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Supplementary comparison of Parallel Thread Gauges

EURAMET.L-S21

FINAL REPORT

by

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and

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Contents

1 INTRODUCTION

Value of the pitch diameter depends on several parameters that have to be either measured or assumed, depending on the method that is used. Different approaches can be used which can lead to significantly different values of pitch diameter and associated uncertainties. The last comparison of screw thread calibration between European laboratories "EAL Interlaboratory Comparison M 19" took place in 1997. The comparability of screw gauge calibration within participating laboratories was poor and many questions were raised in discussion between the coordinator and the participating laboratories. Conclusion was that harmonization of procedures for determination of the pitch diameter is absolutely necessary.

In order to enhance the equivalence and mutual recognition of calibration results obtained by laboratories performing calibrations of determination of pitch diameter of parallel thread gauges by mechanical probing, EA Committee 2 (Technical Activities), based on the draft produced by EA Expert Group on Dimensional Metrology, have published Guide EA-10/10. This document was revised and republished by the EURAMET Technical Committee for Lengths in several occasions. Last edition of this document (EURAMET cg-10, Version 2.1) was published in December 2012 .

This document gives guidance on how to determine the pitch diameter and the associated uncertainty of measurement.

During the Euramet annual TCL meeting in October 2011 HMI/FSB-LPMD proposed to start and pilot a EURAMET comparison of parallel thread gauges.

Scope of this comparison is:

- to confirm existing measurement methods and procedures
- to verify and compare the uncertainty estimations

2 ORGANIZATION

2.1 Organization body

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2.2 Participants

Table 2-1 - List of participants

Country (code)	Laboratory	Name of contact	Address	Contact details
1 – Croatia (HR)	HMI/FSB-LPMD	Vedran Mudronja	Croatian Metrology Institute National Laboratory for Length Ivana Lučića 5 10000 Zagreb, Croatia	Tel: +385 1 6168 327 Fax: +385 1 6168 599 Email: vedran.mudronja@fsb.hr
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3 – Austria (AT)	BEV	Michael Matus	Bundesamt für Eich- und Vermessungswesen Gruppe Eichwesen (Metrology Service) Arltgasse 35 A-1160 Wien, Austria	Tel: +43 1 21110-6540 Fax +43 1 21110-6000 Email: michael.matus@bev.gv.at
4 – Hungary (HU)	MKEH	Edit Bánréti	Hungarian Trade Licensing Office Németvölgyi út 37-39 HU-1124 Budapest XII. Hungary	Tel: +36 1 458 59 97 Fax: +36 1 458 59 27 Email: banretie@mkeh.hu
5 – Switzerland (CH)	METAS	Rudolf Thalmann	Federal Institute of Metrology METAS Lindenweg 50 CH-3003-Bern-Wabern Switzerland	Tel:+41 58 387 03 85 Fax: +41 58 387 02 10 E-mail: rudolf.thalmann@metas.ch
6 – Finland (FI)	MIKES	Antti Lassila	Centre for Metrology and Accreditation Tekniikantie 1 FI-02151 Espoo, P.O. Box 9 Finland	Tel: +358 10 6054 000 Fax: +358 10 6054 499 Email: antti.lassila@mikes.fi
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8 – Italy (IT)	INRIM	Gian Bartolo Picotto	Istituto Nazionale di Ricerca Metrologica Strada delle Cacce 91 IT-10135 Torino, Italy	Tel: +39 011 3919 969 Fax: +39 011 3919 959 Email: g.picotto@inrim.it

9 – Turkey (TR)	TUBİTAK-UME	Doc. Dr.Tanfer Yandayan Okhan Ganioglu İlker Meral	TÜBİTAK UME Gebze Yerleşkesi Barış Mah. Dr.Zeki Acar Cad. No:1 41470 Gebze KOCAELİ TÜRKİYE	Tel: +90 262 679 5000 - 5300,5353,5303 Fax: +90 262 679 5001 Email: tanfer.yandayan@ume.tubitak.gov.tr okhan.ganioglu@ume.tubitak.gov.tr ilker.meral@ume.tubitak.gov.tr
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2.3 Time schedule

The comparison was carried out in one measurement loop. The circulation of standards started in March 2012 and was completed in November 2013. The detailed schedule is given in Table 2-2. A period of five weeks was allowed for the measurements in each laboratory, including the time necessary for transportation. The standards were re-measured by the pilot laboratory at the end of the loop in order to detect potential changes of standards related to transport. Original time schedule was changed in several occasions due to the problems with the custom documentation (ATA carnet).

Table 2-2 - Comparison schedule

Country	Laboratory	Period (starting date)
Croatia	HMI/FSB-LPMD	12 March 2012
Slovenia	MIRS/UM-FS/LTM	16 April 2012
Austria	BEV	21 May 2012
Hungary	MKEH	25 June 2012
Summer holidays		
Switzerland	METAS	03 September 2012
Finland	MIKES	08 October 2012
Estonia	Metrosert	12 November 2012
Italy	INRIM	17 December 2012
Turkey	TUBİTAK-UME	22 February 2013
France	LNE	17 April 2013
Croatia	HMI/FSB-LPMD	31 May 2013
Italy	INRIM	21 November 2013

Note:

In November 2013 INRIM requested the re-measurement of standards with different measurement equipment. After consent from participating laboratories Pilot approved INRIM re-measurement and standards were sent to INRIM in November 21st. INRIM finished with measurements in December 18th 2013.

3 DESCRIPTION OF THE STANDARDS

Six thread gauges were measured: three thread plugs (GO side) and three thread rings.

Table 3-1 - Thread gauges

	Thread gauges	Serial Number
Thread plugs	GO M6x1 6H	FSB 01
	GO M12x1,75 6H	FSB 02
	GO M36x1,5 6H	FSB 03
Thread rings	GO M18x2,5 6g	BDU 096
	GO M42x4,5 6g	BDP 105
	GO M30x1,5 6g	BEI 234

4 MEASUREMENT INSTRUCTIONS

Participating laboratories were encouraged to follow Calibration Guide EURAMET cg-10, Version 2.0 (03/2011), however adapted to their instruments and procedures.

Each laboratory could, according to its measurement capabilities, measure:

- Simple pitch diameter
- Pitch diameter
- Thread angle
- Pitch

Detailed measurement instructions with description of calibration categories were given in Technical Protocol. The comparison was carried out according to the protocol. All the laboratories were encouraged to calculate results for 1a, 1b and 2a calibration categories if these calculations were possible. (e.g. if reported result was for the pitch diameter within 2b category, laboratory was ask to report results for 1a, 2a, and 1b categories as well).

4.1 Measurement positions

Measurement plane: Sectional plane defined by axis and marking direction.

Diameters measurement: Approximately middle of the cylinder.

Pitch measurement: Average over the three threads for pitch measurement in approximate middle of the cylinder.

Angle measurement: Approximately middle of the cylinder.

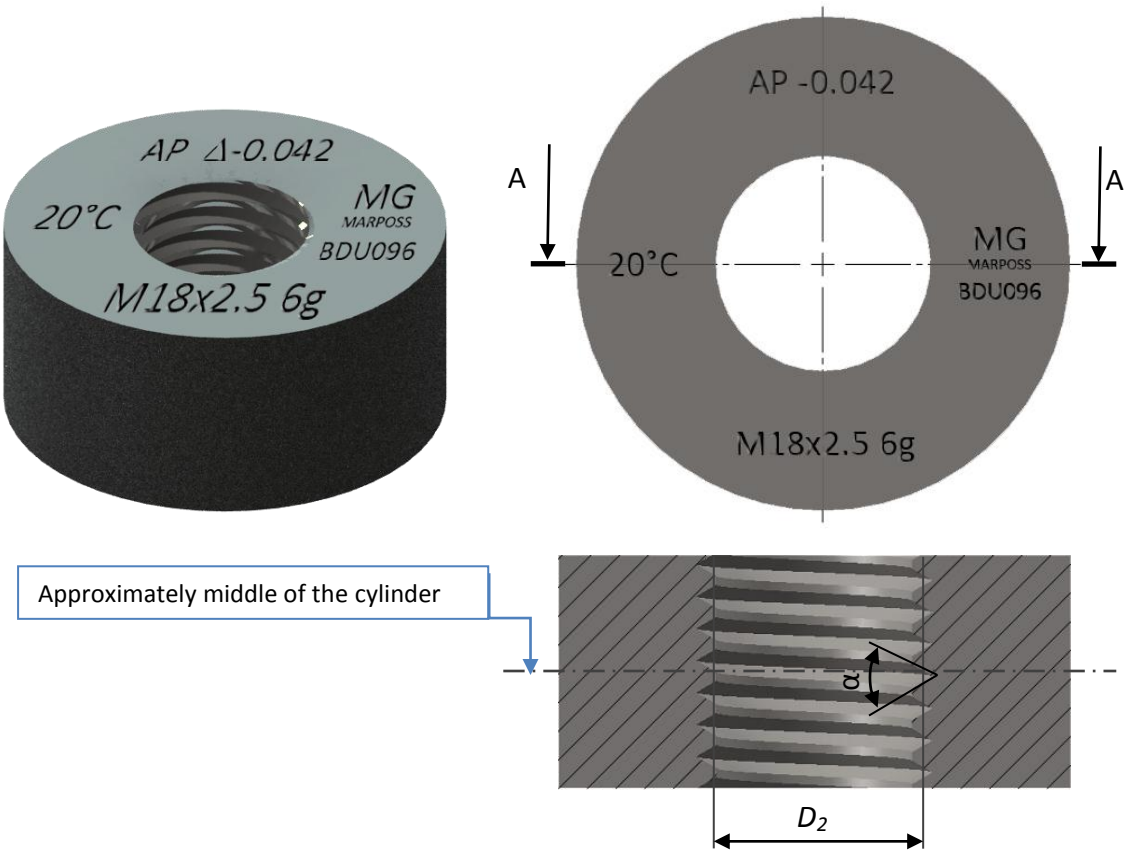


Figure 4-1 - Measurement positions - thread rings

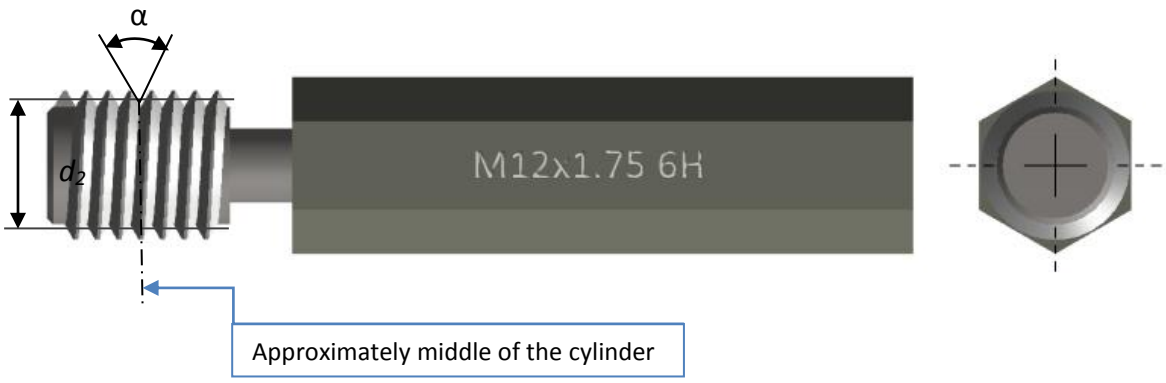


Figure 4-2 - Measurement positions - thread plugs

5 MEASUREMENT EQUIPMENT USED BY THE PARTICIPANTS

Table 5-1 - Equipment for thread plug measurements

Participant	Measurement device	Measurement Method
HMI/FSB-LPMD	*Pitch diameter*: Joint DMS680 Universal Length Measuring System *Pitch, Thread angle*: Retrofitted Carl-Zeiss tool microscope	Three wires method
MIRS/UM-FS/LTM	*Pitch diameter*: Digital micrometer	Three wires method
BEV	*Pitch diameter*: SIP 3002M + Laser interferometer PTB reference software	Three wires method
MKEH	*Pitch diameter*: SIP 550M length measuring machine *Pitch, Thread angle*: Microscope (optics for the plugs)	Three wires method
METAS	*Pitch diameter*: SIP 3002M + Laser interferometer *Pitch, Flank angles*: Taylor Hobson Talysurf FTS 120 (0,3 mm stylus)	Two wires method
MIKES	*Pitch diameter* : SIP 550 *Pitch, Thread angle*: Taylor Hobson Talysurf Series 2	Three wires method
Metrosert	*Pitch diameter* : ULM Opal 600	Three wires method
INRIM I	*Pitch diameter* : Moore based measuring machine + Laser interferometer *Pitch, Thread angle*: Form Talysurf	Two-ball
TUBİTAK-UME	*Pitch diameter* : Mahr 1D stylus measuring machine *Pitch, Thread angle*: CMM	Three wires method
LNE	*Pitch diameter* : SIP 550 machine + laser interferometer	Three wires method (Two step method)

Table 5-2 - Equipment for thread ring measurements

Participant	Measurement device	Measurement Method
HMI/FSB-LPMD	*Pitch diameter, Pitch*: Joint DMS680 Universal Length Measuring System *Thread angle*: Retrofitted Carl-Zeiss tool microscope (impress)	Two-ball
MIRS/UM-FS/LTM	*Pitch diameter*: CMM	Two-ball
BEV	*Pitch diameter*: SIP 3002M + Laser interferometer PTB reference software	Two-ball
MKEH	*Pitch diameter*: SIP 550M length measuring machine *Pitch*: Microscope (optics for the rings)	Two-ball

METAS	*Pitch diameter*: SIP LMM5 + Laser interferometer *Pitch, Flank angles*: Taylor Hobson Talysurf FTS 120 (0,3 mm stylus)	Two-ball
MIKES	*Pitch diameter* : SIP 550 + Mahr militron sensor *Pitch, Thread angle*: Taylor Hobson Talysurf Series 2	Two-ball
Metrosert	*Pitch diameter* : ULM Opal 600	Two-ball
INRIM I	*Pitch diameter* : Moore based measuring machine + Laser interferometer + Tesa mod. I-DIM *Pitch, Thread angle*: Form Talysurf	Two-ball
TUBİTAK-UME	*Pitch diameter* : Mahr 1D stylus measuring machine *Pitch, Thread angle*: CMM	Two-ball
LNE	*Pitch diameter* : SIP 214 machine + laser interferometer	Two-ball (Compared with Vee groove cylinder)

Table 5-3 - Equipment for thread plug INRIM re-measurements

Participant	**Measurement device**	**Measurement Method**
INRIM II	*Pitch diameter* : Moore based measuring machine + Laser interferometer + SIP-3D *Pitch, Thread angle*: Form Talysurf	Two-ball

Table 5-4 - Equipment for thread ring INRIM re-measurements

Participant	**Measurement device**	**Measurement Method**
INRIM II	*Pitch diameter* : Moore based measuring machine + Laser interferometer + SIP-3D *Pitch, Thread angle*: Form Talysurf	Two-ball

6 STABILITY OF THE STANDARDS

Pitch diameter (2b calibration category) was chosen to indicate the stability of standards. It was measured by HMI/FSB-LPMD prior to and after the comparison. Results are given in figures from 6-1 to 6-6.

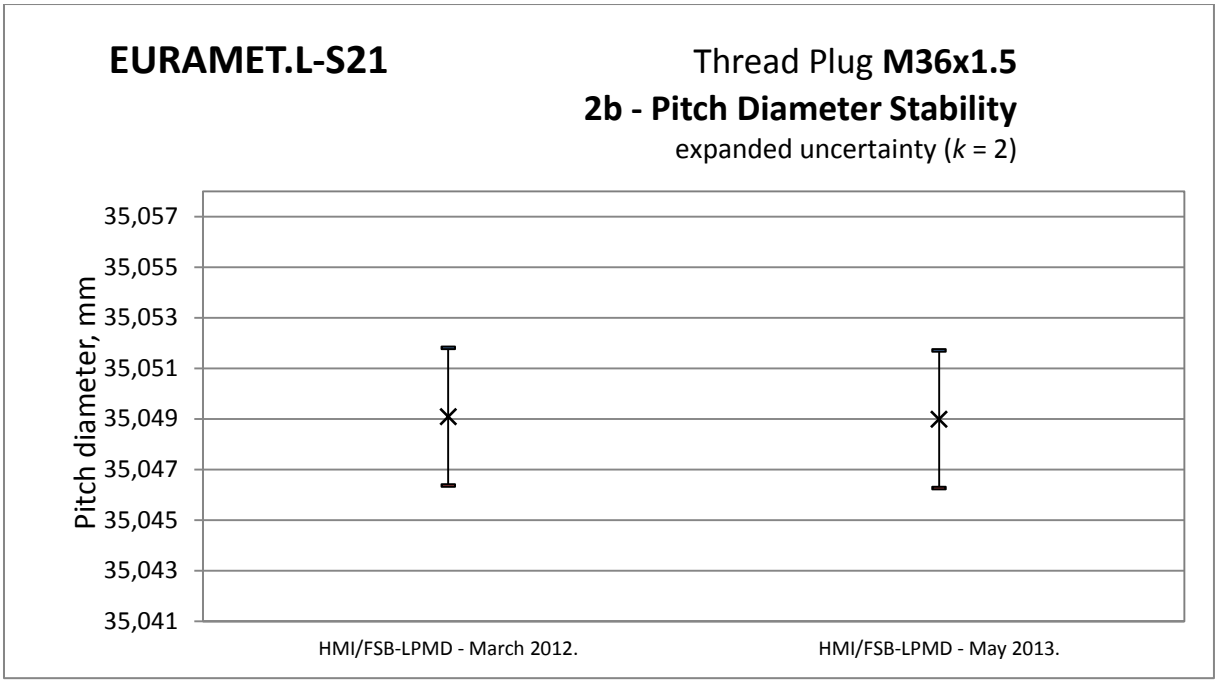


Figure 6-1 - Stability of the thread plug M35x1.5

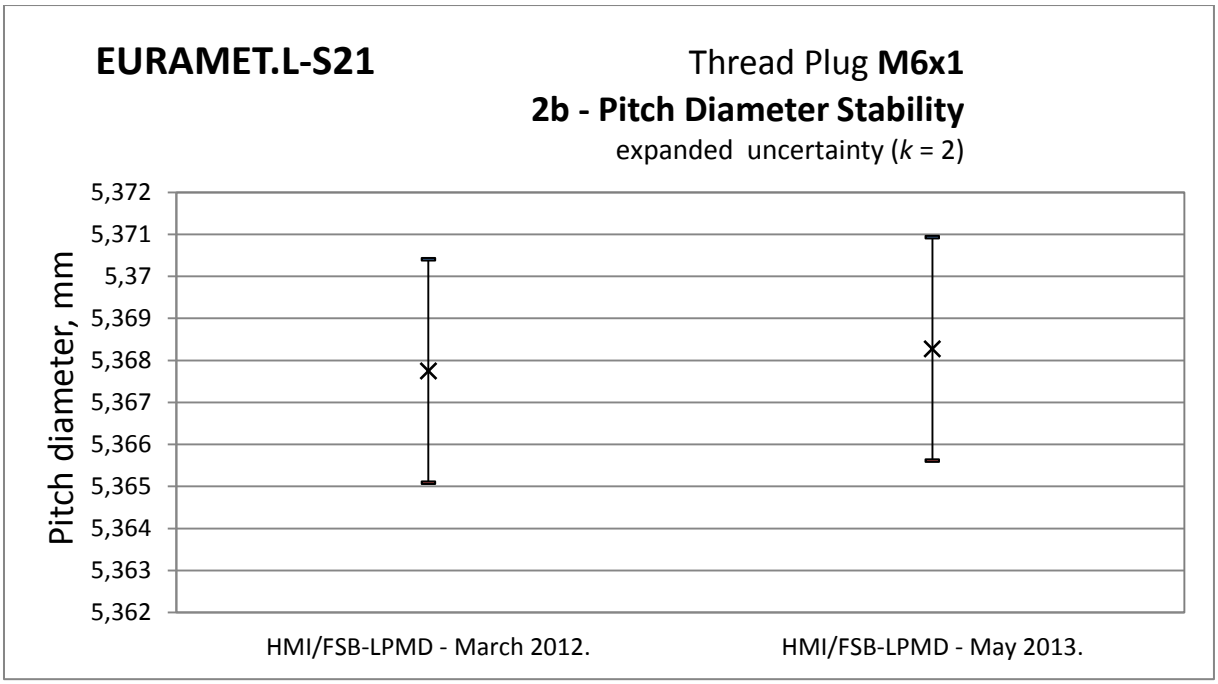


Figure 6-2 - Stability of the thread plug M6x1

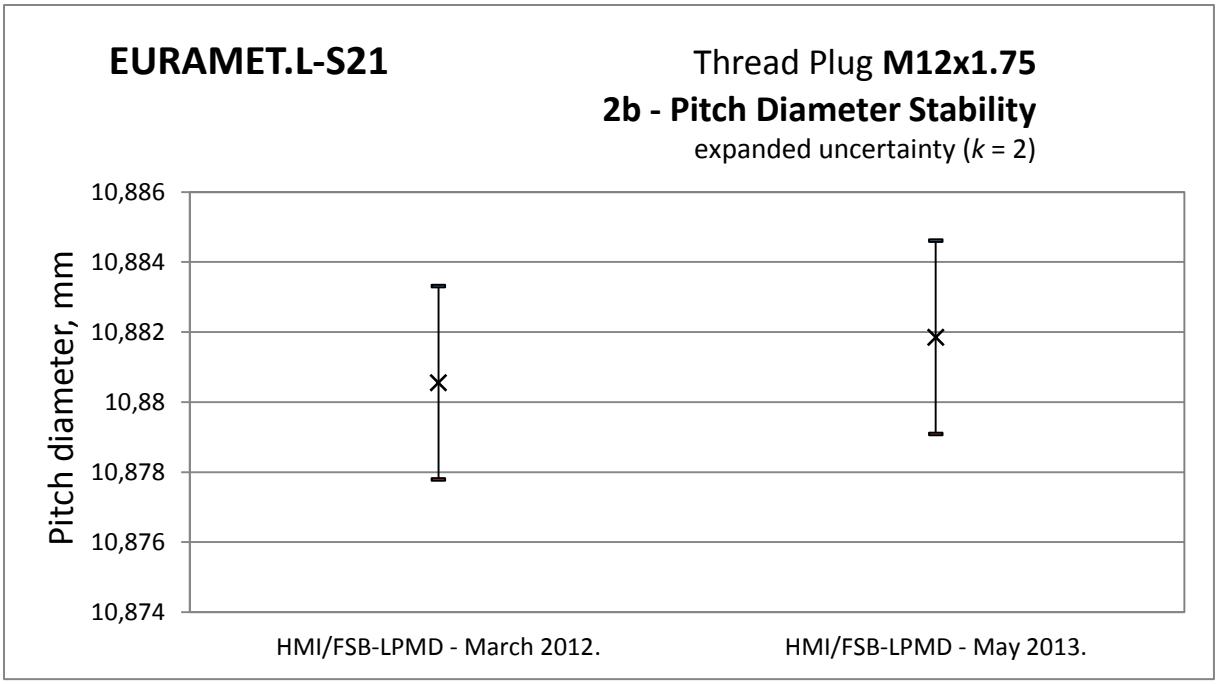


Figure 6-3 - Stability of the thread plug M12x1.75

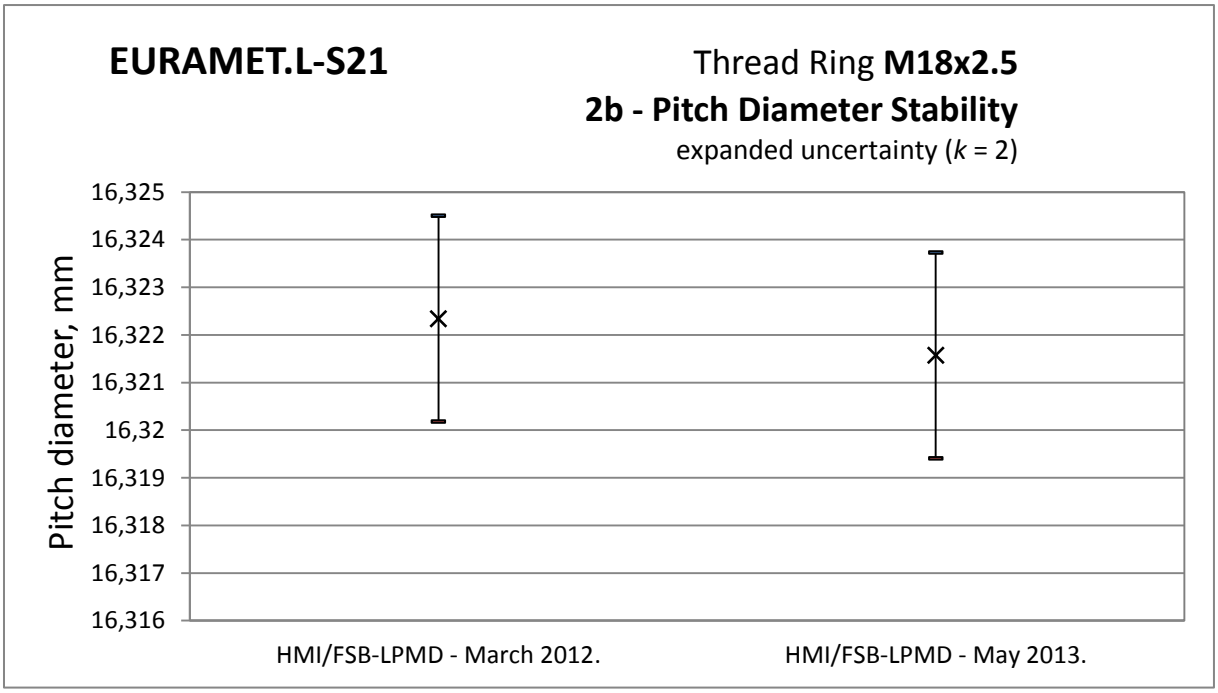


Figure 6-4 - Stability of the thread ring M18x12.5

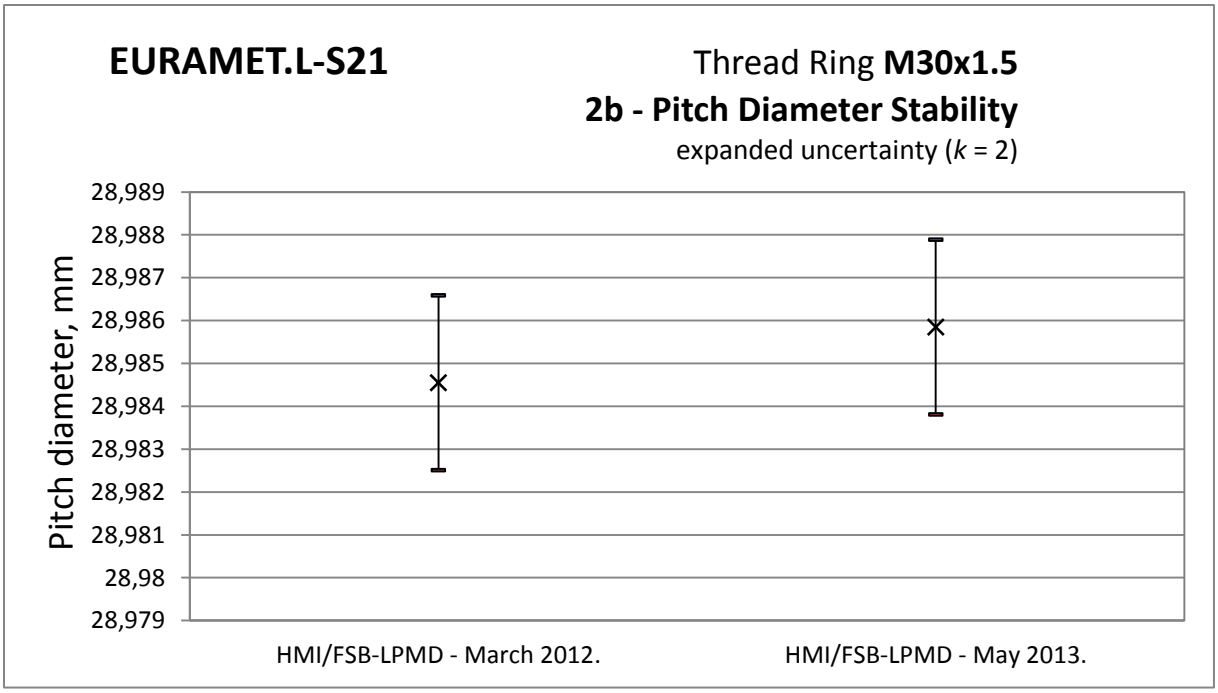


Figure 6-5 - Stability of the thread ring M30x1.5

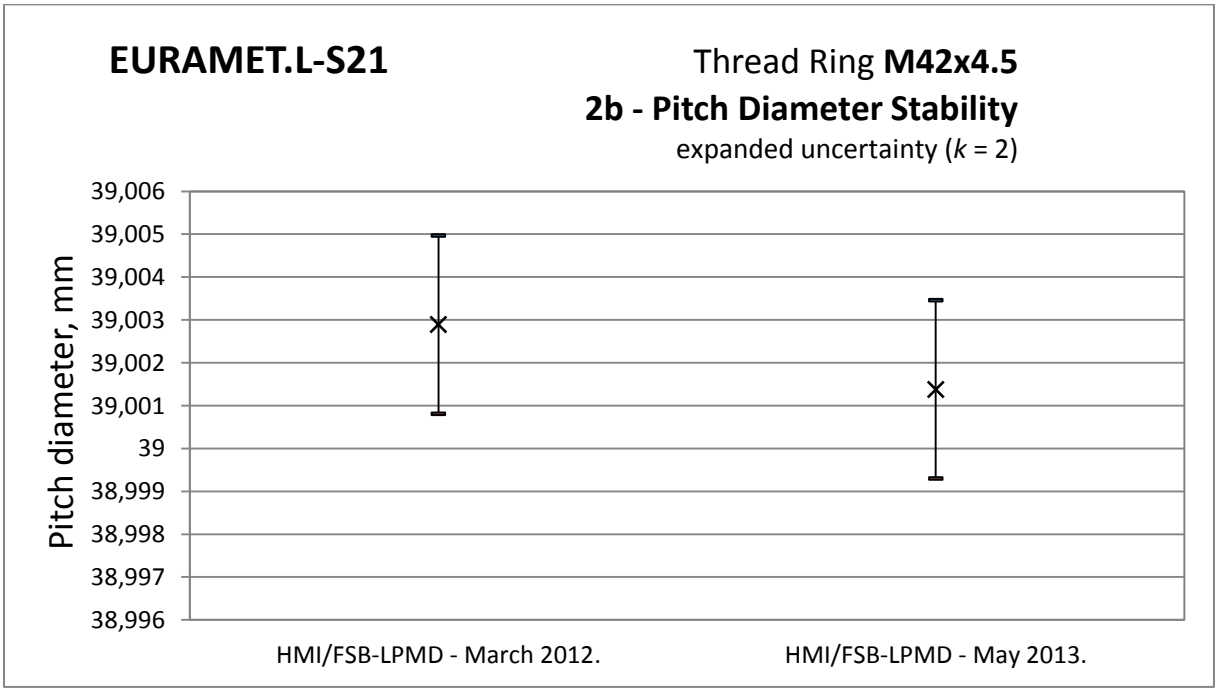


Figure 6-6 - Stability of the thread ring M42x4.5

7 ANALYSIS OF RESULTS

The weighed mean is used as the reference value in the comparison.

