graphite flakes, the amount of free ferrite and lamellar pearlite that decide the strength and hardness of the grey iron. Alloying elements such as C, Si, S and Si/Mn improve the machinability. The elements Mo, Cr and P have the opposite effect with Mo being the most detrimental and P the least. If the content of free ferrite is below 10%, grey irons can usually be machined with PCBN. Free ferrite above 10% causes chemical wear at a rate dependent on the amount of free ferrite.

Material categories – Grey cast irons

Examples of typical grey cast iron components

- Engine blocks
- Brake discs/ Brake rotors
- Brake drums
- Cylinder liners
- Fly wheels
- Clutch plates
- Machine beds

Cutting tool grade selection

Roughing or finishing

Generally machining with PCBN requires high cBN content grades to be used for roughing operations and low cBN content grades to be used for finishing operations.

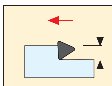
However, grey cast iron exhibits very different properties to those generally hard workpiece materials that are well-documented PCBN applications. Grey cast irons are relatively soft, but very abrasive, making high cBN content grades with their high abrasion resistance the first choice for both roughing and finishing of grey cast iron components.

When machining grey cast irons, roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between the insert and the material can be large in all of these operations.

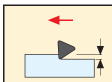
Definition of the operation in this way is very important for grade selection, since several PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	**Turning**	**CBN300** / CBN200	**CBN200** / CBN400C
	Milling	N/A	**CBN200** / CBN300

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	**Turning**	**CBN400C** / CBN300 / CBN200	**CBN400C** / CBN200 / CBN300
	Milling	N/A	**CBN200** / CBN300
	Plunging	**CBN400C** / CBN300 / CBN200	N/A
	Threading	**CBN200** / CBN300	N/A
	Grooving	**CBN200** / CBN300	**CBN200**

Bold = First choice

Comment

If the cutting speed is below 400 m/min or the free ferrite content of the grey cast iron is higher than 10%, CBN100 or CBN10 can be an option. The use of CBN100/CBN10 at lower cutting speeds can sometimes offer a machining solution in grey cast iron materials where the free ferrite content is higher than 10%. Where CBN100/CBN10 has been successful is generally when high dimensional accuracy is required and the component configuration does not allow the use of high speeds.

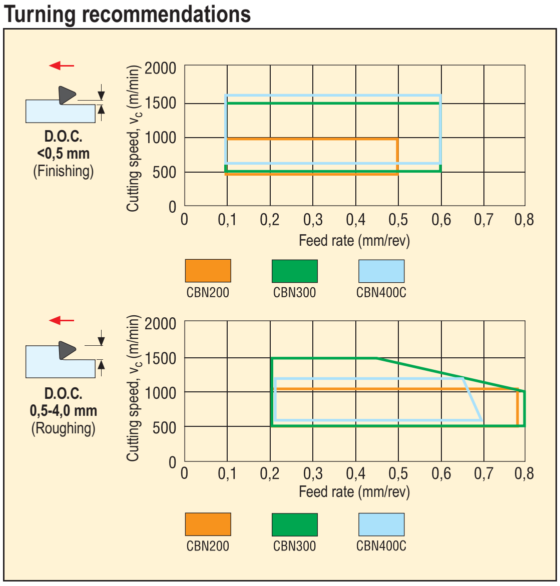
The majority of successful examples are where machine downtime justifies an improvement in tool life of 15 times over carbide such as in high volume automotive applications. Typical examples are bearing journals in soft cast iron, camshaft and crankshafts and reaming of small bores.

Parameter guide – Recommended machining conditions

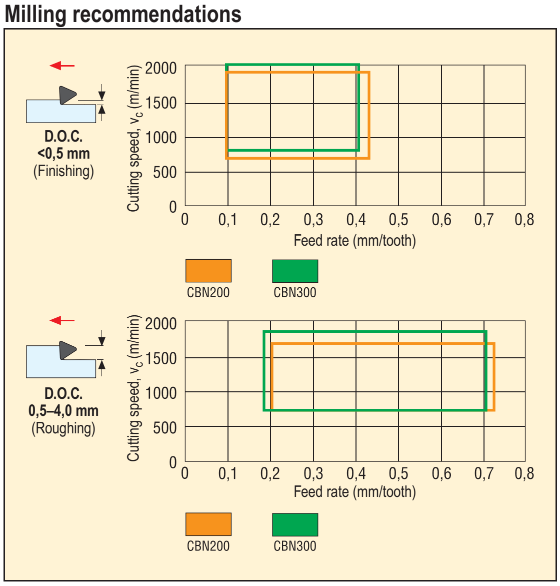
Grey cast iron

The following charts show the recommended cutting data for grey cast iron applications.

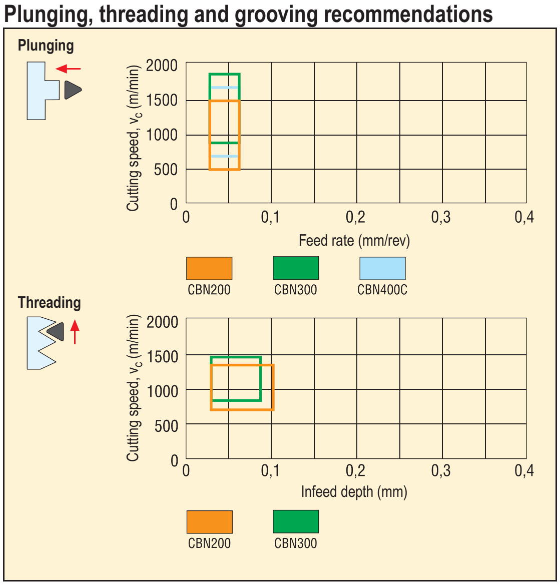
Turning recommendations

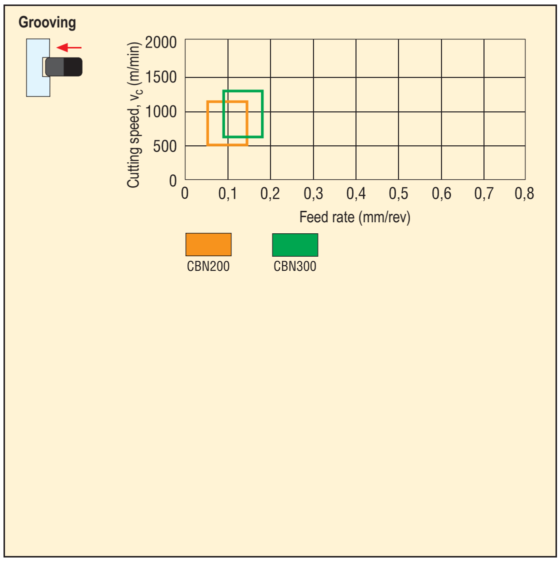


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Grey cast irons

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of grey cast iron components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is sometimes necessary to reduce the tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further decrease tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

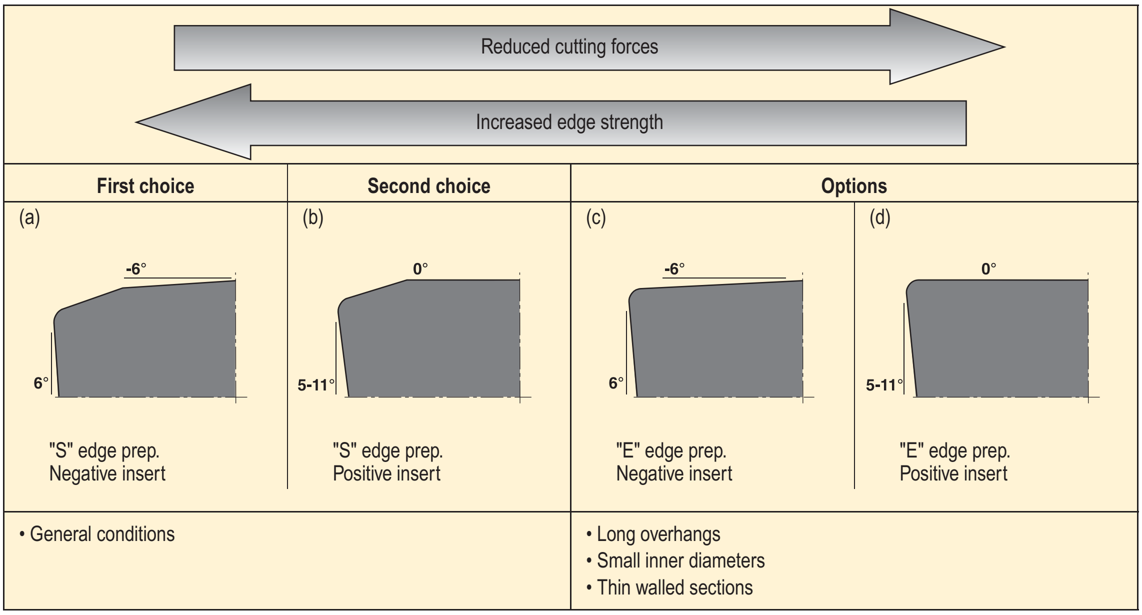
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

Rough machining

Rough machining of grey cast iron requires chamfered and honed cutting edges (a). The skin of grey cast iron can be rough, hard and contain impurities such as sand from the casting process. These and the larger depth of cut mean much more pressure on the cutting edge. Chamfering of the insert strengthens the PCBN cutting edge and thereby ensuring consistent and maximum tool life.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



Material categories – Grey cast irons

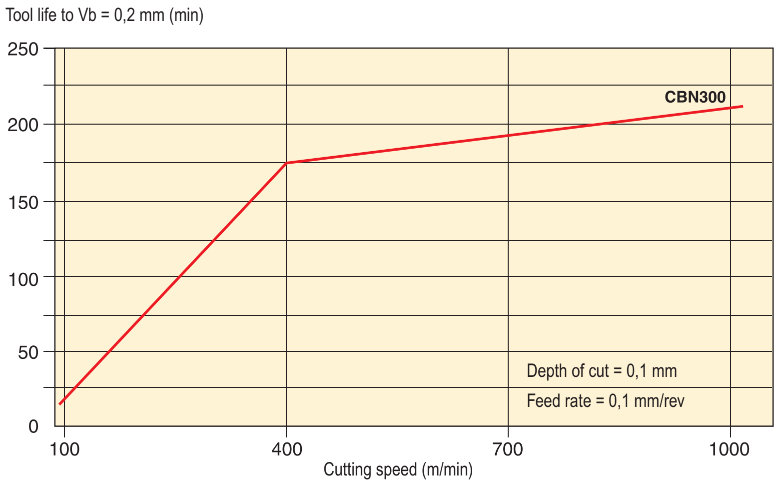
Successful Machining of Grey Cast Iron with PCBN

The use of PCBN grades such as Secomax CBN200, CBN300 and CBN400C have proven to be very successful over the years in machining of grey cast iron, offering unrivalled productivity and significant costs savings. In many cases, applying PCBN to grey cast iron machining is a straight forward process. However, there are occasions where the make up of the grey cast iron and the machining process make applying PCBN difficult and on occasions not cost effective.

In the past, these problems were identified and summarised by identifying the level of free ferrite in the castings and maintaining adequate cutting speed. It has now been realized that this was an over simplification of a complex machining process. Recent research has identified some other indicators which should be adhered to in order to achieve optimised PCBN tool life. While this recent research is not a complete understanding of all the factors responsible for the tool life of a PCBN insert, it takes us significantly closer in understanding what is required to offer sustained and stable PCBN tool life when machining grey cast iron. This section is a summary and explanation of the known factors that influence PCBN tool life when machining grey cast iron.

Cutting speed

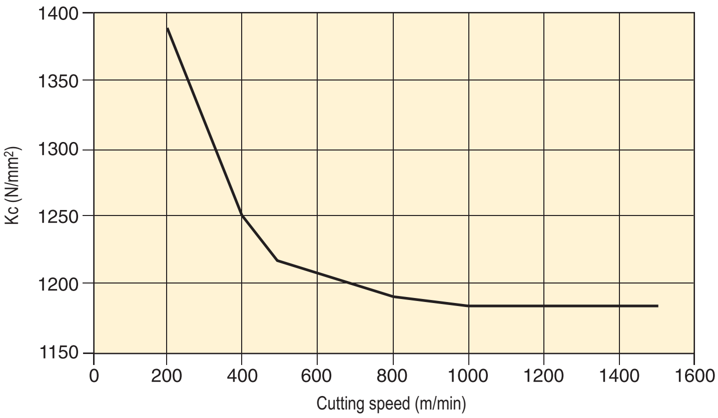
Since PCBN was first applied to grey cast iron machining, the importance of cutting speed has been well documented. Early tests, as shown below, showed that tool life increases rapidly when cutting speed are increased from 100 m/min to 400 m/min. It is only at cutting speeds above 400 m/min that the increase stabilises. Consequently running at cutting speeds below 400 m/min are not cost effective for PCBN cutting tools. Optimised cutting speed related to PCBN tool life is between 1 000 m/min and 2 000 m/min. Successful PCBN machining is typically carried out at cutting speeds between 800 m/min and 1 200 m/min. This improvement in tool life with increasing cutting speed is peculiar to PCBN, the opposite occurs for conventional tooling such as ceramic.



- Ideal cutting speed for PCBN = more than 1 000 m/min
- Acceptable cutting speed for PCBN = not less than 400 m/min

Specific cutting force (cutting resistance)

The specific cutting force, kc, is a variable describing the force needed to remove a specific amount of material. Tests show a significantly higher specific cutting force at speeds lower than 400 m/min.



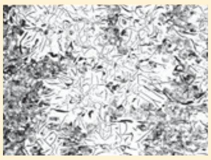
Material categories – Grey cast irons

Material Ferrite Content

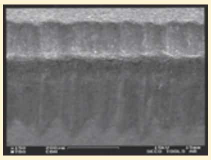
When machining grey cast iron with PCBN, the balance of ferrite and pearlite in the iron's microstructure is critical to the performance of PCBN. Ideally the grey iron microstructure should be fully pearlitic with no free ferrite present. The free ferrite content of a grey cast iron component has a major effect on PCBN tool life. To maximise PCBN performance, the free ferrite levels in a casting should be less than 5% and ideally zero. Grey cast iron with free ferrite levels of between 5–10% have also proven to be successfully machined with PCBN. However, if free ferrite levels in the castings are above 10%, then tool life is significantly reduced. Free ferrite in grey cast iron is known to chemically attack PCBN. The heat generated in the cutting process facilitates a chemical reaction between elements in the cutting tool and the free ferrite in the iron. Essentially there is diffusion of boron and nitride elements from the cutting tool into the ferrite in the iron. The result is rapid flank wear of the cutting tool.

The schematic below shows two very similar grey cast iron materials in the form of brake discs, with large differences in their free ferrite content. When machined with PCBN the difference in performance is massive. Up to 2 000 discs with the 2% ferrite castings and only 80 discs with the 80% ferrite castings. The images of the cutting tool wear scars shown in the centre of the schematic support this result. The top image shows typical chemical wear on the cutting edge with vertical striations. The distance between striation peeks is equal to the feed rate value, a sure sign of chemical attack. Compare this with the wear scar image below that, which shows the cutting edge after x25 the number of discs machined with the ferritic discs. The flank wear is small and exhibits a built up layer known as the protective layer, which is key to the success of PCBN.

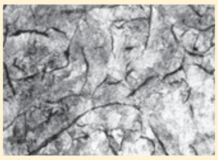
GG20 80% ferrite



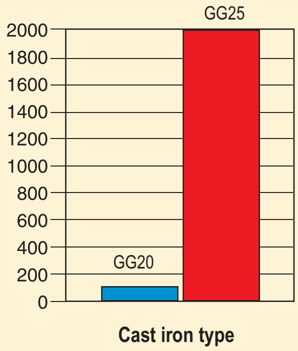
Tool life = 80 discs/edge



GG25 2% ferrite



Tool life = 2000 discs/edge



Cutting speed 1200 m/min
Feed rate 0,35 mm/rev

Unfortunately ferrite levels present in a casting are generally not recorded in a material properties data sheet, and therefore, have to be requested. Alternatively, often the easiest and cheapest way of establishing the free ferrite levels is to run a trial with a PCBN tool and monitor the tool life. The rate and type of flank wear on the cutting edge will give a clear indication to PCBN's suitability in an application.

It is also not unusual for the ferrite/pearlite level of a particular casting to be recorded as an average for the whole casting. This can be misleading as quite often the grey cast iron core is fully pearlitic and only the skin of the casting exhibits any significant free ferrite. Needless to say, in these cases, once the skin is removed PCBN is the best tooling choice for such a casting.

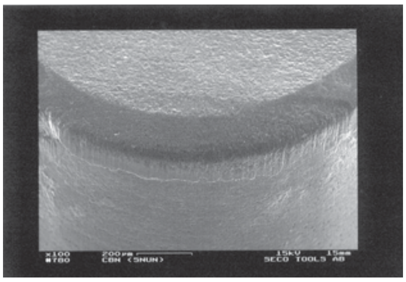
Cooling rate is important for avoiding ferrite. Faster cooling rate often promotes the formation of ferrite, which can happen on smaller components, or at the surface of a larger component. In the picture, there is a surface layer of almost 100% free ferrite to a depth of 0,1 mm (left). Below this, the parts are fully pearlitic.

There can also be seasonal differences in the machinability depending on the air temperature if the parts are cooled outside, or in a room without temperature control. Higher cooling rate promotes the formation of free ferrite.

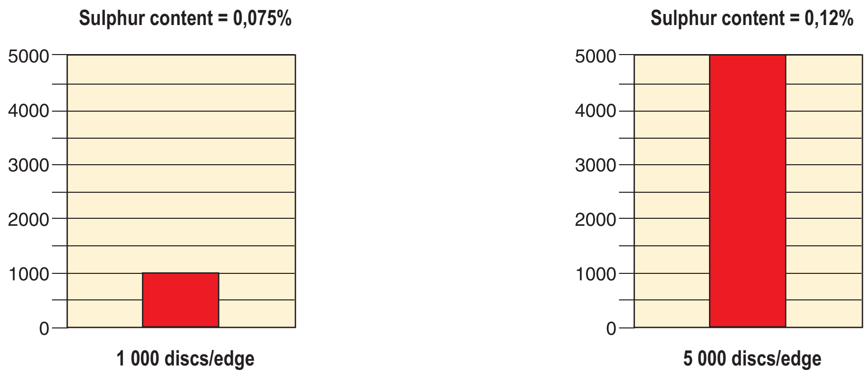
Material categories – Grey cast irons

Material Sulphur Levels

Manganese sulphide (MnS) is generally well known as a machinability enhancing compound in steels. Manganese sulphide also enhances the performance of PCBN by creating a protective layer on the cutting edge. While this mechanism is not totally understood, the MnS protective layer appears essential to the PCBN performance. It seems that it is continuously self generating process where MnS is deposited and adheres to the cutting edge at the same rate as it is being removed by abrasion. MnS is formed from the sulphur content of the casting during pouring. Insufficient sulphur means not enough MnS is formed during the cooling process, the result is the MnS protective layer (during machining) can not be formed or replaced sufficiently. The result is poor tool life. Recent research has shown that sulphur levels in a casting should be higher than 0.1%. Fortunately, sulphur levels are generally recorded in the material properties data sheet that accompanies each casting batch.



A recent trial supports this synopsis. Trials conducted where machining conditions were identical albeit subtle differenced in sulphur levels in the casting prior to machining show significant differences in tool life.



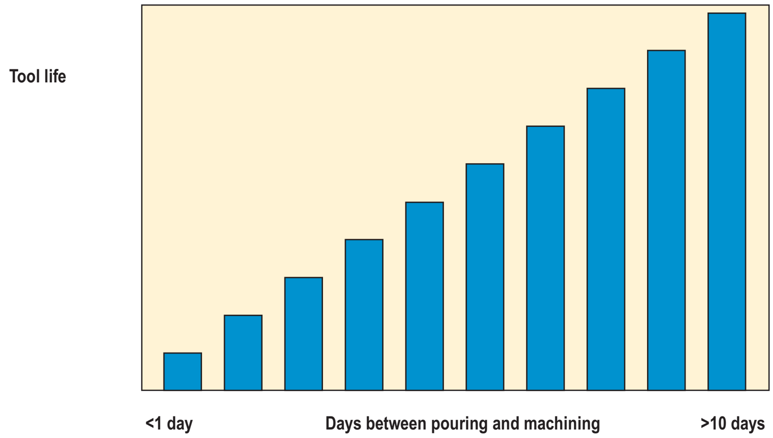
Note: All other variables the same for both examples.

