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Using the MTM calculator to determine the time norms for technological operations

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Abstract

Successful business and production in the clothing sector are based on JIT (Just in Time), QR (Quick Response), and TTM (Time to Market) strategies, in which the production process is organized as part of a team using the time-accuracy-quality model, with the main goal of reducing time (faster), increasing quality (better), and lowering costs (more valuable). The work in the technological process of sewing is determined by the kind and character of the workpiece, the type of sewing machine, the design of the workplace, and the work method. By applying the basic motions of the MTM-1 system, elaborated standard sets of hand suboperations and the RAV and ZAK method for determining machine-hand sewing times, it is possible to determine the time of technological operation. The MTM calculator tool was intended to make it simpler to identify work methods and time norms based on the MTM system. It calculates the production time for a technical sewing process

1 Introduction

Production is the core of every organization, and its efficiency, management, and planning are critical to the firm's success and profitability [1, 2].

In the technological processes of sewing clothes, work is carried out in production lines that contain a large number of workplaces where individual technological operations are performed [3, 4]. The sewing process is classified as piece production and, depending on the organization, as a closed form of workplace with set execution. To successfully organize such a manner of working for the aim of a continuous flow of materials, individual workplaces must be ergonomically designed, as well as a favorable work method with the appropriate execution time [5].

Sewing work is distinguished by its diversity and character, a large mix of manual and machine work, limited use of machines, and working in a sitting posture with an often forced posture of the spine and forward bending of the head. To conduct the sewing process correctly and accurately, the worker must have strong visual abilities, a high degree of motor skills and movement coordination, good tactile skills, and rapid responses to visual and auditory stimuli.

In the garment industry the technological process of sewing accounts for around 70% of total clothing manufacturing time, while the technological process of cutting and finishing accounts for roughly 30%.

According to research on the organization of working time during a single shift in the sewing phase, 25% of the time is spent on technological machine-hand sewing suboperations, 65% on auxiliary hand processes, and 10% on non-production activities [6–8].

When designing workplaces and work methods for the sewing process, it is critical to achieve dimensional compatibility between man-machine and the interphase transport system, as well as a correct physiological sitting posture that allows for fast and accurate motor movements when turning on

the machine and guiding the workpiece, a high degree of movement coordination, the correct position of the spine, and good head posture [9, 10].

The MTM (Motion Timestudy Measurement) system is used to analyze technological sewing operations down to the level of basic movements, and associated variables are determined based on the length of the movement, the accuracy and dynamics of execution, the required visual and muscular control, and the possibilities of coordinated work with combined and simultaneous movements [11, 12]. In the development of the working method, the working motions should be of a lower level since this allows for a shorter execution time, a uniform rhythm of work, a greater degree of movement coordination, and a lower degree of required visual control. This system may influence the work approach in terms of the needed level of motor and visual control, as well as the worker's workload [13, 14]. The study of the work process using the MTM system allows for: finding, developing, and preparing optimal work methods prior to the start of clothing production, designing production systems of clothing technologies, selecting the optimal layout of equipment and machines, training workers according to the developed and established optimal work method, and determining the degree of utilization of production capacities [15, 16].

2 Guiding principles for designing working methods in the technological sewing process

The technological sewing operation consists of a number of technological operations depending on the type, model and use of the garment. The structure of the sewing operation contains necessary support-hand suboperations: taking, putting together, positioning, suboperations during sewing breaks and laying off as well as the technological machine-hand suboperation of sewing (Fig. 1) [7, 17].

Individual suboperations in the structure of the technological operation can be carried out in several ways depending on the size and number of work pieces, degree of the technical equipment of sewing machines, size and form of the work surface, necessary work zones and visual fields as well as the level of worker training (Table 1) [17].