For each laboratory (*i*) the normalized weight, w_i was calculated by the following expression:

$$w_i = C \cdot \frac{1}{u^2(x_i)} \quad (1)$$

where $u(x_i)$ is the standard uncertainty given by the laboratory "*i*" and *C* is the normalizing factor calculated by the expression:

$$C = \frac{1}{\sum_{i=1}^{n} \frac{1}{u^2(x_i)}} \quad (2)$$

where *n* is number of laboratories. The weighted mean (reference value) is:

$$\bar{x}_w = \sum_{i=1}^{n} w_i \cdot x_i \quad (3)$$

The uncertainty of the deviation of weighed mean is:

$$u(x_i - \bar{x}_w) = \sqrt{u^2(x_i) - {u_{int}}^2(\bar{x}_w)} \quad (4)$$

where u_{int} is internal standard deviation based on the estimated uncertainties as reported by the participants:

$$u_{int}(\bar{x}_w) = \sqrt{C} \quad (5)$$

The statistical consistency of the results with uncertainties given by the participants is checked by the normalized deviation (*En* value) calculated for each laboratory:

$$E_n = \frac{x_i - \bar{x}_w}{2 \cdot \sqrt{u^2(x_i) - {u_{int}}^2(\bar{x}_w)}} \quad (6)$$

where $x_i - \bar{x}_w$ is the deviation from the weighted mean for the result of a laboratory.

Reference values for the angle measurements are calculated by the means of arithmetic mean:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \quad (7)$$

Where n is number of the laboratories/results taken in the calculation.

The statistical consistency of the results of angle measurements was checked by the normalized deviation (*En* value $k = 2$) calculated for each laboratory using following:

$$E_n = \frac{x_i - \bar{x}}{2 \cdot \sqrt{\left(1 - \frac{2}{n}\right) \cdot u^2(x_i) + u^2(\bar{x})}} \qquad (8)$$

where $u(\bar{x})$ is uncertainty of arithmetic mean calculated by:

$$u(\bar{x}) = \frac{1}{n} \sqrt{\sum_{i=1}^{n} u^2(x_i)} \qquad (9)$$

Absolute values of E_n are expected to be less than 1 for a factor of k = 2.

The statistical consistency of the comparison is analysed by the Birge ratio test. Birge ratio compares the observed spread of the results with the spread expected from the individual reported uncertainties.

The Birge ratio is:

$$R_B = \frac{u_{ext}(\bar{x}_w)}{u_{int}(\bar{x}_w)} \qquad (10)$$

Where $u_{ext}(\bar{x}_w)$ is external standard deviation and can be calculated by the following formula:

$$u_{ext}(\bar{x}_w) = \sqrt{\frac{1}{n-1} \cdot \frac{\sum_{i=1}^{n} \frac{(x_i - \bar{x}_w)^2}{u^2(x_i)}}{\sum_{i=1}^{n} \frac{1}{u^2(x_i)}}} \qquad (11)$$

The Birge ratio has an expectation value of R_B = 1, when considering standard uncertainties. For a coverage factor of k = 2, the expectation value is increased and data in a comparison are consistent when:

$$R_B < \sqrt{1 + \sqrt{\frac{8}{n-1}}} \qquad (12)$$

If the results are inconsistent, the largest consistent subset is determined by elimination, starting with excluding the result having the largest E_n value that makes the largest contribution to overall chi-squared value. The iteration runs until $R_B < R_{Bcrit}$.

When result x_i is excluded from the calculation of the reference value, its E_n value is calculated by:

$$E_n = \frac{x_i - \bar{x}_w}{2 \cdot \sqrt{u^2(x_i) + {u_{int}}^2(\bar{x}_w)}} \qquad (13)$$

Or, in the case of arithmetic mean, by:

$$E_n = \frac{x_i - \bar{x}}{2 \cdot \sqrt{u^2(x_i) + u^2(\bar{x})}} \qquad (14)$$

8 RESULTS AS REPORTED BY THE PARTICIPANTS AND ANALYSIS OF RESULTS

8.1 Correction to the original results

After all participants have reported their results, Pilot noticed that results reported by MIRS/UM-FS/LTM and INRIM appeared to be anomalous. MIRS/UM-FS/LTM and INRIM were invited to check their results. Both laboratories answered that they made an error in calculation of simple pitch diameter and pitch diameter. MIRS/UM-FS/LTM made an error in calculation of correction for deformation of the probing element for thread plugs calibration. INRIM has recalculated results of simple pitch and pitch diameter for thread rings M18x2.5, M30x1.5; thread plug M6x1; and simple pitch diameter of thread plug M36x1.5 Pilot has accepted the corrected measurement results of both laboratories.

As INRIM reported two sets of results (see note on page 5), comparison **reference value was calculated only with the first set (INRIM I) of INRIM results.** Second set of INRIM results (INRIM II) was included in tables and graphs in order to show differences between both sets INRIM results and the SCRV (Supplementary Comparison Reference Value).

Since INRIM's re-measurement took place after EURAMET TC-L meeting where measurement results of thread plug M12x1.75 and thread ring M18x2.5 have been partially presented, the results of INRIM II shown in charts (chapter 9) are marked with a green dot.

After first version of Draft A was sent to all the participants, additional changes took place in the second version of Draft A:

UME has reported that a clerical error was made in the reported uncertainties of the pitch measurement; reported uncertainty of pitch measurement of 1 µm was reported for coverage factor k = 2 instead of k = 1. Therefore, standard uncertainty of 1 µm is changed to 0,5 µm.

BEV results of pitch diameter (2a) for thread rings are excluded from this comparison since BEV didn't measure the Pitch. BEV used the nominal value for Pitch and has set the pitch diameter value to be equal to the simple pitch diameter, which is not in accordance with EURAMET cg-10/v.2.1 calibration guide (chapter 4.2.3): "measurement of diameter and pitch (2a)". The document states that pitch diameter is calculated from the measured diameter and from the **measured pitch** with assumed nominal values only for the thread angle.

Uncertainty for pitch diameter should include the uncertainty of the thread pitch measurement.

Since **INRIM** results for the thread angle completely dominated the reference value, INRIM was invited to check their measurement uncertainty for the flank angle. INRIM has reported new uncertainties for the both first and second run of measurement with the value of 0,3 mrad for thread ring and thread plugs. Consequently, this change in the uncertainty of the thread angle expanded the uncertainty of the simple pitch diameter - 1b of M6x1 thread plug from 0,8 µm to the 0,9 µm.

INRIM has also reported that a numerical error occurred in calculating the simple pitch diameters and pitch diameters of the thread ring gauge M30x1.5 and the simple pitch diameter (1b) of the thread plug gauges M6x1 and M12x1.75, all these given in their second-run report. The reported corrections have been checked by the unchanged data of m, d_0, F, α, P and corrections of results are accepted only for the thread M30x1.5 with recalculated values of:

D_2 – 2a: 28,9840 mm;

$D_{2Simple}$ – 1a: 28,9840 mm;

D_2 – 2b: 28,9839 mm;

$D_{2Simple}$ – 1b: 28,9839 mm.

MIKES has reported that the results for the diameter of thread rings M42 and M18 are anomalous and that problem was detected by the difference of the reported results and results on the automatic report printed out by QM-Thread software.

Normally MIKES uses QM-Thread software for customer calibrations and gives to customers only 1a simple pitch diameter values. The measurement is carried out according to advice of the software so that operator measures ΔL as average of two diameters: ΔL=(ΔL_{12} + ΔL_{23})/2. See figure 2 from EURAMET cg-10

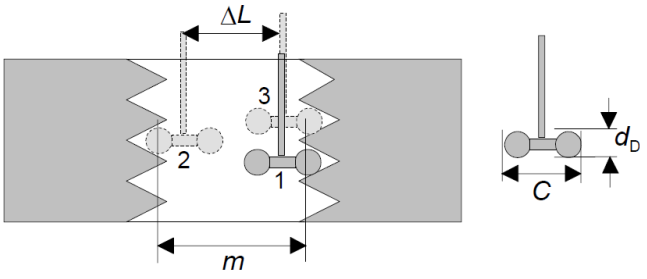


Fig. 2 Calibration of an internal thread using a double-ended spherical stylus.

In case of S21 measurements MIKES operator was using SIP machine with QM-Thread software, but since several other parameters were asked he recorded ΔL values by hand. The mistake that happened was that he didn't take the average of ΔL_{12} and ΔL_{23} as ΔL but

just one of these. This value was then used in later calculations for *m* and D_2. So in case of angular position error, Abbe error was not eliminated.

The original prints of QM-Thread software were available and they gave *m* values the software calculated from recorded ΔL and given *C* and d_D values. Using these prints Mikes recalculated results based on original measurement data without this error:

Corrected results for diameter

Thread	*dD* /mm	C /mm	*m* /mm	ΔL /mm	2B /mm	2A /mm	1B /mm	1A /mm
M42	2,48178	15,39095	**37,93280**	25,0236	39,0017	39,0018	39,0017	39,0018
M30	0,87834	5,51828	**28,52710**	23,8872	28,9848	28,9847	28,9850	28,9849
M18	1,34678	7,30053	**15,78980**	9,8361	16,3209	16,3208	16,3208	16,3208

m from QM-Thread report

Previous results for diameter

Thread	*dD* /mm	C /mm	*m* /mm	ΔL /mm	2B /mm	2A /mm	1B /mm	1A /mm
M42	2,48178	15,39095	37,93163	**25,0225**	39,0005	39,0006	39,0005	39,0006
M30	0,87834	5,51828	28,52694	**23,8870**	28,9847	28,9846	28,9848	28,9848
M18	1,34678	7,30053	15,78891	**9,8352**	16,3200	16,3199	16,3199	16,3199

ΔL from hand written table

Since this mistake is related with measurement procedure and effect the results of pitch diameter for all thread rings, results of Mikes for all thread rings (M30, M42 and M18) are not used in the calculation of reference value. Corrected values are included at all charts and tables in chapter 9, and the difference between original values and corrected values is shown. Corrected results are marked red.

Overview of measurement results as they were reported by the participating laboratories are given in chapter 8.1 and chapter 8.2.

8.2 Results of Thread Plugs

8.2.1 Measurement results reported by participants

Table 8-1 Reported measurement results of thread plug M36 x 1.5

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Plug M36 x 1.5	*1a* - $d_{2\,Simple}$, mm	35,04880	35,0428	35,0495	35,0474	35,0487	35,0505	35,05093		35,0502	35,0490	35,0489
	1b - $d_{2\,Simple}$, mm	35,04859			35,0473	35,0487	35,0505		35,0475	35,0500		35,0495
	2a - d_2, mm	35,04929	35,0430	35,0497	35,0474	35,0488	35,0505	35,05137		35,0501		
	2b - d_2 , mm	35,04908			35,0473	35,0488	35,0505			35,0499		
	P, mm	1,50057	1,5002	1,5002	1,5000	1,50015	1,5002	1,50045		1,5001		
	α, °	59,73			59,80	59,70	59,43		59,67	59,79		59,67
	β,°					29,84				29,84		
	γ, °					29,86				29,95		

Table 8-2 Reported measurement uncertainties of thread plug M36 x 1.5 (*k = 1*)

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Plug M36 x 1.5	*1a* - $d_{2\,Simple}$, µm	1,15	1,5	2,3	1,75	0,55	1,0	0,68		1,00	0,3	1,1
	1b - $d_{2\,Simple}$, µm	1,14			1,75	0,55	1,0		1,3	1,00		1,0
	2a - d_2, µm	1,37	1,5	3,4	1,75	0,60	1,0	0,90		1,00		
	2b - d_2 , µm	1,36			1,25	0,60	1,0			1,00		
	P, µm	0,86	0,4	1,0	1	0,26	0,80	0,67		0,5		
	α, °	0,10			0,07	0,19	0,07		0,02	0,10		0,02
	β,°					0,19				0,10		
	γ, °					0,19				0,10		

Table 8-3 Reported measurement results of thread plug M12 x 1.75

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Plug M12 x 1.75	*1a* - $d_{2\,Simple}$, mm	10,88066	10,8764	10,8795	10,8792	10,8796	10,8775	10,88051		10,8803	10,8796	10,8802
	1b - $d_{2\,Simple}$, mm	10,88065			10,8792	10,8796	10,8775		10,8784	10,8806		10,8795
	2a - d_2, mm	10,88056	10,8765	10,8796	10,8800	10,8797	10,8774	10,88051		10,8806		10,8807
	2b - d_2 , mm	10,88055			10,8800	10,8797	10,8774		10,8789	10,8808		10,8799
	P, mm	1,74989	1,7501	1,7501	1,7509	1,7501	1,7499	1,74995	1,7506	1,7497		1,7506
	α, ˚	60,00			60,00	60,10	60,05		60,12	60,09		60,12
	β,˚					30,04				30,02		
	γ, ˚					30,06				30,06		

Table 8-4 Reported measurement uncertainties of thread plug M12 x 1.75 (*k = 1*)

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Plug M12 x 1.75	*1a* - $d_{2\,Simple}$, µm	1,26	1,5	2,4	1,70	0,54	1,0	0,66		1,11	0,3	1,4
	1b - $d_{2\,Simple}$, µm	1,16			1,60	0,54	1,0		0,4	1,00		0,5
	2a - d_2, µm	1,46	1,5	3,4	1,40	0,81	1,0	0,71		1,03		1,5
	2b - d_2 , µm	1,38			1,30	0,81	0,83		0,7	1,00		0,7
	P, µm	0,86	0,4	1,0	1	0,7	0,4	0,31	0,6	0,5		0,6
	α, ˚	0,10			0,07	0,05	0,15		0,02	0,10		0,02
	β,˚					0,05				0,10		
	γ, ˚					0,05				0,10		

Table 8-5 Reported measurement results of thread plug M6 x 1

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Plug M6 x 1	*1a* - $d_{2\,Simple}$, mm	5,36682	5,3632	5,3659	5,3655	5,3651	5,3662	5,36625		5,3643	5,3660	5,3674
	1b - $d_{2\,Simple}$, mm	5,36812			5,3653	5,3651	5,3661		5,3536	5,3646		5,3652
	2a - d_2, mm	5,36643	5,3634	5,3666	5,3654	5,3647	5,3666	5,36629		5,3647		5,3683
	2b - d_2 , mm	5,36774			5,3652	5,3647	5,3666		5,3544	5,3650		5,3657
	P, mm	0,99955	1,0002	1,0008	0,9999	0,99956	1,0006	1,00005	1,0010	0,9995		1,0010
	α, ˚	61,15			59,87	60,97	60,74		61,13	60,23		61,13
	β,˚					30,33				30,03		
	γ, ˚					30,64				30,20		

Table 8-6 Reported measurement uncertainties of thread plug M6 x 1 (*k = 1*)

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Plug M6 x 1	*1a* - $d_{2\,Simple}$, µm	1,18	1,5	2,5	1,65	0,55	1,0	0,68		1,01	0,3	1,1
	1b - $d_{2\,Simple}$, µm	1,12			1,55	0,55	1,0		0,80	1,00		0,9
	2a - d_2, µm	1,40	1,5	3,4	1,40	1,10	1,0	0,79		1,00		1,2
	2b - d_2 , µm	1,33			1,25	1,10	1,0		1,00	1,00		1,0
	P, µm	0,86	0,4	1,0	1	1,10	0,8	0,47	0,7	0,5		0,7
	α, ˚	0,10			0,07	0,15	0,10		0,02	0,10		0,02
	β,˚					0,15				0,10		
	γ, ˚					0,15				0,10		

8.2.2 Statistical parameters and SCRV

Table 8-7 Statistical parameters of measurements results (Thread plug M36 x 1.5)

Standards	Measurand	C	$\overline{x}_w$	$\overline{x}$	$u_{int}(\overline{x}_w)$	$u(\overline{x})$	$u_{ext}(\overline{x}_w)$	R_B/R_{Bcrit}	R_B	R_{Bcrit}
Thread Plug M36 x 1.5	*1a* - $d_{2\,Simple}$, mm	5,04E-08	**35,04927**	35,0494	2,24E-04	0,0004	0,00029	0,893	1,28396	1,43842
	1b - $d_{2\,Simple}$, mm	1,43E-07	**35,04896**	35,0488	3,78E-04	0,0005	0,00041	0,724	1,09023	1,50496
	2a - d_2, mm	1,44E-07	**35,04967**	35,0496	3,79E-04	0,0006	0,00045	0,801	1,17642	1,46789
	2b - d_2 , mm	1,68E-07	**35,04913**	35,0491	4,10E-04	0,0005	0,00045	0,714	1,10870	1,55377
	P, mm	3,11E-08	**1,50019**	1,5002	1,76E-04	0,00026	0,00004	0,174	0,25038	1,43842
	α, °	2,61E-04	59,68	**59,74**	1,61E-02	0,0494	0,02	0,739	1,14894	1,55377
	β,°	7,86E-03	29,84	**29,84**	8,87E-02	0,1074	0,00	0,001	0,00167	1,95664
	γ, °	7,86E-03	29,93	**29,91**	8,87E-02	0,1074	0,04	0,220	0,43063	1,95664

note: *SCRV* is bolded

Table 8-8 Statistical parameters of measurements results (Thread plug M12 x 1.75)

Standards	Measurand	C	$\overline{x}_w$	$\overline{x}$	$u_{int}(\overline{x}_w)$	$u(\overline{x})$	$u_{ext}(\overline{x}_w)$	R_B/R_{Bcrit}	R_B	R_{Bcrit}
Thread Plug M12 x 1.75	*1a* - $d_{2\,Simple}$, mm	4,94E-08	**10,87958**	10,8793	2,22E-04	0,0004	0,00027	0,867	1,22569	1,41421
	1b - $d_{2\,Simple}$, mm	7,80E-08	**10,87898**	10,8793	2,79E-04	0,0004	0,00040	0,955	1,43715	1,50496
	2a - d_2, mm	1,44E-07	**10,87960**	10,8794	3,79E-04	0,0006	0,00050	0,919	1,32156	1,43842
	2b - d_2 , mm	1,40E-07	**10,87924**	10,8796	3,74E-04	0,0004	0,00051	0,899	1,35272	1,50496
	P, mm	2,85E-08	**1,75003**	1,7501	1,69E-04	0,00023	0,00009	0,383	0,54096	1,41421
	α, °	2,35E-04	60,11	**60,06**	1,53E-02	0,0377	0,01	0,638	0,95970	1,50496
	β,°	2,00E-03	30,04	**30,03**	4,47E-02	0,0560	0,01	0,075	0,14672	1,95664
	γ, °	2,00E-03	30,06	**30,06**	4,47E-02	0,0560	0,00	0,014	0,02763	1,95664

note: *SCRV* is bolded

Table 8-9 Statistical parameters of measurements results (Thread plug M6 x 1)

Standards	Measurand	*C*	$\bar{x}_w$	$\bar{x}$	$u_{int}(\bar{x}_w)$	$u(\bar{x})$	$u_{ext}(\bar{x}_w)$	R_B/R_{Bcrit}	R_B	R_{Bcrit}
Thread Plug M6 x 1	*1a* - $d_{2\,Simple}$, mm	4,94E-08	**5,36577**	5,3655	2,22E-04	0,0004	0,00023	0,734	1,03860	1,41421
	1b - $d_{2\,Simple}$, mm	1,53E-07	**5,36556**	5,3658	3,92E-04	0,0005	0,00052	0,861	1,33841	1,55377
	2a - d_2, mm	1,67E-07	**5,36558**	5,3655	4,09E-04	0,0006	0,00037	0,636	0,91416	1,43842
	2b - d_2 , mm	2,48E-07	**5,36575**	5,3658	4,98E-04	0,0005	0,00054	0,692	1,07570	1,55377
	P, mm	4,43E-08	**1,00010**	1,0001	2,11E-04	0,00027	0,00016	0,544	0,76952	1,41421
	α, °	2,83E-04	61,13	**61,09**	1,68E-02	0,0604	0,01	0,452	0,78274	1,73205
	β,°	6,95E-03	30,12	**30,18**	8,34E-02	0,0902	0,14	0,855	1,67301	1,95664
	γ, °	6,95E-03	30,34	**30,42**	8,34E-02	0,0902	0,20	1,240	2,42579	1,95664

note: *SCRV* is bolded

For thread angle *α* and flank angles *β* and *γ, SCRV* is calculated as arithmetic mean

8.2.3 Overview of measurement results with respect to SCRV

En $(x_i-x_{ref}) \pm U(x_i-x_{ref})$	*En* value Difference of reported result and referent value ± uncertainty of the difference with *k = 2*
En $(x_i-x_{ref}) \pm U(x_i-x_{ref})$	Inconsistent result, |*En*| value > 1 Excluded from calculation of SCRV
En $(x_i-x_{ref}) \pm U(x_i-x_{ref})$	Excluded from calculation of SCRV
En $(x_i-x_{ref}) \pm U(x_i-x_{ref})$	Inconsistent result, |*En*| value > 1

Table 8-10 Thread plug M36 x 1.5 - measurement results with respect to SRCV

Measurand			HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Plug M36 x 1.5	*1a - $d_{2\,Simple}$, µm*	*En*	-0,21	-2,13	0,05	-0,54	-0,57	0,63	1,30	-	0,48	-0,67	-0,16
		Diff	-0,47 ± 2,26	-6,47 ± 3,03	0,23 ± 4,58	-1,87 ± 3,47	-0,57 ± 1	1,23 ± 1,95	1,66 ± 1,28	-	0,93 ± 1,95	-0,27 ± 0,4	-0,37 ± 2,25
	1b - $d_{2\,Simple}$, µm	*En*	-0,17	-	-	-0,49	-0,33	0,83	-	-0,59	0,56	-	0,25
		Diff	-0,37 ± 2,15	-	-	-1,66 ± 3,42	-0,26 ± 0,8	1,54 ± 1,85	-	-1,46 ± 2,49	1,04 ± 1,85	-	0,54 ± 2,14
	2a - d_2, µm	*En*	-0,14	-2,16	0,00	-0,66	-0,94	0,45	1,04	-	0,23	-	-
		Diff	-0,38 ± 2,63	-6,67 ± 3,09	0,03 ± 6,76	-2,27 ± 3,42	-0,87 ± 0,93	0,83 ± 1,85	1,7 ± 1,63	-	0,43 ± 1,85	-	-
	2b - d_2 , µm	*En*	-0,02	-	-	-0,78	-0,38	0,75	-	-	0,42	-	-
		Diff	-0,05 ± 2,59	-	-	-1,83 ± 2,36	-0,33 ± 0,88	1,37 ± 1,82	-	-	0,77 ± 1,82	-	-
	P, µm	*En*	0,23	0,01	0,00	-0,10	-0,11	0,01	0,20	-	-0,10	-	-
		Diff	0,38 ± 1,68	0,01 ± 0,72	0,01 ± 1,97	-0,19 ± 1,97	-0,04 ± 0,38	0,01 ± 1,56	0,26 ± 1,29	-	-0,09 ± 0,94	-	-
	α, °	*En*	-0,04	-	-	0,44	-0,12	-1,74	-	-0,69	0,29	-	-0,67
		Diff	-0,01 ± 0,18	-	-	0,06 ± 0,14	-0,04 ± 0,31	-0,31 ± 0,18	-	-0,07 ± 0,1	0,05 ± 0,18	-	-0,07 ± 0,1
	β,°	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0 ± 0,21	-	-	-	0 ± 0,21	-	-
	γ, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	-0,05 ± 0,21	-	-	-	0,05 ± 0,21	-	-

Table 8-11 Thread plug M12 x 1.75 - measurement results with respect to SCRV

Measurand			HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Plug M12 x 1.75	*1a - $d_{2\,Simple}$, µm*	*En*	0,43	-1,07	-0,02	-0,11	0,02	-1,07	0,75	-	0,33	0,04	0,22
		Diff	1,08 ± 2,48	-3,18 ± 2,97	-0,08 ± 4,78	-0,38 ± 3,37	0,02 ± 0,98	-2,08 ± 1,95	0,93 ± 1,24	-	0,72 ± 2,18	0,02 ± 0,4	0,62 ± 2,84
	1b - $d_{2\,Simple}$, µm	*En*	0,74	-	-	0,07	0,67	-0,77	-	-1,01	0,85	-	0,46
		Diff	1,67 ± 2,25	-	-	0,22 ± 3,15	0,62 ± 0,92	-1,48 ± 1,92	-	-0,58 ± 0,57	1,62 ± 1,92	-	0,52 ± 1,15
	2a - d_2, µm	*En*	0,34	-1,07	-	0,15	0,07	-1,19	0,76	-	0,52	-	0,36
		Diff	0,96 ± 2,82	-3,1 ± 2,9	-	0,4 ± 2,7	0,1 ± 1,43	-2,2 ± 1,85	0,91 ± 1,2	-	1 ± 1,92	-	1,1 ± 3,09
	2b - d_2 , µm	*En*	0,49	-	-	0,30	0,32	-1,25	-	-0,29	0,84	-	0,41
		Diff	1,31 ± 2,66	-	-	0,76 ± 2,49	0,46 ± 1,44	-1,84 ± 1,48	-	-0,34 ± 1,18	1,56 ± 1,85	-	0,66 ± 1,59
	P, µm	*En*	-0,09	0,10	0,04	0,44	0,05	-0,18	-0,15	0,50	-0,35	-	0,46
		Diff	-0,14 ± 1,69	0,07 ± 0,73	0,07 ± 1,97	0,87 ± 1,97	0,07 ± 1,36	-0,13 ± 0,73	-0,08 ± 0,52	0,57 ± 1,15	-0,33 ± 0,94	-	0,57 ± 1,25
	α, °	*En*	-0,34	-	-	-0,44	0,37	-0,05	-	0,77	0,16	-	0,75
		Diff	-0,06 ± 0,18	-	-	-0,06 ± 0,13	0,04 ± 0,11	-0,01 ± 0,26	-	0,06 ± 0,08	0,03 ± 0,18	-	0,06 ± 0,08
	β, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0,01 ± 0,11	-	-	-	-0,01 ± 0,11	-	-
	γ, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0 ± 0,11	-	-	-	0 ± 0,11	-	-