Material categories – Grey cast irons

Ageing Process

When casting grey cast iron components, nitrogen and oxygen are trapped in the castings. The presence of nitrogen and more importantly oxygen in castings is detrimental to the life of the tool as these elements form aggressive oxides during machining.

The generally accepted method for removing the oxygen and nitrogen from the casting is to allow at least 10 days between casting and machining, in order to allow the oxygen and nitrogen to escape from the casting. This process is generally known as “ageing”. By ageing the material for at least 10 days, oxygen and nitrogen are dispersed from the casting. If the castings are machined earlier, oxygen and nitrogen remain dissolved in the iron resulting in increased cutting forces and hotter chips, thus decreasing tool life.



At approximately 10 days of ageing, tool life is optimised. Ageing for more than 10 days or so does not bring any further tool life benefits.

As well as allowing the oxygen and nitrogen to escape from the casting, ageing is also beneficial in that it allows for stress relieving of the component thereby minimising any subsequent component deformation or movement after machining.

Although rarely employed, the ageing process can be accelerated, by heating the castings for 30 minutes in an furnace at 500°C.

Due to the exceptional tool life and productivity offered by PCBN tooling, the ageing process is important to maximising PCBN’s tool life, however, it should be remembered that all cutting tool materials will benefit from allowing the castings to age.

Summary

Certain batches of cast iron may exhibit poor machinability. Check that the following are within the recommendations:

- Cutting speed = >400 m/min
- Ferrite content = <10%, ideally less than 5%
- Sulphur content = >0,1%
- Ageing = >10 days

The understanding of successful machining with PCBN is ever evolving. If the above guidelines do not resolve tool life issues, then please discuss with your Seco representative.

For general troubleshooting recommendations, see page 80.

Material categories – Grey cast irons

Application examples

Machining: Cast iron brake discs

Workpiece

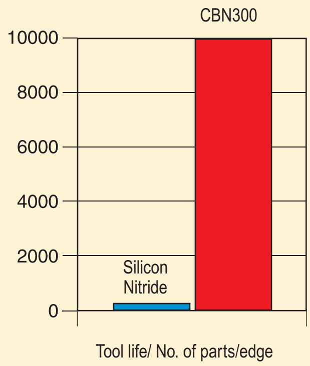
Component:	Brake disc
Material:	Grey cast iron (GG25)
Hardness:	230 HBN
Surface:	Rough

Conditions

Operation:	Roughing of disc plane side
Grade:	CBN300 (Silicon nitride)
Insert:	CNMN120412S
Holder:	
Cutting speed:	1 100–850 m/min (800–650 m/min)
Feed rate:	0,65 mm/rev
Depth of cut:	1–3 mm
Coolant:	No

Result

Tool life:	CBN300: 10 000 parts/edge Silicon nitride: 200 parts/edge



Machining: Cast iron brake discs

Workpiece

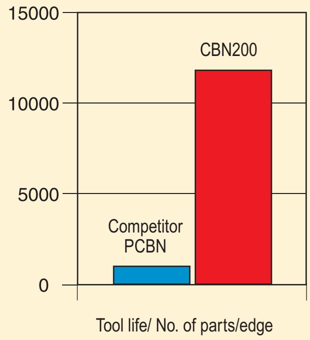
Component:	Brake disc
Material:	Grey cast iron (GG25)
Hardness:	240 HBN
Surface:	Pre-machined

Conditions

Operation:	Finishing
Grade:	CBN200
Insert:	TCGN110312E-WZ-LF
Holder:	
Cutting speed:	840 m/min
Feed rate:	0,3 mm/rev
Depth of cut:	0,5 mm
Coolant:	Yes

Result

Tool life:	12 000 parts/edge Competitor PCBN 1 000 parts/edge



Machining: Brake discs

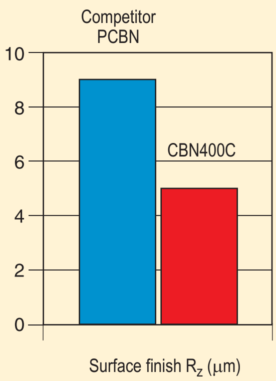
Workpiece

Component:	Brake disc
Material:	Grey cast iron (GG25)
Hardness:	230 HBN
Surface:	Pre-machined

Conditions

Operation:	Tandem finishing
Grade:	CBN400C
Insert:	SNMN090308E-WZ-85
Holder:	
Cutting speed:	600 m/min
Feed rate:	0,31 mm/rev
Depth of cut:	0,30 mm per side
Coolant:	No

Result A surface finish of 6 µm R_z is required
The wiper geometry and wear resistance of CBN400C easily achieves this



Material categories – Grey cast irons

Machining: Brake drums

Workpiece

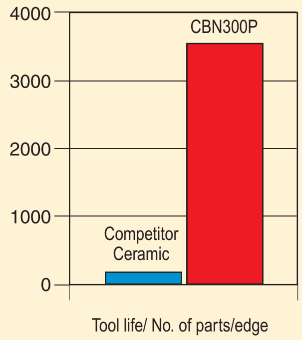
Component:	Brake drum
Material:	Grey cast iron (GG25)
Hardness:	230 HBN
Surface:	Pre-machined

Conditions

Operation:	Roughing
Grade:	CBN300P (Ceramic)
Insert:	CNMN120416S
Holder:	Special boring bar
Cutting speed:	1 000 m/min (600 m/min)
Feed rate:	0,5 mm/rev
Depth of cut:	3,0 mm
Coolant:	No

Result

Tool life:	CBN300P = 3 708 parts/edge Ceramics = 230 parts/edge



Machining: Compressor bearing houses

Workpiece

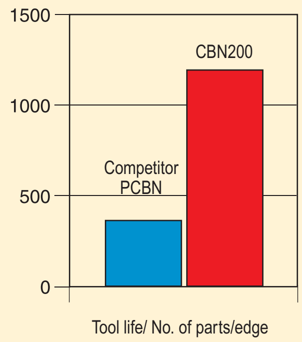
Component:	Compressor bearing housing
Material:	Grey cast iron (GG25)
Hardness:	187–215 HBN
Surface:	Rough

Conditions

Operation:	Rough face grooving
Grade:	CBN200
Insert:	LCGN160508-0500S-02025-LF
Holder:	
Cutting speed:	1 240 m/min
Feed rate:	0,20 mm/rev
Depth of cut:	7,62 mm
Coolant:	Yes

Result

Tool life:	CBN200 = 1 200 parts/edge Competitor PCBN = 350 parts/edge



Machining: Fly wheels

Workpiece

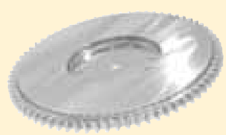
Component:	Fly wheel
Material:	Grey cast iron (GG25)
Hardness:	230 HBN
Surface:	Pre-machined

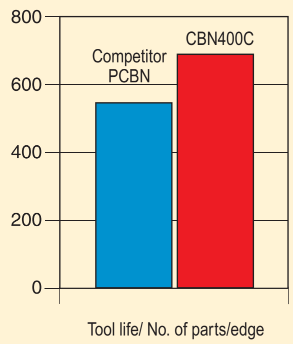
Conditions

Operation:	Finish facing
Grade:	CBN400C
Insert:	CNMN120412S
Holder:	CCLNL2525M09
Cutting speed:	750–1 500 m/min
Feed rate:	0,40 mm/rev
Depth of cut:	0,35 mm
Coolant:	No

Result

Tool life:	CBN400C = 680 parts/edge Competitor = 550 parts/edge





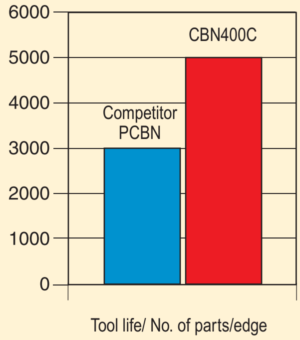
Material categories – Grey cast irons

Machining: Brake discs

Workpiece
Component: Brake disc
Material: Grey cast iron (GG25)
Hardness: 230 HBN
Surface: Pre-machined

Conditions
Operation: Finish facing
Grade: CBN400C
Insert: CNMN090416S
Holder: CCLNL2525M09
Cutting speed: 1 100 m/min
Feed rate: 0,3–0,5 mm/rev
Depth of cut: 1,5 mm
Coolant: No

Result
Tool life: CBN400C = 5 000 parts/edge
Competitor = 3 000 parts/edge

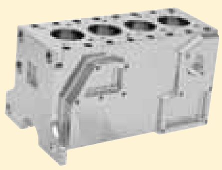


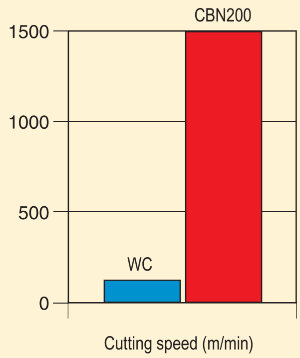
Machining: Engine blocks

Workpiece
Component: Engine block
Material: Grey cast iron (GG25)
Hardness: 230 HBN
Surface: Pre-machined

Conditions
Operation: Face milling
Grade: CBN200 (WC)
Insert: SNGN090312S
Cutter: R220.74-8200-09-12
Cutting speed: 1 500 m/min (150 m/min)
Feed rate: CBN200 = 0,15 mm/tooth = 4 296 mm/min
WC = 0,20 mm/tooth = 560 mm/min
Depth of cut: 0,50 mm
Coolant: No

Result 10x higher cutting speed with CBN200



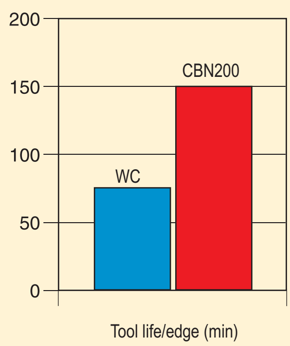


Machining: Vacuum pump casings

Workpiece
Component: Casing cover
Material: Grey cast iron (GG25)
Hardness: 220 HBN
Surface: Cast

Conditions
Operation: Rough face milling
Grade: CBN200 (WC)
Insert: SNEN0903ENS-M08
Cutter: R220.74-0063-09-6
Cutting speed: 2 000 m/min (WC=150 m/min)
Feed rate: CBN200 = 0,05 mm/tooth = 3 000 mm/min
WC = 0,05 mm/tooth = 318 mm/min
Depth of cut: 2,00 mm
Coolant: No

Result
Tool life: CBN200 = 150 minutes/edge
WC = 75 minutes/edge



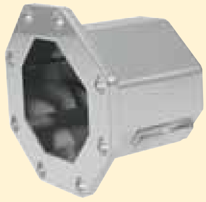
Material categories – Grey cast irons

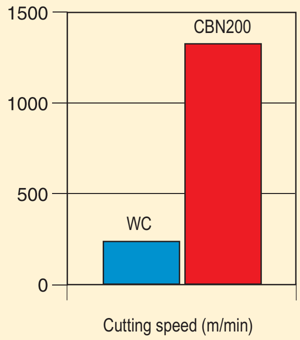
Machining: Gear box casings

Workpiece
Component: Gear box casing
Material: Grey cast iron (GG25)
Hardness: 230 HBN
Surface: Cast

Conditions
Operation: Face milling
Grade: CBN200 (WC)
Insert: SNGN090316S
Cutter: R220.74-0080-09-6
Cutting speed: 1 300 m/min (WC=190 m/min)
Feed rate: 0,12 mm/tooth (WC = 0,25 mm/tooth)
3 724 mm/min (WC=500 mm/min)
Depth of cut: 0,10 mm
Coolant: No

Result Increased capacity 2 752 hours/year based on 48 000 parts per year



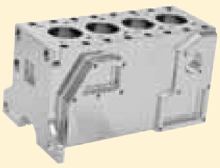


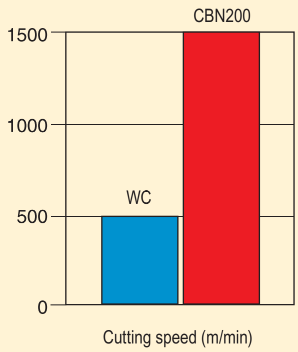
Machining: Engine blocks

Workpiece
Component: Engine block sump housing
Material: Grey cast iron (5% free ferrite)
Hardness:
Surface: Rough

Conditions
Operation: Finish face milling of bearing cup faces
Grade: CBN200 (WC)
Insert: SNGN090312S
Cutter: R220.74-0800-09-6
Cutting speed: 1 500 m/min (500 m/min)
Feed rate: 0,15 mm/tooth = 5 372 mm/min
Depth of cut: 1,00 mm
Coolant: No

Result
Machining time: CBN200 = 0,16 minutes/block
WC = 0,58 minutes/block
Cutting speed 3x WC

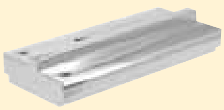




Machining: Machine bed guide ways

Workpiece
Component: Machine bed guide way
Material: Grey cast iron (GG25)
Hardness: 60–63 HRC
Surface: Pre-machined

Conditions
Operation: Finishing of guide way
Grade: CBN200
Insert: TNGN1604PRS
Cutter: R220.68-8160-T16C-10
Cutting speed: 1 000 m/min
Feed rate: 0,1 mm/tooth = 1 989 mm/min
Depth of cut: 0,2 mm
Coolant: No



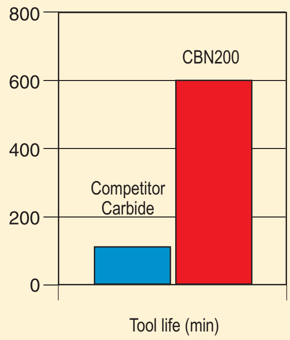
Result Surface finish of 0,8 µm R_a required
Achieved flatness of 0,010 mm over four guide ways each 2 000 mm long

SECO

Machining: Transmission housings

Workpiece
Component: Transmission housing
Material: Grey cast iron (GG25)
Hardness: 230 HBN
Surface: Pre-machined

Conditions
Operation: Finishing face milling
Grade: CBN200 (WC)
Insert: SNGN090312S/SNEX120312ZZ
Cutter: R220.74-8200-09-12
Cutting speed: 1 463 m/min
Feed rate: 0,09 mm/tooth = 2 440 mm/min
Depth of cut: 0,25 mm
Coolant: No

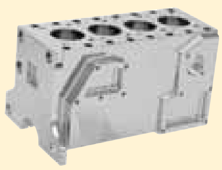


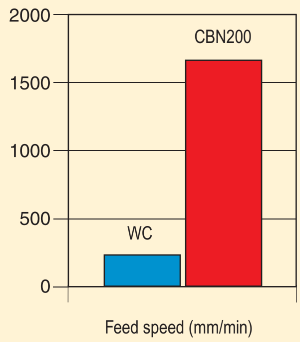
Result
Tool life: CBN200 (WC) = 600 (100) minutes/edge
Feed speed: CBN200 (WC) = 2 440 (228) mm/min

Machining: Cylinder blocks

Workpiece
Component: Cylinder block
Material: Grey cast iron (GG25)
Hardness: 230 HBN
Surface: Pre-machined

Conditions
Operation: Finishing face milling
Grade: CBN200 (WC)
Insert: RNGN090300S
Cutter: R220.70-8200-09-12
Cutting speed: 1 432 m/min
Feed rate: 0,075 mm/tooth = 1 700 mm/min
Depth of cut: 0,075 mm
Coolant: No



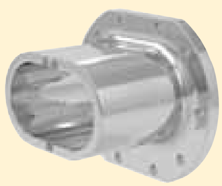


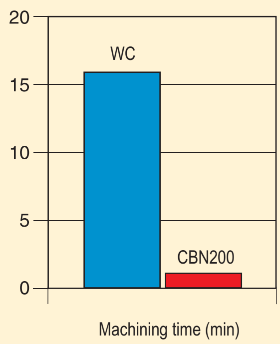
Result
Tool life: CBN200 (WC) = 437 (100) minutes/edge
Feed speed: CBN200 (WC) = 1 700 (228) mm/min

Machining: Pump bodies

Workpiece
Component: Pump body
Material: Grey cast iron (GG25)
Hardness:
Surface: Pre-machined

Conditions
Operation: Finishing face milling
Grade: CBN200
Insert: SEEX09T3AFTN-D09-LF
Cutter: R220.53-0100-09-8C
Cutting speed: 816 m/min
Feed rate: 0,1 mm/tooth = 2 077 mm/min
Depth of cut: 0,2 mm
Coolant: No





Result
Tool life: CBN200 = 60 parts/edge (1,6 min/part)
WC = 5 parts/edge (16,3 min/part)

Material categories – Grey cast irons

Machining: Pump housings

Workpiece

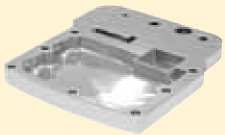
Component: Pump housing
Material: Grey cast iron (GG20)
Hardness: 210 HBN
Surface: Pre-machined

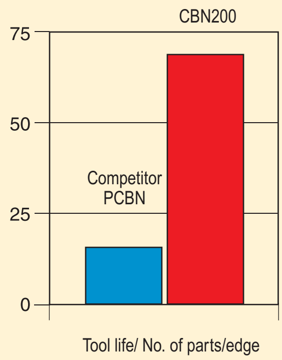
Conditions

Operation: Finish face milling
Grade: CBN200
Insert: TNGN1604PRS
Cutter: R220.68-0100-T16C-6
Cutting speed: 1 194 m/min
Feed rate: 0,063 mm/tooth = 1 436 mm/min
Depth of cut: 0,200 mm
Coolant: No, air blast only

Result

Tool life: CBN200 = 69 parts/edge
Competitor PCBN = 15 parts/edge





Machining: Engine blocks

Workpiece

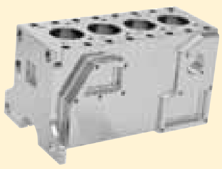
Component: Engine block
Material: Grey cast iron (GG25)
Hardness: 240 HBN
Surface: Pre-machined

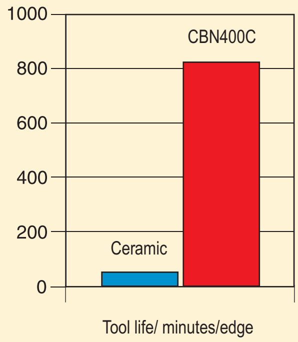
Conditions

Operation: Boring
Grade: CBN400C (Ceramic)
Insert: SNGN090308S
Holder: Special
Cutting speed: 425 m/min
Feed rate: 0,30 mm/rev
Depth of cut: 0,32 mm
Coolant: No

Result

Tool life: CBN400C = 820 minutes/edge
Ceramics = 60 minutes/edge





Machining: Cylinder liners

Workpiece

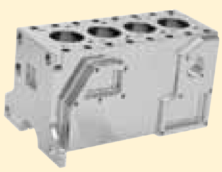
Component: Cylinder liner
Material: Grey cast iron (GG25)
Hardness: 230 HBN
Surface: Pre-machined

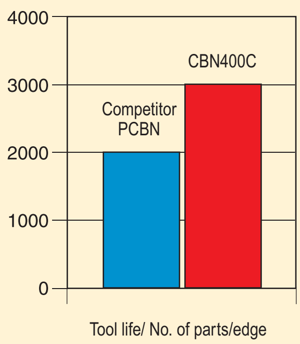
Conditions

Operation: Finish boring
Grade: CBN400C
Insert: SNGF090312S
Holder: Special
Cutting speed: 600 m/min
Feed rate: 0,20 mm/rev
Depth of cut: 0,15 mm
Coolant: No

Result

Tool life: CBN400C = 3 000 parts/edge
Competitor = 2 000 parts/edge





Material categories – Ductile cast irons (Nodular)

The machining of ductile cast irons with PCBN is not usually economically successful and this should be clearly understood before attempting to use PCBN.

Ductile cast irons (135–430 HBN)

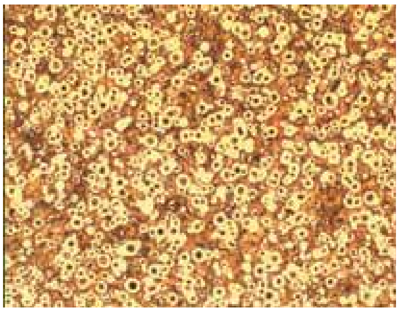
Material introduction

Nodular iron, Spherical Graphite iron (SG iron) and Ferrum Casting Ductile (FCD) are all names which are used to refer to ductile iron. Ductile iron consists basically of the same constituents as grey iron. The demand for purity is higher especially regarding to the sulphur content, which must be kept low. The graphite in ductile iron is present as small nodules.