Table 1
Suboperations of the technological sewing operation and methods of their performing [7, 17]

Suboperations	Method of performing the suboperation
taking	taking one work piece from the bundle
	taking two work pieces from the bundle
	taking two work pieces from two bundles
	taking three work pieces from three bundles
putting together	putting together the contour edges
	putting on the marked place
positioning	positioning under the presser foot
	positioning of the work piece under the needle guided by the foot motion
	positioning the work piece in front of the needle
sewing	joint guidance
	basic guidance
	individual guidance
	guidance with puckering
	guidance of work piece using a ruler
	seam bartacking using the lever of the bartacking mechanism
	seam bartacking using the bartacking button
	programmed (automatic) seam bartacking
	thread trimming using the scissors
	thread trimming using the trimming device
	thread trimming using the automatic thread trimming mechanism
suboperation during sewing break	alignment of the contour edges
	motion around the needle
laying off	with one hand
	with both hands

Suboperation of taking includes taking the work piece from the machine work surface, and it is performed with the set of basic motions: reaching (R) – grasping (G) – moving (M) whereby the work piece is

transferred into the central work zone (SRZ).

Suboperation of putting together includes putting together two or three cutting parts. This suboperation is performed in the central work zone. It requires high precision of performing and control in the central visual field whereby motions P1SE and P2SE are used depending on the necessary degree of precision.

Suboperation of positioning consists of the simultaneous motion of moving (M), positioning under the needle (P1SE) and the foot motion for lifting and lowering the presser foot (FM).

Suboperation during sewing breaks can contain standard sets of work piece alignment and rotation under the needle. These suboperations depend on the method of performing the technological operation, the method of guiding and technical equipment of the sewing machine. They refer to sewing on universal and special machines.

Suboperation of laying off the work piece includes laying off work pieces with one hand (for small-sized work pieces) onto the auxiliary stand, and they are performed with motions of moving (M), releasing off (RL) and returning to the equilibrium position (R).

With regard to the sewing machine type used, suboperation of sewing can be machine suboperation, e.g. when sewing on the automatic sewing machine or machine-hand suboperation, e.g. when sewing on the universal or special sewing machine where the guidance of the work piece during sewing is part of the technical suboperation [7, 18].

The determination of the optimal work method with the belonging normal time consists of:

- collecting information on the technological operation whereby the most suitable sewing machine is found,
- designing the workplace and adapting to the anthropometric measurements of workers whereby, work and visual zones are determined
- breaking down the technological operation into suboperatons and motions and
- determining basic motions using the MTM system with the possibility of performing combined and simultaneous motions.

Based on these procedures the optimal work method is determined with normal belonging time for performing motions, suboperations and technological operations.

The time required for machine-hand sewing procedures is determined by the nominal stitch speed, the curve of the seam, the specific stitch density, the total length of the sewed seam, the number of segments, and the sewing machine's equipment with additional components. To determine the normal machine-hand times of the technological process of sewing straight and curved seams, mathematical models are used, which were obtained through a systematic study of the parameters of the sewing process using a

patented measuring device for measuring process parameters (MMPP), which was developed at the University of Zagreb, Faculty of Textile Technology, Department of Clothing Technology [3, 19, 20]. The mathematical models developed show that the normal times of the machine-hand sub-operations are dependent on changeable values of the process parameter [3]s:

- nominal stitch speed of the sewing machine (v_n): 1000–7000
- number of stitches in a segment (B_u): 10–300
- sewing machine correction factor (K_1): 1.00–1.15
- seam curvature radius coefficient (r_z/mm): 20–3000.

Normal times for straight seams (RAV) are determined according to expression (1), and for curved seams (ZAK) according to expression (2):

$$t_{ar} = \{B_u [0{,}227 - 0{,}025 \ln(v_n)\ ] + 0{,}334\ \} K_1 \qquad (1)$$

$$t_{ar} = \{B_u [0{,}227 - 0{,}025 \ln(v_n) + 0{,}334] \cdot K_1 [3{,}12 - 0{,}30 \ln(r_z)\ ]\ \} \qquad (2)$$

A corresponding computer program [3, 21, 22] was developed for these mathematical models, with which the normal time of the machine-hand sewing process is calculated in various time units (s, TMU, min, h).