Table 8-12 Thread plug M6 x 1 - measurement results with respect to SCRV

Measurand			HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Plug M6 x 1	*1a - $d_{2\,Simple}$, µm*	*En*	0,46	-0,87	0,03	-0,08	-0,66	0,22	0,38	-	-0,74	0,58	0,73
		Diff	1,05 ± 2,32	-2,57 ± 2,97	0,13 ± 4,98	-0,27 ± 3,27	-0,67 ± 1,01	0,43 ± 1,95	0,48 ± 1,29	-	-1,47 ± 1,97	0,23 ± 0,4	1,63 ± 2,24
	1b - $d_{2\,Simple}$, µm	*En*	1,22	-	-	-0,09	-0,59	0,29	-	-6,71	-0,52	-	-0,18
		Diff	2,56 ± 2,1	-	-	-0,26 ± 3	-0,46 ± 0,77	0,54 ± 1,84	-	-11,96 ± 1,78	-0,96 ± 1,84	-	-0,36 ± 1,96
	2a - d_2, µm	*En*	0,32	-0,76	0,15	-0,07	-0,43	0,56	0,52	-	-0,48	-	1,07
		Diff	0,85 ± 2,68	-2,18 ± 2,89	1,02 ± 6,75	-0,18 ± 2,68	-0,88 ± 2,04	1,02 ± 1,83	0,71 ± 1,35	-	-0,88 ± 1,83	-	2,72 ± 2,54
	2b - d_2, µm	*En*	0,81	-	-	-0,24	-0,54	0,49	-	-5,08	-0,43	-	-0,02
		Diff	1,99 ± 2,47	-	-	-0,55 ± 2,29	-1,05 ± 1,96	0,85 ± 1,73	-	-11,35 ± 2,23	-0,75 ± 1,73	-	-0,05 ± 2,23
	P, µm	*En*	-0,33	0,15	0,36	-0,10	-0,25	0,33	-0,06	0,68	-0,66	-	0,62
		Diff	-0,55 ± 1,67	0,1 ± 0,68	0,7 ± 1,96	-0,2 ± 1,96	-0,54 ± 2,16	0,5 ± 1,54	-0,05 ± 0,84	0,9 ± 1,34	-0,6 ± 0,91	-	0,9 ± 1,46
	α, °	*En*	0,40	-	-	-6,79	-0,55	-1,49	-	0,40	-3,65	-	0,39
		Diff	0,07 ± 0,17	-	-	-1,22 ± 0,18	-0,12 ± 0,21	-0,34 ± 0,23	-	0,05 ± 0,12	-0,86 ± 0,23	-	0,05 ± 0,13
	β, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0,15 ± 0,18	-	-	-	-0,15 ± 0,18	-	-
	γ, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0,22 ± 0,18	-	-	-	-0,22 ± 0,18	-	-

8.3 Results of Thread Rings

8.3.1 Measurement results reported by participants

Table 8-13 Reported measurement results of thread ring M18 x 2.5

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Ring M18x2.5	*1a* - $D_{2\,Simple}$, mm	16,32159	16,3217	16,3229	16,3192	16,3226	16,3199	16,32183		16,3211	16,3243	16,3220
	1b - $D_{2\,Simple}$, mm	16,32204				16,3231	16,3199		16,3184	16,3211		16,3218
	2a - D_2, mm	16,32189	16,3209		16,3201	16,3229	16,3199	16,32188		16,3208		16,3226
	2b - D_2 , mm	16,32234				16,3234	16,3200		16,3190	16,3208		16,3224
	P, mm	2,49965	2,4996		2,4990	2,49964	2,4999	2,49994	2,4993	2,4997		2,4993
	α, ˚	60,17				60,15	60,02		59,94	60,00		59,94
	β,˚					30,06				29,96		
	γ, ˚					30,09				30,04		

Table 8-14 Reported measurement uncertainties of thread ring M18 x 2.5 (*k = 1*)

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Ring M18x2.5	*1a* - $D_{2\,Simple}$, µm	1,03	1,47	1,8	1,70	0,80	1,0	0,85		1,10	0,8	0,9
	1b - $D_{2\,Simple}$, µm	0,96				0,66	1,0		0,7	1,10		0,5
	2a - D_2, µm	1,14	1,52		1,35	0,80	1,0	0,89		1,10		1,1
	2b - D_2 , µm	1,08				0,70	0,81		1,0	1,10		0,8
	P, µm	0,58	0,4		1	0,25	0,25	0,3	0,6	0,5		0,6
	α, ˚	0,14				0,06	0,03		0,02	0,10		0,02
	β,˚					0,06				0,10		
	γ, ˚					0,06				0,10		

Table 8-15 Reported measurement results of thread ring M30 x 1.5

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Ring M30x1.5	*1a* - $D_{2\,Simple}$, mm	28,98441	28,9866	28,9834	28,9856	28,9874	28,9848	28,98609		28,9861	28,9878	28,9840
	1b - $D_{2\,Simple}$, mm	28,98429				28,9868	28,9848		28,9741	28,9863		28,9839
	2a - D_2, mm	28,98467	28,9869		28,9861	28,9874	28,9846	28,98666		28,9858		28,9840
	2b - D_2 , mm	28,98455				28,9870	28,9847		28,9742	28,9860		28,9839
	P, mm	1,49970	1,5003		1,4995	1,49970	1,5002	1,49934	1,5000	1,4997		1,5000
	α, ˚	60,14				59,99	59,82		59,91	59,73		59,91
	β,˚					30,01				29,88		
	γ, ˚					29,98				29,85		

Table 8-16 Reported measurement uncertainties of thread ring M30 x 1.5 (*k = 1*)

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Ring M30x1.5	*1a* - $D_{2\,Simple}$, µm	0,90	1,47	2,4	1,80	0,80	1,0	0,77		1,10	0,7	1,1
	1b - $D_{2\,Simple}$, µm	0,89				0,80	1,0		1,1	1,10		1,1
	2a - D_2, µm	1,03	1,52		1,30	0,82	1,0	0,81		1,10		1,2
	2b - D_2 , µm	1,02				0,81	0,80		1,20	1,10		1,2
	P, mm	0,58	0,4		1	0,25	0,25	0,30	0,6	0,5		0,6
	α, ˚	0,14				0,08	0,05		0,02	0,10		0,02
	β,˚					0,08				0,10		
	γ, ˚					0,08				0,10		

Table 8-17 Reported measurement results of thread ring M42 x 4.5

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Ring M42x4.5	*1a* - $D_{2\,Simple}$, mm	39,00237	39,0025	39,0017	39,0037	39,0041	39,0006	39,00198		39,0018	39,0040	39,0040
	1b - $D_{2\,Simple}$, mm	39,00267				39,0041	39,0005		39,0024	39,0018		39,0038
	2a - D_2, mm	39,00259	39,0029		39,0028	39,0048	39,0006	39,00162		39,0018		39,0041
	2b - D_2 , mm	39,00289				39,0047	39,0005		39,0025	39,0018		39,0039
	P, mm	4,49974	4,5005		4,5010	4,49916	4,5000	4,50042	4,4999	4,5000		4,4999
	α, ˚	60,00				59,97	59,97		59,96	59,99		59,95
	β,˚					30,13				30,11		
	γ, ˚					29,84				29,89		

Table 8-18 Reported measurement uncertainties of thread ring M42 x 4.5 (*k = 1*)

Standards	Measurand	HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Ring M42x4.5	*1a* - $D_{2\,Simple}$, µm	0,91	1,47	2,1	1,95	0,70	1,0	0,94		1,10	0,8	0,9
	1b - $D_{2\,Simple}$, µm	0,91				0,70	1,0		0,7	1,10		0,5
	2a - D_2, µm	1,04	1,52		1,41	0,74	1,0	0,97		1,10		1,0
	2b - D_2 , µm	1,04				0,74	0,94		0,9	1,10		0,7
	P, µm	0,58	0,4		1	0,28	0,22	0,30	0,6	0,5		0,6
	α, ˚	0,14				0,08	0,07		0,02	0,10		0,02
	β,˚					0,08				0,10		
	γ, ˚					0,08				0,10		

8.3.2 Statistical parameters and SCRV

Table 8-19 Statistical parameters of measurements results (Thread ring M18 x 2.5)

Standards	Measurand	C	$\bar{x}_w$	$\bar{x}$	$u_{int}(\bar{x}_w)$	$u(\bar{x})$	$u_{ext}(\bar{x}_w)$	R_B/R_{Bcrit}	R_B	R_{Bcrit}
Thread Ring M18x2.5	*1a* - $D_{2\,Simple}$, mm	1,71E-07	**16,32178**	16,3216	4,14E-04	0,0005	0,00034	0,567	0,83302	1,46789
	1b - $D_{2\,Simple}$, mm	2,38E-07	**16,32243**	16,3221	4,88E-04	0,0005	0,00056	0,666	1,15270	1,73205
	2a - D_2, mm	1,85E-07	**16,32175**	16,3214	4,30E-04	0,0005	0,00042	0,641	0,96491	1,50496
	2b - D_2 , mm	2,68E-07	**16,32258**	16,3222	5,18E-04	0,0006	0,00074	0,821	1,42129	1,73205
	P, mm	1,66E-08	**2,49974**	2,4996	1,29E-04	0,00019	0,00007	0,394	0,56723	1,43842
	α, °	5,35E-04	60,04	**60,09**	2,31E-02	0,0460	0,03	0,783	1,26990	1,62265
	β,°	2,65E-03	30,03	**30,01**	5,15E-02	0,0584	0,04	0,430	0,84141	1,95664
	γ, °	2,65E-03	30,08	**30,07**	5,15E-02	0,0584	0,02	0,205	0,40187	1,95664

note: *SCRV* is bolded

Table 8-20 Statistical parameters of measurements results (Thread ring M30 x 1.5)

Standards	Measurand	C	$\bar{x}_w$	$\bar{x}$	$u_{int}(\bar{x}_w)$	$u(\bar{x})$	$u_{ext}(\bar{x}_w)$	R_B/R_{Bcrit}	R_B	R_{Bcrit}
Thread Ring M30x1.5	*1a* - $D_{2\,Simple}$, mm	1,21E-07	**28,98646**	28,9859	3,47E-04	0,0005	0,00046	0,927	1,33279	1,43842
	1b - $D_{2\,Simple}$, mm	2,74E-07	**28,98582**	28,9858	5,23E-04	0,0005	0,00080	0,880	1,52420	1,73205
	2a - D_2, mm	1,72E-07	**28,98636**	28,9863	4,15E-04	0,0005	0,00041	0,655	0,98622	1,50496
	2b - D_2 , mm	3,02E-07	**28,98604**	28,9859	5,50E-04	0,0006	0,00073	0,768	1,33039	1,73205
	P, mm	1,66E-08	**1,49984**	1,4998	1,29E-04	0,00019	0,00013	0,686	0,98640	1,43842
	α, °	2,53E-04	59,91	**59,97**	1,59E-02	0,0426	0,02	0,908	1,47285	1,62265
	β,°	3,90E-03	29,96	**29,94**	6,25E-02	0,0640	0,06	0,520	1,01709	1,95664
	γ, °	3,90E-03	29,93	**29,91**	6,25E-02	0,0640	0,07	0,533	1,04232	1,95664

note: *SCRV* is bolded

Table 8-21 Statistical parameters of measurements results (Thread ring M42 x 4.5)

Standards	Measurand	C	$\overline{x}_w$	$\overline{x}$	$u_{int}(\overline{x}_w)$	$u(\overline{x})$	$u_{ext}(\overline{x}_w)$	R_B/R_{Bcrit}	R_B	R_{Bcrit}
Thread Ring M42x4.5	*1a* - $D_{2\,Simple}$, mm	1,30E-07	**39,00307**	39,0028	3,60E-04	0,0005	0,00037	0,718	1,03276	1,43842
	1b - $D_{2\,Simple}$, mm	1,64E-07	**39,00294**	39,0027	4,04E-04	0,0004	0,00050	0,755	1,22519	1,62265
	2a - D_2, mm	1,79E-07	**39,00305**	39,0028	4,23E-04	0,0005	0,00058	0,906	1,36337	1,50496
	2b - D_2 , mm	2,08E-07	**39,00329**	39,0030	4,56E-04	0,0005	0,00067	0,899	1,45874	1,62265
	P, mm	1,63E-08	**4,49995**	4,5001	1,27E-04	0,00019	0,00018	0,969	1,39425	1,43842
	α, °	2,56E-04	59,96	**59,98**	1,60E-02	0,0405	0,00	0,148	0,23053	1,55377
	β,°	3,91E-03	30,12	**30,12**	6,25E-02	0,0641	0,01	0,095	0,18658	1,95664
	γ, °	3,91E-03	29,86	**29,86**	6,25E-02	0,0641	0,02	0,188	0,36795	1,95664

note: *SCRV* is bolded

For thread angle *α* and flank angles *β* and *γ, SCRV* is calculated as arithmetic mean

8.3.3 Overview of measurement results with respect to SCRV

En	*En* value
$(x_i-x_{ref}) \pm U(x_i-x_{ref})$	Difference of reported result and referent value ± uncertainty of the difference with $k = 2$

En	Inconsistent result, $\lvert En \rvert$ value > 1
$(x_i-x_{ref}) \pm U(x_i-x_{ref})$	Excluded from calculation of SCRV

En	Excluded from calculation of SCRV
$(x_i-x_{ref}) \pm U(x_i-x_{ref})$	

En	Inconsistent result, $\lvert En \rvert$ value > 1
$(x_i-x_{ref}) \pm U(x_i-x_{ref})$	

Table 8-22 Thread ring M18 x 2.5 - measurement results with respect to SCRV

Measurand			HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Ring M18 x 2.5	*1a - $D_{2\ Simple}$, µm*	*En*	-0,10	-0,03	0,32	-0,78	0,60	-0,87	0,03	-	-0,34	1,40	0,11
		Diff	-0,19 ± 1,89	-0,08 ± 2,82	1,12 ± 3,5	-2,58 ± 3,3	0,82 ± 1,37	-1,88 ± 2,16	0,05 ± 1,48	-	-0,68 ± 2,04	2,52 ± 1,8	0,22 ± 1,98
	1b - $D_{2\ Simple}$, µm	*En*	-0,24	-	-	-	0,75	-1,14	-	-2,36	-0,68	-	-0,45
		Diff	-0,39 ± 1,65	-	-	-	0,67 ± 0,89	-2,53 ± 2,23	-	-4,03 ± 1,71	-1,33 ± 1,97	-	-0,63 ± 1,4
	2a - D_2, µm	*En*	0,07	-0,29	-	-0,65	0,85	-0,85	0,08	-	-0,47	-	0,36
		Diff	0,14 ± 2,11	-0,85 ± 2,92	-	-1,65 ± 2,56	1,15 ± 1,35	-1,85 ± 2,18	0,13 ± 1,56	-	-0,95 ± 2,02	-	0,85 ± 2,36
	2b - D_2 , µm	*En*	-0,13	-	-	-	0,87	-1,34	-	-1,59	-0,92	-	-0,09
		Diff	-0,24 ± 1,9	-	-	-	0,82 ± 0,94	-2,58 ± 1,92	-	-3,58 ± 2,25	-1,78 ± 1,94	-	-0,18 ± 1,91
	P, µm	*En*	-0,08	-0,18	-	-0,37	-0,23	0,38	0,37	-0,37	-0,04	-	-0,36
		Diff	-0,09 ± 1,13	-0,14 ± 0,76	-	-0,74 ± 1,98	-0,1 ± 0,43	0,16 ± 0,43	0,2 ± 0,54	-0,44 ± 1,17	-0,04 ± 0,97	-	-0,44 ± 1,23
	α, °	*En*	0,37	-	-	-	0,52	-0,65	-	-1,51	-0,48	-	-1,51
		Diff	0,08 ± 0,22	-	-	-	0,06 ± 0,13	-0,06 ± 0,1	-	-0,15 ± 0,1	-0,08 ± 0,17	-	-0,15 ± 0,1
	β,°	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0,05 ± 0,12	-	-	-	-0,05 ± 0,12	-	-
	γ, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0,02 ± 0,12	-	-	-	-0,02 ± 0,12	-	-

Table 8-23 Thread ring M30 x 1.5 - measurement results with respect to SCRV

Measurand			HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Ring M30 x 1.5	*1a - $D_{2\,Simple}$, µm*	*En*	-1,24	0,05	-0,65	-0,24	0,65	-0,79	-0,27	-	-0,17	1,10	-1,07
		Diff	-2,05 ± 1,66	0,14 ± 2,86	-3,06 ± 4,75	-0,86 ± 3,53	0,94 ± 1,44	-1,66 ± 2,12	-0,37 ± 1,37	-	-0,36 ± 2,09	1,34 ± 1,22	-2,46 ± 2,31
	1b - $D_{2\,Simple}$, µm	*En*	-1,06	-	-	-	0,81	-0,45	-	-4,81	0,25	-	-0,79
		Diff	-1,53 ± 1,44	-	-	-	0,98 ± 1,21	-1,02 ± 2,26	-	-11,72 ± 2,44	0,48 ± 1,94	-	-1,92 ± 2,44
	2a - D_2, µm	*En*	-0,90	0,18	-	-0,11	0,73	-0,82	0,21	-	-0,28	-	-0,93
		Diff	-1,69 ± 1,89	0,54 ± 2,92	-	-0,26 ± 2,46	1,04 ± 1,41	-1,76 ± 2,17	0,3 ± 1,39	-	-0,56 ± 2,04	-	-2,36 ± 2,54
	2b - D_2, µm	*En*	-0,87	-	-	-	0,81	-0,69	-	-4,49	-0,02	-	-0,81
		Diff	-1,49 ± 1,72	-	-	-	0,96 ± 1,19	-1,34 ± 1,94	-	-11,84 ± 2,64	-0,04 ± 1,91	-	-2,14 ± 2,64
	P, µm	*En*	-0,12	0,61	-	-0,17	-0,33	0,84	-0,92	0,14	-0,14	-	0,13
		Diff	-0,14 ± 1,13	0,46 ± 0,76	-	-0,34 ± 1,98	-0,14 ± 0,43	0,36 ± 0,43	-0,5 ± 0,54	0,16 ± 1,17	-0,14 ± 0,97	-	0,16 ± 1,23
	α, °	*En*	0,81	-	-	-	0,17	-1,27	-	-0,59	-1,11	-	-0,57
		Diff	0,17 ± 0,22	-	-	-	0,02 ± 0,14	-0,14 ± 0,11	-	-0,05 ± 0,09	-0,24 ± 0,22	-	-0,05 ± 0,09
	β, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0,07 ± 0,13	-	-	-	-0,07 ± 0,13	-	-
	γ, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0,07 ± 0,13	-	-	-	-0,07 ± 0,13	-	-

Table 8-24 Thread ring M42 x 4.5 - measurement results with respect to SCRV

	Measurand		HMI/FSB-LPMD	MIRS/UM-FS/LTM	BEV	MKEH	METAS	MIKES	Metrosert	INRIM I	TUBİTAK-UME	LNE	INRIM II
Thread Ring M42 x 4.5	*1a - $D_{2\ Simple}$, µm*	*En*	-0,42	-0,20	-0,33	0,16	0,86	-1,16	-0,63	-	-0,61	0,65	0,48
		Diff	-0,7 ± 1,67	-0,57 ± 2,85	-1,37 ± 4,14	0,63 ± 3,83	1,03 ± 1,2	-2,47 ± 2,13	-1,09 ± 1,74	-	-1,27 ± 2,08	0,93 ± 1,43	0,93 ± 1,94
	1b - $D_{2\ Simple}$, µm	*En*	-0,17	-	-	-	1,02	-1,13	-	-0,47	-0,56	-	0,67
		Diff	-0,27 ± 1,63	-	-	-	1,16 ± 1,14	-2,44 ± 2,16	-	-0,54 ± 1,14	-1,14 ± 2,05	-	0,86 ± 1,29
	2a - D_2, µm	*En*	-0,25	-0,05	-	-0,10	1,44	-1,13	-0,82	-	-0,62	-	0,48
		Diff	-0,46 ± 1,9	-0,15 ± 2,92	-	-0,25 ± 2,69	1,75 ± 1,21	-2,45 ± 2,17	-1,43 ± 1,75	-	-1,25 ± 2,03	-	1,05 ± 2,17
	2b - D_2 , µm	*En*	-0,21	-	-	-	1,21	-1,34	-	-0,51	-0,74	-	0,37
		Diff	-0,4 ± 1,87	-	-	-	1,41 ± 1,17	-2,79 ± 2,09	-	-0,79 ± 1,55	-1,49 ± 2	-	0,61 ± 1,67
	P, µm	*En*	-0,19	0,72	-	0,53	-1,59	0,14	0,86	-0,04	0,05	-	-0,04
		Diff	-0,21 ± 1,13	0,55 ± 0,76	-	1,05 ± 1,98	-0,79 ± 0,5	0,05 ± 0,36	0,47 ± 0,54	-0,05 ± 1,17	0,05 ± 0,97	-	-0,05 ± 1,23
	α, °	*En*	0,09	-	-	-	-0,06	-0,06	-	-0,22	0,08	-	-0,35
		Diff	0,02 ± 0,23	-	-	-	-0,01 ± 0,15	-0,01 ± 0,13	-	-0,02 ± 0,09	0,01 ± 0,18	-	-0,03 ± 0,09
	β, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	0,01 ± 0,13	-	-	-	-0,01 ± 0,13	-	-
	γ, °	*En*	-	-	-	-	-	-	-	-	-	-	-
		Diff	-	-	-	-	-0,02 ± 0,13	-	-	-	0,02 ± 0,13	-	-

9 GRAPHICAL REPRESENTATION

9.1 Thread plug M36x1.5 - FSB 03

Table 9-1 - Measurement results of simple pitch diameter (1a)

Participants	1a - Simple pitch diameter, $d_{2\,Simple}$			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	35,04880	1,15	-0,00047	-0,21
MIRS/UM-FS/LTM	35,0428	1,5	-0,00647	*
BEV	35,0495	2,3	0,00023	0,05
MKEH	35,0474	1,75	-0,00187	-0,54
METAS	35,0487	0,55	-0,00057	-0,56
MIKES	35,0505	1,0	0,00123	0,63
Metrosert	35,05093	0,68	0,00166	1,30
INRIM I	-	-	-	-
TUBİTAK-UME	35,0502	1,00	0,00093	0,48
LNE	35,0490	0,3	-0,00027	-0,67
INRIM II	35,0489	1,1	-0,00037	-0,16
n	8			
C	5,03747E-08			
$\bar{x}_w$	35,04927			
u_{int}	0,00022			
u_{ext}	0,00029			
R_B	1,283961857	R_B/R_{BCrit}		
R_{BCrit}	1,438417522	**0,893**		

Excluded from the SCRV

*	*En*
MIRS/UM-FS/LTM	-2,13

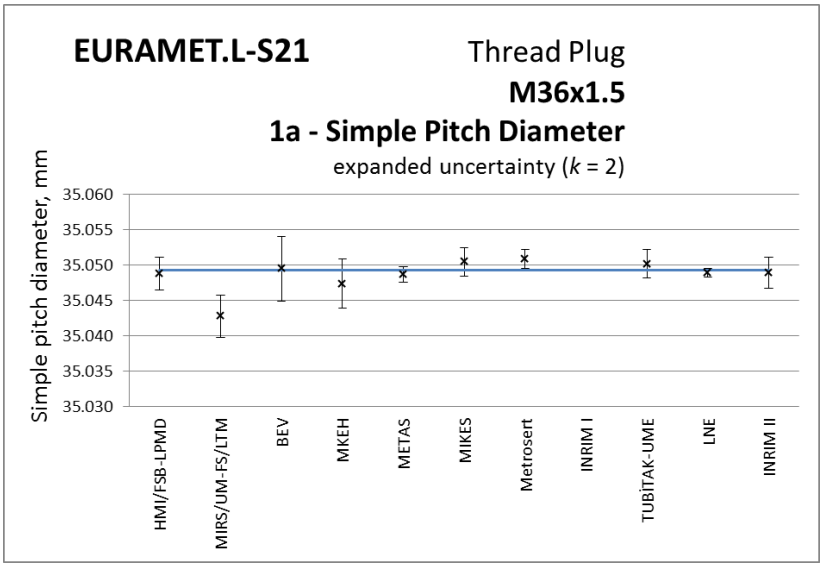


Figure 9-1 - Measurement results of simple pitch diameter (1a)

Table 9-2 - Measurement results of simple pitch diameter (1b)

Participants	1b - Simple pitch diameter, $d_{2\ Simple}$			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	35,04859	1,14	-0,00037	-0,17
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	35,0473	1,75	-0,00166	-0,49
METAS	35,0487	0,55	-0,00026	-0,33
MIKES	35,0505	1,0	0,00154	0,83
Metrosert	-	-	-	-
INRIM I	35,0475	1,3	-0,00146	-0,59
TUBİTAK-UME	35,0500	1,00	0,00104	0,56
LNE	-	-	-	-
INRIM II	35,0495	1,0	0,00054	0,25
n	6			
C	1,4299E-07			
$\bar{x}_w$	35,04896			
u_{int}	0,00038			
u_{ext}	0,00041			
R_B	1,090236	R_B/R_{BCrit}		
R_{BCrit}	1,504962147	**0,724**		

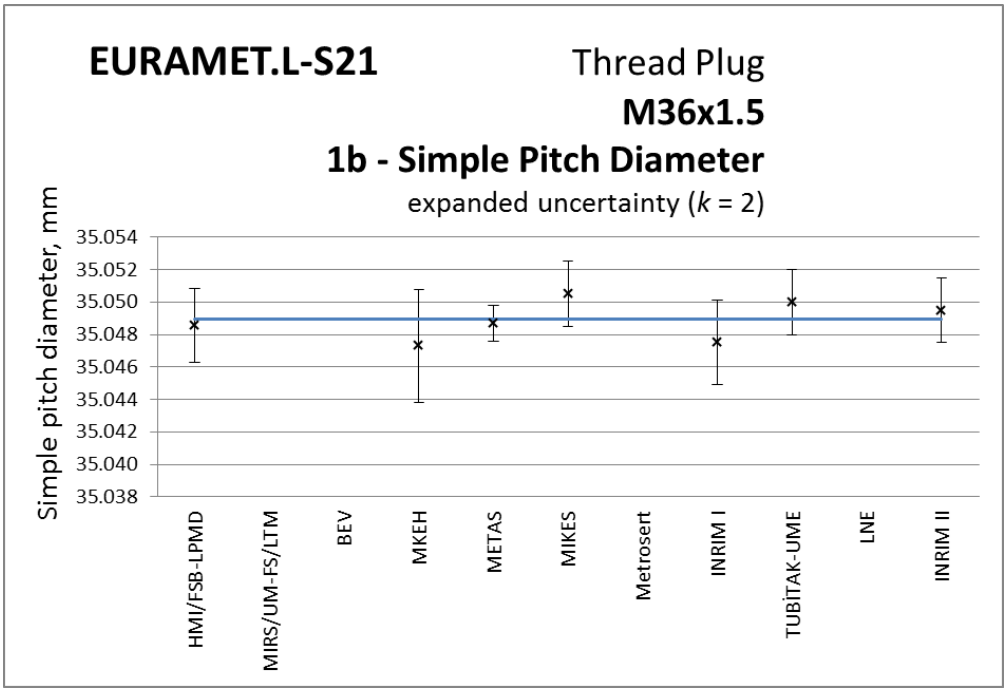


Figure 9-2 - Measurement results of simple pitch diameter (1b)

Table 9-3 - Measurement results of pitch diameter (2a)

Participants	2a - Pitch diameter, d_2			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	35,04929	1,37	-0,00038	-0,14
MIRS/UM-FS/LTM	35,0430	1,5	-0,00667	*
BEV	35,0497	3,4	0,00003	0,00
MKEH	35,0474	1,75	-0,00227	-0,66
METAS	35,0488	0,60	-0,00087	-0,94
MIKES	35,0505	1,0	0,00083	0,45
Metrosert	35,05137	0,90	0,00170	1,04
INRIM I	-	-	-	-
TUBİTAK-UME	35,0501	1,00	0,00043	0,23
LNE	-	-	-	-
INRIM II	-	-	-	-
n	7			
C	1,43716E-07			
$\bar{x}_w$	35,04967			
u_{int}	0,00038			
u_{ext}	0,00045			
R_B	1,176420695	R_B/R_{BCrit}		
R_{BCrit}	1,467889825	**0,801**		

Excluded from the SCRV

*	*En*
MIRS/UM-FS/LTM	-2,16

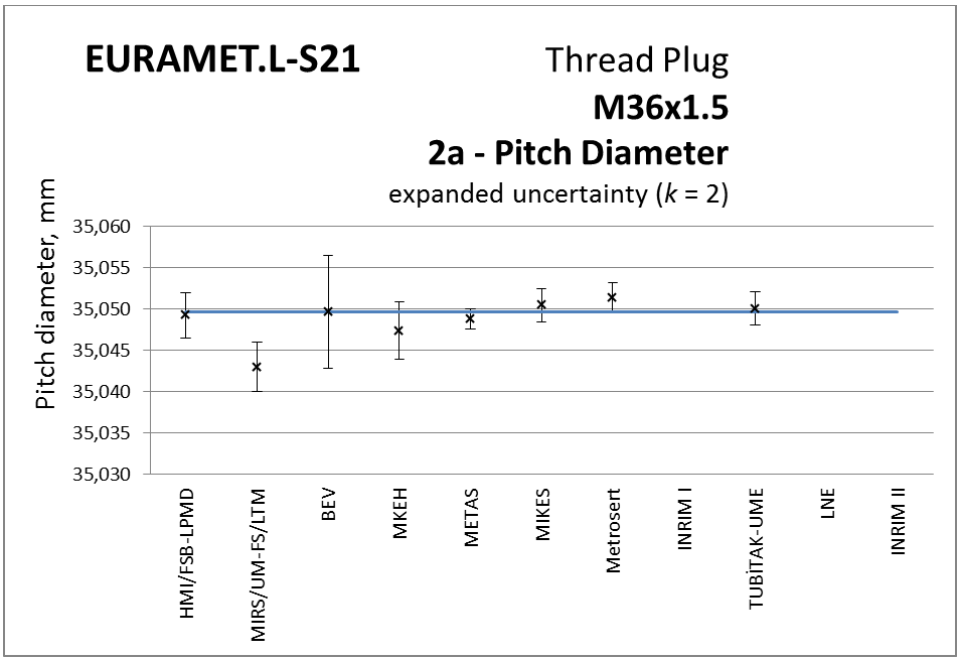


Figure 9-3 - Measurement results of pitch diameter (2a)