To nodulize the graphite a small but definite amount of magnesium and/or cerium is added to the molten iron just before casting.

Similar to the case of grey irons, different national standards for ductile iron exist and are based on a classification of the strength that is related to the microstructure.

Typical ductile cast iron microstructure with graphite nodules (GGG60)



The machinability of ductile irons cannot be directly determined from the hardness. The hardness depends on, among other things, the alloying elements. If the ductile iron is unalloyed there is a close relationship between hardness and pearlite content.

In this case the hardness is a fairly good estimator of machinability.

Examples of representative ductile cast irons

ISO 1083-1976	DIN 1693	ASTM A536-80	SS	Spheroid graphite	Ferrite content	Pearlite content	Free Cemenite	Rm (N/mm²)	HB
370-17	GGG40	60-40-18	0717-02	>80%	>95%	<5%	<1%	Min 400	Min 135
500-7	GGG50	80-55-06	0727-02	>80%	=50%	=50%	<1%	500–720	170–230
600-3	GGG60	80-55-06	0732-03	>80%	=35%	=65%	<1%	600–820	200–260
700-2	GGG70	100-70-03	0737-01	>80%	<5%	>95%	<1%	700–960	230–300
800-2	GGG80	120-90-02	–	>80%	Martensitic	–	–	Min 800	Min 245
–	GGG100	–	0747	100%	Bainitic	–	–	n.a.	n.a.
–	–	Grade 1	–	100%	Bainitic (ADI)	–	–	>900	280–310
–	–	Grade 2	–	100%	Bainitic (ADI)	–	–	>1000	300–350
–	–	Grade 3/4	–	100%	Bainitic (ADI)	–	–	>1200	380–430

The ISO-designation describes the tensile strength in MPa and elongation in %. The ISO grade 500-7 has a tensile strength of minimum 500 MPa and an elongation of at least 7%. In the American system the figures 80-55-06 refers to the values for tensile strength, yield strength and elongation expressed in ksi and %.

Material categories – Ductile cast irons (Nodular)

SECO

Examples of typical ductile cast iron components

- Crankshafts
- Camshafts
- Axle casings
- Machine parts

Cutting tool grade selection

Roughing or finishing

When machining ductile irons, roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

D.O.C 0,5–4,0 mm (Roughing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	N/A	N/A
	Milling	N/A	N/A

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

D.O.C. <0,5 mm (Finishing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	**CBN10/CBN100** / CBN050C / PCD30	**CBN150** / CBN160C
	Milling	N/A	**CBN150** / CBN160C
	Plunging	**CBN10/CBN100**	N/A
	Threading	**CBN10/CBN100**	N/A
	Grooving	**CBN10/CBN100**	N/A

Bold = First choice

Comment

In general the free ferrite associated with ductile irons chemically attacks the cBN particles in the PCBN, resulting in rapid flank wear. The result is a much reduced tool life when compared with PCBN machining a pearlitic grey cast iron. To minimise the chemical attack, low cBN content materials such as CBN100 and CBN10 provide the greatest resistance.

If the nodular iron is hardened, CBN200 can be an option.

The reduced toughness of these PCBN grades means the application areas are generally limited to light to medium depths of cut with minimum interruptions. Where PCBN has been successfully used, tool life is usually only 10–15 times that of tungsten carbide, therefore successful applications are normally limited to high volume operations as found in the automotive industry. The most common use of PCBN for this type of workpiece material is where stable dimensional accuracy is required such as bearing areas on camshaft and crankshaft components.

If the cutting speed can be kept low (180 m/min and below), there are examples where polycrystalline diamond (PCD) has performed well machining ductile iron. The low cutting speed coupled with flood coolant, keeps the cutting edge cool enough to greatly reduce the classic chemical attack that normally takes place when machining a ferrous workpiece with diamond. If the operation is not successful when PCD is tried as recommended, it is unlikely any significant improvement in tool life can be achieved with PCBN.

Material categories – Ductile cast irons (Nodular)

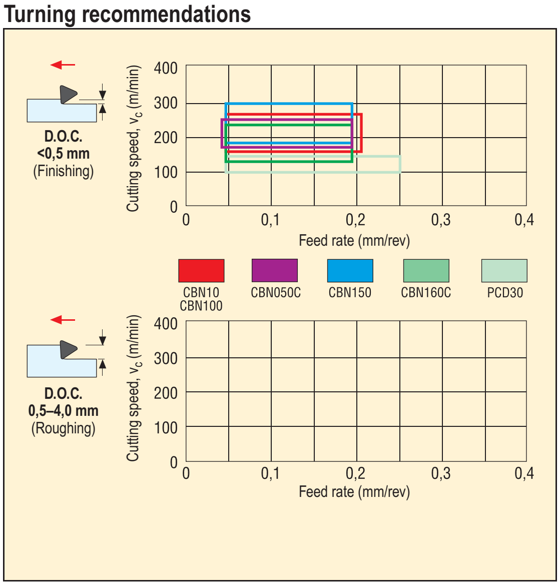
SECO

Parameter guide – Recommended machining conditions

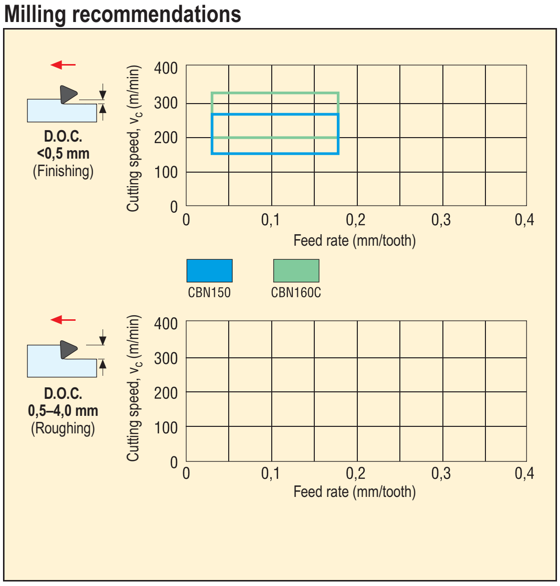
Ductile cast iron (135–430 HBN)

The following charts show the recommended cutting data for ductile cast iron applications.

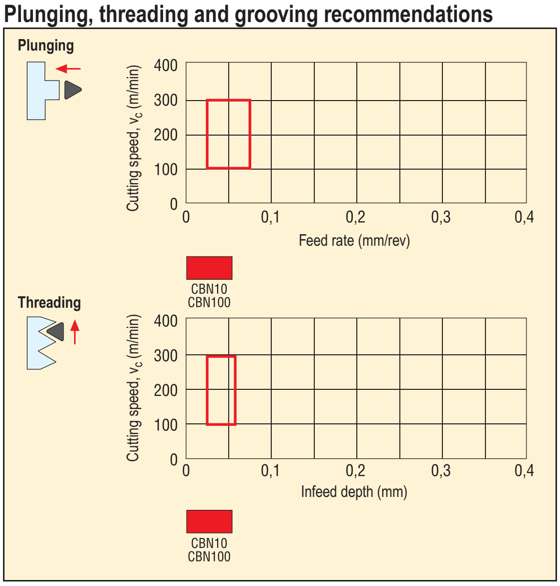
Turning recommendations

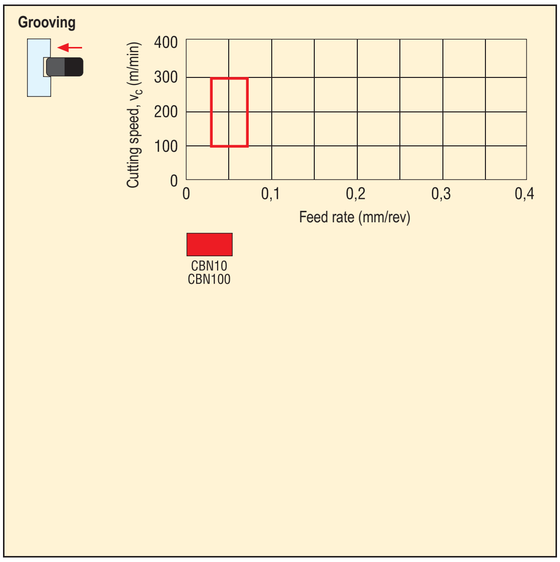


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Ductile cast irons (Nodular)

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for any roughing or finishing of ductile iron components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

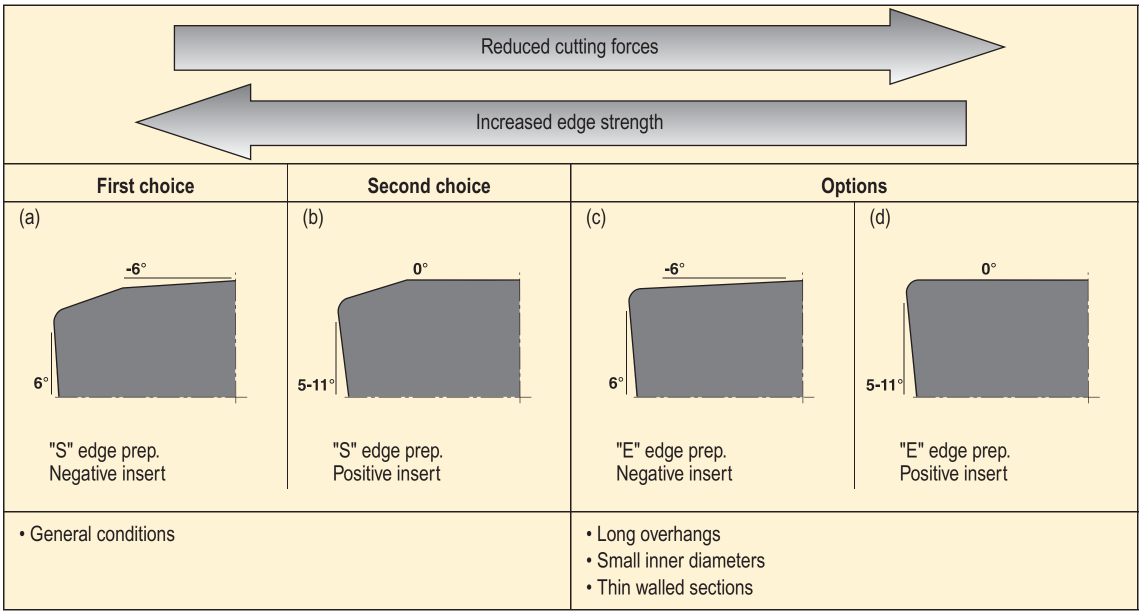
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

Rough machining

Rough machining in ductile iron with PCBN is not possible.

Heavy interruptions and milling

These operations are not possible with PCBN in ductile iron.



Troubleshooting for ductile cast irons

Ductile iron materials are not particularly hard, but exhibit good wear resistance characteristics making them very abrasive and difficult to machine.

For general troubleshooting recommendations, see page 80.

Material categories – Ductile cast irons (Nodular)

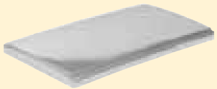
Application examples

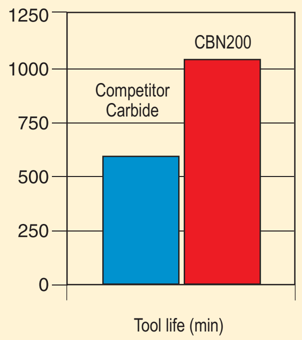
Machining: Moulds

Workpiece
Component: Automotive ceiling mould
Material: Nodular iron (GGG70), heat treated
Hardness: 40–60 HRC
Surface: Pre-machined

Conditions
Operation: Finish face milling
Grade: CBN200
Insert: RDHW0803M0S-01030-LF
Cutter: R217.29-1632.RE-04.5A
Cutting speed: 550 m/min
Feed rate: 0,22 mm/tooth = 6 018 mm/min
Depth of cut: 0,20 mm
Coolant: No

Result
Tool life: CBN200 (WC) = 1 050 (620) minutes
Feed speed: CBN200 (WC) = 6 018 (4 000) mm/min



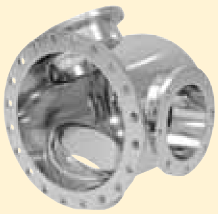


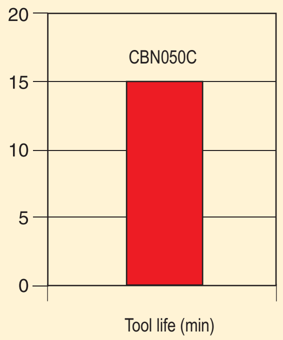
Machining: Bearing houses

Workpiece
Component: Bearing house
Material: Nodular iron (GGG40)
Hardness:
Surface: Pre-machined

Conditions
Operation: Finish boring ∅1400 mm
Grade: CBN050C
Insert: TCGW110208S-01525-L1-WZ-C
Holder:
Cutting speed: 420 m/min
Feed rate: 0,30 mm/rev
Depth of cut: 0,20 mm
Coolant: No

Result
Tool life: CBN050C =15 minutes
Improved metal removal rate
Possible to machine 1 part/edge






CBN400C

Material categories – Compacted graphite irons

The machining of compacted graphite irons with PCBN is possible but is not usually economically successful because of the high ferrite content and low sulphur content, and this should be clearly understood before attempting to use PCBN.

Compacted graphite irons (200–280 HBN)

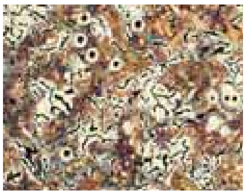
Material introduction

Compacted Graphite iron (CGI) is also known as Ferrum Casting Vermicular (FCV) or Vermicular Graphite Iron. Although not a new material, difficulties in reliably reproducing CGI in a production environment have meant that until recently, the material was rarely used. However, advances in foundry technology have solved the age-old problems associated with mass production.

Microstructure and material properties of CGI fit between those of grey cast iron and ductile iron. The difference is the addition of alloying elements and a different cooling rate during casting. The material is stronger than grey iron and has a better thermal conductivity and better thermal fatigue resistance than nodular cast iron. The content of free ferrite is normally 5 to 30 %. The vermicular structure and the rounded ends of the graphite flakes offer some exciting material properties over other irons. When compared with grey cast iron, CGI offers improved tensile strength, fatigue strength and elastic modulus.

Engine manufacturers from marine to locomotive, as well as the automotive industry have identified these property improvements. The higher strength and rigidity of CGI means engines can be manufactured with improved power to weight ratios (more power/ same weight or same power/ less weight). In addition CGI offer higher corrosion resistance over grey cast iron.

Typical compacted graphite iron (CGI) microstructure



There are two different types of compacted graphite iron:
- LP-CGI = Low pearlite CGI = 70% pearlitic
- HP-CGI = High pearlite CGI = 95% pearlitic

Examples of representative compacted graphite irons

Designation	Average composition (wt%)								
	C	Si	Mn	S	Mg	Al	Cu	Cr	Sn
LP-CGI	3,6–3,8	2,1–2,5	0,20–0,40	0,005–0,020	0,006–0,014	0,003–0,088	0,003–0,088	0,20–0,30	0,03–0,05
HP-CGI	3,6–3,8	2,1–2,4	0,43	0,018	0,012	–	0,960	0,03	1,06

Material categories – Compacted graphite irons

Examples of typical compacted graphite iron components

- Diesel engine blocks
- Diesel cylinder heads
- Marine engines
- Agricultural equipment
- Locomotive diesel engines
- Locomotive brake discs

Cutting tool grade selection

Roughing or finishing

When machining compacted graphite iron materials, roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	**Turning**	**CBN300** / CBN200	**CBN350** / CBN200
	Milling	N/A	**CBN200** / CBN350

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	**Turning**	**CBN050C** / CBN160C / PCD30	**CBN160C** / CBN150
	Milling	N/A	**CBN160C** / CBN150 / PCD30
	Plunging	**CBN050C** / CBN160C	N/A
	Threading	**CBN160C** / CBN050C	N/A
	Grooving	**CBN10**	N/A

Bold = First choice

Comment

Compacted graphite iron's unique properties make machining very difficult for all cutting tool materials. Like grey cast irons, compact graphite irons are relatively soft but very abrasive. When machining, a large amount of heat is generated in the cutting zone. This coupled with the presence of free ferrite produces ideal conditions for chemical attack of the cBN particles in the PCBN composite leading to rapid tool wear.

As a relatively new workpiece material machining conditions and tool selection continue to be evaluated and improved. Grade selection is based on best performances achieved with PCBN. Tungsten carbide cutting tools have also been used successfully in machining of compacted graphite iron.

If cutting speed is low enough (180 m/min or below), then PCD cutting tools have been shown to be viable. The low cutting speed coupled with flood coolant means that heat generation and, therefore, chemical attack is kept to a minimum. This allows the exploitation of the high hardness and abrasion resistance of PCD.

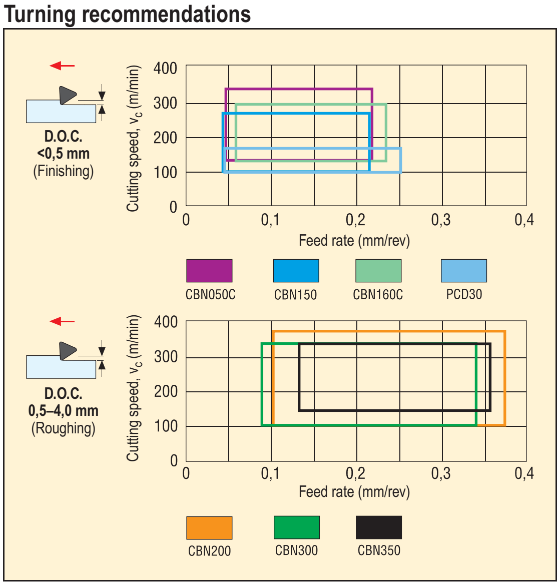
In all machining, it is recommended that coolant is used in order to reduce heat generation at the cutting edge.

Parameter guide – Recommended machining conditions

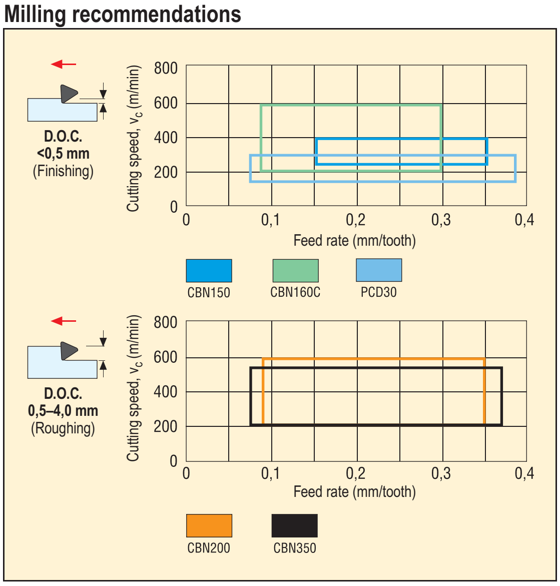
Compacted graphite iron (200–280 HBN)

The following charts show the recommended cutting data for compacted graphite iron applications.

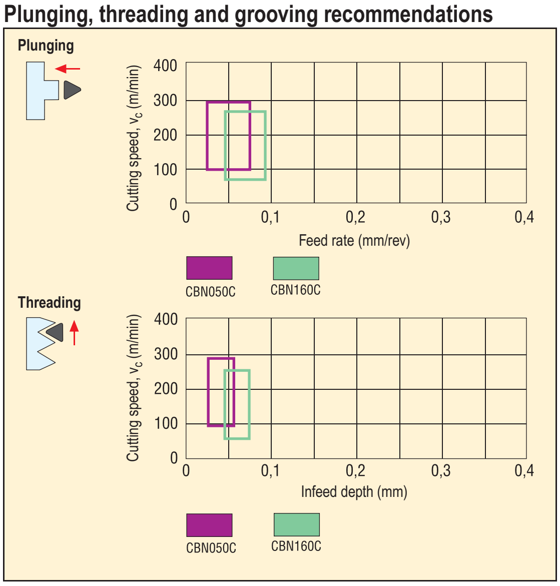
Turning recommendations

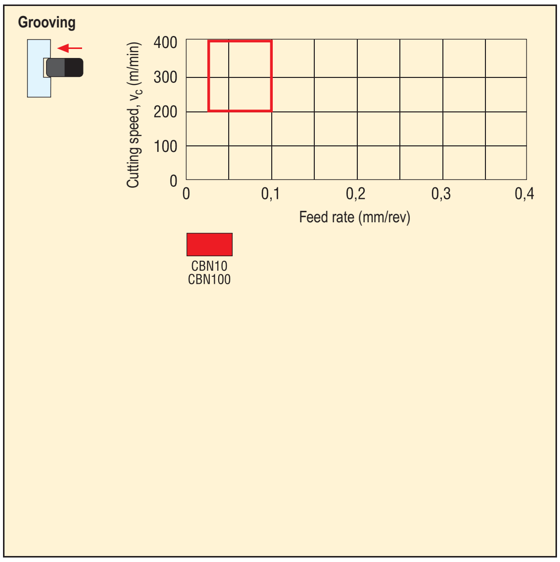


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

The machining of compacted graphite iron with PCBN cannot be compared with that of grey cast iron. Machining of compact graphite iron is difficult for any cutting tool material. Compared to grey cast iron cutting speeds and tool life will be greatly reduced. The success of PCBN machining compact graphite iron is very dependent on the individual circumstances and should be approached based on a case-by-case scenario.