3 Experimental part

Systematic elaborations were carried out utilizing the MTM-1 system as part of the experimental component of the study, and standard sets of hand suboperations of technological sewing processes were developed. Based on the results of the systematic investigation, the following basic concepts were created and established:

- for the suboperation of **taking**, ten types of execution were developed in relation to the size of the workpiece, the position of the bundles, the way in which the cutting layers are laid and the design of the workplaces, which are divided into four groups: taking one workpiece from one bundle, two workpieces from one bundle, two workpieces from two bundles and three workpieces from three bundles. According to the execution method for the suboperation of taking, 12 standard sets have been developed, comprising a total of 26 execution methods with corresponding normal times depending on the movement classes of reaching and moving
- the standard set of motions for the suboperation of **putting together** according to the execution method consists of three execution methods for putting together the edges with elaborated five execution methods with regard to the grip width and two methods for positioning on the marked place with three developed sets with regard to the grip width with the corresponding normal time. In putting together the motions are 4 to 7 cm long, type 1, with the accuracy of moving (MC) and

putting together being (1). This suboperation necessitates a high level of muscle control of motion and eye attention and limits the capacity to make simultaneous actions. Due to the high requirements, these standard sets of motions are classified as class II (needs worker training) and are performed in the field of acute eyesight.

- the standard set of motions for the suboperation of **positioning** consists of three execution methods with corresponding normal times. This suboperation necessitates a high level of control and coordination of motions when putting the workpiece under the presser foot while simultaneously raising the presser foot with the motion of the foot.
- standard sets of motions for the suboperation of **sewing** include the method of guiding the workpiece, seam bartacking and use of auxiliary devices thread cutting. The choice of the method of guiding the workpiece during sewing depends on the characteristics of the fabric, the contours of the cut parts, the nominal stitch speed of sewing, the specific density of the stitches and the training of the worker, whereby four ways of guiding the workpiece are distinguished. Seam bartacking is done with 3 to 5 stitches with changing the sewing direction whereby three methods are distinguished with regard to the technical equipment of the sewing machine. Four methods for execution with the corresponding normal time have been devised for sewing with the assistance of auxiliary equipment. Auxiliary devices provide for a more efficient flow of technical operations, lowering execution time, enabling a more consistent rhythm of technological operations, fewer interruptions in seam sewing, a better seam appearance, and less workload for workers. The standard set of motions for the suboperation of thread cutting is done at the end of the technological operation, depending on the technical equipment of the sewing machine, for which four execution methods with corresponding normal times were developed.
- for the standard set of motions for the suboperation **during sewing interru**ption five execution methods were developed with corresponding normal times. Suboperations during the sewing interruption require vision control towards the needle plate of the sewing machine, they interrupt the dynamism and rhythmicity of the execution of motions.
- standard set of motions for the suboperation of l**aying** off is carried out in a sitting posture with the assistance of the trunk by turning for which three execution methods with the corresponding times were developed.
- nine methods of **execution** with the corresponding normal times were developed for the standard sets of motions for accompanying suboperatios when performing technological sewing operations. Accompanying sub-operations are auxiliary sub-operations that support the execution of the sewing sub-operation. Their use depends on the type of technological process, the working method or the equipment of the sewing machine.

Furthermore, as a framework software solution to speed up the process of determining standard times and time norms for technological operations in garment manufacturing, a program named "MTM Calculator" was developed. This software was developed using the Microsoft Access® program tool and is based on the findings of a study of standard sets of motions. The word "framework" alludes to the

program's universality, which suggests several paths of possible future growth and design (technologically and in application), as well as the ability to act as a standalone program or as part of a broader industrial information system. The concept of sets of motions and elementary movements for processing and storing within relational databases had to be hierarchically and cyclically structured before this software could be created.