Table 9-4 - Measurement results of pitch diameter (2b)

Participants	2b - pitch diameter, d_2			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	35,04908	1,36	-0,00005	-0,02
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	35,0473	1,25	-0,00183	-0,78
METAS	35,0488	0,60	-0,00033	-0,38
MIKES	35,0505	1,0	0,00137	0,75
Metrosert	-	-	-	-
INRIM I	-	-	-	-
TUBİTAK-UME	35,0499	1,00	0,00077	0,42
LNE	-	-	-	-
INRIM II	-	-	-	-
n	5			
C	1,67829E-07			
$\bar{x}_w$	35,04913			
u_{int}	0,00041			
u_{ext}	0,00045			
R_B	1,108697649	R_B/R_{BCrit}		
R_{BCrit}	1,553773974	**0,714**		

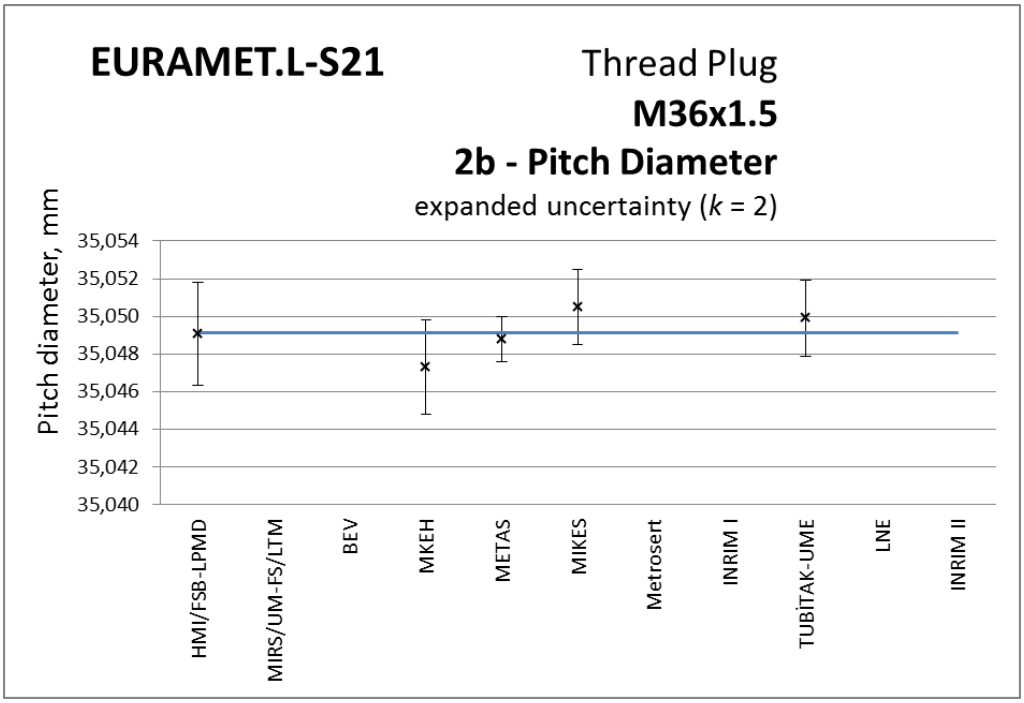


Figure 9-4 - Measurement results of pitch diameter (2b)

Table 9-5 - Measurement results of thread pitch

Participants	Thread pitch, *P*			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	1,50057	0,86	0,00038	0,22
MIRS/UM-FS/LTM	1,5002	0,4	0,00001	0,01
BEV	1,5002	1,0	0,00001	0,00
MKEH	1,5000	1	-0,00019	-0,10
METAS	1,50015	0,26	-0,00004	-0,11
MIKES	1,5002	0,80	0,00001	0,01
Metrosert	1,50045	0,67	0,00026	0,20
INRIM I	-	-	-	-
TUBİTAK-UME	1,5001	0,5	-0,00009	-0,10
LNE	-	-	-	-
INRIM II	-	-	-	-
n	8			
C	3,10702E-08			
$\bar{x}_w$	1,50019			
u_{int}	0,00018			
u_{ext}	0,00004			
R_B	0,250380475	R_B/R_{BCrit}		
R_{BCrit}	1,438417522	**0,174**		

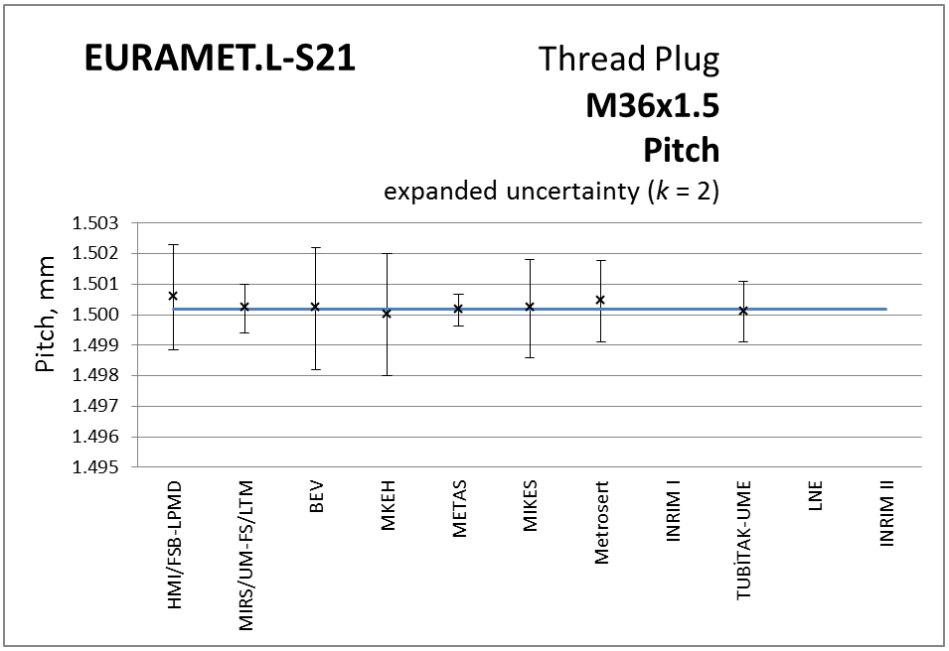


Figure 9-5 - Measurement results of thread pitch

Table 9-6 - Measurement results of thread angle – arithmetic mean for the calculation of the SCRV

Participants	Thread angle, α			
	measured value, °	uncertainty (k=1), °	$x_i-\bar{x}$, °	*En*
HMI/FSB-LPMD	59,73	0,10	-0,00804	-0,04
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	59,80	0,07	0,06215	0,44
METAS	59,70	0,19	-0,03803	-0,12
MIKES	59,43	0,07	-0,31085	*
Metrosert	-	-	-	-
INRIM I	59,67	0,02	-0,07021	-0,69
TUBİTAK-UME	59,79	0,10	0,05413	0,29
LNE	-	-	-	-
INRIM II	59,67	0,02	-0,07021	-0,67

n	5			
C	0,000260576	$\bar{x}_w$	Excluded from the SCRV	
$\bar{x}$	59,74	59,68	*	***En***
$u(\bar{x})$	0,04936		**MIKES**	-1,74
u_{ext}	0,01855			
R_B	1,148942059	R_B/R_{BCrit}		
R_{BCrit}	1,553773974	**0,739**		

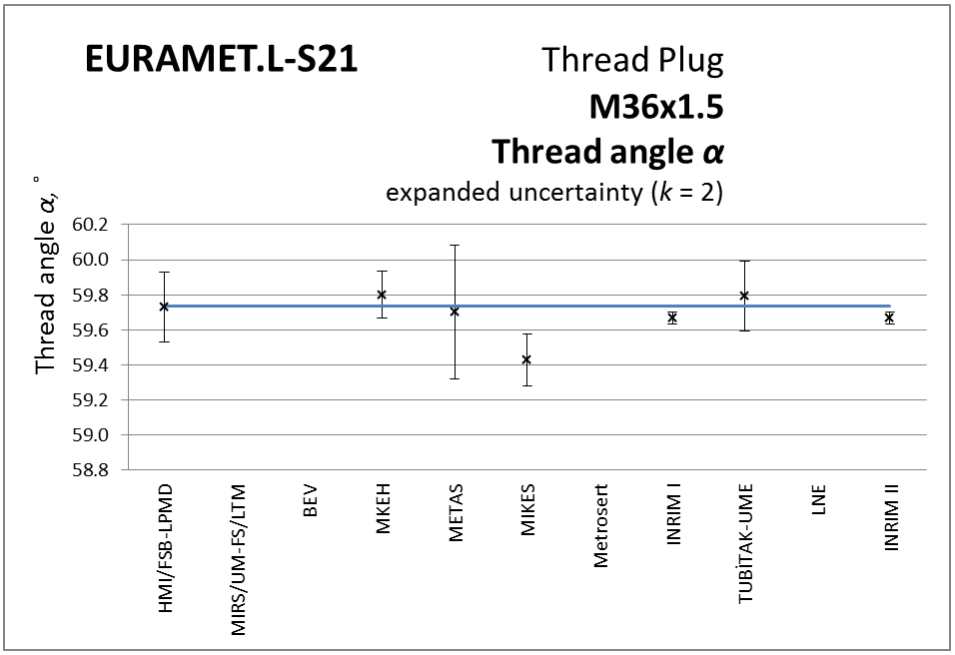
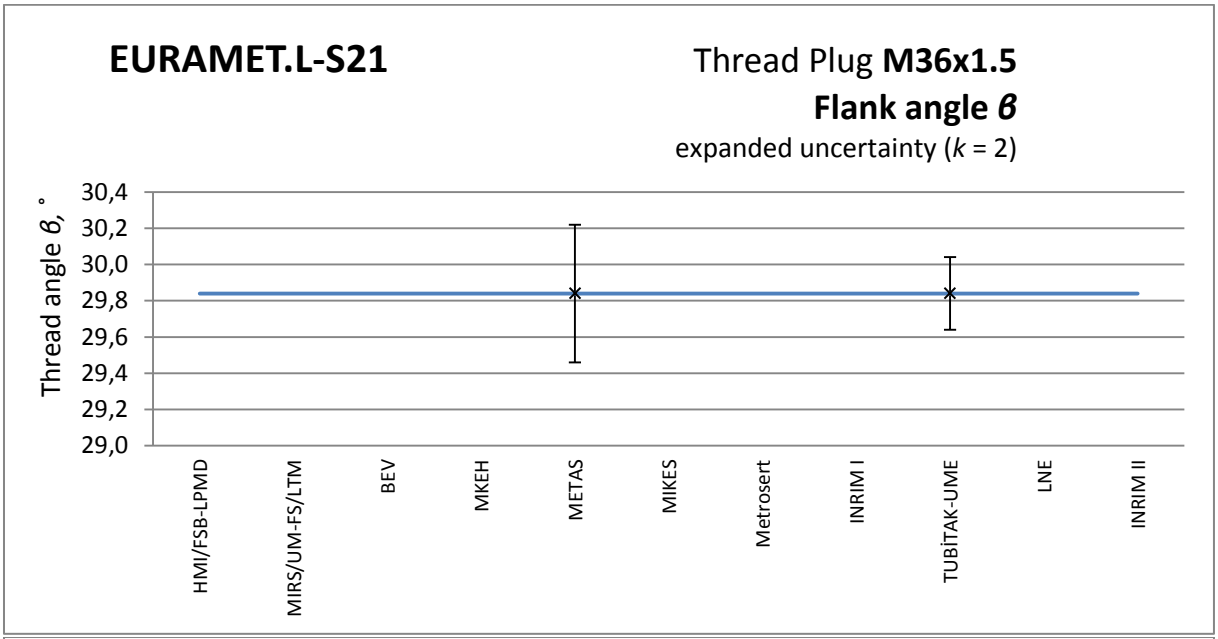


Figure 9-6 - Measurement results of thread angle

Table 9-7 - Measurement results of flank angles

Participants	Flank angle, β		Flank angle, γ	
	measured value, °	uncertainty (k=1), °	measured value, °	uncertainty (k=1), °
METAS	29,84	0,19	29,86	0,19
TUBİTAK-UME	29,84	0,10	29,95	0,10
	n 2		n	2
	C 0,007863629		C	0,007863629
	$\bar{x}_w$ 29,84		$\bar{x}_w$	29,93
	$\bar{\bar{x}}$ **29,84**		$\bar{\bar{x}}$	**29,91**



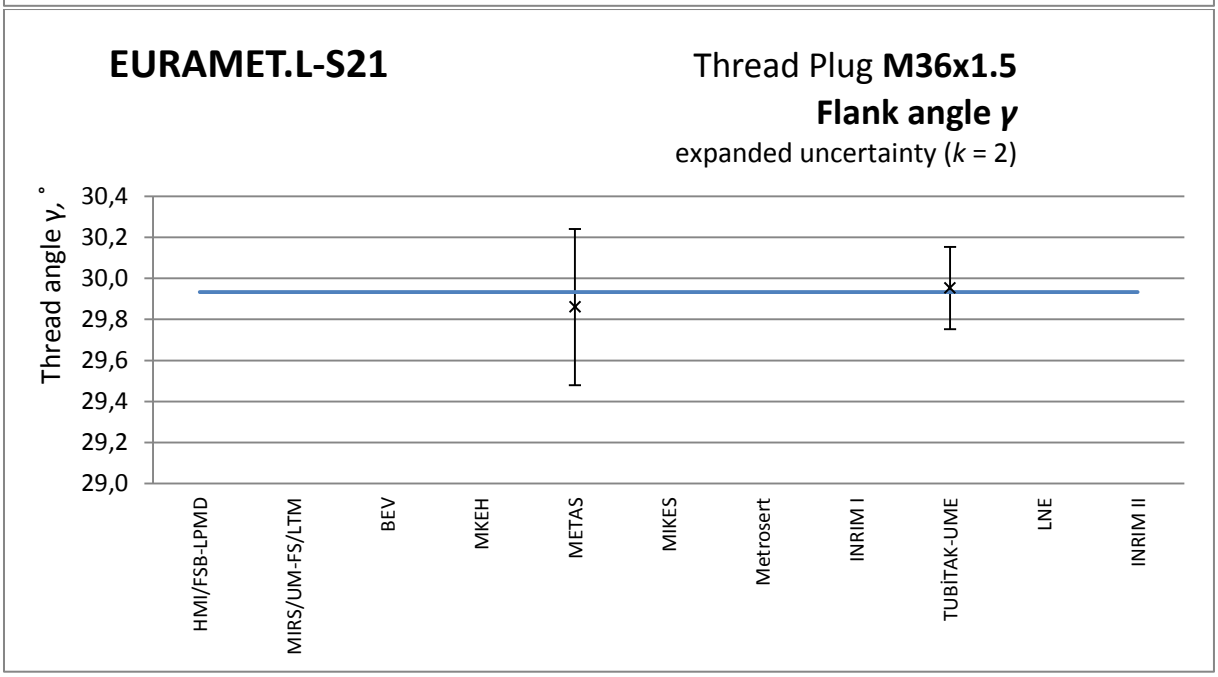


Figure 9-7 - Measurement results of flank angles

9.2 Thread plug M12x1.75 - FSB 02

Table 9-8 - Measurement results of simple pitch diameter (1a)

Participants	1a - Simple pitch diameter, $d_{2\ Simple}$			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	10,88066	1,26	0,00108	0,43
MIRS/UM-FS/LTM	10,8764	1,5	-0,00318	-1,07
BEV	10,8795	2,4	-0,00008	-0,02
MKEH	10,8792	1,70	-0,00038	-0,11
METAS	10,8796	0,54	0,00002	0,02
MIKES	10,8775	1,0	-0,00208	-1,07
Metrosert	10,88051	0,66	0,00093	0,75
INRIM I	-	-	-	-
TUBİTAK-UME	10,8803	1,11	0,00072	0,33
LNE	10,8796	0,3	0,00002	0,04
INRIM II	10,8802	1,4	0,00062	0,22
n	9			
C	4,94029E-08			
$\bar{x}_w$	10,87958			
u_{int}	0,00022			
u_{ext}	0,00027			
R_B	1,225690451	R_B/R_{BCrit}		
R_{BCrit}	1,414213562	**0,867**		

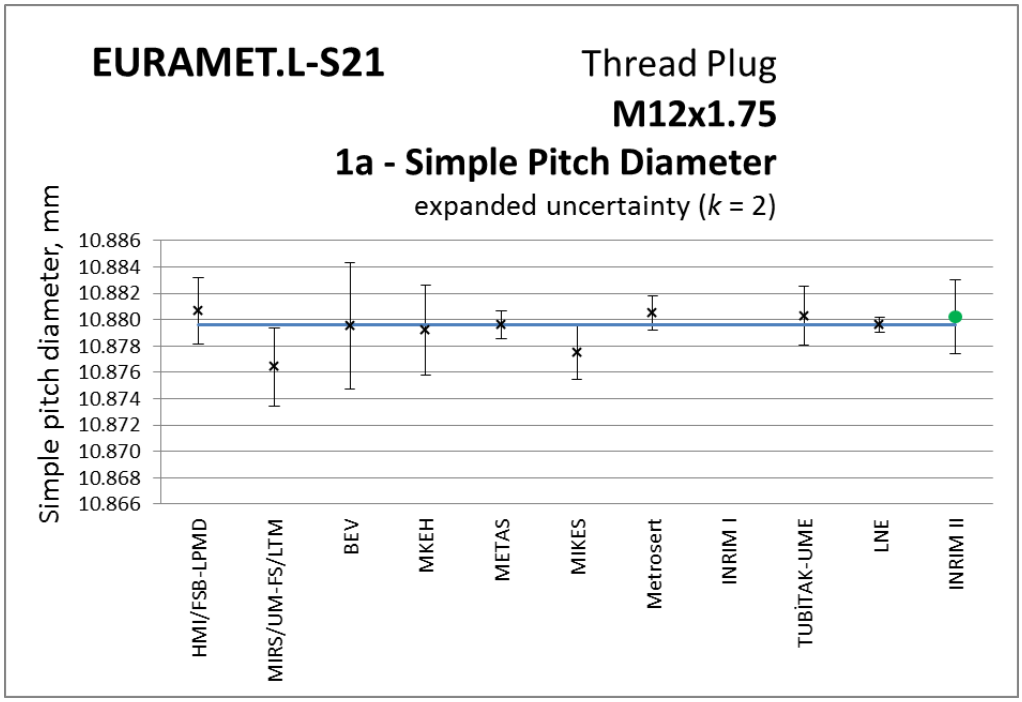


Figure 9-8 - Measurement results of simple pitch diameter (1a)

Table 9-9 - Measurement results of simple pitch diameter (1b)

Participants	1b - Simple pitch diameter, $d_{2\ Simple}$			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	10,88065	1,16	0,00167	0,74
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	10,8792	1,60	0,00022	0,07
METAS	10,8796	0,54	0,00062	0,67
MIKES	10,8775	1,0	-0,00148	-0,77
Metrosert	-	-	-	-
INRIM I	10,8784	0,4	-0,00058	-1,01
TUBİTAK-UME	10,8806	1,00	0,00162	0,84
LNE	-	-	-	-
INRIM II	10,8795	0,5	0,00052	0,46
n	6			
C	7,80449E-08			
$\bar{x}_w$	10,87898			
u_{int}	0,00028			
u_{ext}	0,00036			
R_B	1,283933191	R_B/R_{BCrit}		
R_{BCrit}	1,504962147	**0,955**		

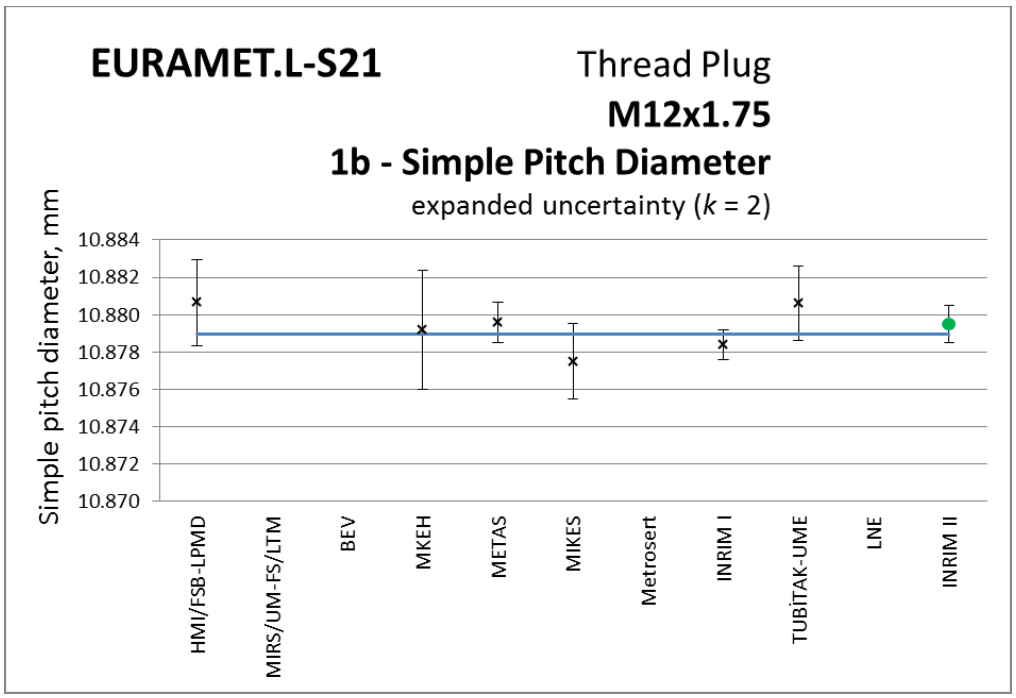


Figure 9-9 - Measurement results of simple pitch diameter (1b)

Table 9-10 - Measurement results of pitch diameter (2a)

Participants	2a - Pitch diameter, d_2			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	10,88056	1,46	0,00096	0,34
MIRS/UM-FS/LTM	10,8765	1,5	-0,00310	-1,07
BEV	10,8796	3,4	0,00000	0,00
MKEH	10,8800	1,40	0,00040	0,15
METAS	10,8797	0,81	0,00010	0,07
MIKES	10,8774	1,0	-0,00220	-1,19
Metrosert	10,88051	0,71	0,00091	0,76
INRIM I	-	-	-	-
TUBİTAK-UME	10,8806	1,03	0,00100	0,52
LNE	-	-	-	-
INRIM II	10,8807	1,5	0,00110	0,36
n	8			
C	1,43662E-07			
$\bar{x}_w$	10,87960			
u_{int}	0,00038			
u_{ext}	0,00050			
R_B	1,321556731	R_B/R_{BCrit}		
R_{BCrit}	1,438417522	**0,919**		

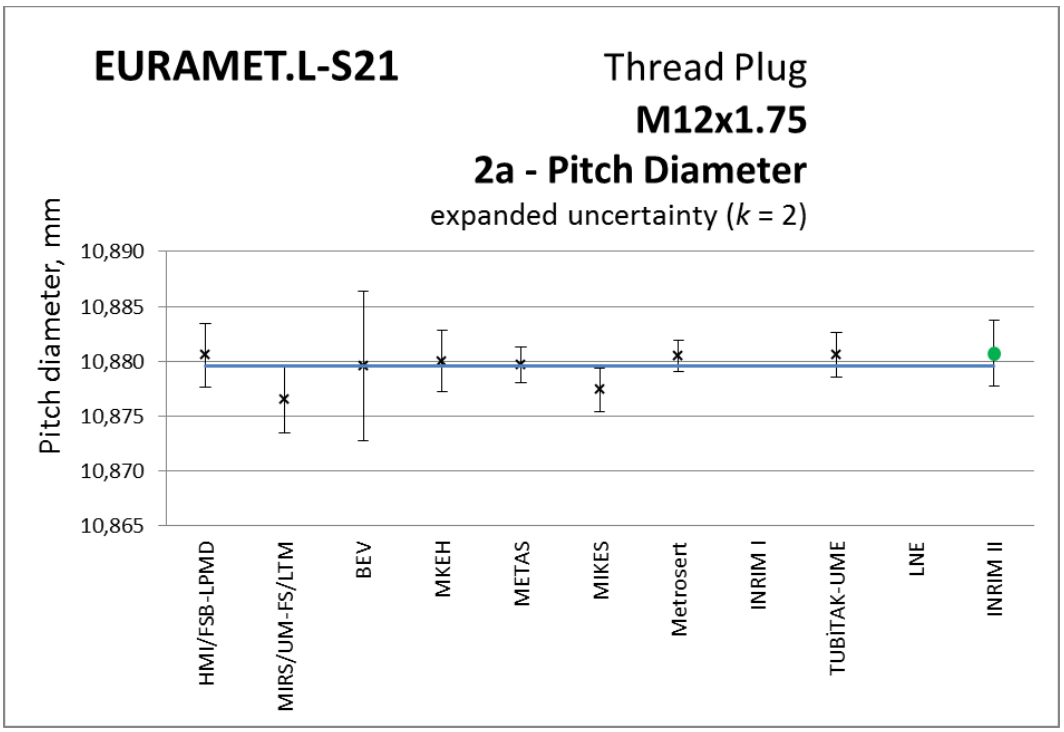


Figure 9-10 M12x1.75 – Measurement results of pitch diameter (2a)

Table 9-11 - Measurement results of pitch diameter (2b)

Participants	2b - Pitch diameter, d_2			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	10,88055	1,38	0,00131	0,49
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	10,8800	1,30	0,00076	0,30
METAS	10,8797	0,81	0,00046	0,32
MIKES	10,8774	0,83	-0,00184	-1,25
Metrosert	-	-	-	-
INRIM I	10,8789	0,7	-0,00034	-0,29
TUBİTAK-UME	10,8808	1,00	0,00156	0,84
LNE	-	-	-	-
INRIM II	10,8799	0,7	0,00066	0,41
n	6			
C	1,40186E-07			
$\bar{x}_w$	10,87924			
u_{int}	0,00037			
u_{ext}	0,00051			
R_B	1,352720914	R_B/R_{BCrit}		
R_{BCrit}	1,504962147	**0,899**		

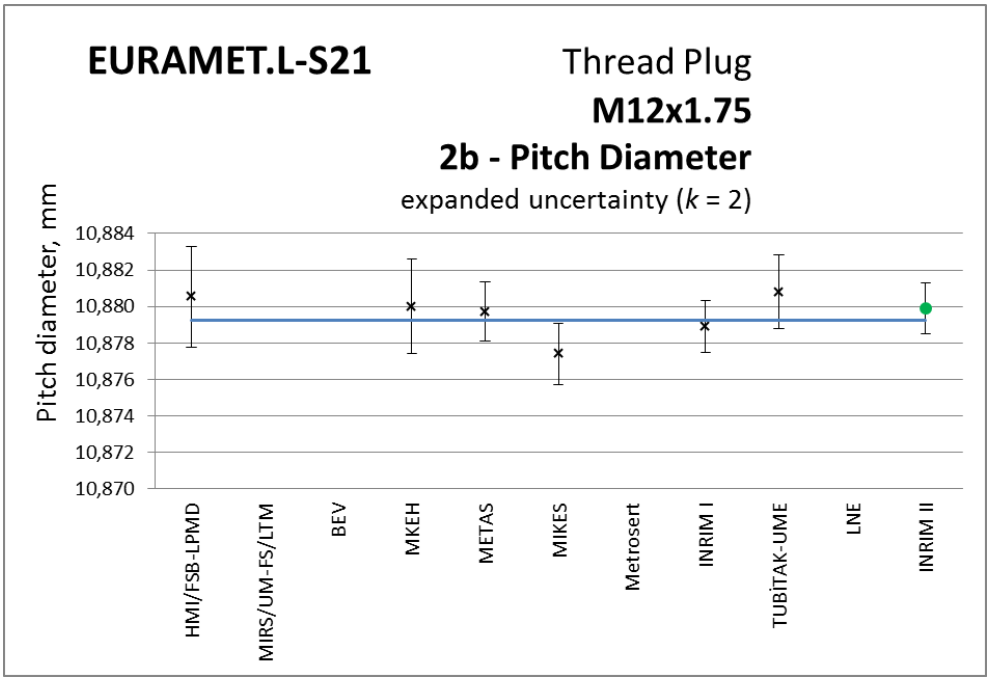


Figure 9-11 - Measurement results of pitch diameter (2b)

Table 9-12 - Measurement results of thread pitch

Participants	Thread pitch, *P*			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	1,74989	0,86	-0,00014	-0,09
MIRS/UM-FS/LTM	1,7501	0,4	0,00007	0,10
BEV	1,7501	1,0	0,00007	0,04
MKEH	1,7509	1	0,00087	0,44
METAS	1,7501	0,7	0,00007	0,05
MIKES	1,7499	0,40	-0,00013	-0,18
Metrosert	1,74995	0,31	-0,00008	-0,15
INRIM I	1,7506	0,60	0,00057	0,50
TUBİTAK-UME	1,7497	0,5	-0,00033	-0,35
LNE	-	-	-	-
INRIM II	1,7506	0,6	0,00057	0,46
n	9			
C	2,85091E-08			
$\bar{x}_w$	1,75003			
u_{int}	0,00017			
u_{ext}	0,00009			
R_B	0,540957615	R_B/R_{BCrit}		
R_{BCrit}	1,414213562	**0,383**		