Material categories – Compacted graphite irons

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of compacted graphite iron components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

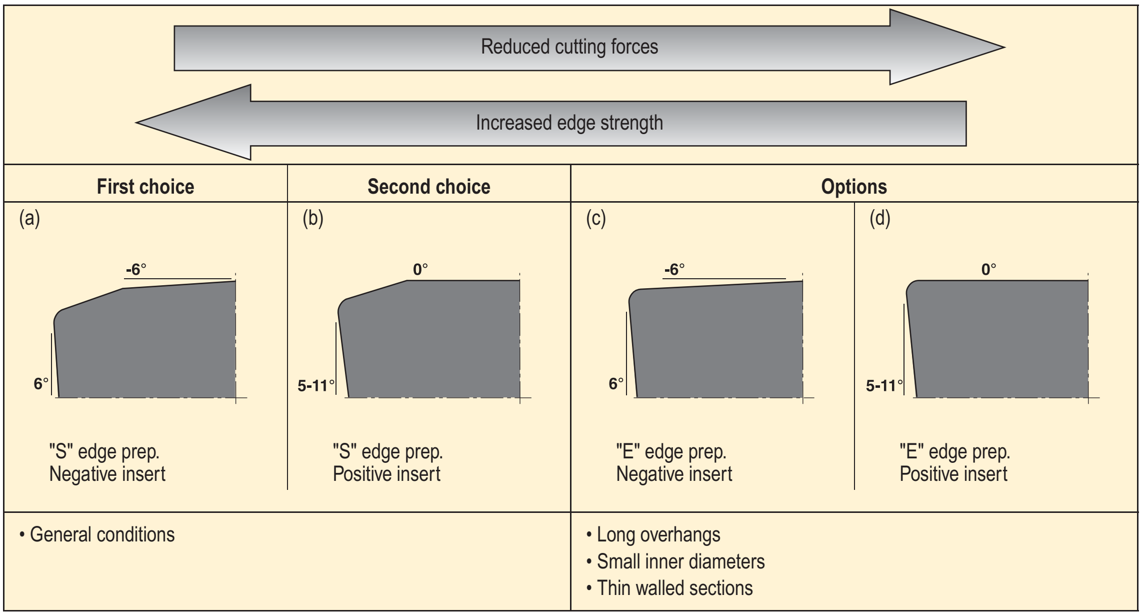
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

Rough machining

Rough machining of compacted graphite iron requires chamfered and honed cutting edges (a). The skin of compacted graphite iron can be rough, hard and contain impurities such as sand from the casting process. These and the larger depth of cut mean much more pressure on the cutting edge. Chamfering of the insert strengthens the PCBN cutting edge and thereby ensuring consistent and maximum tool life.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



Troubleshooting for compacted graphite irons

Compared with grey cast iron, compacted graphite iron is very difficult to machine. Compacted graphite iron materials are not particularly hard, but exhibit good wear resistance. Machining generates very high cutting temperatures, which assist in the degradation of the cutting edge. In order to minimise this phenomenon, relatively low cutting speeds are employed.

To further reduce the heat generation at the edge, honed only edges coupled with flooding coolant can be used in finishing operations.

For general troubleshooting recommendations, see page 80.

Material categories – Ferrous powder materials (25–70 HRC)

SECO

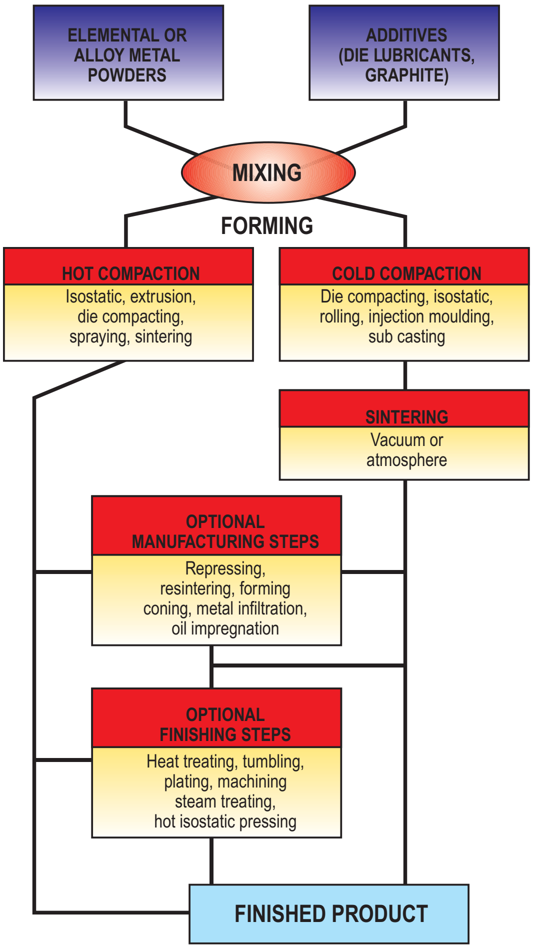
Powder Metallurgy (PM) alloys (25–70 HRC)

Material introduction

The first step in the PM process is mixing of pure metal and/or alloy powders. The mixture is then compacted in a die, and the resultant shapes are sintered or heated in a controlled atmosphere to bond the particles metallurgically. This technique is often referred to as PM technology, or powder metal, powder metallurgy or sintered metal. The PM process permits a wide variety of alloy systems covering all forms from pure iron to high alloyed steel and superalloys to be produced.

POWDER METALLURGY PROCESS

RAW MATERIAL



Powder Metal technology offers the following benefits to the customer when compared to alternative component production methods such as forging, casting or machining from solid bar.

- Near net shape opportunities
- Reduced environmental impact
- Lower energy consumption
- Weight reduction opportunities
- Reduced operational noise levels
- Better heat transfer
- Reduced waste
- Self lubricating properties

Material categories – Ferrous powder materials (25–70 HRC)

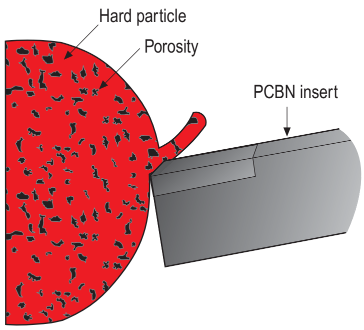
Approximately 80% of all PM parts are made from iron and steel powders. Other important alloy systems include copper, aluminium, tungsten and nickel based powders. Most of the iron and steel powders are alloyed with copper or nickel and are designated FC and FN respectively. For example, FC 0208, one of the most popular alloys, contains 2% copper and 0,8% carbon. Similarly, FN 0205 would contain 2% nickel and 0,5% carbon. Simple carbon steels are designated by the prefix F and contain no other alloying elements. The nickel steels (FN) are usually stronger, tougher and more heat treatable than the F or FC alloys.

Examples of representative PM alloys

Type	Designation	Average composition (wt%)					
		C	Mo	Cr	Ni	Cu	Fe
Carbon steel	F-0008	0,8	–	–	–	–	Bal
Copper steel	FC-0205	0,5	–	–	–	2,0	Bal
	FC-0208	0,8	–	–	–	2,0	Bal
Nickel steel	FN-0205	0,5	–	–	2,00	–	Bal
	FN-0208	0,8	–	–	2,00	–	Bal
Low-alloyed steel	FL-4405	0,5	0,85	–	–	–	Bal
	FLN-4405	0,5	0,85	–	2,00	–	Bal
Alloyed steel	FD-0205	0,5	0,50	–	1,75	1,5	Bal
	FLC-4608	0,8	0,50	–	1,75	2,0	Bal
Stainless steel	SS-316N1	–	0,25	17	12,00	–	Bal

Unfortunately, the very properties that make these parts commercially attractive also make them difficult to machine. PM materials consist of hard particles in a soft, sometimes porous matrix and hardness values can be misleading. To obtain an accurate measurement of the machinability of PM materials, measurement of both the particle and the bulk hardness (often referred to as the apparent hardness) is required. Particle hardnesses can be as high as 70 HRC, while bulk hardness can be as low as 10 HRC.

Hard particles and porosity can result in micro-fatigue of the insert edge. The edge is in and out of cut as it passes from particle to particle and from pore to pore. The repetitive small impacts result in the creation of small cracks on the cutting edge. This chipping is so fine that it often appears as normal abrasive wear.



Examples of typical PM components

Engine
- Bearings
- Camshaft lobes
- Bearing caps
- Retainer rings
- Sprockets
- Flanges
- Gears
- Rings

Transmission
- Hubs
- Rings
- Gears
- Rotors
- Sleeves
- Spacers
- Guides

Miscellaneous
- Collars
- Bolts
- Plates
- Brake sensor rings
- Brake pistons
- Lock parts
- Electric motor cores
- Armatures

Material categories – Ferrous powder materials (25–70 HRC)

Sintered valve seat materials (300–450 HBN)

Material introduction

Although valve seat materials are commonly referred to as sintered iron, current generations of materials are more likely to be a type of sintered steel rather than a sintered iron, due to the increasing demands of modern engines. For the majority of current gas engines, low alloy steel valve seat materials are employed. For diesel engines, the higher fuel pressures mean that medium alloy steels are exclusively employed for their increased wear resistance. Occasionally high speed steel PM materials are also used.

For the latest ethanol (E85) powered engines, high speed steel PM materials are the only choice. E85, which is also known as bio-fuel, is a mix of 85% ethanol produced from plants and 15% petrol and is considered environmentally friendly when compared with gas or diesel, due to its mainly renewable source. These HSS materials used in ethanol engines are extremely difficult to machine with anything other than PCBN, and even with PCBN tools, the tool life is comparatively short when compared with PM irons and steels.

Valve seat materials

Engine type	Typical outlet valve seat material
Petrol engine	Low alloy iron/steel
Diesel engine	Medium alloy steel
Ethanol (E85) engine	High alloy steel (HSS)

Typical inlet valve seat microstructure

Typical outlet valve seat microstructure

Examples of representative valve seat materials

Valve type	Average composition (wt%)				
	C	Mo	Co	Ni	Cu
Inlet	1,0	0,5	–	0,5	10,0
Outlet	1,0	3,0	10,0	1,5	–

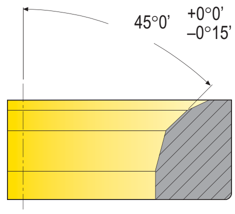
The major suppliers all produce a wide variety of PM materials, some of which are developed exclusively for a particular customer and some that are produced as standard and offered to a number of customers. It is also common that different materials are used for the inlet and outlet valve seats in the cylinder head. The outlet valves are exposed to harsh environment of hot combustion gasses and are produced from a PM material which is much more wear resistant and therefore more difficult to machine.

Sintered iron or steels for valve seat applications are not generally specified in international standards as they are generally made to customer's specific requirements. Therefore, each supplier of sintered iron has their own nomenclature system.

The major suppliers are Bleistahl, Federal Mogul (Brico) and Mahle (Pleuco) to name but a few.

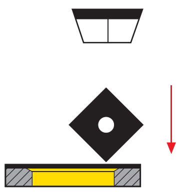
Material categories – Ferrous powder materials (25–70 HRC)

The valve seat profile shown below is very typical for the majority of engines. The 45° angle is the most important as this is the sealing surface for the valve. The angles on either side of the sealing angle are known as the top and bottom clearance angles. These non-critical angles are applied to improve the air flow and are typically between 50°-70° for the top clearance and between 15°-25° for the bottom clearance.

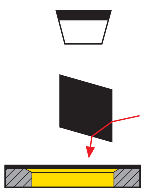


Sintered valve seats are usually produced by sintering to near net shape, and then supplied to engine manufacturers. The majority of valve seats are finish machined after they are pressed into the cylinder head, where the internal angles are machined. These angles form the seal with the valve stems in a working engine.

PCBN is usually the first choice for valve seat machining due to its unmatched wear resistance. This in-turn gives less down time and increased productivity. To machine these angles using a cutting tool, one of two methods is employed. The most common is to plunge the angles using the long edge of the cutting tool, as shown in the schematic below.



Plunging



Generating

The other and not so common machining method is to generate the internal angles. This is done by using the cutting nose of the insert in a traditional turning method. This usually requires specially designed custom hydraulically activated tooling to generate the profile.

Material categories – Ferrous powder materials (25–70 HRC)

Cutting tool grade selection

Roughing or finishing

In the machining of PM materials roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness; wear resistance and thermal conductivity of the PCBN grade.

Machining valve seats in the cylinder head is essentially a finishing operation. The machining method is either by generating or more commonly, plunging. Generating of the valve seat profile is similar to conventional turning. In that point contact between the tool and workpiece surface produces the required profile, dimensional and surface finish tolerances.

Plunging of valve seat profile is where the tooling head is setup with the inserts (usually three) set to the required profile angles. Grade selection is not affected by the method of machining. Optimum tool performance is determined by grade selection based on toughness, wear resistance, and thermal conductivity of the PCBN grade and specific edge preparation.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. 0,5–4,0 mm (Roughing)	Turning	**CBN200**/ CBN300	**CBN200**/ CBN300
	Milling	N/A	**CBN200**/ CBN300

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	Turning	**CBN200**/ CBN050C/ CBN10/CBN100	**CBN200**/ CBN160C
	Milling	N/A	**CBN200**/ CBN160C
	Plunging	**CBN200**/ CBN050C/ CBN10/CBN100	N/A
	Threading	**CBN200**/ CBN160C	N/A
	Grooving	**CBN200**	N/A

Bold = First choice

Comment

The same grade is recommended for both roughing and finishing operations. Powder materials are relatively soft, but very abrasive, making high cBN content grades with their high abrasion resistance the first choice for both roughing and finishing of ferrous powder metal components.

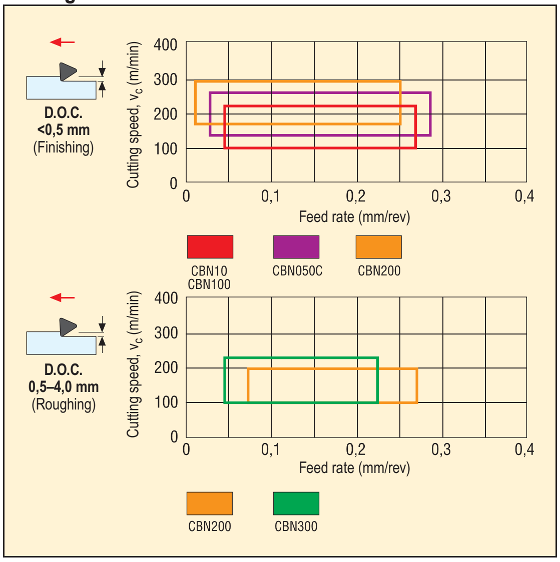
Material categories – Ferrous powder materials (25–70 HRC)

Parameter guide – Recommended machining conditions

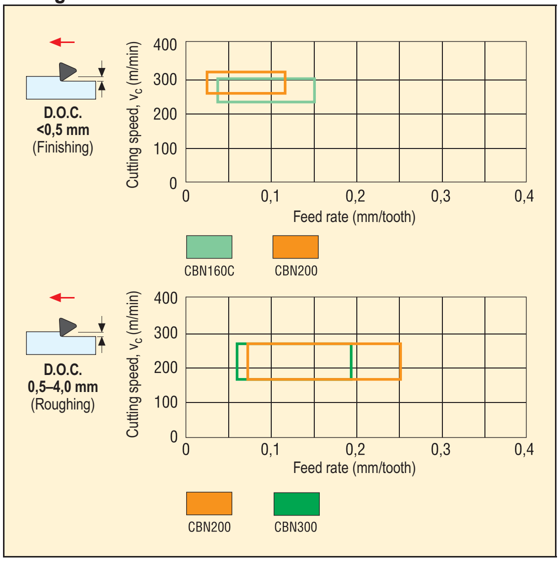
Ferrous powder metal (45–70 HRC)

The following charts show the recommended cutting data for ferrous powder metal applications.

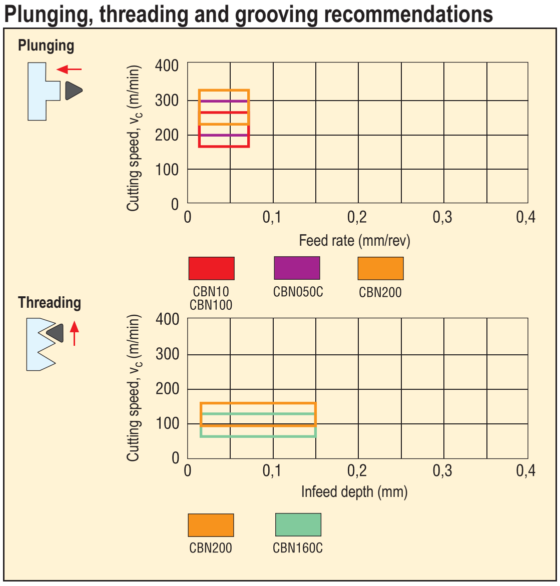
Turning recommendations

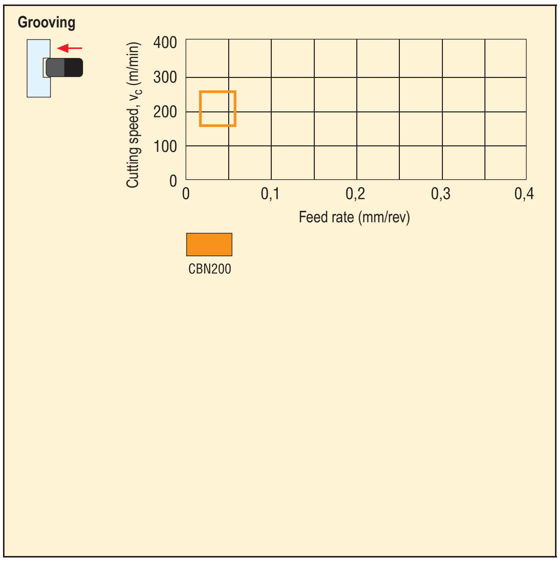


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Ferrous powder materials (25–70 HRC)

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of ferrous powder metal components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

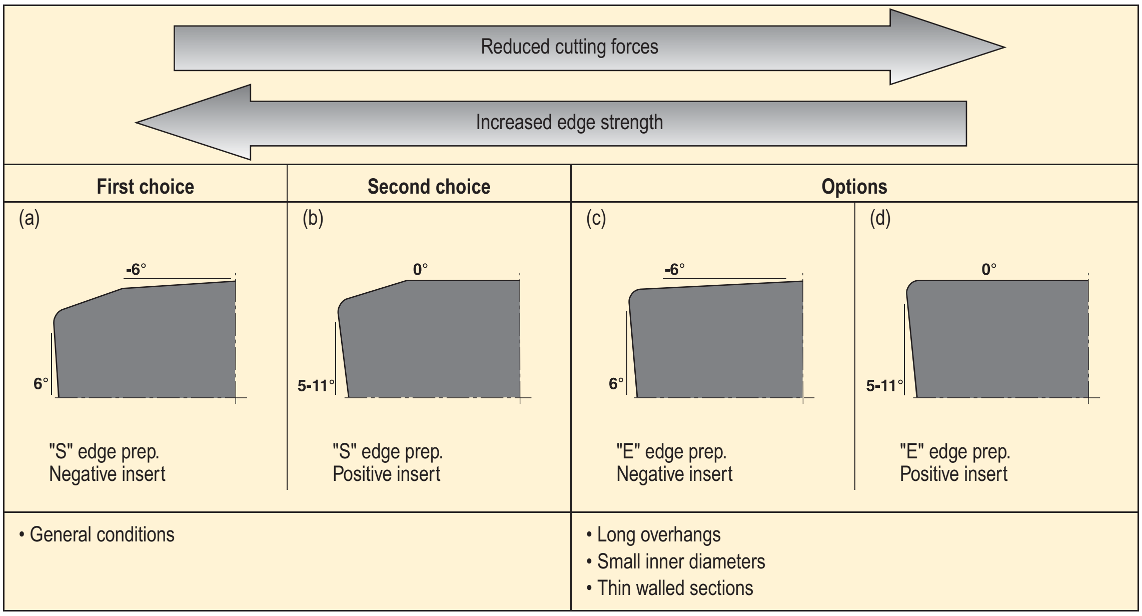
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

Rough machining

The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a), and provides a balance between optimum edge stability and minimised cutting forces.