4 Results

Table 2 presents a detailed set of motions, for each technology suboperation used in the sewing process.

Table 2
Standard set of motions for taking two workpieces from one bundle with both hands for classes 50 and 80

Class 50/A07c50A; A07d50A					
No.	Left hand movement description	Symbol	TMU	Symbol	Right hand movement description
1.	Reach for the bundle	mR45B	14,2		
2.	taking the first workpiece	G5/G2	5,6		
3.	reach the fingers to first bundle	R4B	3,4		
4.	taking the second workpiece	G5/G2	5,6		
5.	joint lifting of both workpieces	(M10B)	7,9	mR40Am	reach the workpieces
6.			0,0	G5	grasping by touch contact
7.			7,9	mR20E	reach the hand along the edge
8.			2,0	G1A	grasp both workpieces
9.	lifting both workpieces	M10Bm	4,3	(M10Bm)	lift both workpieces
10.	moving workpieces to the central work zone	mM50B	15,4	(mM50B)	move the workpieces to the central zone
		∑TMU (s)	66,3 (2,39)		
Class 80/A07c80A; A07d80A					
No.	Left hand movement description	Symbol	TMU	Symbol	Right hand movement description
1.	reach for the bundle	mR70B	21,4		
2.	grasp the first bundle	G5/G2	5,6		
3.	reach the fingers to the second workpiece	R4B	3,4		
4.	grasp the second bundle	G5/G2	5,6		
5.	joint lifting of both workpieces	(M10B)	7,9	mR40Am	reach for the bundle
6.			0,0	G5	grasping by touch contact
8.			7,9	mR20E	reach the hand along the edge
9.			2,0	G1A	reach for both workpieces

Class 50/A07c50A; A07d50A					
10.	lift both workpiece	M10Bm	4,3	(M10Bm)	lift both workpieces
11.	move the workpieces to the central work zone	mM80B	23,7	(mM80B)	move the workpieces to the central work zone
		∑TMU (s)	81,8 (2,94)		

The program “MTM Calculator” is designed in such a way that the combination of the defined sets of hand suboperations of the MTM system and the basic movements form work methods for each technological operation, and by applying the RAV method and the ZAK method the machine-hand time of sewing operations is determined, which by addition gives normal execution time of technological sewing operations. The final result is obtained by incorporating the fatigue coefficients, environmental factors, and the additional time coefficient into the equations used to calculate the time for the product unit, also known as the time standard (measured in TMU, hours, minutes, and seconds). In the program, various technological operations can be employed to generate a series of procedures essential for manufacturing customized clothing items.

The initial section of the program's "Main menu" is labelled as "Review and adding", and it holds significant importance as it is the primary component of the program. After choosing the "Review and adding" option, a comprehensive screen form (Fig. 2) will appear, allowing you to design the work method for technological operations and provide detailed information on fundamental movements. Within the screen form, there exists a subform called "Fr_List" where it is possible to include or remove individual movements or sets of movements for specific technological sewing operations.

Since the technological operations may consist of many motion sets and basic movements, which have to be calculated on their own in accordance with parameters such as shape and type of movement, duration of motion, etc. Command buttons for adding specific elements for motion sets, individual basic movements (which do not need to be calculated separately), eye movements, and special parameters used to calculate the time of the machine-hand suboperation of sewing straight and curved seams (calculated using formulas) are found in the column on the left side of the form. Additional data, such as the workplace designation, the technological operation name, the name of the production model to which the specified technological operation is applied, the fatigue coefficient (K_n), the environmental effect coefficient (K_a), and the supplementary coefficient of additional time $(K_d)$are needed in order to design and calculate the execution time of technological operations.

Complex SQL filtering was conducted according to the partial contents of up to four characteristics (name, class, hand, and description) for an easier search and selection of an individual set of motions, as shown in Fig. 3.