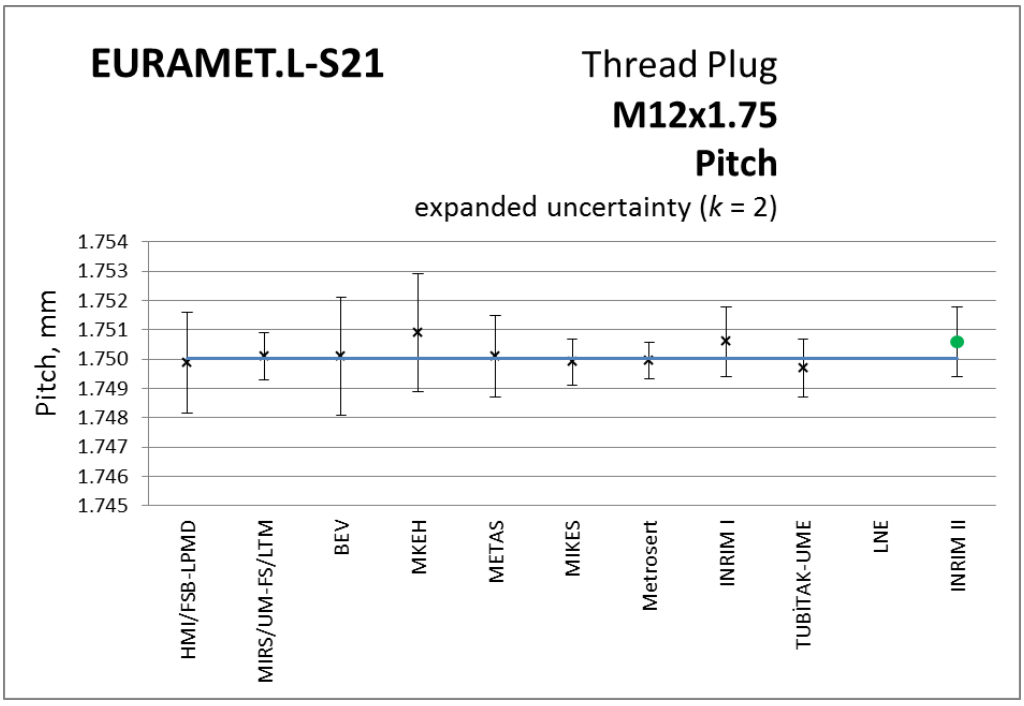


Figure 9-12 – Measurement results of thread pitch

Table 9-13 – Measurement results of thread angle – arithmetic mean for the calculation of the SRCV

Participants	Thread angle, α			
	measured value, °	uncertainty (k=1), °	x_i-$\bar{x}$,°	*En*
HMI/FSB-LPMD	60,00	0,10	-0,06096	-0,34
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	60,00	0,07	-0,05832	-0,44
METAS	60,10	0,05	0,04154	0,37
MIKES	60,05	0,15	-0,01248	-0,05
Metrosert	-	-	-	-
INRIM I	60,12	0,02	0,06201	0,77
TUBİTAK-UME	60,09	0,10	0,02820	0,16
LNE	-	-	-	-
INRIM II	60,12	0,02	0,06201	0,75
n	6			
C	0,000235198	$\bar{x}_w$		
$\bar{x}$	60,06	60,11		
$u(\bar{x})$	0,03773			
u_{ext}	0,01472			
R_B	0,959699927	R_B/R_{BCrit}		
R_{BCrit}	1,504962147	**0,638**		

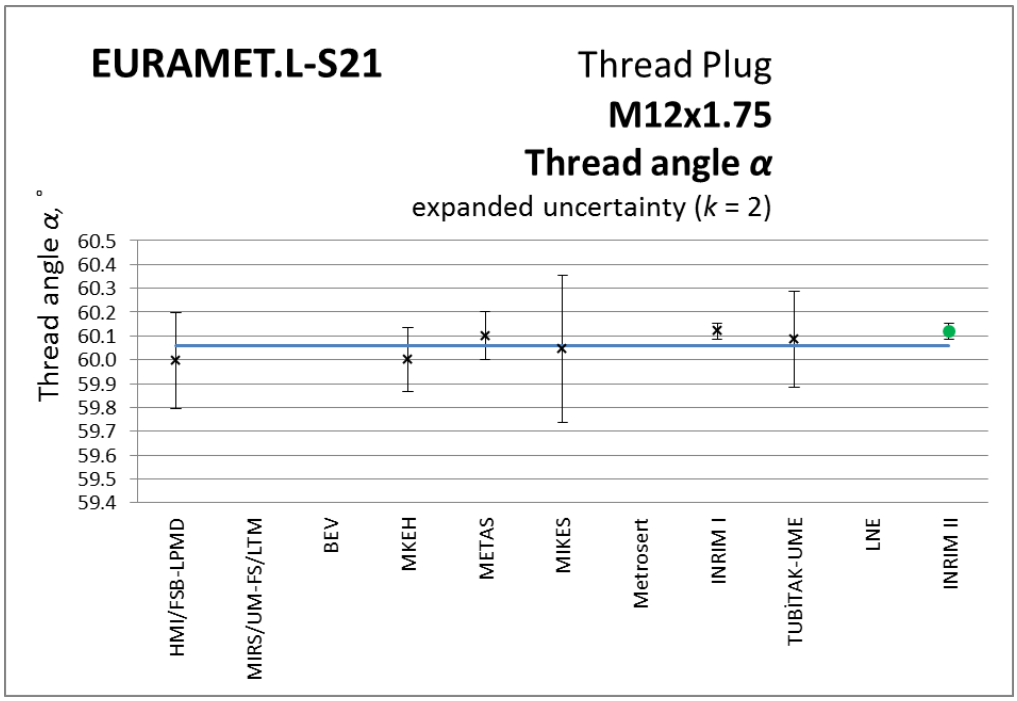
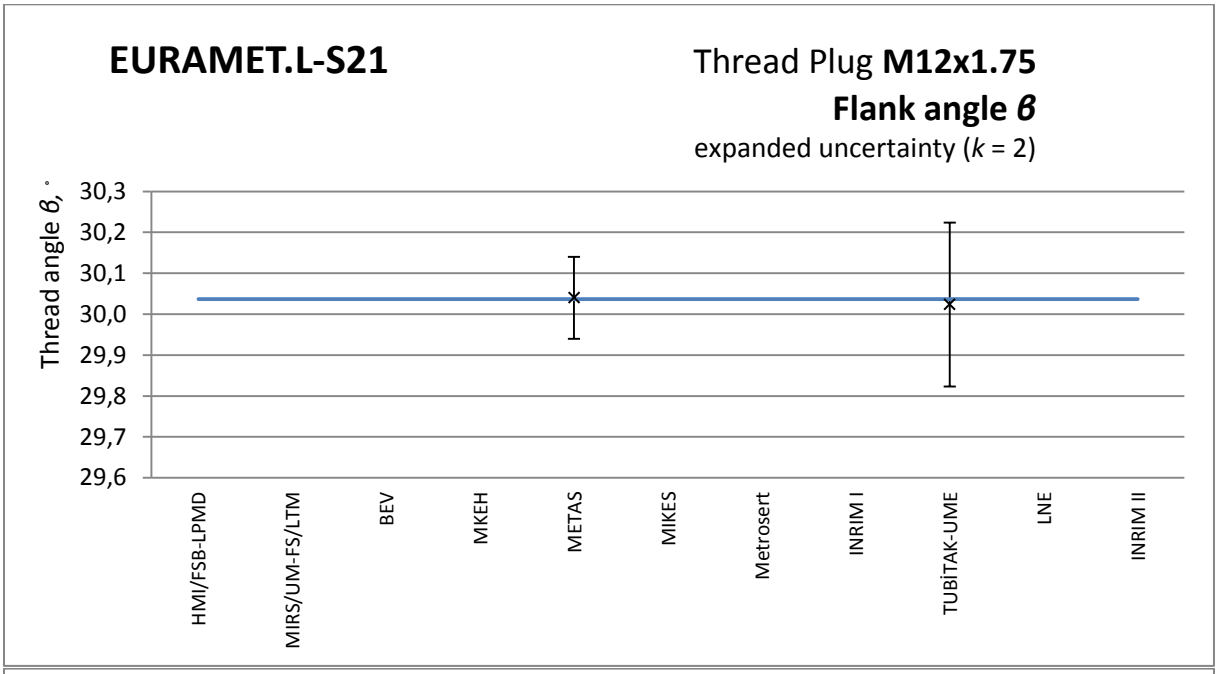


Figure 9-13 - Measurement results of thread angle

Table 9-14– Measurement results of flank angles

Participants	Flank angle, β		Flank angle, γ	
	measured value, °	uncertainty (k=1), °	measured value, °	uncertainty (k=1), °
METAS	30,04	0,05	30,06	0,05
TUBİTAK-UME	30,02	0,10	30,06	0,10
	n	2	n	2
	C	0,002002135	C	0,002002135
	$\bar{x}_w$	30,04	$\bar{x}_w$	30,06
	$\bar{\bar{x}}$	**30,03**	$\bar{\bar{x}}$	**30,06**



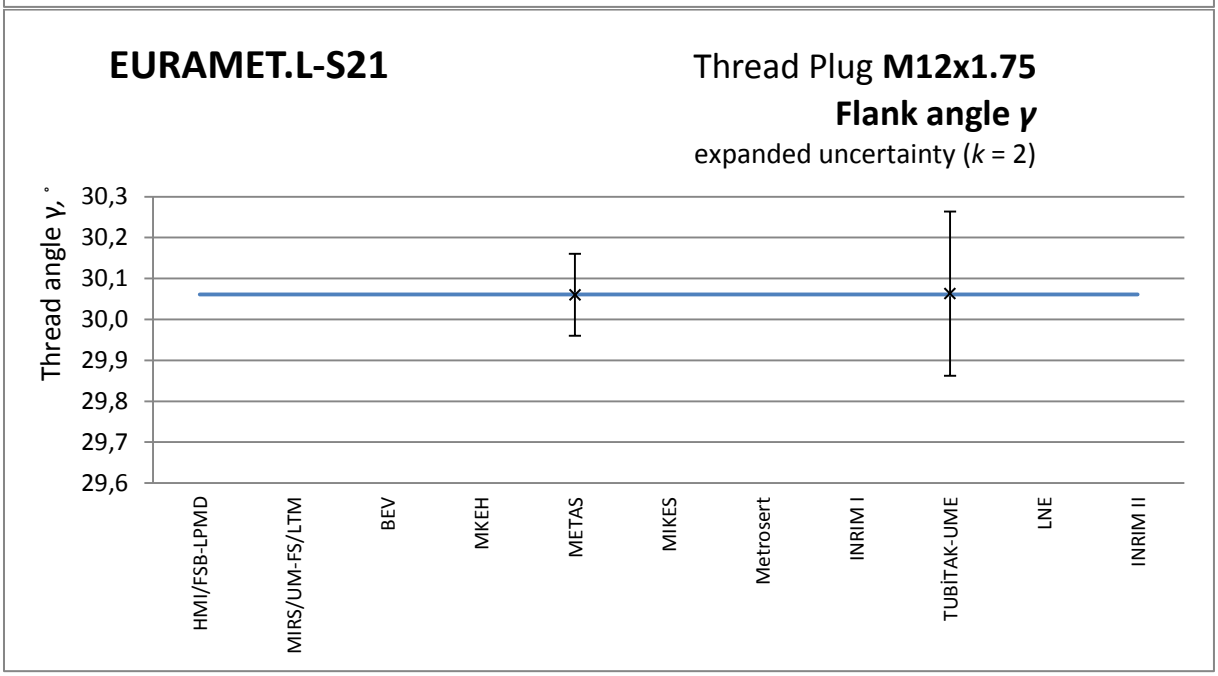


Figure 9-14 – Measurement results of flank angles

9.3 Thread plug M6x1 - FSB 01

Table 9-15 – Measurement results of simple pitch diameter (1a)

Participants	1a - Simple pitch diameter, $d_{2\ Simple}$			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	5,36682	1,18	0,00105	0,46
MIRS/UM-FS/LTM	5,3632	1,5	-0,00257	-0,86
BEV	5,3659	2,5	0,00013	0,03
MKEH	5,3655	1,65	-0,00027	-0,08
METAS	5,3651	0,55	-0,00067	-0,66
MIKES	5,3662	1,0	0,00043	0,22
Metrosert	5,36625	0,68	0,00048	0,38
INRIM I	-	-	-	-
TUBİTAK-UME	5,3643	1,01	-0,00147	-0,74
LNE	5,3660	0,3	0,00023	0,58
INRIM II	5,3674	1,1	0,00163	0,73
n	9			
C	4,93833E-08			
$\bar{x}_w$	5,36577			
u_{int}	0,00022			
u_{ext}	0,00023			
R_B	1,038601502	R_B/R_{BCrit}		
R_{BCrit}	1,414213562	**0,734**		

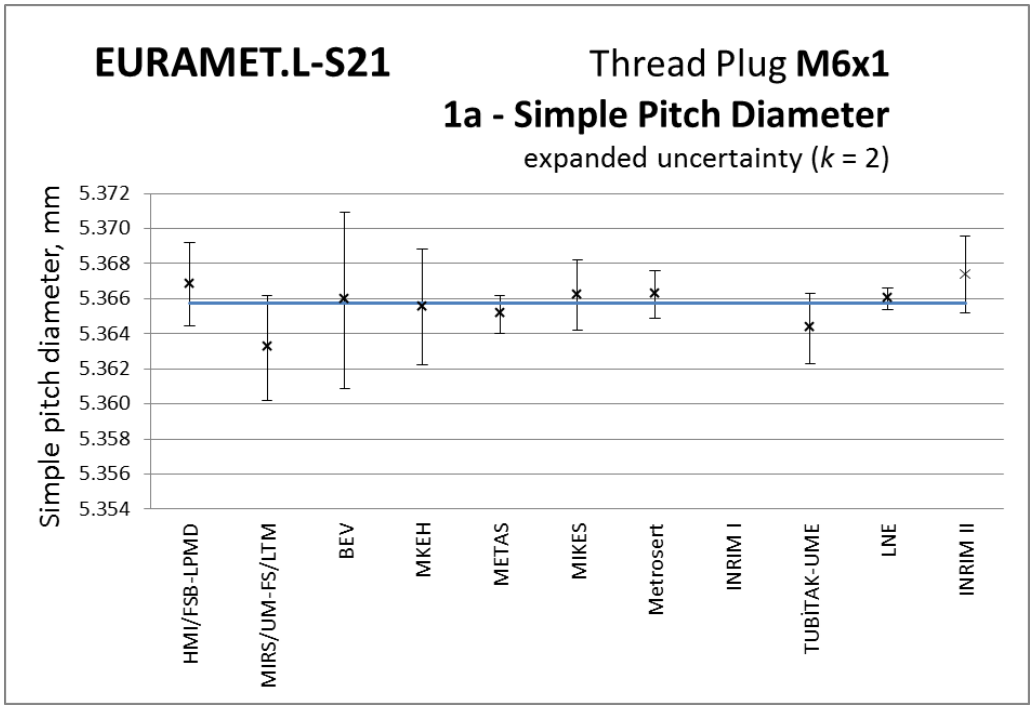


Figure 9-15 – Measurement results of simple pitch diameter (1a)

Table 9-16 – Measurement results of simple pitch diameter (1b)

Participants	1b - Simple pitch diameter, $d_{2\ Simple}$		$x_i - \bar{x}_w$, mm	En
	measured value, mm	uncertainty (k=1), µm		
HMI/FSB-LPMD	5,36812	1,12	0,00256	1,22
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	5,3653	1,55	-0,00026	-0,09
METAS	5,3651	0,55	-0,00046	-0,59
MIKES	5,3661	1,0	0,00054	0,29
Metrosert	-	-	-	-
INRIM I	5,3536	0,80	-0,01196	*
TUBİTAK-UME	5,3646	1,00	-0,00096	-0,52
LNE	-	-	-	-
INRIM II	5,3652	0,9	-0,00036	-0,18
n	5			
C	1,53393E-07			
$\bar{x}_w$	5,36556			
u_{int}	0,00039			
u_{ext}	0,00052			
R_B	1,33840589	R_B/R_{BCrit}		
R_{BCrit}	1,553773974	**0,861**		

Excluded from the SCRV

*	En
INRIM I	-6,71

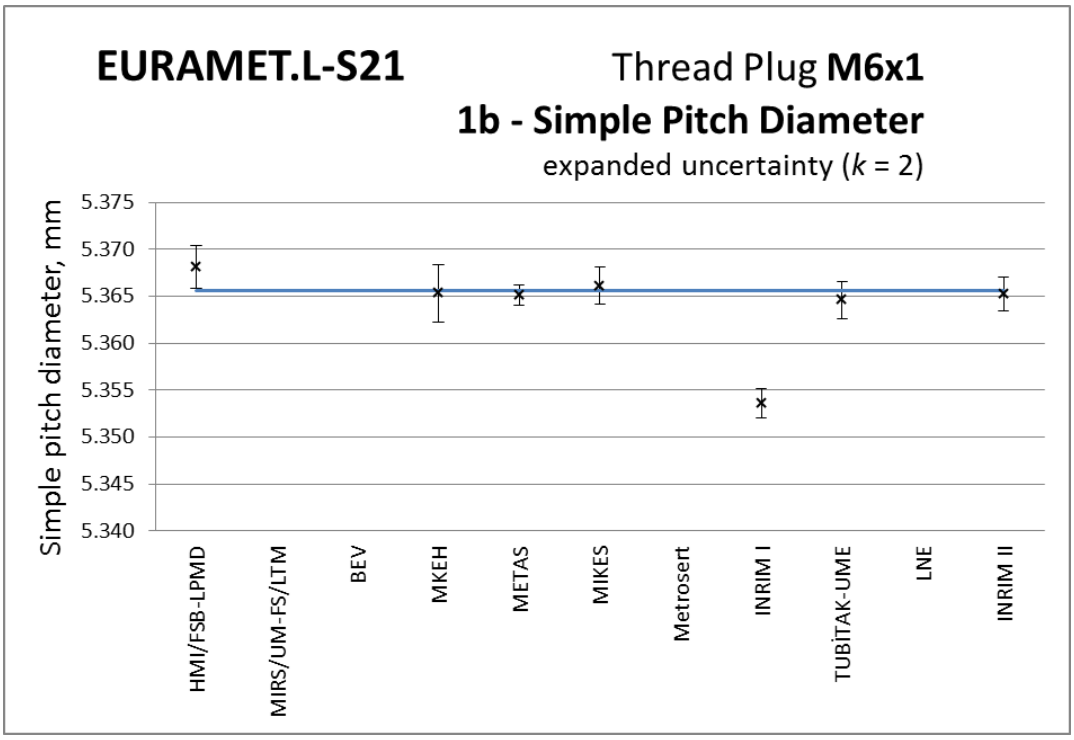


Figure 9-16 – Measurement results of simple pitch diameter (1b)

Table 9-17 – Measurement results of pitch diameter (2a)

Participants	2a - Pitch diameter, d_2			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	5,36643	1,40	0,00085	0,32
MIRS/UM-FS/LTM	5,3634	1,5	-0,00218	-0,76
BEV	5,3666	3,4	0,00102	0,15
MKEH	5,3654	1,40	-0,00018	-0,07
METAS	5,3647	1,10	-0,00088	-0,43
MIKES	5,3666	1,0	0,00102	0,56
Metrosert	5,36629	0,79	0,00071	0,52
INRIM I	-	-	-	-
TUBİTAK-UME	5,3647	1,00	-0,00088	-0,48
LNE	-	-	-	-
INRIM II	5,3683	1,2	0,00272	1,07
n	8			
C	1,67221E-07			
$\bar{x}_w$	5,36558			
u_{int}	0,00041			
u_{ext}	0,00037			
R_B	0,914160947	R_B/R_{BCrit}		
R_{BCrit}	1,438417522	**0,636**		

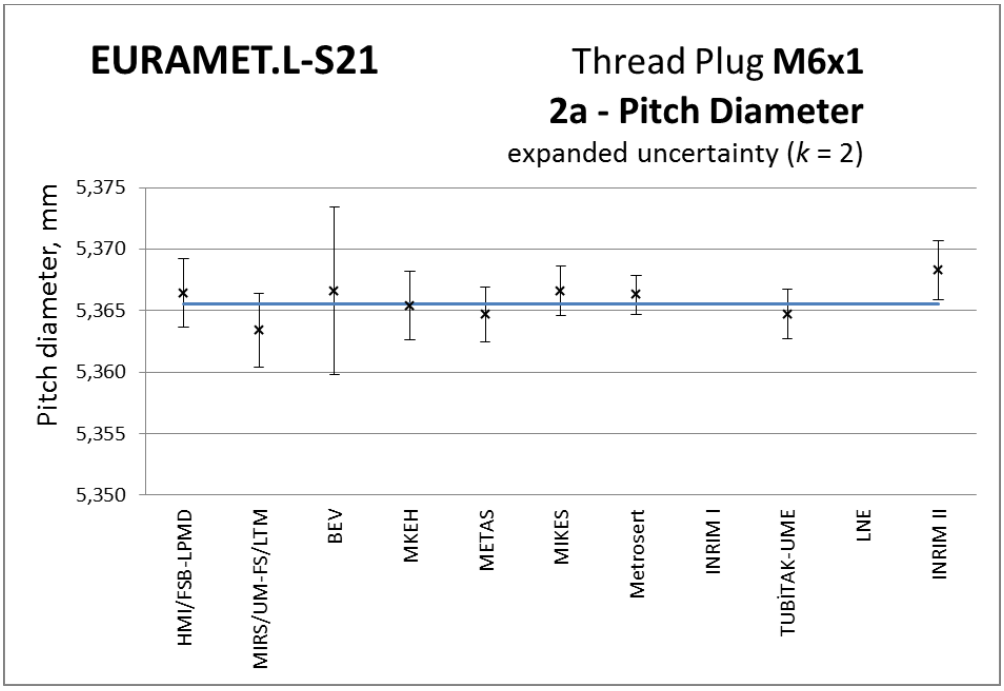


Figure 9-17 – Measurement results of pitch diameter (2a)

Table 9-18 – Measurement results of pitch diameter (2b)

Participants	2b - Pitch diameter, d_2			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	5,36774	1,33	0,00199	0,81
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	5,3652	1,25	-0,00055	-0,24
METAS	5,3647	1,10	-0,00105	-0,54
MIKES	5,3666	1,0	0,00085	0,49
Metrosert	-	-	-	-
INRIM I	5,3544	1,00	-0,01135	*
TUBİTAK-UME	5,3650	1,00	-0,00075	-0,43
LNE	-	-	-	-
INRIM II	5,3657	1,0	-0,00005	-0,02
n	5			
C	2,4803E-07			
$\bar{x}_w$	5,36575			
u_{int}	0,00050			
u_{ext}	0,00054			
R_B	1,075695844	R_B/R_{BCrit}		
R_{BCrit}	1,553773974	**0,692**		

Excluded from the SCRV

	*	*En*
INRIM I		-5,08

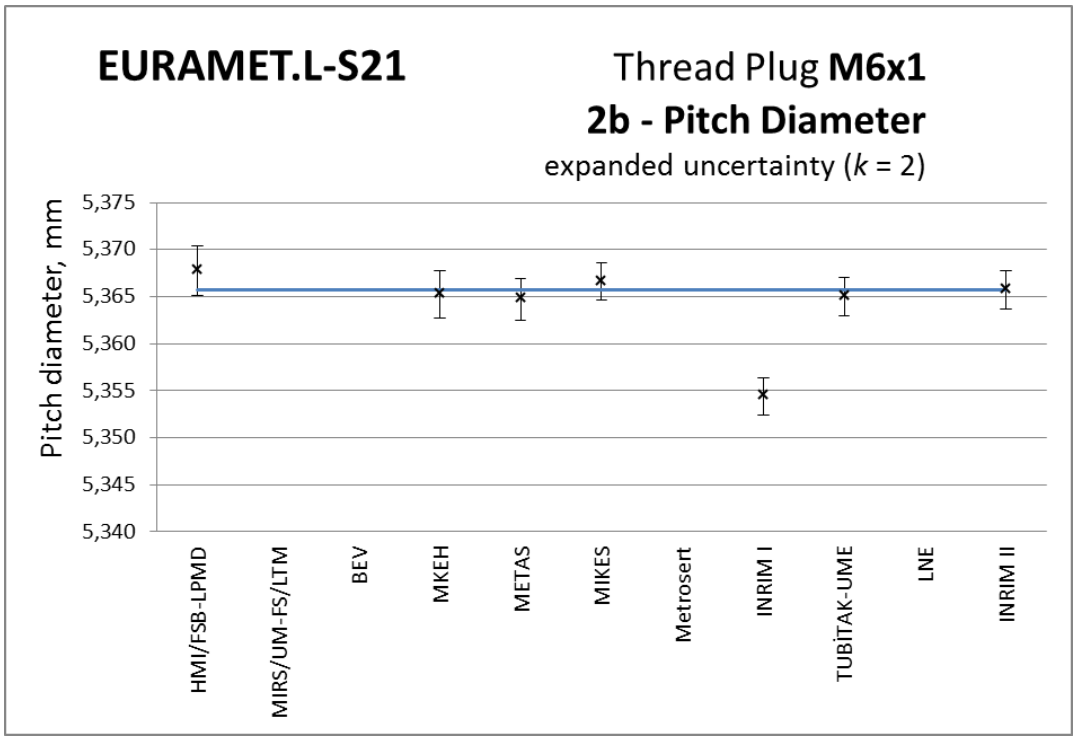


Figure 9-18 – Measurement results of pitch diameter (2b)

Table 9-19 – Measurement results of thread pitch

Participants	Thread pitch, *P*			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	0,99955	0,86	-0,00055	-0,33
MIRS/UM-FS/LTM	1,0002	0,4	0,00010	0,15
BEV	1,0008	1,0	0,00070	0,36
MKEH	0,9999	1	-0,00020	-0,10
METAS	0,99956	1,10	-0,00054	-0,25
MIKES	1,0006	0,8	0,00050	0,33
Metrosert	1,00005	0,47	-0,00005	-0,06
INRIM I	1,0010	0,7	0,00090	0,68
TUBİTAK-UME	0,9995	0,5	-0,00060	-0,66
LNE	-	-	-	-
INRIM II	1,0010	0,7	0,00090	0,62
n	9			
C	4,43286E-08			
$\bar{x}_w$	1,00010			
u_{int}	0,00021			
u_{ext}	0,00016			
R_B	0,769517874	R_B/R_{BCrit}		
R_{BCrit}	1,414213562	**0,544**		

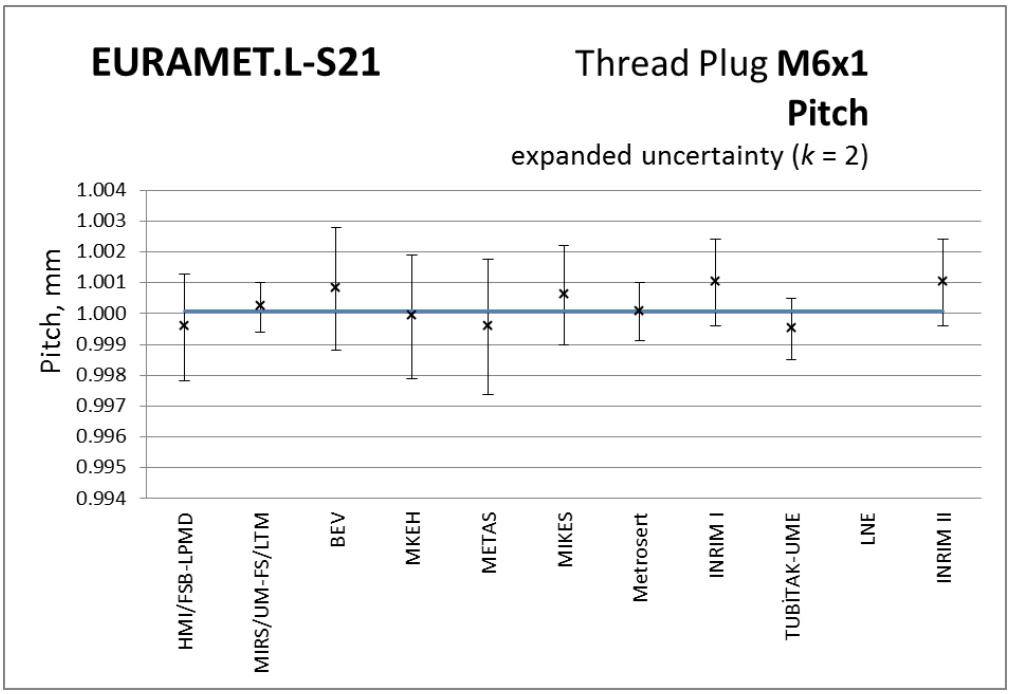


Figure 9-19 – Measurement results of thread pitch

Table 9-20 – Measurement results of thread angle – arithmetic mean for the calculation of the SCRV