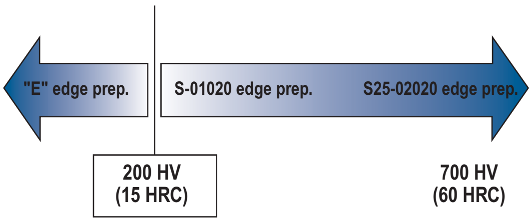
Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



Comment

Experiences when machining PM components have shown that, apart from operation and condition, the insert edge preparation should be selected based on the material's apparent hardness. In higher hardness materials, a larger edge hone increases tool life.



Troubleshooting for ferrous powder metal

For general troubleshooting recommendations, see page 80.

Material categories – Ferrous powder materials (25–70 HRC)

Machining: Application examples

Machining: Syncromesh gears

Workpiece

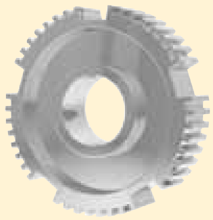
Component:	Syncromesh gear
Material:	Powder metal
Hardness:	Apparent 38 HRC, particles 57 HRC
Surface:	Sintered

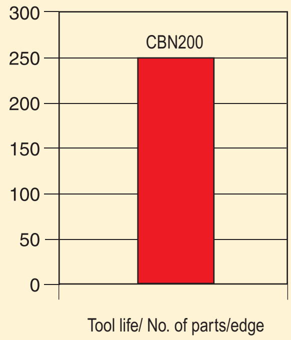
Conditions

Operation:	Facing
Grade:	CBN200
Insert:	CNGA120408S-02020-L1-B
Holder:	
Cutting speed:	120 m/min
Feed rate:	0,2 mm/rev
Depth of cut:	0,2 mm
Coolant:	No

Result

Tool life:	CBN200 = 250 parts/edge





Machining: Gear wheels

Workpiece

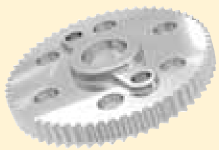
Component:	Gear wheel
Material:	Powder metal (D39)
Hardness:	Apparent 65 HRC
Surface:	Sintered

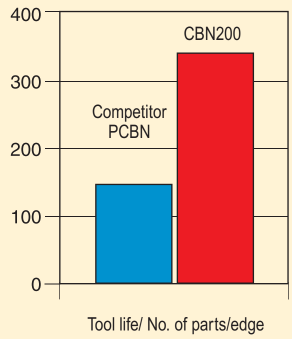
Conditions

Operation:	ID turning
Grade:	CBN200
Insert:	DCGW11T308S25-01020-L1-B
Holder:	
Cutting speed:	150 m/min
Feed rate:	0,03 mm/rev
Depth of cut:	0,20 mm
Coolant:	No

Result

Tool life:	CBN200 = 340 parts/edge Competitor PCBN = 150 parts/edge





Machining: Reaction cones

Workpiece

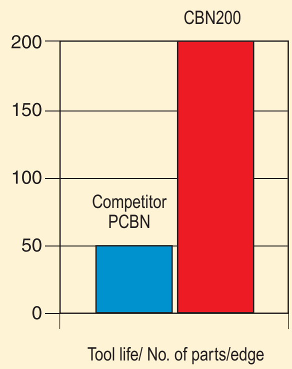
Component:	Reaction cone
Material:	Powder metal (FC208)
Hardness:	Apparent 38 HRC, particles 57 HRC
Surface:	Sintered

Conditions

Operation:	ID turning
Grade:	CBN200
Insert:	TNGN110308S25-02020-LF
Holder:	
Cutting speed:	226 m/min
Feed rate:	0,05 mm/rev
Depth of cut:	0,20 mm
Coolant:	No

Result

Tool life:	CBN200 = 200 parts/edge Competitor PCBN = 50 parts/edge



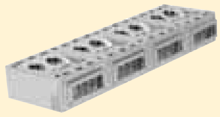
Material categories – Ferrous powder materials (25–70 HRC)

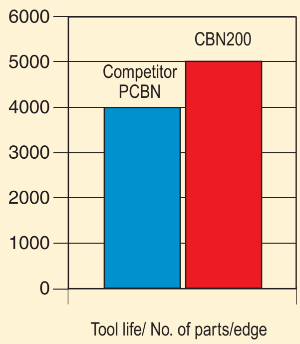
Machining: Valve seats

Workpiece
Component: Valve seat
Material: Sintered steel
Hardness:
Surface: Pre-machined

Conditions
Operation: Finishing, generating
Grade: CBN200
Insert: CCMW060204E-L0-B
Holder:
Cutting speed: 150 m/min
Feed rate: 0,04–0,09 mm/rev
Depth of cut: 0,10–0,30 mm
Coolant: Yes

Result
Tool life: CBN200 = 5 000 parts/edge
Competitor PCBN = 4 000 parts/edge



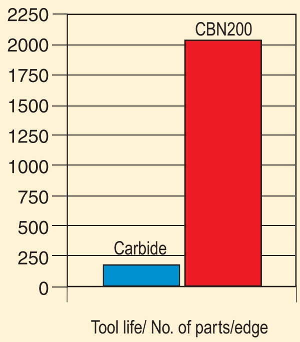


Machining: Valve seats

Workpiece
Component: Valve seat
Material: Sintered steel
Hardness: 280 HB
Surface: Pre-machined

Conditions
Operation: Finishing, plunging
Grade: CBN200
Insert: TPGW090202S-LF
Holder:
Cutting speed: 75 m/min
Feed rate: 0,1 mm/rev
Depth of cut: 0,3 mm
Coolant: Yes

Result
Tool life: CBN200 = 2 020 parts/edge
Carbide = 150 parts/edge

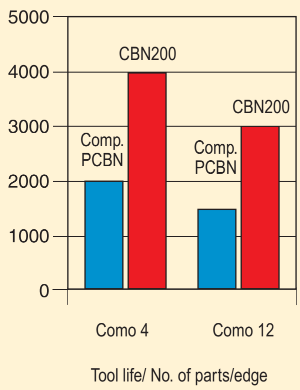


Machining: Valve seats

Workpiece
Component: Valve seat
Material: Sintered steel
Como 4 (inlet), Como12 (outlet)
Hardness:
Surface: Pre-machined

Conditions
Operation: Finishing, plunging
Grade: CBN200
Insert: SCGW060208S-LF
Holder:
Cutting speed: 220 m/min
Feed rate: 0,14 mm/rev
Depth of cut: 0,05 mm
Coolant: Yes

Result
Tool life: CBN200 = 4 000 parts/edge (Como 4)
Competitor PCBN = 2 000 parts/edge
CBN200 = 3 000 parts/edge (Como 12)
Competitor PCBN = 1 300 parts/edge

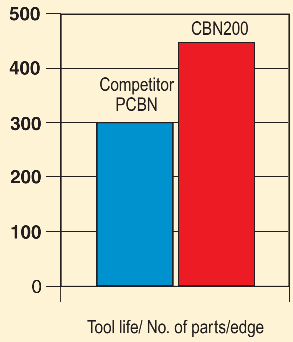


Machining: Pulley wheels

Workpiece
Component: Pulley wheel
Material: Steam treated powder metal
Hardness: Apparent 24 HRC, particles 65 HRC
Surface: Sintered

Conditions
Operation: Finish boring
Grade: CBN200
Insert: CNGA120408S-02020-L1-B
Holder:
Cutting speed: 150 m/min
Feed rate: 0,25 mm/rev
Depth of cut: 0,25 mm
Coolant: No

Result
Tool life: CBN200 = 450 parts/edge
Competitor PCBN = 300 parts/edge

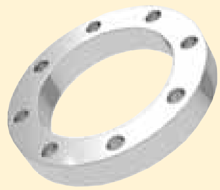


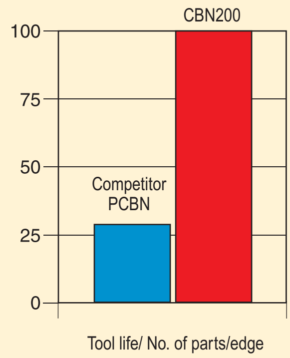
Machining: Guide rings

Workpiece
Component: Guide ring
Material: Powder metal
Hardness: Apparent 45–50 HRC, particles 64–68 HRC
Surface: Sintered

Conditions
Operation: Facing across holes
Grade: CBN200
Insert: CNGA120408S25-02020-L1-B
Holder:
Cutting speed: 300 m/min
Feed rate: 0,15–0,25 mm/rev
Depth of cut: 0,25 mm
Coolant: No

Result
Tool life: CBN200 = 100 parts/edge
Competitor PCBN = 30 parts/edge



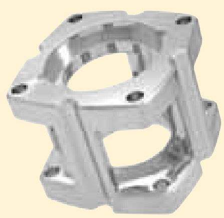


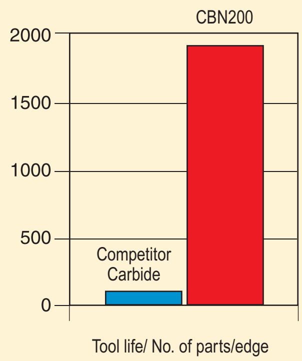
Machining: Carriers

Workpiece
Component: Carrier
Material: Powder metal
Hardness: Apparent 50 HRC, particles 60 HRC
Surface: Sintered

Conditions
Operation: Face milling
Grade: CBN200
Insert: SEEX09T3AFTN-D08-LF
Cutter: R220.53-0080-09-8A
Cutting speed: 407 m/min
Feed rate: 0,125 mm/tooth = 1 619 mm/min
Depth of cut: 1,0 mm
Coolant: No

Result
Tool life: CBN200 = 1 900 parts/edge
Competitor carbide = 100 parts/edge





Material categories – Powder tool steels (45–65 HRC)

Powder tool steels (45–65 HRC)

Material introduction

Sintered powder steels are 100% dense materials, with finer carbides that are more evenly distributed. Unlike powder irons, powder steels are often manufactured in billet or bar stock format and are manufactured to improve machinability compared to conventionally produced steels. The majority of powder steels are typically high speed steels, although tool steels are also produced. Limited experiences have shown that when machining in the hardened condition with PCBN, some powder steels are more difficult to machine and therefore the working windows are generally smaller.

Typical powder tool steel microstructure

Examples of representative powder tool steels

Designation					Average composition (wt%)							
SAE	DIN	AFNOR	BS	SS	C	Cr	Mo	Si	Mn	Co	W	V
M4	–	–	–	–	1,35	4,25	5,0	0,35	0,25	–	6,0	4,2
ASP23	–	Z 85WDCV6452	–	–	1,28	4,20	5,0	0,62	0,28	0,41	6,4	3,1
ASP30	–	–	–	–	1,28	4,20	5,0	0,60	0,32	8,50	6,4	3,1
ASP60	–	–	–	–	2,30	4,20	7,0	0,41	0,30	10,50	6,5	6,5

Material categories – Powder tool steels (45–65 HRC)

Examples of typical powder tool steel components

- Tools for plastic forming, like punches etc
- Tools for plastic extrusion, like dies etc

Cutting tool grade selection

Roughing or finishing

Machining of powder tool steels is considerably harder than machining conventional tool steels. High stock removal by roughing is not viable due to edge breakage, but the material can be successfully machined using relatively light depths of cut. As mentioned this material is often manufactured in billet or bar stock format but in many cases components are also produced as near net shape and so finishing is normally all that is required.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Preferred grade – Roughing (Depth of cut >0,5 mm)

D.O.C 0,5–4,0 mm (Roughing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	N/A	N/A
	Milling	N/A	N/A

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

D.O.C. <0,5 mm (Finishing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	**CBN10/CBN100**	N/A
	Milling	N/A	N/A
	Plunging	**CBN10/CBN100**	N/A
	Threading	**CBN10/CBN100**	N/A
	Grooving	**CBN10**	N/A

Bold = First choice

Comment

These materials are very hard and abrasive. Interrupted cutting is not possible.

Material categories – Powder tool steels (45–65 HRC)

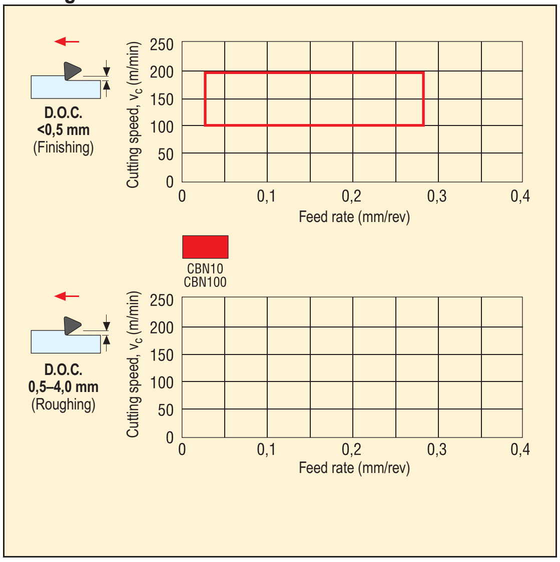
SECO

Parameter guide – Recommended machining conditions

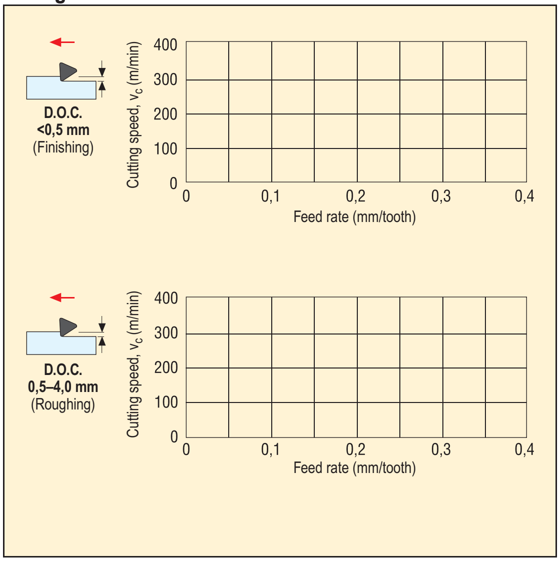
Powder tool steels (45–65 HRC)

The following charts show the recommended cutting data for powder tool steel applications.

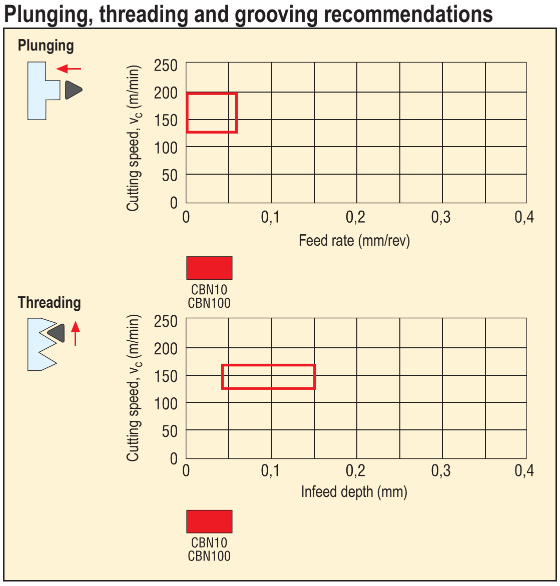
Turning recommendations

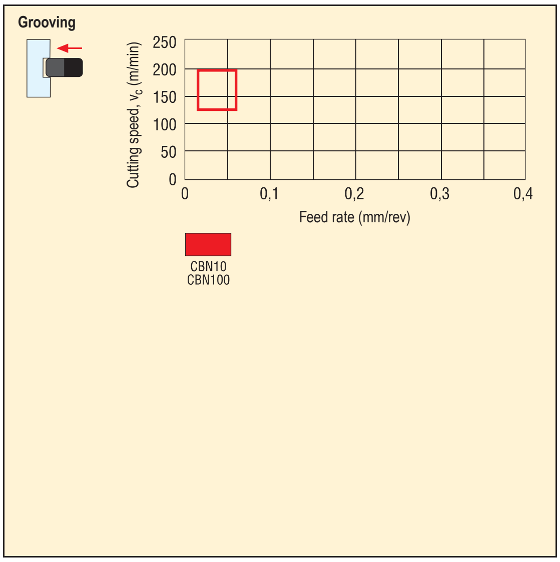


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Powder tool steels (45–65 HRC)

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for finishing of powder tool steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

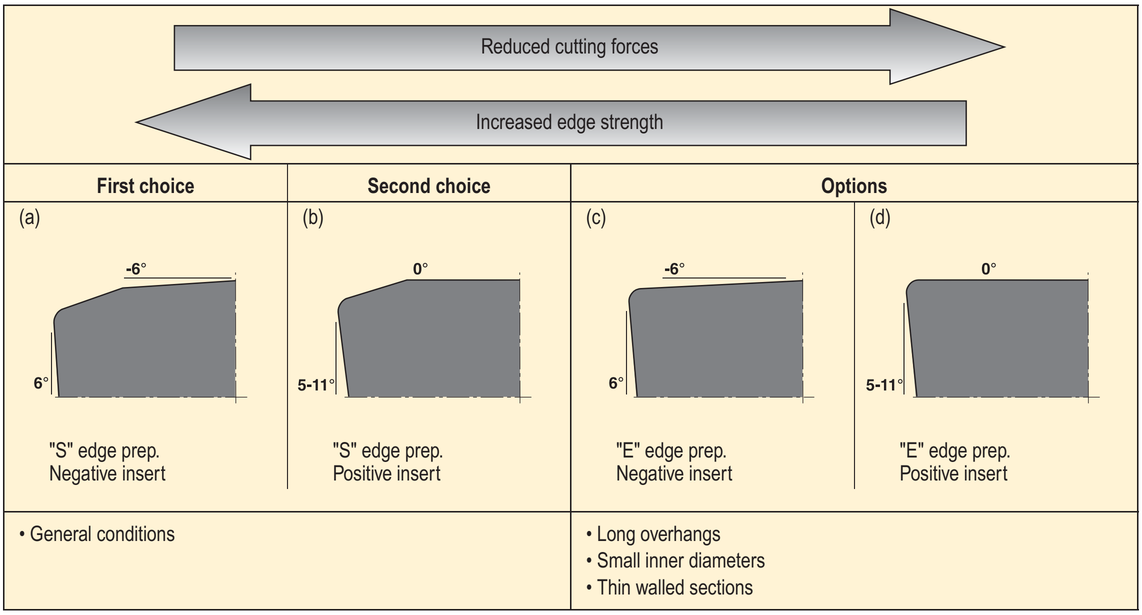
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

Rough machining

Rough machining in powder tool steels with PCBN is not possible.

Heavy interruptions and milling

These operations are not possible in powder tool steels with PCBN.



Troubleshooting for powder tool steels

The main problems likely to be encountered when machining these types of materials are edge chipping, notching and cratering.

For general troubleshooting recommendations, see page 80.

Material categories – Superalloys (30–45 HRC)

Superalloys (30–45 HRC)

Material introduction

The term “superalloy” describes a broad range of nickel, iron and cobalt based alloys developed specifically for applications demanding exceptional mechanical and chemical properties often at elevated temperatures. Roughly two-thirds of the superalloys are used by the aerospace industry for the manufacture of turbines and related components.

The classic use of these alloys is in the hot end of aircraft engines. The remaining third is used by the chemical, medical and structural industries where extraordinary high temperature properties and/or exceptional corrosion or oxidation resistance is required.

The most "common" superalloy is Inconel 718, which is a precipitation hardenable nickel chromium alloy containing significant amounts of iron, niobium, and molybdenum along with lesser amounts of aluminium and titanium. It combines corrosion resistance and high strength with outstanding weldability, including resistance to post weld cracking. The alloy has excellent creep-rupture strength at temperatures up to 700°C.