Participants	Thread angle, α			
	measured value, °	uncertainty (k=1),°	x_i-$\bar{x}$,°	*En*
HMI/FSB-LPMD	61,15	0,10	0,06647	0,40
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	59,87	0,07	-1,21889	*
METAS	60,97	0,15	-0,11553	-0,55
MIKES	60,74	0,10	-0,34055	*
Metrosert	-	-	-	-
INRIM I	61,13	0,02	0,04907	0,40
TUBİTAK-UME	60,23	0,10	-0,85506	*
LNE	-	-	-	-
INRIM II	61,13	0,02	0,04907	0,39

n	3		Excluded from the SCRV	
C	0,000283403	$\bar{x}_w$	*	*En*
$\bar{x}$	61,09	61,13	**MKEH**	-6,79
$u(\bar{x})$	0,06041		**TUBİTAK-UME**	-3,65
u_{ext}	0,01318		**MIKES**	-1,49
R_B	0,78274234	R_B/R_{BCrit}		
R_{BCrit}	1,732050808	**0,452**		

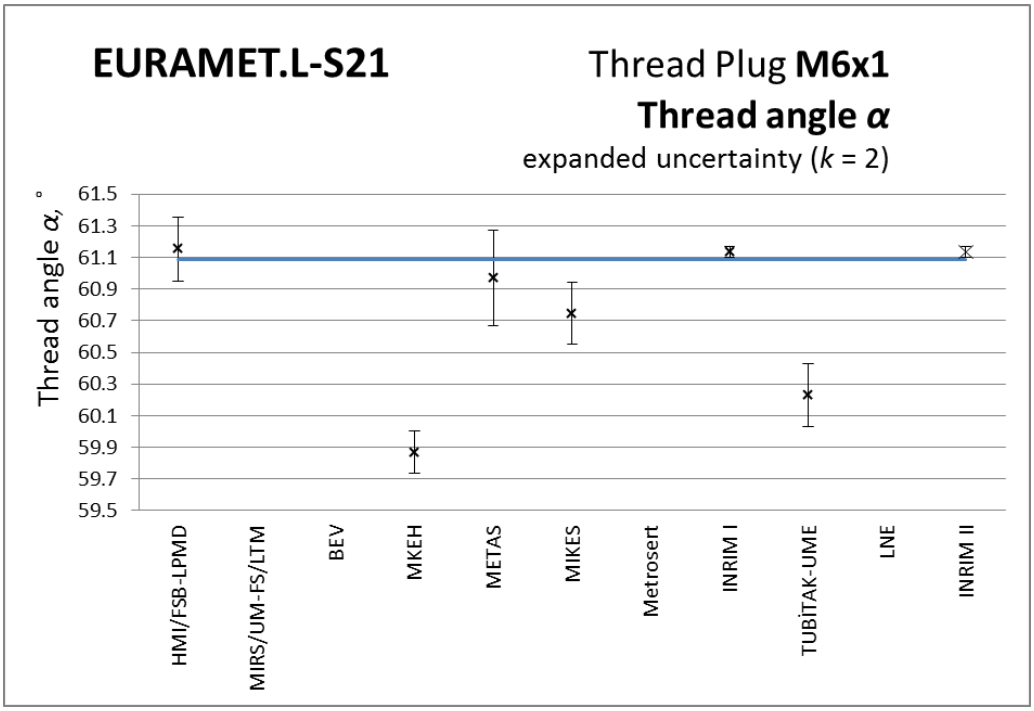


Figure 9-20 – Measurement results of thread angle

Table 9-21– Measurement results of flank angles

Participants	Flank angle, β		Flank angle, γ	
	measured value, °	uncertainty (k=1), °	measured value, °	uncertainty (k=1), °
METAS	30,33	0,15	30,64	0,15
TUBİTAK-UME	30,03	0,10	30,20	0,10
	n 2		n	2
	C 0,006948722		C	0,006948722
	$\bar{x}_w$ 30,12		$\bar{x}_w$	30,34
	$\bar{\bar{x}}$ **30,18**		$\bar{\bar{x}}$	**30,42**

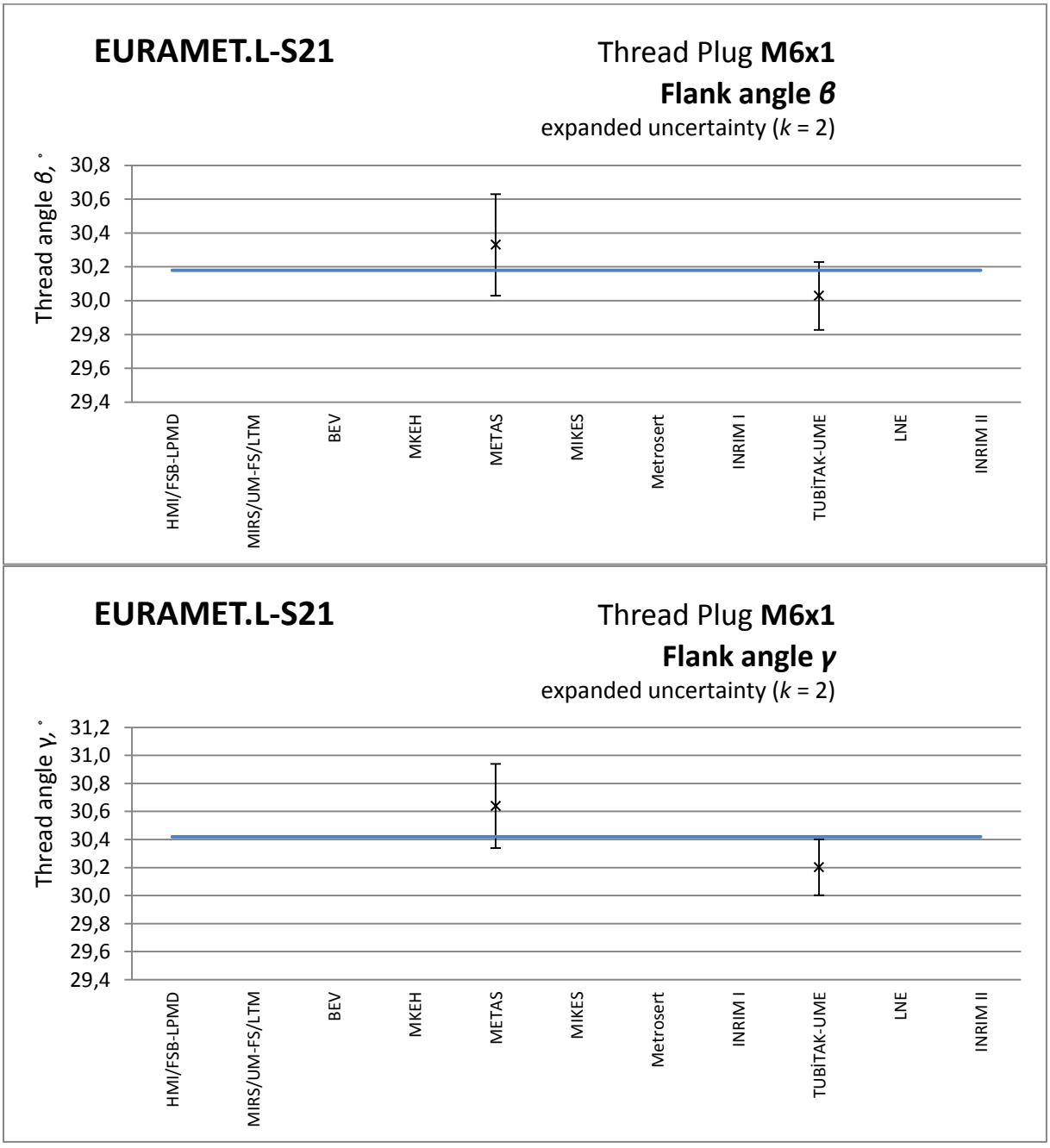


Figure 9-21 – Measurement results of flank angles

9.4 *Thread ring M18x2.5* - BDU 096

Table 9-22 – Measurement results of simple pitch diameter (1a)

Participants	1a - Simple pitch diameter, $D_{2\ Simple}$			
	measured value, mm	uncertainty (k=1), µm	$x_i - \bar{x}_w$, mm	*En*
HMI/FSB-LPMD	16,32159	1,03	-0,00019	-0,10
MIRS/UM-FS/LTM	16,3217	1,47	-0,00008	-0,03
BEV	16,3229	1,8	0,00112	0,32
MKEH	16,3192	1,70	-0,00258	-0,78
METAS	16,3226	0,80	0,00082	0,60
MIKES	16,3199	1,0	-0,00188	*
Metrosert	16,32183	0,85	0,00005	0,03
INRIM I	-	-	-	-
TUBİTAK-UME	16,3211	1,10	-0,00068	-0,34
LNE	16,3243	0,8	0,00252	*
INRIM II	16,3220	0,9	0,00022	0,11
n	7			
C	1,71437E-07			
$\bar{x}_w$	16,32178			
u_{int}	0,00041			
u_{ext}	0,00034			
R_B	0,833019283	R_B/R_{BCrit}		
R_{BCrit}	1,467889825	**0,567**		

Excluded from the SCRV

*	*En*
LNE	1,40
MIKES	-0,87

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	$x_i - \bar{x}_w$, mm	*En*
MIKES	16,3208	1,0	-0,00098	-0,45

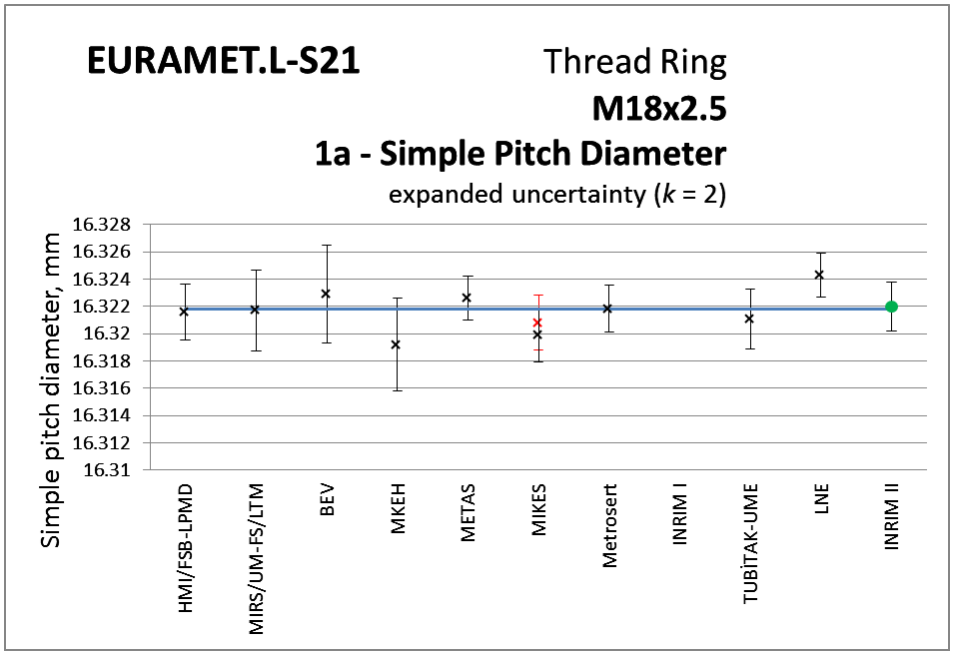


Figure 9-22 – Measurement results of simple pitch diameter (1a)

Table 9-23 – Measurement results of simple pitch diameter (1b)

Participants	1b - Simple pitch diameter, $D_{2\ Simple}$			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	16,32204	0,96	-0,00039	-0,24
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	-	-	-	-
METAS	16,3231	0,66	0,00067	0,75
MIKES	16,3199	1,0	-0,00253	*
Metrosert	-	-	-	-
INRIM I	16,3184	0,7	-0,00403	*
TUBİTAK-UME	16,3211	1,10	-0,00133	-0,68
LNE	-	-	-	-
INRIM II	16,3218	0,5	-0,00063	-0,45
n	3			
C	2,37688E-07			
$\bar{x}_w$	16,32243			
u_{int}	0,00049			
u_{ext}	0,00056			
R_B	1,152695421	R_B/R_{BCrit}		
R_{BCrit}	1,732050808	**0,666**		

Excluded from the SCRV

*	*En*
INRIM I	-2,36
MIKES	-1,14

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	$x_i-\bar{x}_w$, mm	*En*
MIKES	16,3208	1,0	-0,00163	-0,73

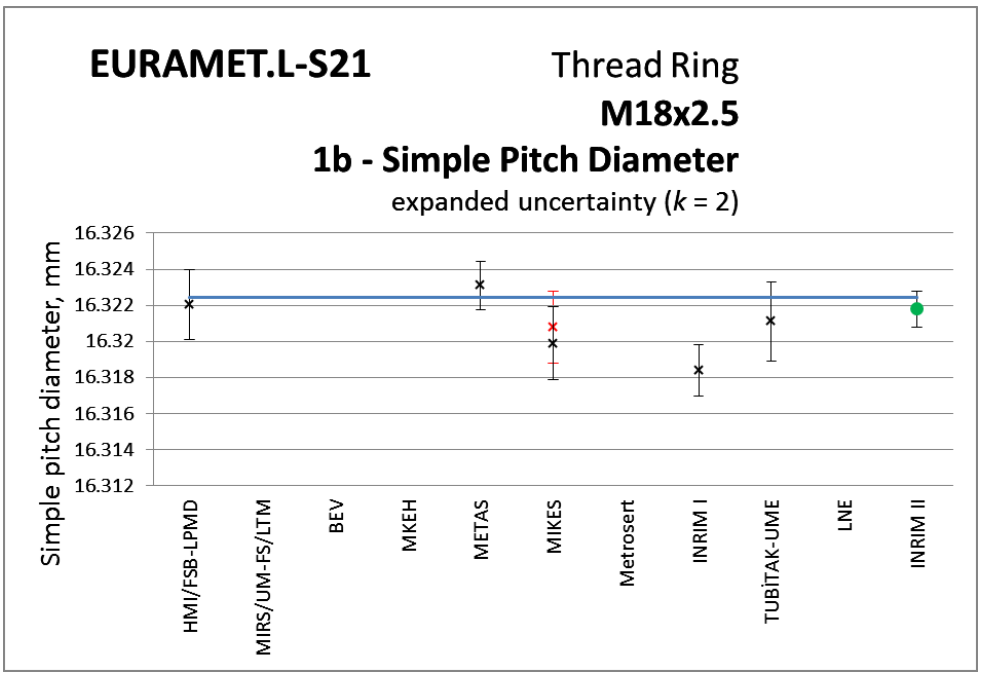


Figure 9-23 – Measurement results of simple pitch diameter (1b)

Table 9-24 – Measurement results of pitch diameter (2a)

Participants	2a - Pitch diameter, D_2			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	16,32189	1,14	0,00014	0,07
MIRS/UM-FS/LTM	16,3209	1,52	-0,00085	-0,29
BEV	-	-	-	-
MKEH	16,3201	1,35	-0,00165	-0,65
METAS	16,3229	0,80	0,00115	0,85
MIKES	16,3199	1,0	-0,00185	*
Metrosert	16,32188	0,89	0,00013	0,08
INRIM I	-	-	-	-
TUBİTAK-UME	16,3208	1,10	-0,00095	-0,47
LNE	-	-	-	-
INRIM II	16,3226	1,1	0,00085	0,36
n	6			
C	1,85103E-07			
$\bar{x}_w$	16,32175			
u_{int}	0,00043			
u_{ext}	0,00042			
R_B	0,964905698	R_B/R_{BCrit}		
R_{BCrit}	1,504962147	**0,641**		

Excluded from the SCRV

*	*En*
MIKES	-0,85

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	$x_i-\bar{x}_w$, mm	*En*
MIKES	16,3208	1,0	-0,00095	-0,44

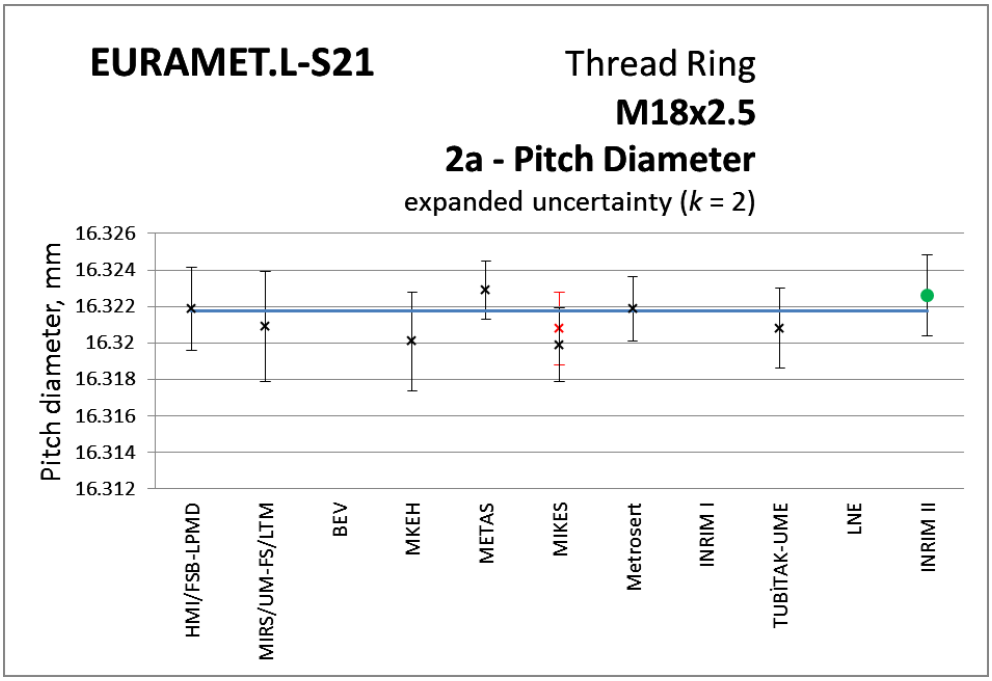


Figure 9-24 – Measurement results of pitch diameter (2a)

Table 9-25 – Measurement results of pitch diameter (2b)

Participants	2b - Pitch diameter, D_2			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	16,32234	1,08	-0,00024	-0,13
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	-	-	-	-
METAS	16,3234	0,70	0,00082	0,87
MIKES	16,3200	0,81	-0,00258	*
Metrosert	-	-	-	-
INRIM I	16,3190	1,0	-0,00358	*
TUBİTAK-UME	16,3208	1,10	-0,00178	-0,92
LNE	-	-	-	-
INRIM II	16,3224	0,8	-0,00018	-0,09

n	3
C	2,68485E-07
$\bar{x}_w$	16,32258
u_{int}	0,00052
u_{ext}	0,00074
R_B	1,421291133
R_{BCrit}	1,732050808

R_B/R_{BCrit} **0,821**

Excluded from the SCRV

*	*En*
INRIM I	-1,59
MIKES	-1,34

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	$x_i-\bar{x}_w$, mm	*En*
MIKES	16,3209	0,81	-0,00168	-0,87

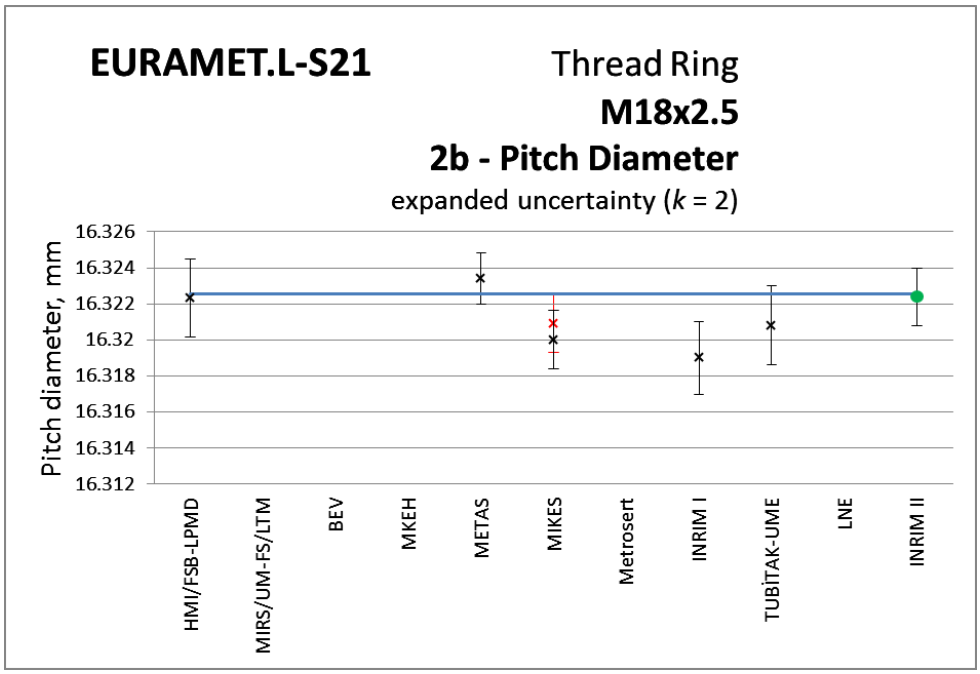


Figure 9-25 – Measurement results of pitch diameter (2b)

Table 9-26 – Measurement results of thread pitch

Participants	Thread pitch, *P*			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	2,49965	0,58	-0,00009	-0,08
MIRS/UM-FS/LTM	2,4996	0,4	-0,00014	-0,18
BEV	-	-	-	-
MKEH	2,4990	1	-0,00074	-0,37
METAS	2,49964	0,25	-0,00010	-0,23
MIKES	2,4999	0,25	0,00016	0,38
Metrosert	2,49994	0,3	0,00020	0,37
INRIM I	2,4993	0,6	-0,00044	-0,37
TUBİTAK-UME	2,4997	0,5	-0,00004	-0,04
LNE	-	-	-	-
INRIM II	2,4993	0,6	-0,00044	-0,36
n	8			
C	1,66357E-08			
$\bar{x}_w$	2,49974			
u_{int}	0,00013			
u_{ext}	0,00007			
R_B	0,567234817	R_B/R_{BCrit}		
R_{BCrit}	1,438417522	**0,394**		

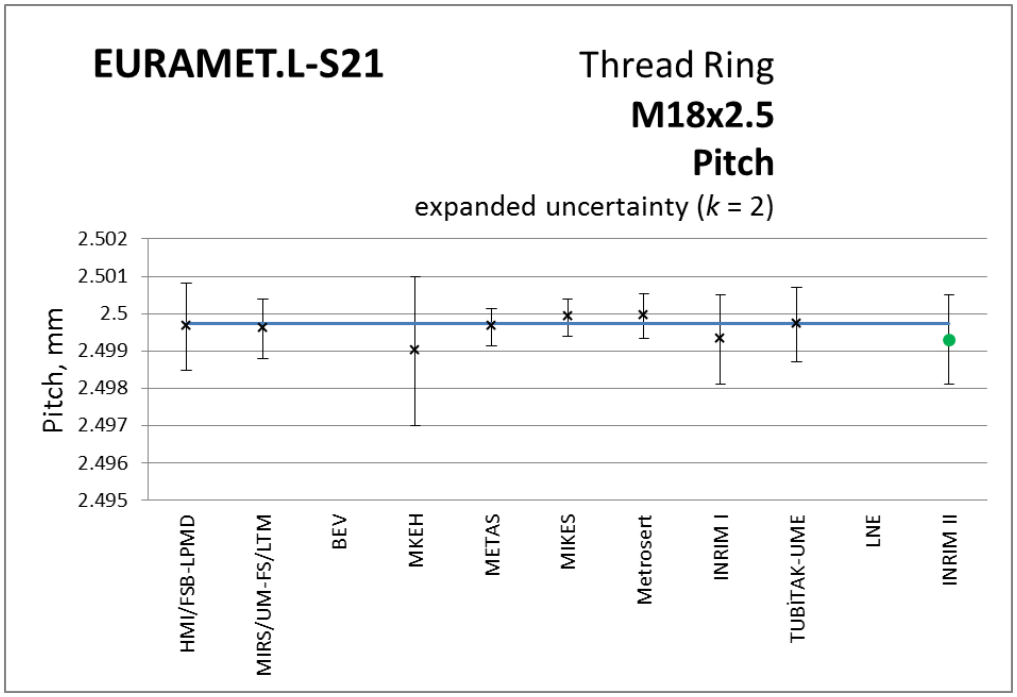


Figure 9-26 – Measurement results of thread pitch

Table 9-27 – Measurement results of thread angle – arithmetic mean for the calculation of the SCRV

Participants	Thread angle, α			
	measured value, °	uncertainty (k=1), °	x_i-$\bar{x}$,°	*En*
HMI/FSB-LPMD	60,17	0,14	0,08013	0,37
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	-	-	-	-
METAS	60,15	0,06	0,06498	0,52
MIKES	60,02	0,03	-0,06482	-0,65
Metrosert	-	-	-	-
INRIM I	59,94	0,02		*
TUBİTAK-UME	60,00	0,10	-0,08029	-0,47
LNE	-	-	-	-
INRIM II	59,94	0,02	-0,14790	-1,51
n	4		Excluded from the SCRV	
C	0,000535332	$\bar{x}_w$		**En**
$\bar{x}$	60,09	60,04	**INRIM I**	-1,51
$u(\bar{x})$	0,04602			
u_{ext}	0,02938			
R_B	1,269904282	R_B/R_{BCrit}		
R_{BCrit}	1,622650043	**0,783**		

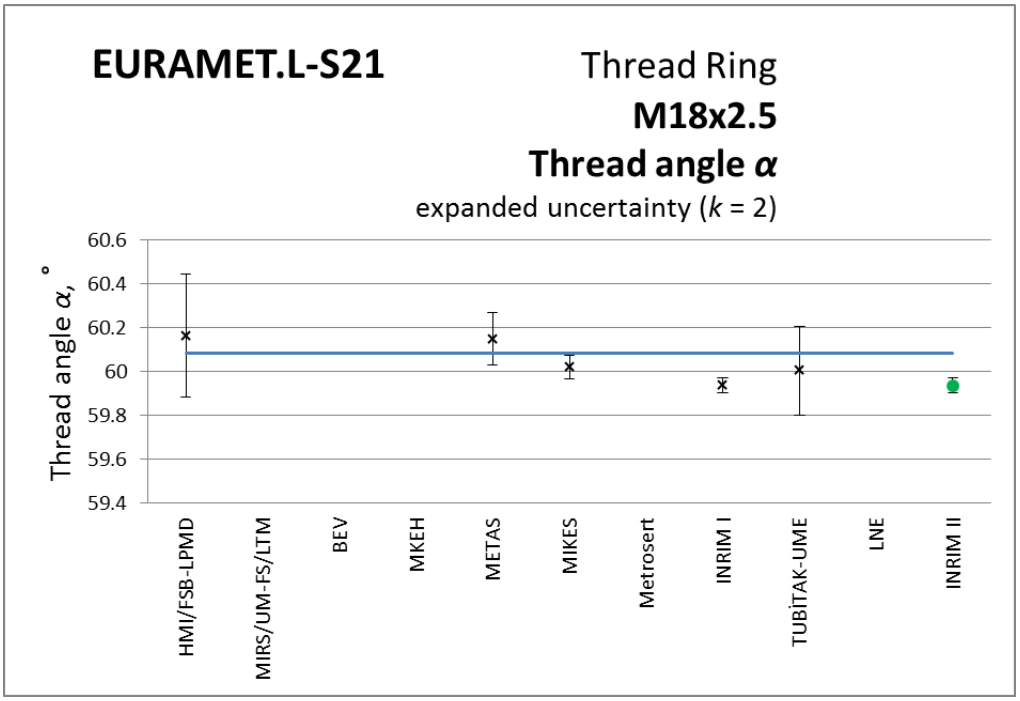
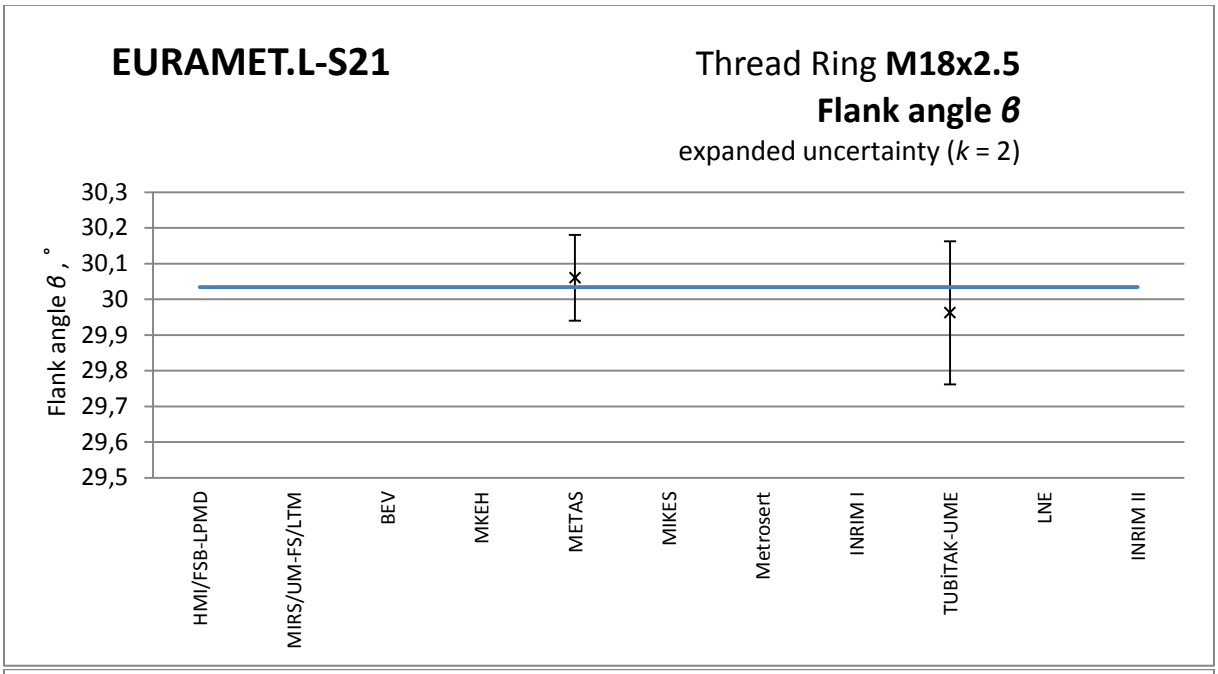


Figure 9-27 – Measurement results of thread angle

Table 9-28– Measurement results of flank angles

Participants	Flank angle, β		Flank angle, γ	
	measured value, °	uncertainty (k=1), °	measured value, °	uncertainty (k=1), °
METAS	30,06	0,06	30,09	0,06
TUBİTAK-UME	29,96	0,10	30,04	0,10
	n	2	*n*	2
	C	0,002650799	*C*	0,002650799
	$\bar{x}_w$	30,03	$\bar{x}_w$	30,08
	$\bar{\bar{x}}$	**30,01**	$\bar{\bar{x}}$	**30,07**



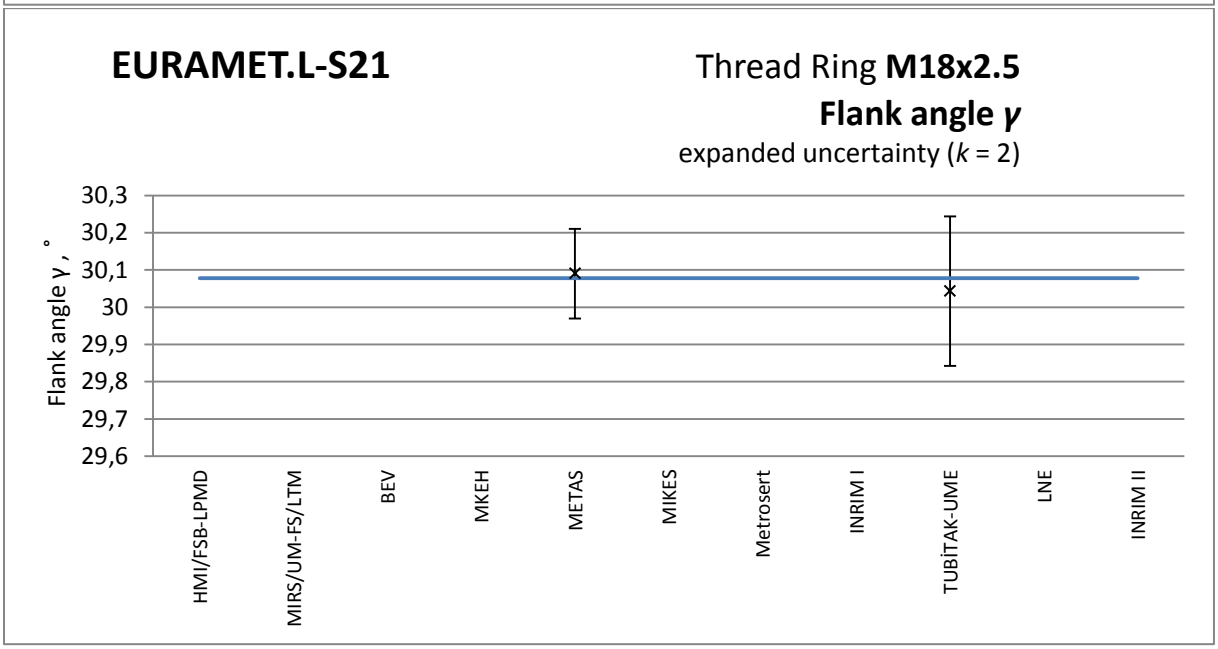


Figure 9-28 – Measurement results of flank angles

9.5 *Thread ring M30x1.5* - BEI 234

Table 9-29 – Measurement results of simple pitch diameter (1a)

Participants	1a - Simple pitch diameter, $D_{2\,Simple}$		$x_i-\bar{x}_w$, mm	*En*
	measured value, mm	uncertainty (k=1), µm		
HMI/FSB-LPMD	28,98441	0,90	-0,00205	-1,24
MIRS/UM-FS/LTM	28,9866	1,47	0,00014	0,05
BEV	28,9834	2,4	-0,00306	-0,64
MKEH	28,9856	1,80	-0,00086	-0,24
METAS	28,9874	0,80	0,00094	0,65
MIKES	28,9848	1,0	-0,00166	*
Metrosert	28,98609	0,77	-0,00037	-0,27
INRIM I	-	-	-	-
TUBİTAK-UME	28,9861	1,10	-0,00036	-0,17
LNE	28,9878	0,7	0,00134	1,10
INRIM II	28,9840	1,1	-0,00246	-1,07
n	8			
C	1,2054E-07			
$\bar{x}_w$	28,98646			
u_{int}	0,00035			
u_{ext}	0,00046			
R_B	1,33279061	R_B/R_{BCrit}		
R_{BCrit}	1,438417522	**0,927**		

Excluded from the SCRV

*	*En*
MIKES	-0,79

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	$x_i-\bar{x}_w$, mm	*En*
MIKES	28,9848	1,0	-0,0016	-0,74

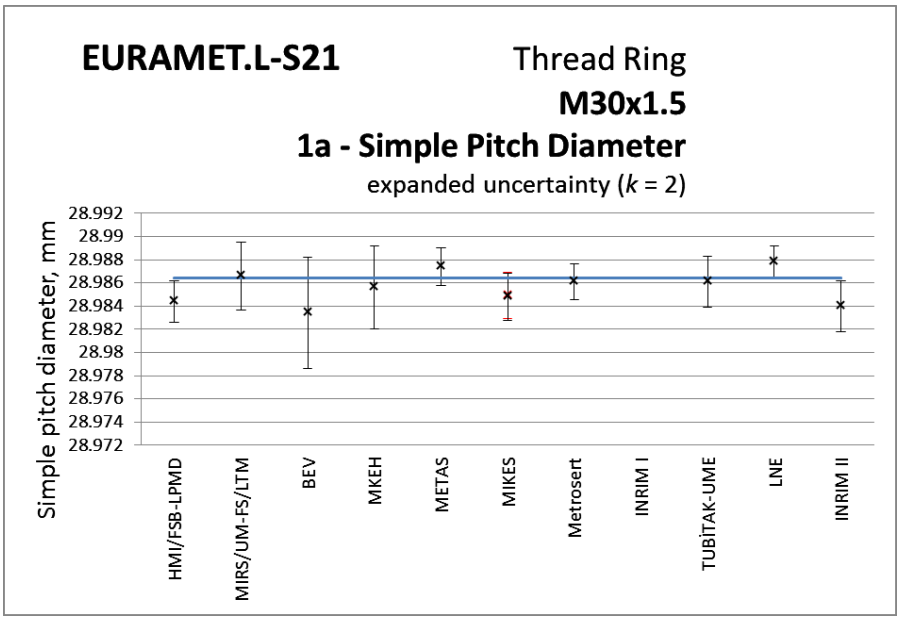


Figure 9-29 – Measurement results of simple pitch diameter (1a)

Table 9-30 – Measurement results of simple pitch diameter (1b)

Participants	1b - Simple pitch diameter, $D_{2\,Simple}$			
	measured value, mm	uncertainty (k=1), µm	x_i-$\bar{x}_w$,mm	*En*
HMI/FSB-LPMD	28,98429	0,89	-0,00153	-1,06
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	-	-	-	-
METAS	28,9868	0,80	0,00098	0,81
MIKES	28,9848	1,0	-0,00102	*
Metrosert	-	-	-	-
INRIM I	28,9741	1,1	-0,01172	*
TUBİTAK-UME	28,9863	1,10	0,00048	0,25
LNE	-	-	-	-
INRIM II	28,9839	1,1	-0,00192	-0,79

n	3		
C	2,73867E-07		
$\bar{x}_w$	28,98582		
u_{int}	0,00052		
u_{ext}	0,00080		
R_B	1,524195409	R_B/R_{BCrit}	
R_{BCrit}	1,732050808	**0,880**	

Excluded from the SCRV

*	*En*
INRIM I	-4,81
MIKES	-0,45

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	x_i-$\bar{x}_w$,mm	*En*
MIKES	28,9850	1,0	-0,00082	-0,36

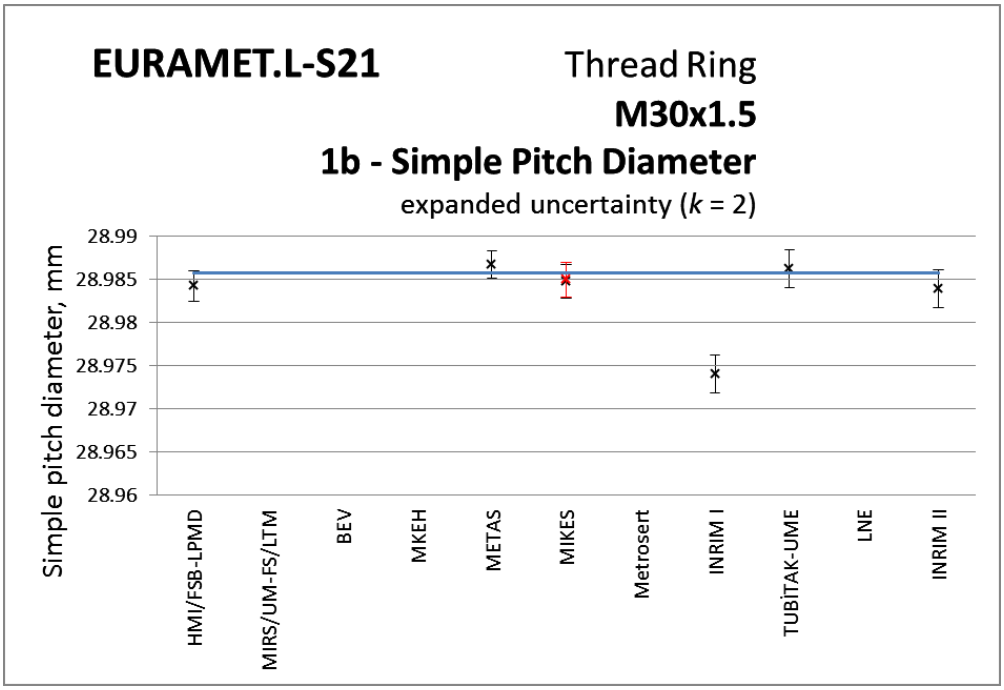


Figure 9-30 – Measurement results of simple pitch diameter (1b)

Table 9-31 – Measurement results of pitch diameter (2a)

Participants	2a - Pitch diameter, D_2			
	measured value, mm	uncertainty (k=1), µm	x_i-$\bar{x}_w$,mm	*En*
HMI/FSB-LPMD	28,98467	1,03	-0,00169	-0,90
MIRS/UM-FS/LTM	28,9869	1,52	0,00054	0,18
BEV	-	-	-	-
MKEH	28,9861	1,30	-0,00026	-0,11
METAS	28,9874	0,82	0,00104	0,73
MIKES	28,9846	1,0	-0,00176	*
Metrosert	28,98666	0,81	0,00030	0,21
INRIM I	-	-	-	-
TUBİTAK-UME	28,9858	1,10	-0,00056	-0,28
LNE	-	-	-	-
INRIM II	28,9840	1,2	-0,00236	-0,93
n	6			
C	1,72267E-07			
$\bar{x}_w$	28,98636			
u_{int}	0,00042			
u_{ext}	0,00041			
R_B	0,986218926	R_B/R_{BCrit}		
R_{BCrit}	1,504962147	**0,655**		

Excluded from the SCRV

*	*En*
MIKES	-0,82

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	x_i-$\bar{x}_w$,mm	*En*
MIKES	28,9847	1,0	-0,00166	-0,77

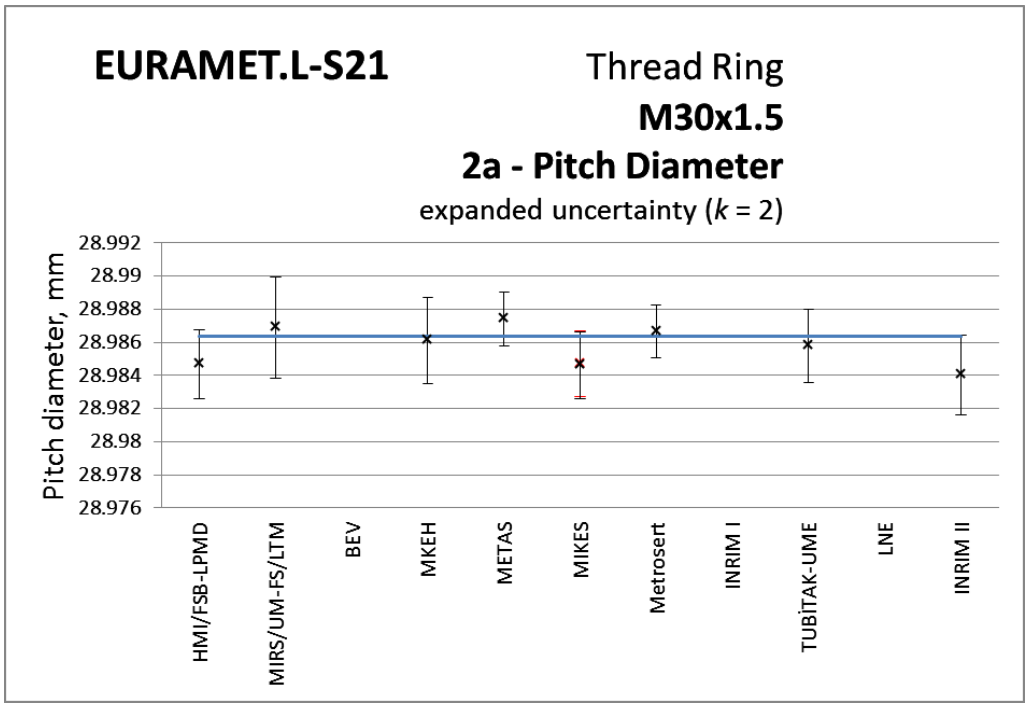


Figure 9-31 – Measurement results of pitch diameter (2a)

Table 9-32 – Measurement results of pitch diameter (2b)

Participants	2b - Pitch diameter, D_2			
	measured value, mm	uncertainty (k=1), µm	x_i-$\bar{x}_w$,mm	*En*
HMI/FSB-LPMD	28,98455	1,02	-0,00149	-0,87
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	-	-	-	-
METAS	28,9870	0,81	0,00096	0,81
MIKES	28,9847	0,80	-0,001339	*
Metrosert	-	-	-	-
INRIM I	28,9742	1,2	-0,011839	*
TUBİTAK-UME	28,9860	1,10	-0,00004	-0,02
LNE	-	-	-	-
INRIM II	28,9839	1,2	-0,00214	-0,81

n	3
C	3,01953E-07
$\bar{x}_w$	28,98604
u_{int}	0,00055
u_{ext}	0,00073
R_B	1,330390137
R_{BCrit}	1,732050808

R_B/R_{BCrit}
0,768

Excluded from the SCRV

*	*En*
INRIM I	-4,49
MIKES	-0,69

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	x_i-$\bar{x}_w$,mm	*En*
MIKES	28,9848	0,80	-0,00124	-0,64

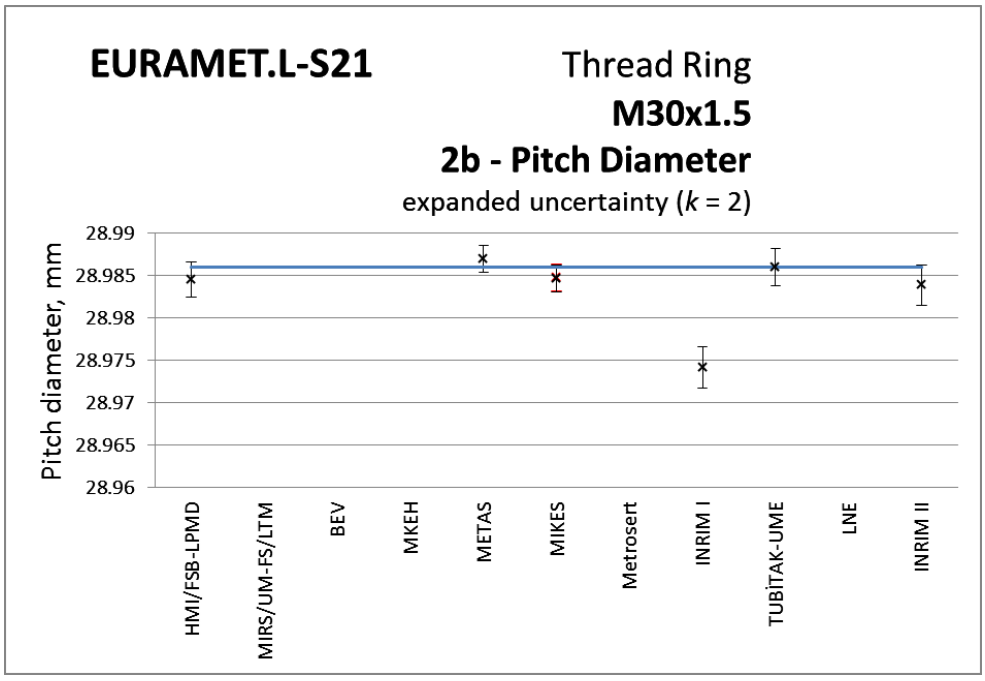


Figure 9-32 – Measurement results of pitch diameter (2b)

Table 9-33 – Measurement results of thread pitch

Participants	Thread pitch, *P*			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	1,49970	0,58	-0,00014	-0,12
MIRS/UM-FS/LTM	1,5003	0,4	0,00046	0,61
BEV	-	-	-	-
MKEH	1,4995	1	-0,00034	-0,17
METAS	1,49970	0,25	-0,00014	-0,33
MIKES	1,5002	0,25	0,00036	0,84
Metrosert	1,49934	0,30	-0,00050	-0,92
INRIM I	1,5000	0,60	0,00016	0,14
TUBİTAK-UME	1,4997	0,5	-0,00014	-0,14
LNE	-	-	-	-
INRIM II	1,5000	0,6	0,00016	0,13
n	8			
C	1,66357E-08			
$\bar{x}_w$	1,49984			
u_{int}	0,00013			
u_{ext}	0,00013			
R_B	0,986395713	R_B/R_{BCrit}		
R_{BCrit}	1,438417522	**0,686**		

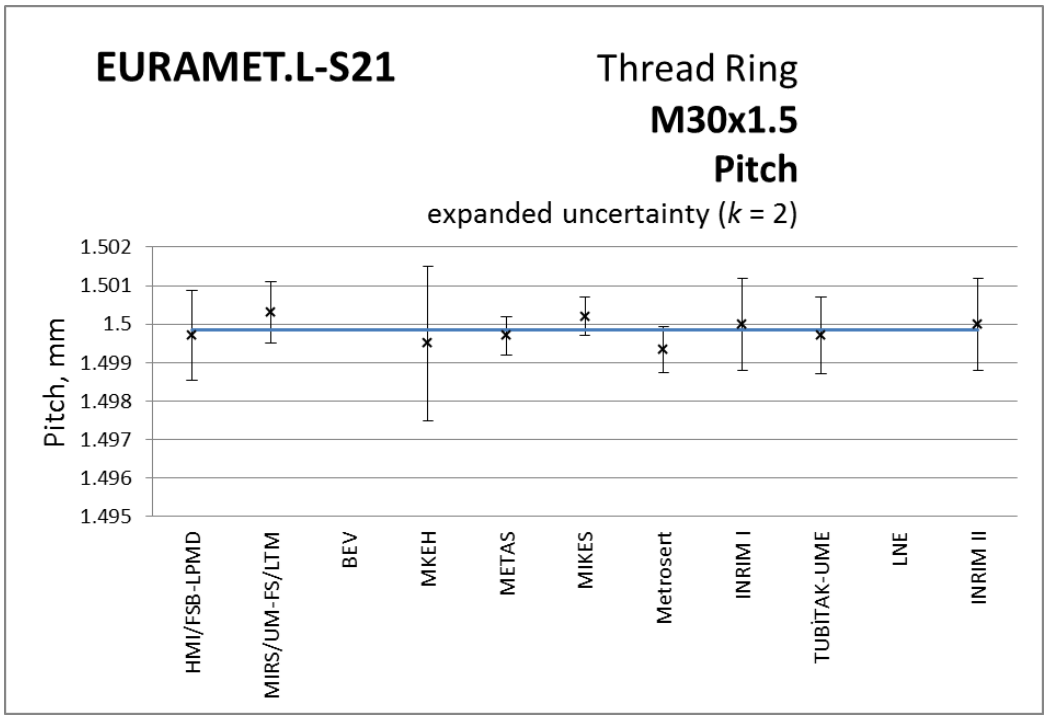


Figure 9-33 – Measurement results of thread pitch

Table 9-34 – Measurement results of thread angle – arithmetic mean for the calculation of the SCRV

Participants	Thread angle, α			
	measured value, °	uncertainty (k=1), °	$x_i-\bar{x}$, °	*En*
HMI/FSB-LPMD	60,14	0,14	0,17332	0,81
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	-	-	-	-
METAS	59,99	0,08	0,02332	0,16
MIKES	59,82	0,05	-0,14416	-1,27
Metrosert	-	-	-	-
INRIM I	59,91	0,02	-0,05248	-0,59
TUBİTAK-UME	59,73	0,10	-0,24041	*
LNE	-	-	-	-
INRIM II	59,91	0,02	-0,05248	-0,57

n	4			
C	0,00025304	$\bar{x}_w$	Excluded from the SCRV	
$\bar{x}$	59,97	59,91	*	**En**
$u(\bar{x})$	0,04259		**TUBİTAK-UME**	-1,10
u_{ext}	0,02343			
R_B	1,472850639	R_B/R_{BCrit}		
R_{BCrit}	1,622650043	**0,908**		

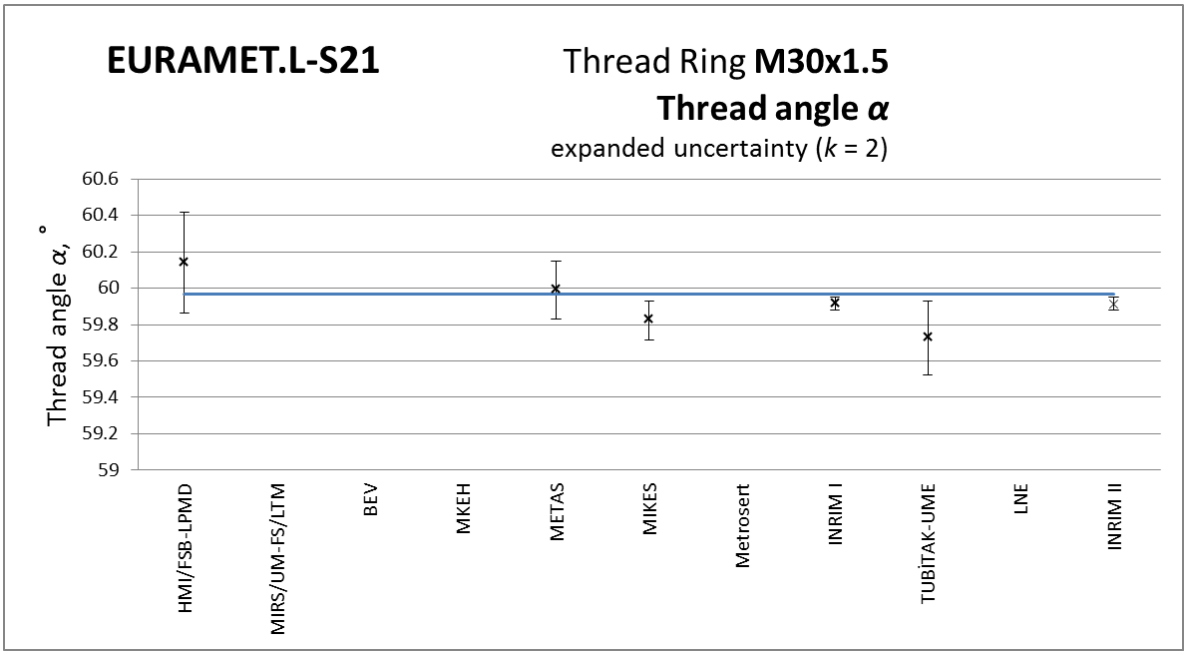
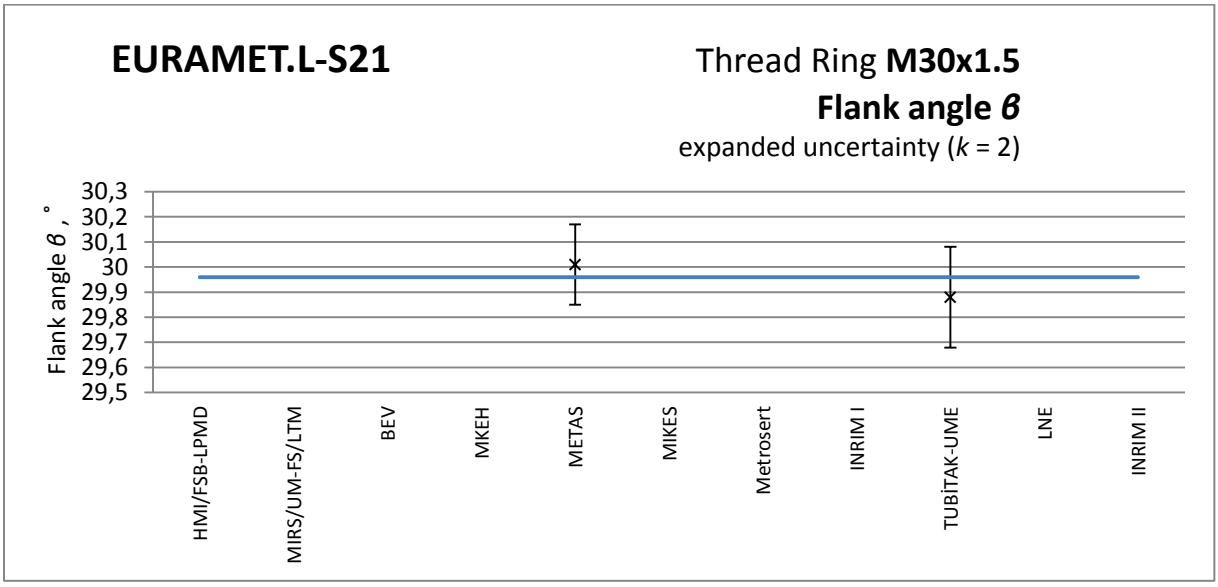


Figure 9-34 – Measurement results of thread angle

Table 9-35 - Measurement results of flank angles

Participants	Flank angle, β		Flank angle, γ	
	measured value, °	uncertainty (k=1), °	measured value, °	uncertainty (k=1), °
METAS	30,01	0,08	29,98	0,08
TUBİTAK-UME	29,88	0,10	29,85	0,10
	n	2	n	0,52092
	C	0,003910574	C	0,003910574
	$\bar{x}_w$	29,96	$\bar{x}_w$	29,93
	$\bar{x}$	**29,94**	$\bar{x}$	**29,91**



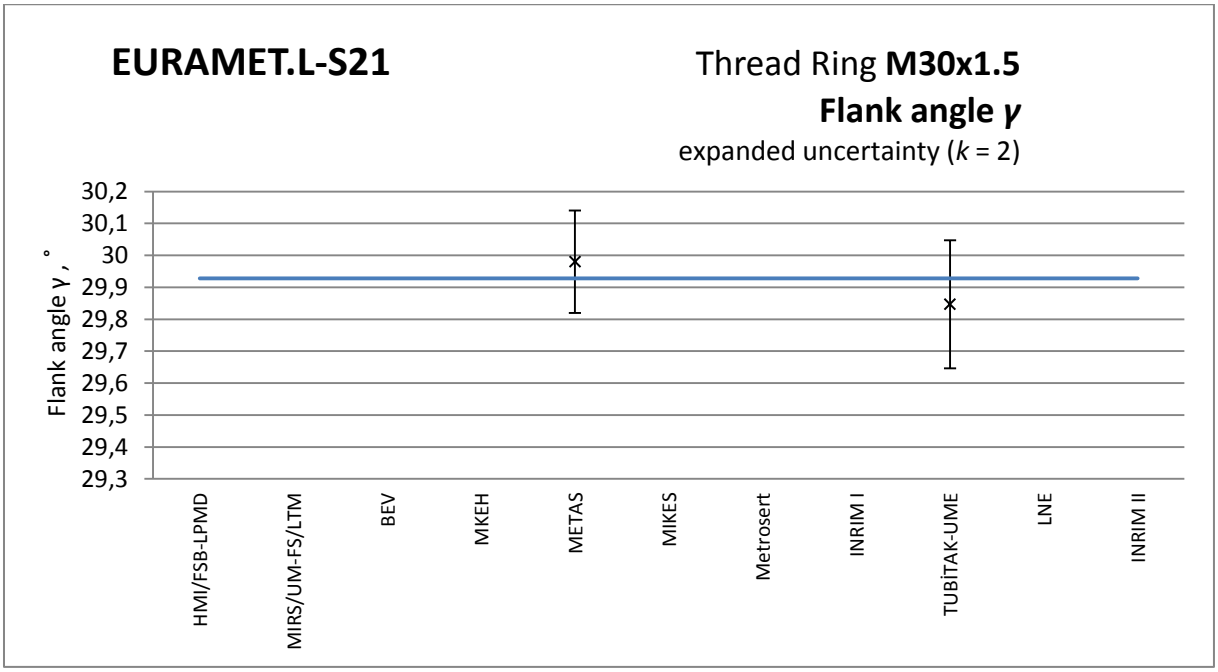


Figure 9-35 – Measurement results of flank angles

9.6 Thread ring M42x4.5 - BDP 105

Table 9-36 - Measurement results of simple pitch diameter (1a)