Other common superalloy names are:
- Hastalloy
- Haynes
- Incoloy
- MAR
- Nimonic
- Rene
- Udimet

Increasing the amounts of alloying elements, such as chrome and nickel, will make the material more difficult to machine.

Typical Inconel 718 microstructure

Examples of representative superalloys

Designation					Average composition (wt%)							
Trade Name	DIN	AFNOR	BS	SS	Ni	Cr	Fe	Mo	Al	Mn	Si
Inconel 718	–	–	–	–	52,5	19,0	19,0	3,0	–	–	–
Inconel 713	–	–	–	–	75,0	12,5	–	4,2	6,1	–	–
Inconel 625	–	–	–	–	61,0	21,5	2,5	9,0	0,4	0,5	0,5

Material categories – Superalloys (30–45 HRC)

Examples of typical superalloy components

- Gas turbines
- Rocket motors
- Nuclear reactors
- Pumps
- Shafts
- Connectors

Cutting tool grade selection

Roughing or finishing

The machining of superalloys with existing available grades of PCBN is very specific. Depths of cut less than 0,5 mm have proven to be very successful in continuous cutting. Roughing operations i.e. depths of cut larger than 0,5 mm are usually not successful.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Preferred grade – Roughing (Depth of cut >0,5 mm)

D.O.C 0,5–4,0 mm (Roughing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	N/A	N/A
	Milling	N/A	N/A

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

D.O.C. <0,5 mm (Finishing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	**CBN10/CBN100**	N/A
	Milling	N/A	N/A
	Plunging	**CBN10/CBN100**	N/A
	Threading	**CBN10/CBN100**	N/A
	Grooving	**CBN10/CBN100**	N/A

Bold = First choice

Comment

Semi-finishing operations have proven very successful, finishing operations generally require approval before being implemented due to possible effects on surface integrity.

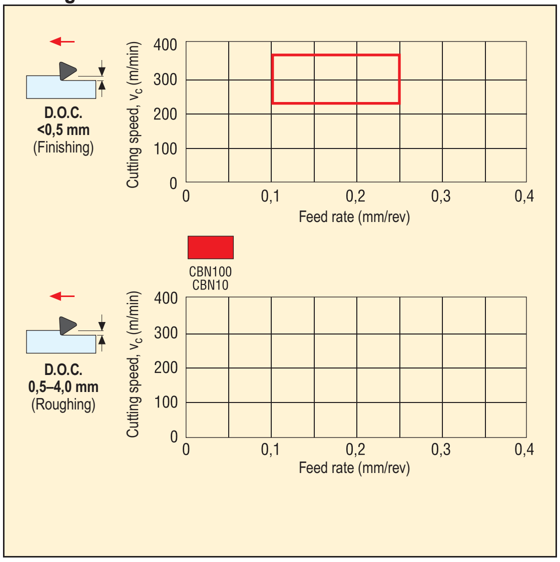
Material categories – Superalloys (30–45 HRC)

Parameter guide – Recommended machining conditions

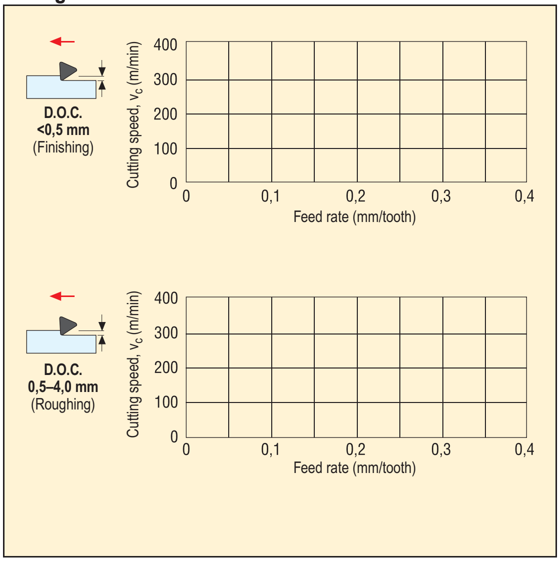
Superalloys (30–45 HRC)

The following charts show the recommended cutting data for superalloy applications.

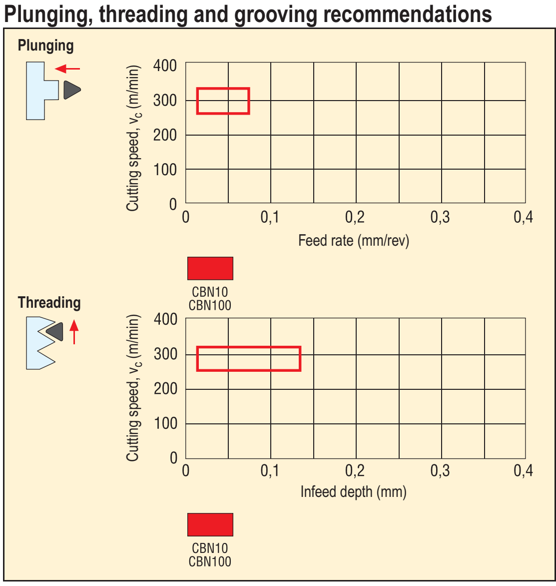
Turning recommendations

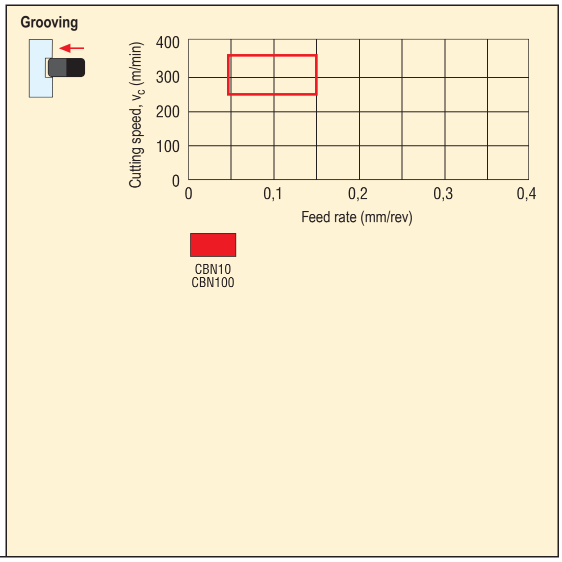


Milling recommendations



Plunging, threading and grooving recommendations





Note: Interrupted cutting not possible. Use E25 edge preparation.

Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Superalloys (30–45 HRC)

Tool geometry and edge preparation

Finishing machining

Selection of edge preparation when machining nickel based superalloys is different from normal PCBN machining. The 6° negative rake combined with a honed only cutting edge (a) is the first choice for finishing of nickel based superalloys components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it might be necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish. In these operations, the only way to reduce tool pressure is to try the honed only cutting edge with a neutral rake angle (d).

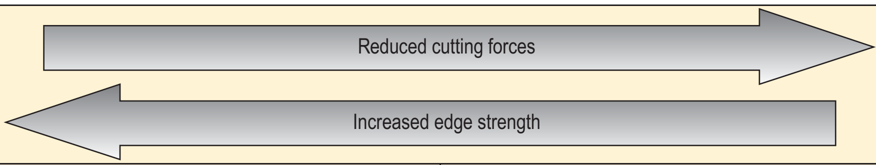
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (a).

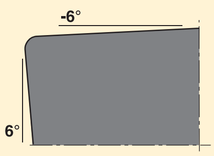
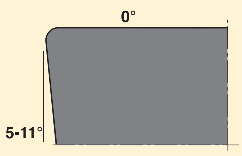
Rough machining

Rough machining in superalloys with PCBN is not possible.

Heavy interruptions and milling

These operations are not possible in superalloys with PCBN.



First choice	Second choice
(a)  "E25" edge prep. Negative insert	(b)  "E25" edge prep. Positive insert
• General conditions	• Long overhangs • Small inner diameters • Thin walled sections

Troubleshooting for superalloys

In general superalloys are difficult materials to machine, machining parameters should to be optimised for each component to ensure maximum tool life. Edge chipping, rapid flank wear and notching are the most common problems encountered machining these materials.

Edge preparation has a significant effect on tool life. Care should be taken when trying to exceed recommended depths of cut.

For general troubleshooting recommendations, see page 80.

Material categories – Superalloys (30–45 HRC)

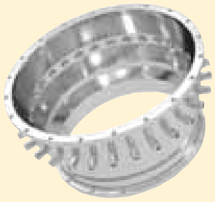
Application examples

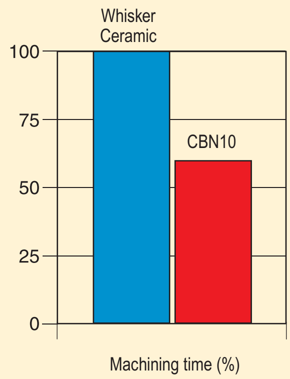
Machining: Combustion chamber bores

Workpiece
Component: Combustion chamber bore
Material: Inconel 718
Hardness: 35 HRC
Surface: Pre-machined

Conditions
Operation: Semi-finishing
Grade: CBN10
Insert: TNGN110308E25-L1-C
Holder:
Cutting speed: 350 m/min
Feed rate: 0,25 mm/rev
Depth of cut: 0,50 mm
Coolant: Yes

Result
Tool life: CBN10 = 6 minutes machining time
Whisker ceramics = 10 minutes



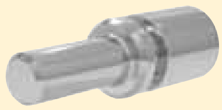


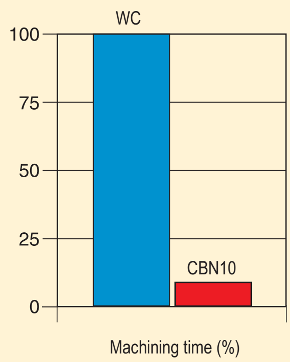
Machining: Shafts

Workpiece
Component: Shaft
Material: Inconel 718 forged blank
Hardness: 35 HRC
Surface: Pre-machined

Conditions
Operation: OD turning semi-finishing
Grade: CBN10
Insert: TNGA160408E25-L1-C
Holder:
Cutting speed: 300 m/min
Feed rate: 0,1 mm/rev
Depth of cut: 0,5 mm
Coolant: Yes

Result
Tool life: CBN10 = 12 minutes
Machining time reduced with 90%



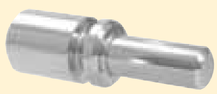


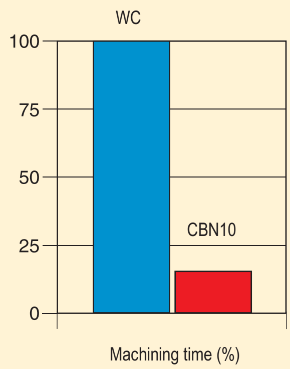
Machining: Shafts

Workpiece
Component: Shaft
Material: Inconel 718 forged blank
Hardness: 35 HRC
Surface: Pre-machined

Conditions
Operation: Grooving
Grade: CBN10 (WC)
Insert: LCGN1604M0-0400E25-LF
Holder:
Cutting speed: 170 m/min (30 m/min)
Feed rate: 0,1 mm/rev
Depth of cut: 0,5 mm
Coolant: Yes

Result
Tool life: CBN10 = 12 minutes
WC = 10 minutes
Cutting time reduced with 85% compared to carbide






CBN060K

Material categories – Hard facing alloys (30–62 HRC)

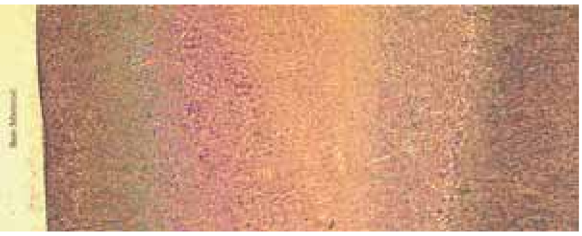
Hard facing alloys (30–62 HRC)

Material introduction

The primary purpose of a hard facing alloy material is to cover a softer less wear resistant area of a component with a harder more wear resistant material. So by the very nature of the purpose of these materials they are ultimately difficult to machine. Hard facing alloys can be applied either by welding or spray coated (i.e. plasma) or cast (this is less common). Hard facing alloys are also produced in billet format for use as homogeniser etc. Hard facing alloys generally fall into 4 categories, cobalt, nickel, iron and chrome based.

The different alloy components affect both the application areas in which they are used as well as the machinability. The most common alloys are cobalt and nickel with trade names such as Stellite, Colmonoy, Castolin and Dameron.

Typical hard facing alloy microstructure (stellite)



- Also known as hard surfacing alloys
- Their purpose is to add a hard wear resistant surface to a soft tough core
- Can be applied by weld deposit, plasma spray or by casting
- Also available in a solid billet form
- Most common alloys used are cobalt and nickel

Examples of different hard facing alloys

- **Cobalt based >35 HRC**
  Stellite (weld or cast) OK for PCBN
  Spray coated OK for PCBN

- **Nickel based ~35 HRC**
  Colmonoy, castolin (sprayed), wallex OK for PCBN

- **Iron based <60 HRC**
  Weld hard OK for PCBN
  Soft unsuccessful

- **Chrome based <60 HRC**
  Weld OK for PCBN
  Cr based alloy with high carbide content gives short tool life
  Cr plating is not suitable for PCBN

Examples of representative hard facing alloys

Material	Typical composition (wt%)									
	C	Cr	Mn	Mo	Si	W	V	Co	Ni	Fe
Co-based	1,2	28,0	1,0	–	1,1	4,5	–	Bal	<3,0	<3,0
Ni-based	0,1	0,7	–	–	2,3	–	–	–	Bal	<1,0
Fe-based	0,8	4,0	–	5,0	–	6,0	2,0	–	–	Bal
Cr-based	9,7	Bal	–	–	–	–	–	–	20,0	–
W-based	5,5	–	–	–	–	Bal	–	12,0	–	<2,0

Material categories – Hard facing alloys (30–62 HRC)

Examples of typical hard facing alloy components

- Augers
- Extruders
- Rolls
- Gate valves
- Oil and gas parts
- Bottle moulds
- Plungers

Cutting tool grade selection

Roughing or finishing

In the machining of hard facing alloys roughing or finishing is defined by depth of cut. A depth of cut larger than 0,5 mm is considered to be a roughing operation, whereas anything below 0,5 mm depth of cut is defined as a finishing operation.

Grooving, threading and plunging are all considered to be finishing operations even though the contact area between insert and material can be large in each of these operations.

Definition of the operation in this way is very important for grade selection, since different Secomax PCBN grades are available for both operations. Optimum tool performance is determined by grade selection based on toughness, wear resistance, and thermal conductivity of the PCBN grade.

Preferred grade – Roughing (Depth of cut >0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C 0,5–4,0 mm (Roughing)	**Turning**	**CBN350** / CBN200	**CBN350** / CBN200
	Milling	N/A	**CBN200** / CBN350

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
D.O.C. <0,5 mm (Finishing)	**Turning**	**CBN10/CBN100** / CBN150 / CBN050C	**CBN160C** / CBN150
	Milling	N/A	**CBN160C** / CBN150
	Plunging	**CBN10/CBN100** / CBN050C	N/A
	Threading	**CBN160C** / CBN150	N/A
	Grooving	**CBN10/CBN100**	N/A

Bold = First choice

Comment

The main advantage of using PCBN is the high stock removal rates achievable compared to tungsten carbide and the longer tool life compared to ceramics.

The machinability is very dependent on hard facing type so information on the hard facing alloy is fundamental to determining the correct machining conditions and PCBN grades for success.

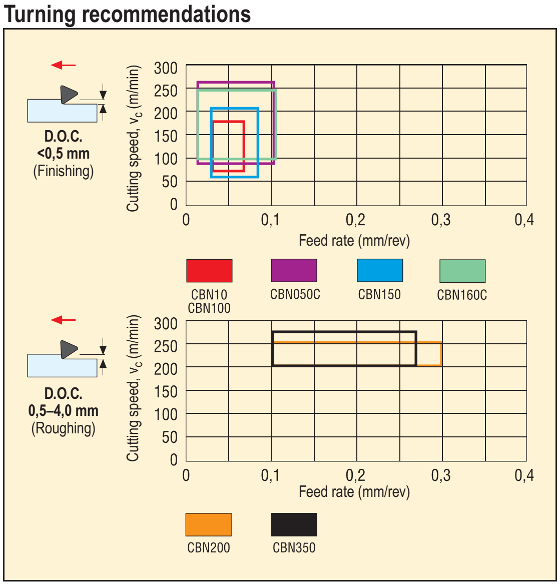
Material categories – Hard facing alloys (30–62 HRC)

Parameter guide – Recommended machining conditions

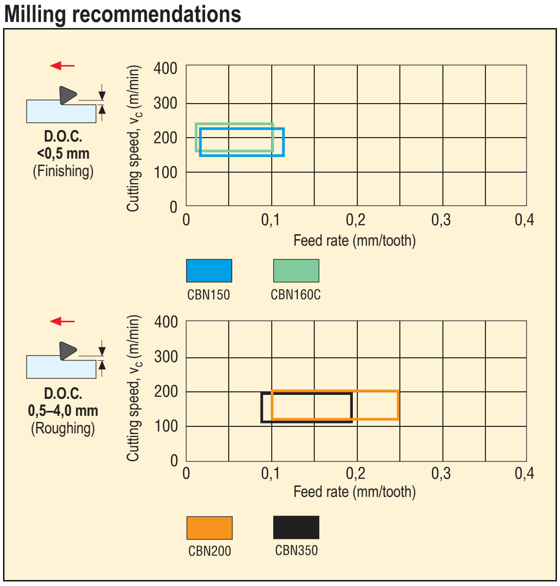
Hard facing alloys – Cobalt based (>35 HRC)

The following charts show the recommended cutting data for cobolt based hard facing alloy applications.

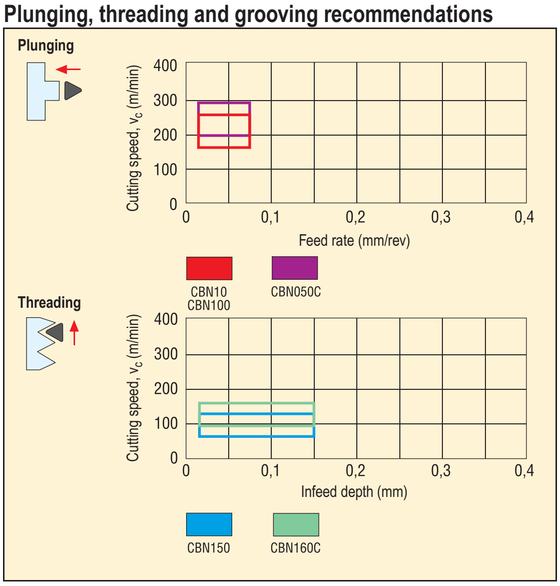
Turning recommendations

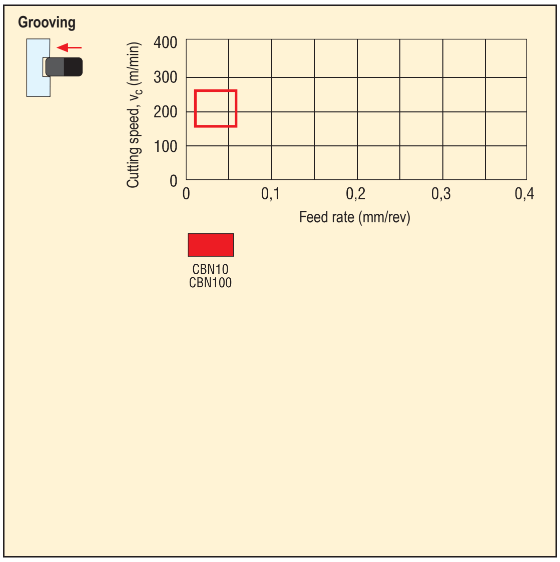


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Hard facing alloys (30–62 HRC)

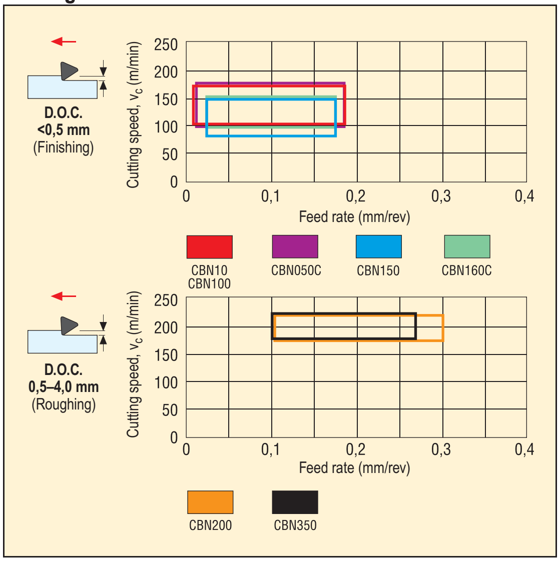
SECO

Parameter guide – Recommended machining conditions

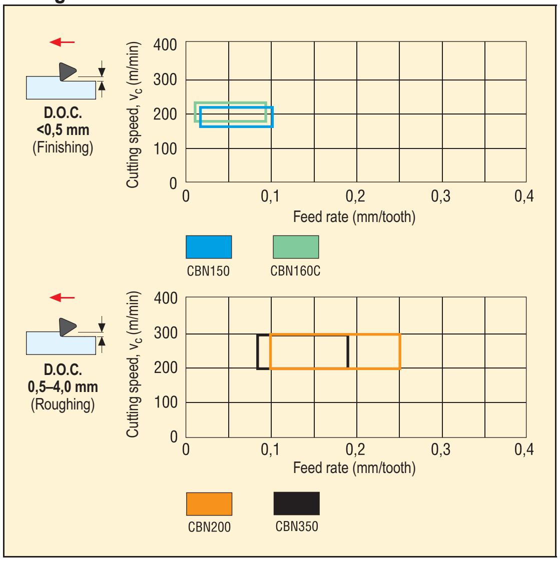
Hard facing alloys – Nickel based (>35 HRC)

The following charts show the recommended cutting data for nickel based hard facing alloy applications.

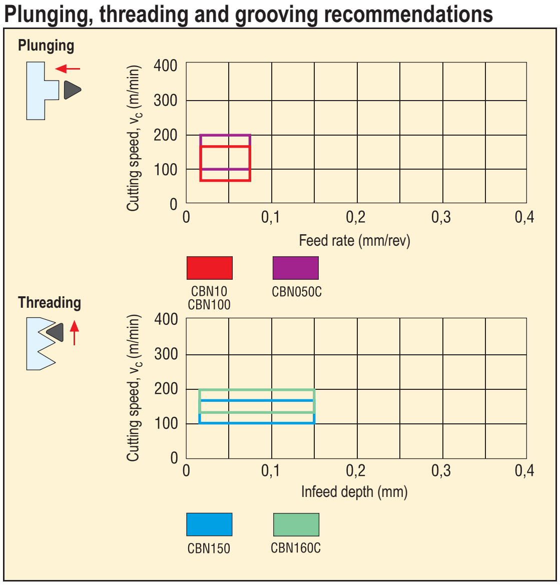
Turning recommendations

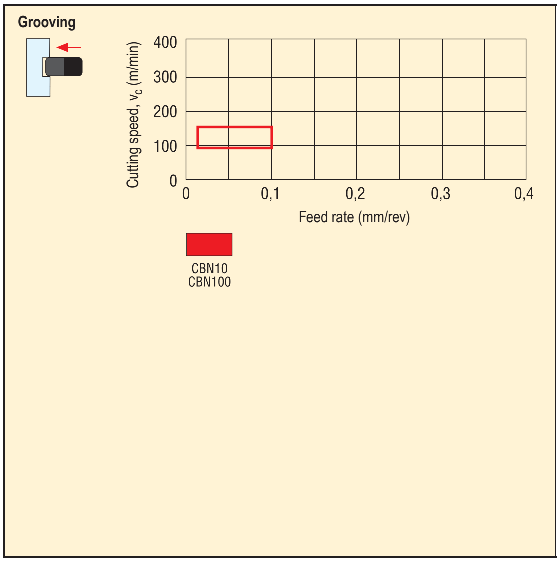


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Hard facing alloys (30–62 HRC)

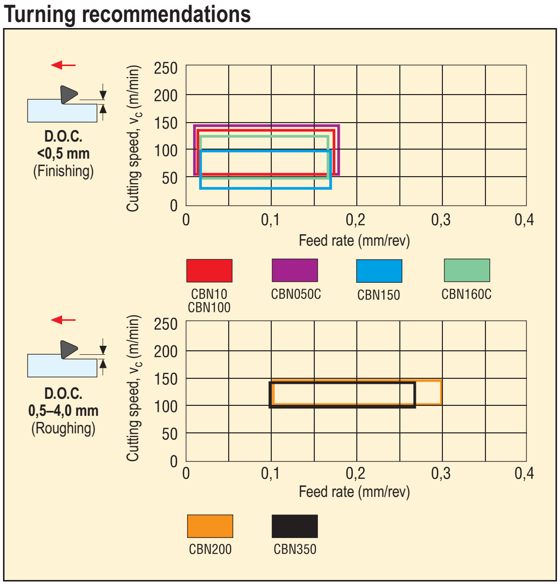
SECO

Parameter guide – Recommended machining conditions

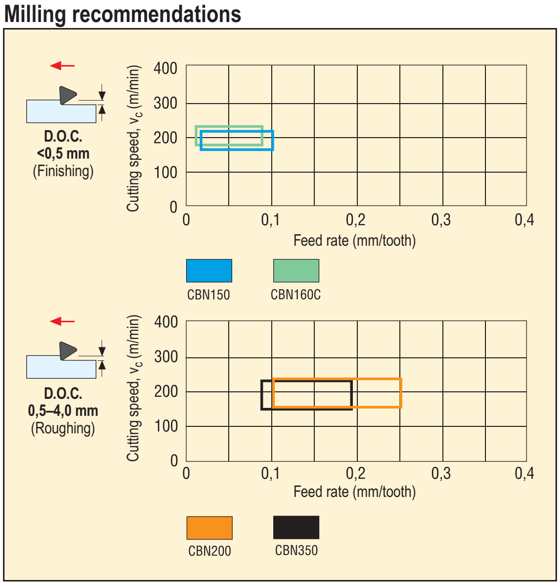
Hard facing alloys – Iron based (<60 HRC)

The following charts show the recommended cutting data for iron based hard facing alloy applications.

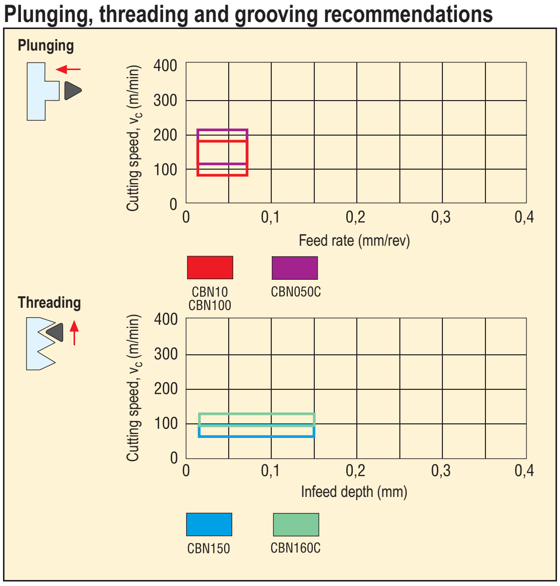
Turning recommendations

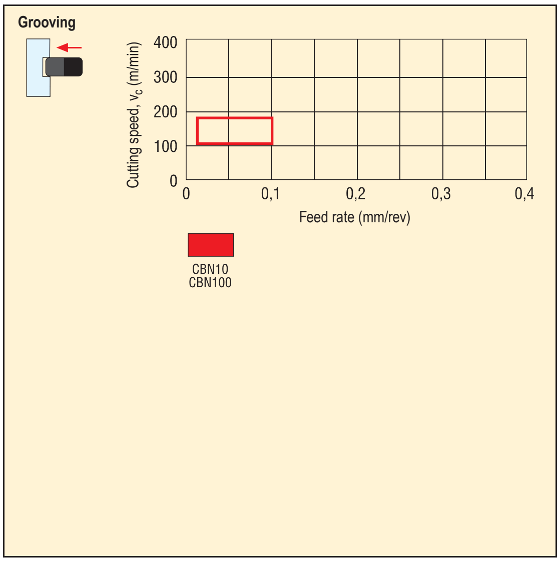


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

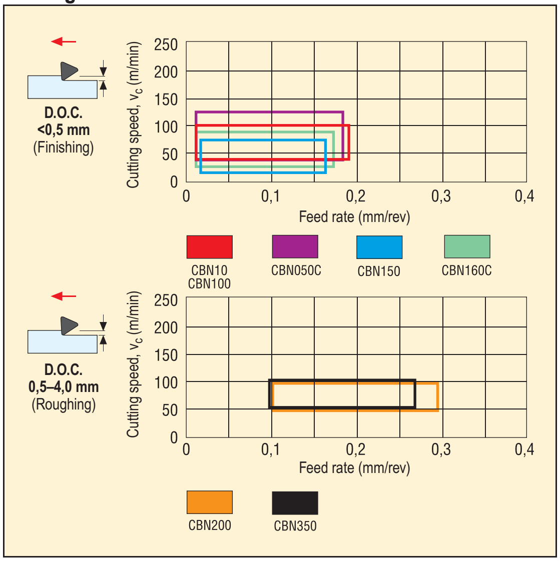
Material categories – Hard facing alloys (30–62 HRC)

Parameter guide – Recommended machining conditions

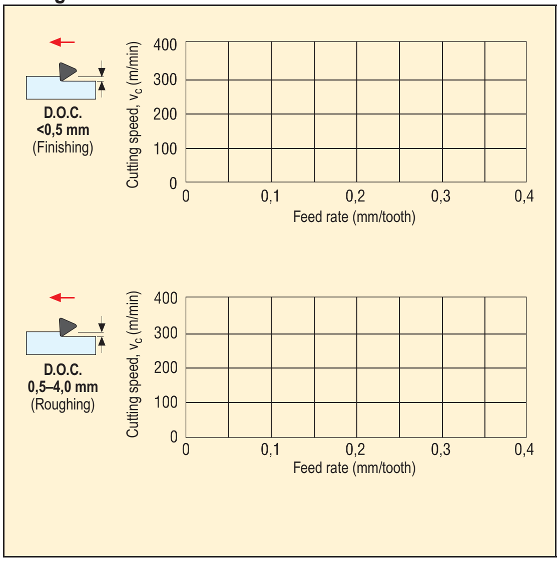
Hard facing alloys – Chrome based (<60 HRC)

The following charts show the recommended cutting data for chrome based hard facing alloy applications.

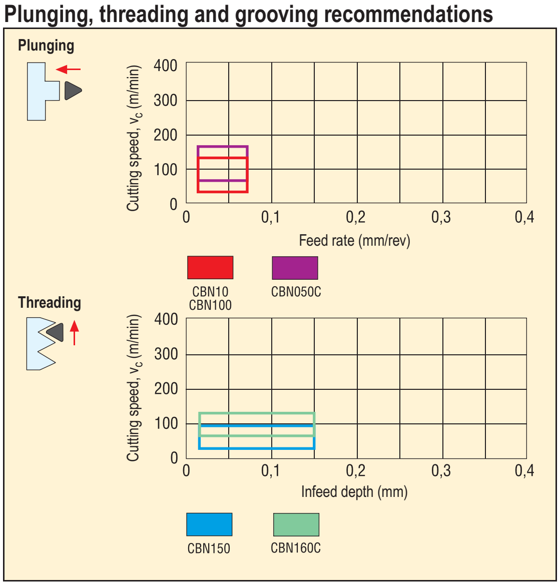
Turning recommendations

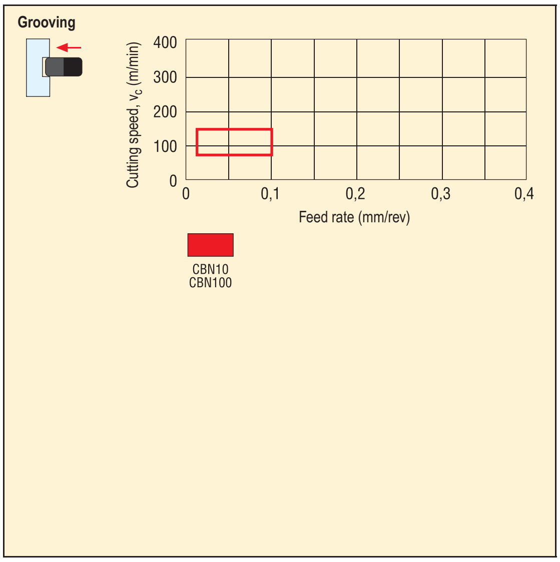


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Hard facing alloys (30–62 HRC)

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for any roughing or finishing of hard facing alloy components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

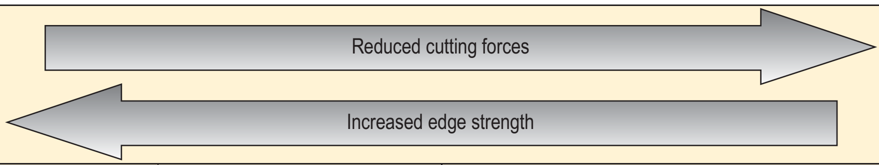
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

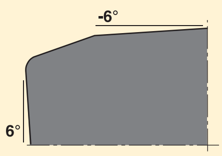
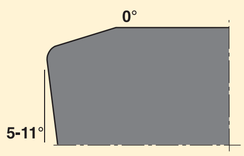
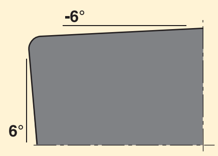
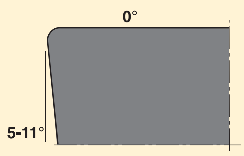
Rough machining

The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a), and provides a balance between optimum edge stability and minimised cutting forces.

Heavy interruptions and milling

In these operations, a negative rake angle combined with chamfered and honed cutting edges (a) should always be used.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for hard facing alloys

The operating windows for the different types of hard facing alloys are keys to achieving success with PCBN. Most hard facing alloys are typically work hardening therefore it is important to ensure the cutting tool is working effectively.

In general cobalt, iron and chrome hard facing alloys are more often weld deposited, whereas nickel based tend to be sprayed.

When removing the skin of the material every effort should be made to remove it in one pass, machining within the skin will greatly reduce tool life. In roughing operations round inserts should be used wherever possible, to maximise tool life feed rates should be increased but not so as to produce depth of cut notching.

For general troubleshooting recommendations, see page 80.

Material categories – Hard facing alloys (30–62 HRC)

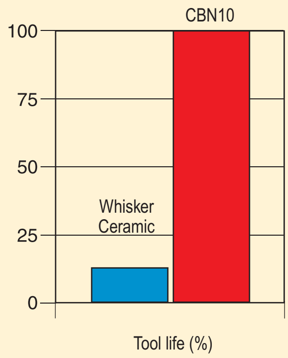
Application examples

Machining: Homogeniser components

Workpiece
Component: Homogeniser component
Material: Wallox20, Co hard facing alloy
Hardness: 60 HRC
Surface: Pre-machined

Conditions
Operation: Facing
Grade: CBN10
Insert: CNGA120408S-L1-B
Holder:
Cutting speed: 120 m/min
Feed rate: 0,10 mm/rev
Depth of cut: 0,25 mm
Coolant: No

Result
Tool life: 8x higher tool life with CBN10

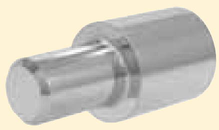


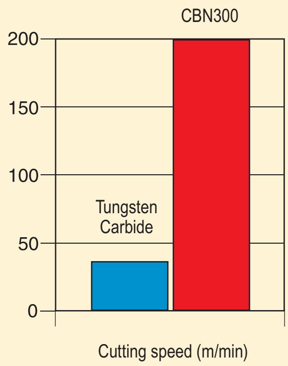
Machining: Rolls

Workpiece
Component: Roll
Material: Cobalt hard facing alloy
Hardness: 40 HRC
Surface: Rough cast

Conditions
Operation: OD turning
Grade: CBN300
Insert: RNMN120300S
Holder:
Cutting speed: 200 m/min
Feed rate: 0,4 mm/rev
Depth of cut: 2,5 mm
Coolant: No

Result CBN300 machines at 6 times higher cutting speeds than tungsten carbide



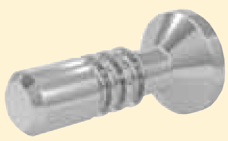


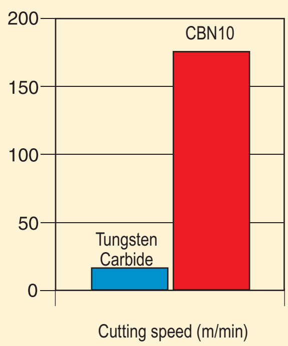
Machining: Homogeniser components

Workpiece
Component: Homogeniser component
Material: Wallex 20-10/40 Co hard facing alloy
Hardness: 59 HRC
Surface: Pre-machined

Conditions
Operation: Grooving
Grade: CBN10
Insert: LCGN160404-0400S-LF
Holder:
Cutting speed: 180 m/min
Feed rate: 0,05 mm/rev
Depth of cut:
Coolant: Yes

Result CBN10 machines at 9 times higher cutting speeds than tungsten carbide



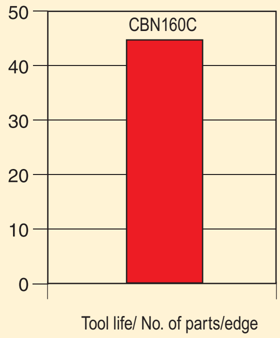


Material categories – Hard facing alloys (30–62 HRC)

SECO

Machining: Bottle moulds

Workpiece	
Component:	Bottle mould
Material:	Co based hard facing alloy (6% Co, 6% Cr, 4% W)
Hardness:	58–62 HRC
Surface:	Spray coated
Conditions	
Operation:	OD Turning
Grade:	CBN160C
Insert:	DNGA150608S-01525-L1-B
Holder:	
Cutting speed:	70 m/min
Feed rate:	0,075 mm/rev
Depth of cut:	0,1 mm
Coolant:	Yes
Result	
Tool life:	45 parts/edge



Machining: Oil well valve guides

Workpiece	
Component:	Oil well valve guide
Material:	Ni hard facing alloy (Colmonoy 5)
Hardness:	45 HRC
Surface:	Rough cast
Conditions	
Operation:	Face milling
Grade:	CBN200
Insert:	RNMN090300S
Cutter:	R220.70-0100-09-8
Cutting speed:	225 m/min
Feed rate:	0,2 mm/tooth = 1 145 mm/min
Depth of cut:	0,5 mm
Coolant:	No
Result	Increased productivity with CBN300 compared to WC

Machining: Shearing knives

Workpiece	
Component:	Shearing knife
Material:	Co based hard facing alloy
Hardness:	35–40 HRC
Surface:	Rough
Conditions	
Operation:	Face milling
Grade:	CBN200
Insert:	RNGN090300S-LF
Cutter:	R220.70-0063-09-6
Cutting speed:	320 m/min
Feed rate:	0,20 mm/tooth = 1 939 mm/min
Depth of cut:	0,75 mm
Coolant:	No
Result	
Tool life:	10 passes/edge

Material categories – Sintered tungsten carbide

Sintered tungsten carbide (85–90 HRA)

Material introduction

Cemented carbides belong to a class of hard, wear resistant, refractory materials in which the hard particles are bound together, or cemented, by soft and ductile metal binders. These materials were first developed in Germany in the early 1920's in response to demands for a die material having sufficient wear resistance for drawing tungsten incandescent filament wires to replace the expensive diamond dies then in use.

The first cemented carbides to be produced consisted of tungsten carbide (WC) with a cobalt binder. Although the term cemented carbide is widely used in the United States, the materials are better known internationally as hard metals. The ideal microstructure of WC-Co alloys should exhibit only two phases: angular WC grains and cobalt binder phase. These alloys exhibit excellent resistance to simple abrasive wear and thus have many applications in metal cutting. The commercially significant alloys contain cobalt in the range of 3 to 25%. For cutting tools, alloys with 3–12% Co and carbide grain sizes from 0,5 to 5,0 μm are commonly used.

Typical WC +19% Co microstructure

Material categories – Sintered tungsten carbide

Examples of typical tungsten carbide components

- Cutting tools
- Dies and anvils
- Threading dies
- Rolls
- Wear parts
- Form rolls
- Punches

Cutting tool grade selection

Roughing or finishing

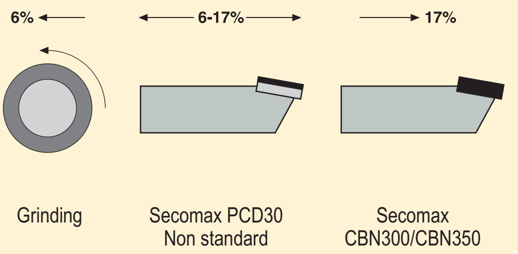
Although a very hard workpiece material, the cutting action when machining WC is very different to hardened steels. WC has much higher heat resistance than hard steel. The result is that softening of cutting zone does not take place when machining with PCBN.