Participants	1a - Simple pitch diameter, $D_{2\ Simple}$			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	39,00237	0,91	-0,00070	-0,42
MIRS/UM-FS/LTM	39,0025	1,47	-0,00057	-0,20
BEV	39,0017	2,1	-0,00137	-0,33
MKEH	39,0037	1,95	0,00063	0,16
METAS	39,0041	0,70	0,00103	0,86
MIKES	39,0006	1,0	-0,00247	*
Metrosert	39,00198	0,94	-0,00109	-0,63
INRIM I	-	-	-	-
TUBİTAK-UME	39,0018	1,10	-0,00127	-0,61
LNE	39,0040	0,8	0,00093	0,65
INRIM II	39,0040	0,9	0,00093	0,48
n	8			
C	1,29507E-07			
$\bar{x}_w$	39,00307			
u_{int}	0,00036			
u_{ext}	0,00037			
R_B	1,032756674	R_B/R_{BCrit}		
R_{BCrit}	1,438417522	**0,718**		

Excluded from the SCRV

*	*En*
MIKES	-1,16

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	$x_i-\bar{x}_w$, mm	*En*
MIKES	39,0018	1,0	-0,00127	-0,60

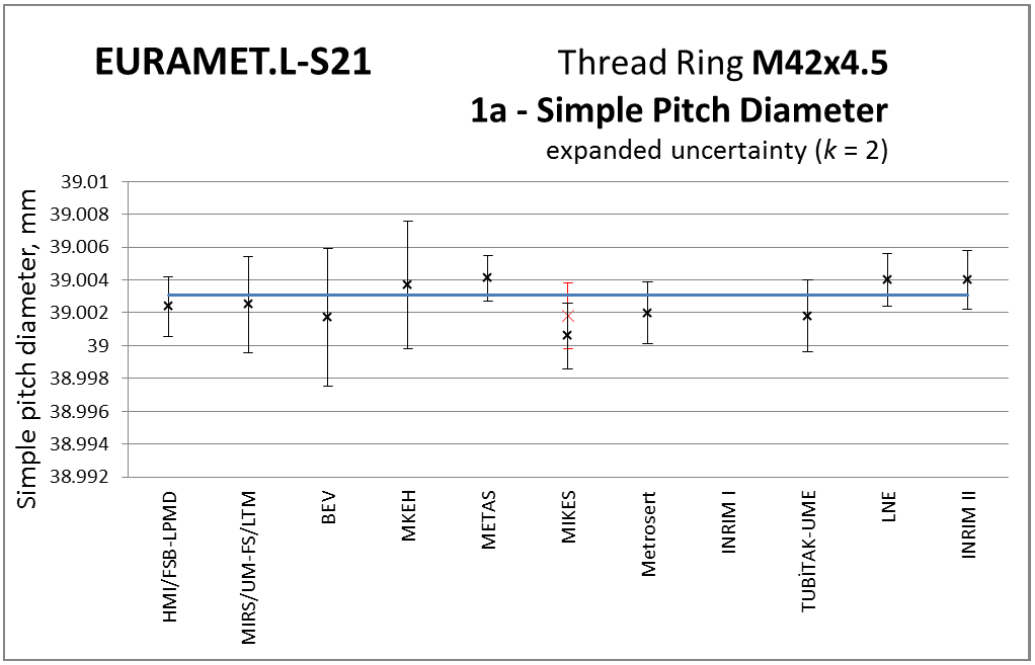


Figure 9-36 – Measurement results of simple pitch diameter (1a)

Table 9-37 – Measurement results of simple pitch diameter (1b)

Participants	1b - Simple pitch diameter, $D_{2\,Simple}$		$x_i-\bar{x}_w$, mm	*En*
	measured value, mm	uncertainty (k=1), µm		
HMI/FSB-LPMD	39,00267	0,91	-0,00027	-0,17
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	-	-	-	-
METAS	39,0041	0,70	0,00116	1,02
MIKES	39,0005	1,0	-0,00244	*
Metrosert	-	-	-	-
INRIM I	39,0024	0,7	-0,00054	-0,47
TUBİTAK-UME	39,0018	1,10	-0,00114	-0,56
LNE	-	-	-	-
INRIM II	39,0038	0,5	0,00086	0,67
n	4			
C	1,63515E-07			
$\bar{x}_w$	39,00294			
u_{int}	0,00040			
u_{ext}	0,00050			
R_B	1,225194618	R_B/R_{BCrit}		
R_{BCrit}	1,622650043	**0,755**		

Excluded from the SCRV

*	*En*
MIKES	-1,13

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	$x_i-\bar{x}_w$, mm	*En*
MIKES	39,0017	1,0	-0,00124	-0,57

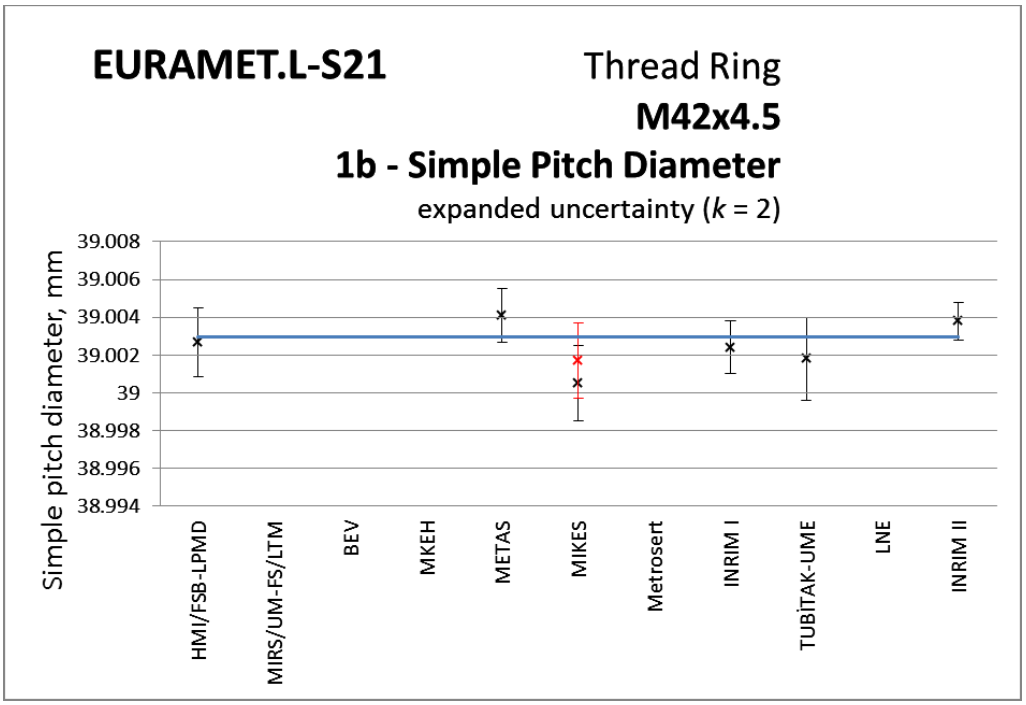


Figure 9-37 – Measurement results of simple pitch diameter (1b)

Table 9-38 – Measurement results of pitch diameter (2a)

Participants	2a - Pitch diameter, D_2			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	39,00259	1,04	-0,00046	-0,24
MIRS/UM-FS/LTM	39,0029	1,52	-0,00015	-0,05
BEV	-	-	-	-
MKEH	39,0028	1,41	-0,00025	-0,09
METAS	39,0048	0,74	0,00175	1,44
MIKES	39,0006	1,0	-0,00245	*
Metrosert	39,00162	0,97	-0,00143	-0,82
INRIM I	-	-	-	-
TUBİTAK-UME	39,0018	1,10	-0,00125	-0,62
LNE	-	-	-	-
INRIM II	39,0041	1,0	0,00105	0,48
n	6			
C	1,79347E-07			
$\bar{x}_w$	39,00305			
u_{int}	0,00042			
u_{ext}	0,00058			
R_B	1,36337336	R_B/R_{BCrit}		
R_{BCrit}	1,504962147	**0,906**		

Excluded from the SCRV

*	*En*
MIKES	-1,13

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	$x_i-\bar{x}_w$, mm	*En*
MIKES	39,0018	1,0	-0,00125	-0,58

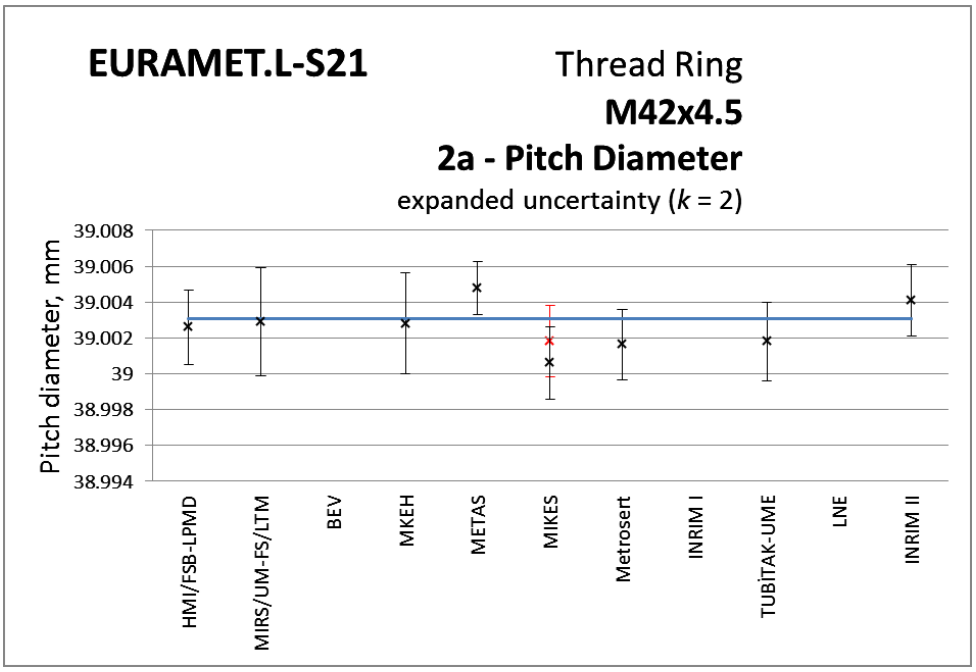


Figure 9-38 – Measurement results of pitch diameter (2a)

Table 9-39 – Measurement results of pitch diameter (2b)

Participants	2b - Pitch diameter, D_2		$x_i-\bar{x}_w$,mm	*En*
	measured value, mm	uncertainty (k=1), µm		
HMI/FSB-LPMD	39,00289	1,04	-0,00040	-0,21
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	-	-	-	-
METAS	39,0047	0,74	0,00141	1,21
MIKES	39,0005	0,94	-0,00279	*
Metrosert	-	-	-	-
INRIM I	39,0025	0,9	-0,00079	-0,51
TUBİTAK-UME	39,0018	1,10	-0,00149	-0,74
LNE	-	-	-	-
INRIM II	39,0039	0,7	0,00061	0,37

n	4	
C	2,07826E-07	
$\bar{x}_w$	39,00329	
u_{int}	0,00046	
u_{ext}	0,00067	
R_B	1,458742083	R_B/R_{BCrit}
R_{BCrit}	1,622650043	**0,899**

Excluded from the SCRV

*	**En**
MIKES	-1,34

Results of Mikes are excluded from the SCRV due to error made in measurement procedure.

Corrected results:

Participants	x_i	$u(x_i)$	$x_i-\bar{x}_w$,mm	*En*
MIKES	39,00170	0,94000	-0,00159	-0,76

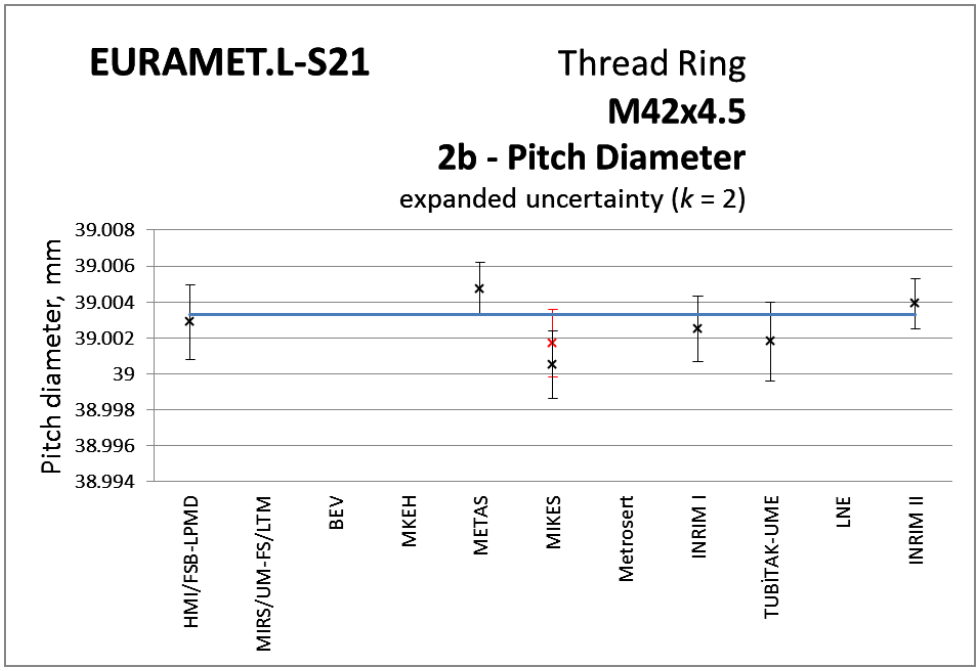


Figure 9-39 – Measurement results of pitch diameter (2b)

Table 9-40 - Measurement results of thread pitch

Participants	Thread pitch, *P*			
	measured value, mm	uncertainty (k=1), µm	$x_i-\bar{x}_w$, mm	*En*
HMI/FSB-LPMD	4,49974	0,58	-0,00021	-0,19
MIRS/UM-FS/LTM	4,5005	0,4	0,00055	0,72
BEV	-	-	-	-
MKEH	4,5010	1	0,00105	0,53
METAS	4,49916	0,28	-0,00079	-1,59
MIKES	4,5000	0,22	0,00005	0,13
Metrosert	4,50042	0,30	0,00047	0,86
INRIM I	4,4999	0,6	-0,00005	-0,04
TUBİTAK-UME	4,5000	0,5	0,00005	0,05
LNE	-	-	-	-
INRIM II	4,4999	0,6	-0,00005	-0,04
n	8			
C	1,62528E-08			
$\bar{x}_w$	4,49995			
u_{int}	0,00013			
u_{ext}	0,00018			
R_B	1,394250804	R_B/R_{BCrit}		
R_{BCrit}	1,438417522	**0,969**		

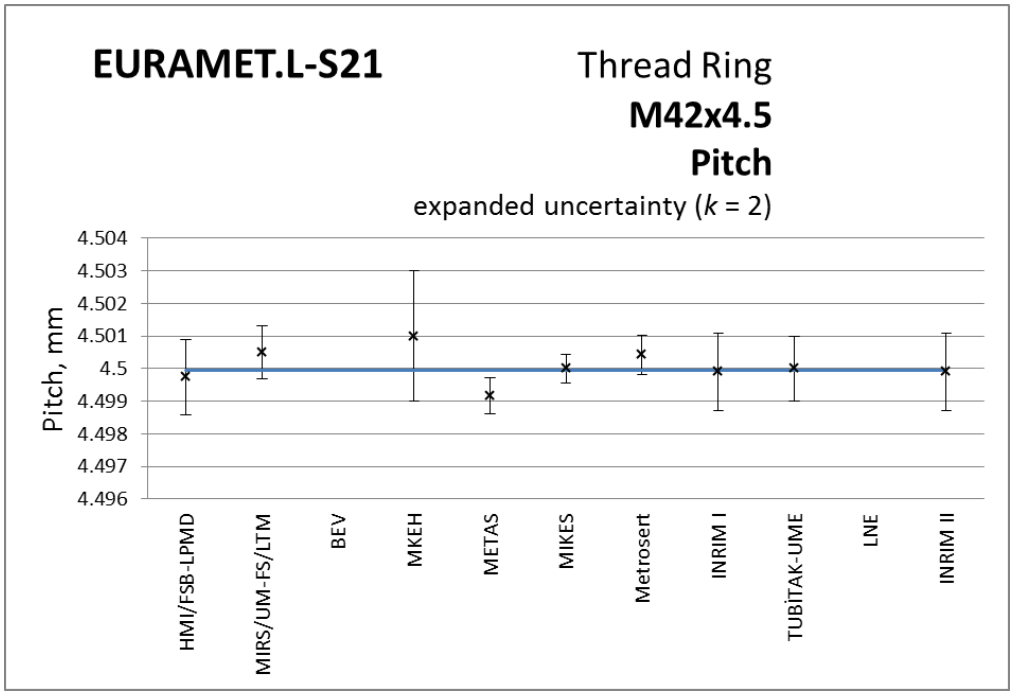


Figure 9-40 – Measurement results of thread pitch

Table 9-41 – Measurement results of thread angle – arithmetic mean for the calculation of the SCRV

Participants	Thread angle, α			
	measured value, ˚	uncertainty (k=1), ˚	$x_i-\bar{x}$,˚	*En*
HMI/FSB-LPMD	60,00	0,14	0,02104	0,09
MIRS/UM-FS/LTM	-	-	-	-
BEV	-	-	-	-
MKEH	-	-	-	-
METAS	59,97	0,08	-0,00896	-0,06
MIKES	59,97	0,07	-0,00747	-0,06
Metrosert	-	-	-	-
INRIM I	59,96	0,02	-0,01893	-0,23
TUBİTAK-UME	59,99	0,10	0,01431	0,08
LNE	-	-	-	-
INRIM II	59,95	0,02	-0,03038	-0,35
n	5			
C	0,0002562	$\bar{x}_w$		
$\bar{x}$	59,98	59,96		
$u(\bar{x})$	0,04051			
u_{ext}	0,00137			
R_B	0,230527666	R_B/R_{BCrit}		
R_{BCrit}	1,553773974	**0,148**		

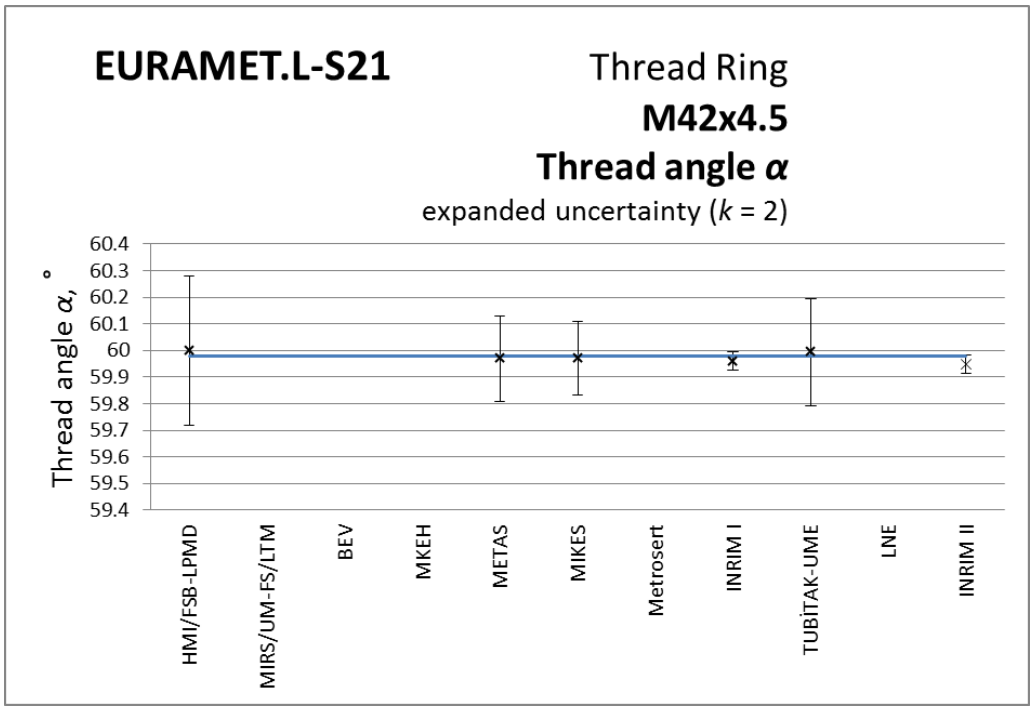
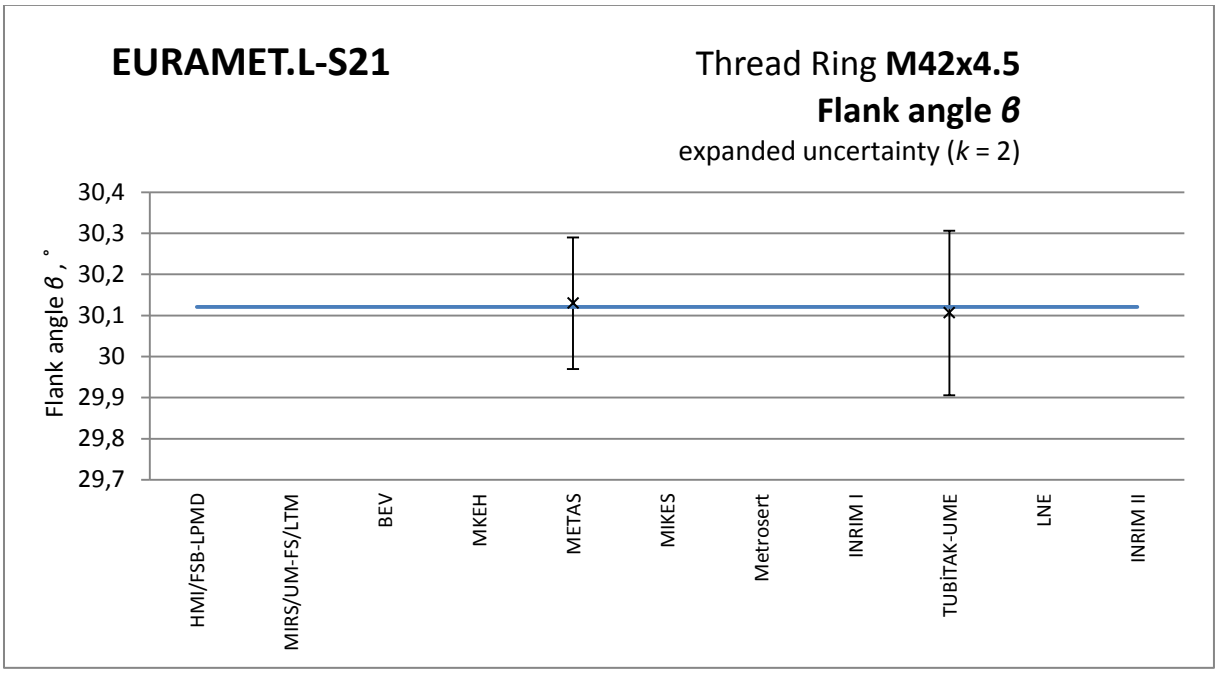


Figure 9-41 – Measurement results of thread angle

Table 9-42 Measurement results of flank angles

Participants	Flank angle, β		Flank angle, γ	
	measured value, °	uncertainty (k=1), °	measured value, °	uncertainty (k=1), °
METAS	30,13	0,08	29,84	0,08
TUBİTAK-UME	30,11	0,10	29,89	0,10
	n	2	n	2
	C	0,003910574	C	0,003910574
	$\bar{x}_w$	30,12	$\bar{x}_w$	29,86
	$\bar{\bar{x}}$	**30,12**	$\bar{\bar{x}}$	**29,86**



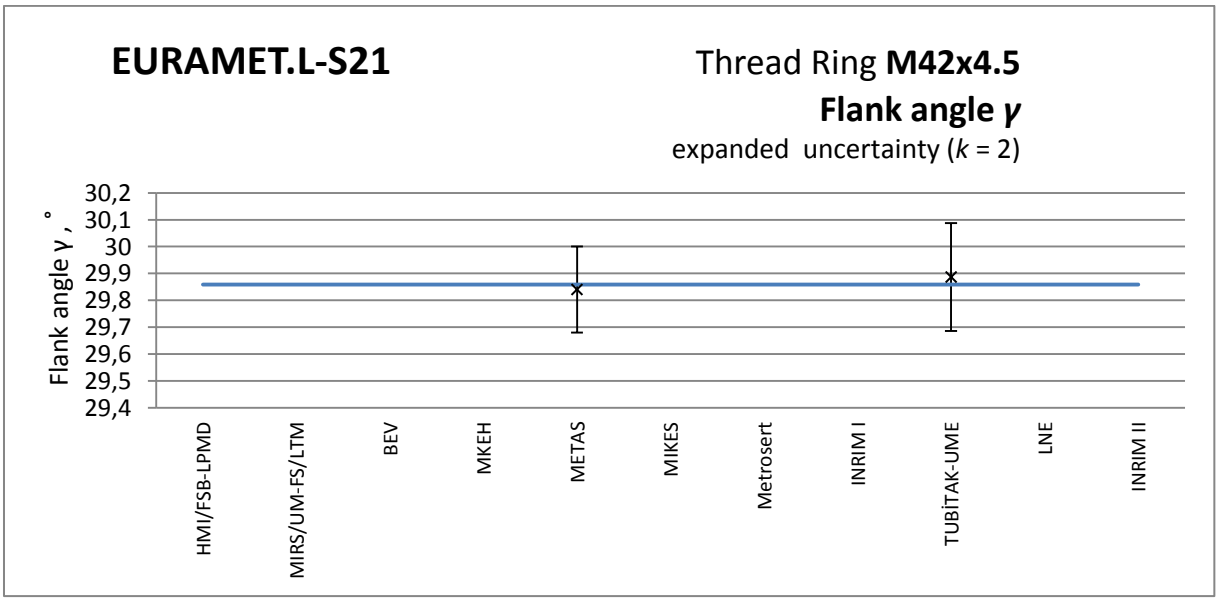


Figure 9-42 - Measurement results of flank angles

10 CONCLUSION

The goal of this comparison was to preform and compare measurement results of Pitch Diameter and Simple Pitch Diameter of parallel thread gauges within calibration categories according to EURAMET-cg10 calibration guide (*1a*, *2a*, *1b* and *2b*). From the very beginning of the comparison Pilot encouraged all the participating laboratories to report the results for all calibration categories if possible. That caused a large number of measurement data reported, therefore, Pilot had to communicate in several occasion with the participants to ensure that all the results are reported correctly (in respect to calibration category).

After all participants have reported their results INRIM requested to preform another set of measurements with the new equipment they acquired in the meantime. As INRIM reported two sets of results, comparison reference value was calculated only with the first set. Furthermore, MIKES has reported that results for the diameter of thread rings M42 and M18 are anomalous and that problem was detected by the difference of the reported results and results on the automatic report printed out by QM-Thread software. Since this mistake is related with measurement procedure and affects the results of pitch diameter for all thread rings, results of MIKES for all thread rings (M30, M42 and M18) were not used in the calculation of SCRV.

The measurement results were evaluated by Birge test and statistical consistency was checked by the normalized deviation (*En* value) calculated for each NMI. SCRV was calculated as a weighted mean except for the thread angle where reference value was calculated as arithmetic mean due to the large contribution of INRIM results to the SCRV.

The consistency of the results checked by Birge test was satisfactory – at most one laboratory had to be excluded to obtain the consistent set, except for the thread angle of plug M6 x 1 where results of three out of six laboratories were excluded.

Only 13% of all results had the equivalence degrees values $|En| > 1$. In addition, 29% of those results had the equivalence degrees values slightly larger than 1 and did not exceed $|En| = 1.1$.

This was the first EURAMET comparison of parallel thread gauges based on EURAMET ctg-10 calibration guide. This comparison have revealed that results of Pitch Diameter as well as the Simple Pitch Diameter from the different categories (*a* and *b*) are consistent with each other. Therefore, in future comparisons of thread gauges, there is no need to make a distinction between *a* and *b* calibration categories when measuring Pitch Diameter or Simple Pitch Diameter.

11 REFERENCES

1. Calibration Guide EURAMET cg-10, Determination of Pitch Diameter of Parallel Thread Gauges by Mechanical Probing, Version 2.1 (12/2012), ISBN 978-3-942992-27-5.
2. ISO Guide for the Expression of Uncertainty in Measurement (ISO/IEC Guide 98-3:2008).