Therefore, a grade with the highest abrasion resistance is required. If we consider single point turning, then PCD with its high abrasion resistance would be the most suitable grade. However, PCD is only suitable for WC with cobalt contents between 6 and 17%.

Anything above results in the cobalt chemically attacking the diamond (cobalt is a catalyst for diamond) and, therefore, is better machined with PCBN grade CBN300. The higher Cobalt content (17% and above) makes the WC easier to machine and means that both PCD and PCBN compliment each other in machining WC with cobalt contents larger than 6%. WC materials with cobalt contents below 6% are too hard to be single point machined and, therefore, generally ground with diamond grinding wheels.

Insert material selection

Tungsten carbide cobalt content



Preferred grade – Roughing (Depth of cut >0,5 mm)

D.O.C 0,5–4,0 mm (Roughing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	**CBN300** / CBN350	N/A
	Milling	N/A	N/A

Bold = First choice

Preferred grade – Finishing (Depth of cut <0,5 mm)

D.O.C. <0,5 mm (Finishing)	Machining method	Preferred grade for continuous and light interrupted cuts	Preferred grade for heavily interrupted cuts
	Turning	**CBN300** / PCD30	N/A
	Milling	N/A	N/A
	Plunging	**CBN300** / PCD30	N/A
	Threading	**CBN300** / PCD30	N/A
	Grooving	**CBN200**	N/A

Bold = First choice

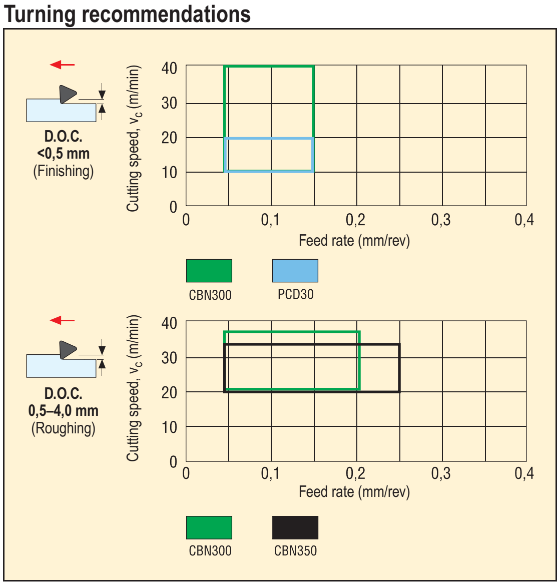
Material categories – Sintered tungsten carbide

Parameter guide – Recommended machining conditions

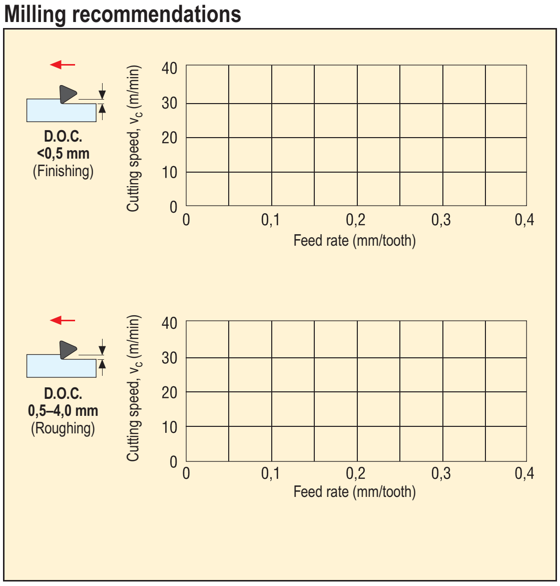
Sintered tungsten carbide (>6% Co)

The following charts show the recommended cutting data for sintered tungsten carbide applications.

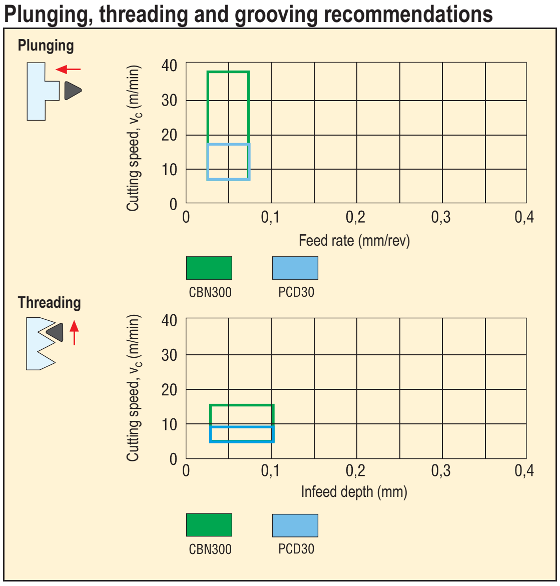
Turning recommendations

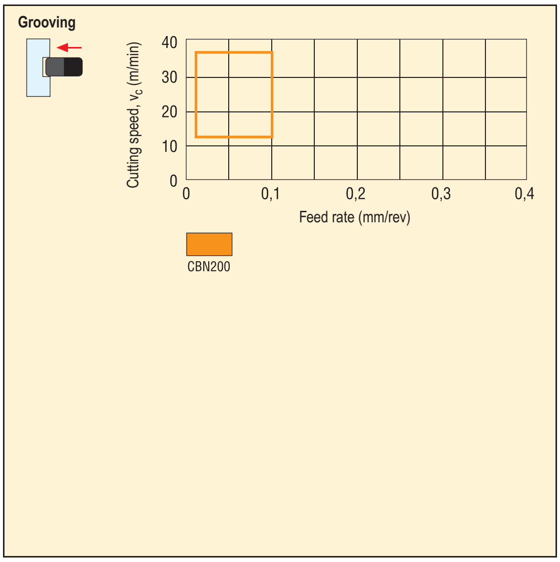


Milling recommendations



Plunging, threading and grooving recommendations





Comment

The parameter guide should be viewed as typical machining parameters for the various grades of Secomax PCBN. There are always exceptions where successful application parameters have been used which are outside the parameter guide ranges shown.

Material categories – Sintered tungsten carbide

SECO

Tool geometry and edge preparation

Finishing machining

The 6° negative rake combined with a chamfered and honed cutting edge (a) is the first choice for any roughing or finishing of martensitic stainless steel components, and offers the best combination of edge strength, stability and tool performance. The selected nose radius should always be as large as possible.

When machining thin walled sections, long slender parts or small internal diameters, it is often necessary to reduce tool pressure. A high tool pressure can deform the part, making it difficult to reach necessary dimensions and tolerances, and cause vibrations, which will destroy the surface finish.

In these operations, the first step to reduce tool pressure is to try the chamfered and honed cutting edge with a neutral rake angle (b). A negative rake angle with a honed only insert (c) would further reduce tool pressure, but the sharper edge reduces the strength of the insert, and increases the risk of edge chipping. A neutral rake with a honed only edge (d) should be used with caution and only when everything else has failed.

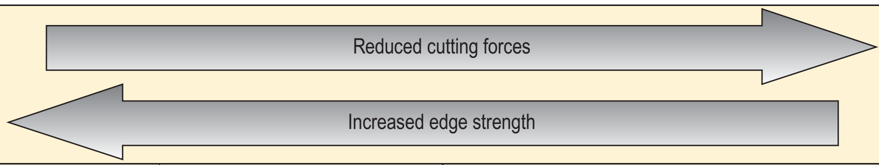
To achieve the best dimensional accuracy in plunging, it is recommended to use negative top rake combined with a honed only cutting edge (c).

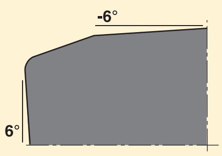
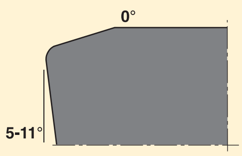
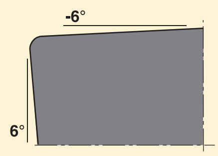
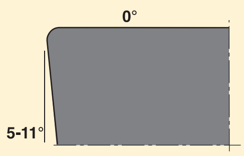
Rough machining

The most commonly used tool geometry for roughing operations is the negative rake angle combined with the chamfered and honed cutting edge (a), and provides a balance between optimum edge stability and minimised cutting forces.

Heavy interruptions and milling

These operations are not possible with PCBN.



First choice	Second choice	Options	
(a)  "S" edge prep. Negative insert	(b)  "S" edge prep. Positive insert	(c)  "E" edge prep. Negative insert	(d)  "E" edge prep. Positive insert
• General conditions		• Long overhangs • Small inner diameters • Thin walled sections	

Troubleshooting for sintered tungsten carbide

Recommended cutting speeds are low, but relatively large depths of cut can be taken.

Because of the hardness and toughness of tungsten carbide interrupted cutting is not viable and insert chipping will occur almost immediately. It is possible when machining tungsten carbide components that the material can break out at the end of the cut, and this can be eliminated by chamfering the exit edge of the material or machining from both ends towards the centre.

Tool life should be maximised by reducing contact time on the component, this can be achieved by increasing feed rates rather than cutting speed, although too high feed rates will result in notching. Coolant should be used in all cases.

For general troubleshooting recommendations, see page 80.

Material categories – Sintered tungsten carbide

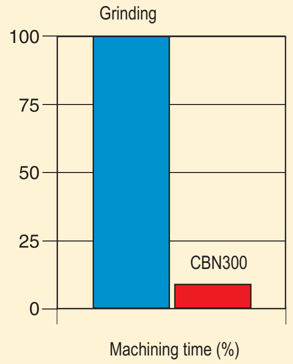
Application examples

Machining: Forming rolls

Workpiece
Component: Forming roll
Material: G50 Sintered tungsten carbide (25%Co)
Hardness:
Surface: Sintered

Conditions
Operation: Rough profiling
Grade: CBN300
Insert: RNMN090300S
Holder:
Cutting speed: 24 m/min
Feed rate: 0,1 mm/rev
Depth of cut: 0,5 mm
Coolant: Yes

Result
Machining time: CBN300 reduced machining time with 90% compared to grinding

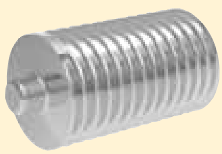


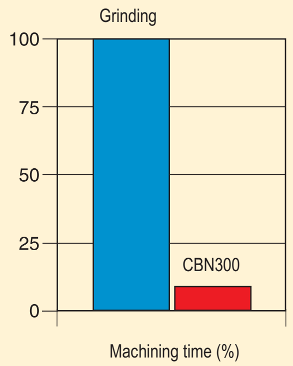
Machining: Forming rolls

Workpiece
Component: Forming roll
Material: Sintered tungsten carbide (20%Co)
Hardness: 68 HRC
Surface: Sintered

Conditions
Operation: OD turning
Grade: CBN300
Insert: RNMN090300S
Holder:
Cutting speed: 24 m/min
Feed rate: 0,1 mm/rev
Depth of cut: 0,5 mm
Coolant: Yes

Result
Machining time: CBN300 reduced machining time with 90% compared to grinding





Workpiece material index

SECO

Material categories	Designation				
	SAE	DIN	AFNOR	BS	SS
Case hardening steels	1016	CK15	XC18	080M15	1370
	8620	21 NiCrMo2	–	805M20	2506
	5115	16 MnCr5	16MC5	590M17	2511
	–	St52-5	20M5	150M19	2172
	–	C45E	–	–	1672
	–	25 CrMoS4	–	–	2225
	–	42 CrMoS4	–	–	2244
	4340	34 CrNiMo6	817M40	–	2541
Bearing steels	52100	100Cr6	100C6	EN31	2258
	–	100Cr6Mo7	100CD7	–	–
	50100	100Cr2	100C2	–	–
Cold work tool steels	L3	115 CrV3	–	–	2140
	D3	X210 Cr 12	Z 200 C12	BD 3	2312
	A2	X100CrMoV51	Z 100 CDV5	BA 2	2260
	S2	45WCrV7	55 C20	BS 2	2710
	D2	X155CrMoV 12 1	Z 160 CDV12	BD 2	2310
	S7	–	–	–	–
Hot work tool steels	H10	X32 CrMoV 3 3	32 DCV 28	BH 10	–
	H11	X38 CrMoV 5 1	Z 38 CDV 5	BH 11	–
	H12	X37 CrMoV 5 1	Z 35 CWDV 5	BH 12	–
	H13	X40 CrMoV 5 1	Z 40 CDV 5	BH 13	2242
High tensile steels	4340	34CrNiMo6	–	817 M 40	–
	4330	–	–	–	–
	Aermet 100	–	–	–	–
	A300M	–	–	–	–
High speed steels	T1	S 18-0-1	Z80 WCV 18-4-1	BT1	–
	M35	S 6-5-2-5	Z85 WDKCV 6-5-2-5	BM35	2723
	M2	S 5-5-2	Z85 WDCV 6-5-2	BM2	2722
	M42	S 2-10-1-8	Z110 DKCWV 2-9-1-8	BM42	–
	T4	S 18-1-2-5	Z80 WKCV 19-5-4-1	BT4	–

Average composition (wt%)											
C	Si	Mn	S	Cr	Mo	Ni	Al	Cu	V	Co	W
0,15	0,30	0,75	–	–	–	–	–	–	–	–	–
0,21	<0,40	0,80	0,02	0,55	0,20	0,55	–	–	–	–	–
0,16	<0,40	1,15	0,02	0,95	0,10	1,10	–	–	–	–	–
0,20	0,55	1,60	0,02	–	–	–	–	–	–	–	–
0,47	0,25	0,60	–	–	–	–	–	–	–	–	–
0,26	0,25	0,62	0,03	1,05	0,20	–	–	–	–	–	–
0,42	0,25	0,75	0,03	1,05	0,20	–	–	–	–	–	–
0,34	0,40	0,65	0,03	1,50	0,23	1,50	–	–	–	–	–
1,00	0,20	0,35	–	1,50	–	–	–	–	–	–	–
1,00	0,20	0,70	–	1,50	0,30	–	–	–	–	–	–
1,00	0,20	0,35	–	0,50	–	–	–	–	–	–	–
0,93	0,30	1,20	–	0,50	–	–	–	–	0,10	–	0,50
2,15	0,60	0,60	–	12,20	–	0,30	–	–	1,00	–	1,00
1,00	0,20	0,60	–	5,20	1,10	–	–	–	0,20	–	–
0,49	0,90	0,30	–	1,20	0,25	–	–	–	0,15	–	2,30
1,50	0,60	0,60	–	12,00	1,00	0,30	–	–	1,10	1,00	–
0,50	0,60	0,50	–	3,25	1,55	–	–	–	0,25	–	–
0,40	1,00	0,50	–	3,30	2,50	0,30	–	0,25	0,50	–	–
0,38	1,00	0,35	–	5,20	1,35	0,30	–	0,25	0,45	–	–
0,35	1,00	0,35	–	5,20	1,50	0,30	–	0,25	0,50	–	1,35
0,38	1,00	0,35	–	5,20	1,40	0,30	–	–	1,00	–	–
0,38	0,22	0,66	–	0,69	0,19	1,99	–	–	–	0,02	–
0,25	<0,80	<1,00	–	0,50	0,40	1,25	–	–	–	–	–
0,23	–	–	–	3,00	1,20	11,10	–	–	–	13,40	–
0,42	1,65	0,75	–	0,80	0,40	1,80	–	–	–	–	–
0,75	–	–	–	4,00	18,00	–	–	–	1,00	–	–
0,93	–	–	–	4,20	5,00	–	–	–	2,70	4,80	6,40
0,85	–	–	–	4,00	5,00	–	–	–	2,00	–	6,00
1,05	–	–	–	3,90	9,50	–	–	–	1,15	8,00	1,50
0,75	–	–	–	4,00	18,00	–	–	–	1,00	5,00	–

Workpiece material index

SECO

Material categories	Designation				
	SAE	DIN	AFNOR	BS	SS
Martensitic stainless steels	403	1.4006	Z 6C13	403S17	2302
	410	1.4006	Z 6C13	410S21	2302
	416	1.4006	Z 12CF13	416S21	2380
	420	1.4021	Z 20C13	420S37	2303
	420F	1.4028	Z 30C13	420S45	2304
	431	1.4057	–	431S29	2321
White cast irons	CL 1 A	GJN-HV550	–	2B	0513-00
	CL 1 B	GJN-HV520	–	2A	0512-00
	CL 1 C	–	–	–	–
	CL 1 D	GJN-HV600	–	2C, 2D, 2E	0457-00
	CL II A	GJN-HV600XCr11	–	–	–
	CL II B	GJN-HV600XCr14	–	–	–
	CL II D	GJN-HV600XCr18	–	–	–
	CL III A	GJN-HV600XCr23	–	–	0466-00
Grey cast irons	–	GG00	–	–	0100
	Class 20	GG10	Ft10D	Grade 100	0110
	Class 25	GG15	Ft15D	Grade 150	0115
	Class 30	GG20	Ft20D	Grade 200	0120
	Class 35/40	GG25	Ft25D	Grade 250	0125
	Class 45	GG30	Ft30D	Grade 300	0130
	Class 50	GG35	Ft35D	Grade 350	0135
	Class 55	GG40	Ft40D	Grade 400	0140
Powder tool steels	M4	–	–	–	–
	ASP23	–	Z 85WDCV6452	–	–
	ASP30	–	–	–	–
	ASP60	–	–	–	–
Superalloys	Inconel 718	–	–	–	–
	Inconel 713	–	–	–	–
	Inconel 625	–	–	–	–

Average composition (wt%)											
C	Si	Mn	S	Cr	Mo	Ni	Al	Cu	V	Co	W
0,12	–	–	–	13,0	–	<1,0	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–
0,12	–	–	0,25	13,0	<0,6	<1,0	–	–	–	–	–
0,20	–	–	–	13,0	–	<1,0	–	–	–	–	–
0,30	–	–	–	13,0	–	<1,0	–	–	–	–	–
0,18	–	–	–	16,5	–	2,0	–	–	–	–	–
2,8-3,6	0,8	2,0	–	1,0-4,0	1,0	3,3-5,0	–	–	–	–	–
2,4-3,0	–	–	–	1,0-4,0	1,0	3,3-5,0	–	–	–	–	–
2,5-3,7	–	–	–	1,0-2,5	1,0	4,0	–	–	–	–	–
2,7-3,6	–	–	–	7,0-11,0	1,5	5,0-7,0	–	–	–	–	–
2,0-3,3	1,5	2,0	–	11,0-14,0	3,0	2,5	–	1,2	–	–	–
2,0-3,3	1,5	2,0	–	14,0-18,0	3,0	2,5	–	1,2	–	–	–
2,0-3,3	2,2	2,0	–	18,0-23,0	3,0	2,5	–	1,2	–	–	–
2,0-3,3	1,5	2,0	–	23,0-30,0	3,0	2,5	–	1,2	–	–	–
3,5-3,8	2,8-2,2	0,4-0,8	–	–	–	–	–	–	–	–	–
3,5-3,8	2,8-2,2	0,4-0,8	<0,15	–	–	–	–	–	–	–	–
3,4-3,7	2,6-2,0	0,5-0,8	<0,15	–	–	–	–	–	–	–	–
3,3-3,6	2,1-1,8	0,6-0,8	<0,15	–	–	–	–	–	–	–	–
3,2-3,5	2,1-1,5	0,6-0,8	<0,15	–	–	–	–	–	–	–	–
3,1-3,3	1,8-1,3	0,7-0,9	<0,10	–	–	–	–	–	–	–	–
3,0-3,2	1,5-1,1	0,8-1,0	<0,10	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–
1,35	0,35	0,25	–	4,25	5,0	–	–	–	4,2	–	6,0
1,28	0,62	0,28	–	4,20	5,0	–	–	–	3,1	0,41	6,4
1,28	0,60	0,32	–	4,20	5,0	–	–	–	3,1	8,50	6,4
2,30	0,41	0,30	–	4,20	7,0	–	–	–	6,5	10,50	6,5
–	–	–	–	19,0	3,0	52,5	–	–	–	–	–
–	–	–	–	12,5	4,2	75,0	6,1	–	–	–	–
–	0,5	0,5	–	21,5	9,0	61,0	0,4	–	–	–	–