It is possible to search and select individual basic movements in a similar way, Fig. 4.

When the required movement is selected, it appears in the dark grey control fields (red coloured content), the precision of the selection is confirmed, and the selection is recorded in the list of technological operations by pressing the "Entry in list" button.

Figure 5 shows a form for selecting and calculating the time required to conduct eye movements. The EF amount is fixed and equals 7.3 TMU, however the ET movement is computed using a formula and needs the actual length of the gaze shift and the distance from the eyes to be entered beforehand. The data and values for these motions can be put into the technological operation sheet by clicking the corresponding button.

Figures 6 and 7 show forms for estimating the machine-hand sewing time of a straight and curved seam using RAV and ZAK methods. The sewing time value provided by these formulas is initially in seconds, however, the numbers may be translated into TMU and placed straight into the technical worksheet.

Figure 8 shows a printed report on the contents of a single technological operation list in its basic form. It is possible to produce an expanded report that includes the movements contained in a certain set of motions. The report printout is initiated by clicking on the "Report" or "Report (movements)" buttons.

Each technological operation with advanced sets and basic motions may be archived and subsequently deleted ("Upload saved TO" button in the main menu), updated if required, and added to the list of another garment model. It is also possible to develop a whole new list or table for a technological process by clicking the "Initialize a new table" option in the main menu).

In the main menu there is also an "Edit database" button (Fig. 9), which can be used to access the editing of four key tables in the database: Motion Sets, Basic Movements, Names of Technological Operations and Names of Garment Models.

When you click the "Edit sets" button, a combined form with a subform displays. The intended elaborated set of motions is available via a combo box with a drop-down menu in the form's header. The main data of the motion set may be edited and added in the upper part of the form, while the basic movements that comprise the set can be added and edited in the sub-form.

5 Discussion

A systematic development was made and standard sets of hand suboperations of the technological sewing operation based on the basic movements of the MTM-1 system with a view to the structure of technological sewing operation having been established. By combining the standard sets of hand suboperations and calculating the time utilizing the RAV and ZAK methods, it is conceivable to get the production time for the technological sewing operation.

The software solution called "MTM Calculator" was developed using Microsoft Access®. It utilizes tables for basic motions from the MTM-1 system and incorporates standard motion sets for hand auxiliary operations in sewing processes. It is possible to calculate the duration of machine-hand suboperation of

sewing according to RAV and ZAK methods as part of the "MTM Calculator" software solution, in addition to the development of technological tasks according to the MTM method (motion sets, basic motions, or their combination) and include them in the calculation of the normal times of the entire technological operation.

Within the framework of this software solution, it is possible to calculate the time norm for the technological operation in addition to the normal duration of technological operations by calculating fatigue coefficients, environmental effects, and the supplementary coefficient of additional time.

The program is designed in such a way that a database can be created with elaborated technological operations up to the level of movement based on clothing models, and each technological operation can be called up separately, modified if necessary, and saved again in the database of technological operations. In this way, all technological activities inside a model and/or collection of clothing items with the exact work method and time norms may be systematically developed, which can have a good influence on the planning and organization of the clothing manufacturing process.

6 Conclusion

The technological process of sewing is the basic purpose of working at a designed workplace where a functional change is made to the product, with the worker and the machine working together. The sewing process is carried out facing the central field of vision, with the operator working in the front position, using his hands to guide the workpiece and his feet to regulate the sewing speed.

The RAV and ZAK methods are used for the machine-hand suboperation of sewing, while standard sets of motions are made in accordance with the technological structure of sewing, which consists of hand suboperations: taking, positioning together, positioning, suboperations during the sewing interruption, and laying off. By combining standard motion sets and calculation of normal times according to the RAV and ZAK method, it is possible to determine the time of the technological sewing process.

In order to speed up the process of designing the work method and calculating normal times and time norms of technological sewing operations, a framework software solution "MTM calculator" was created in the Microsoft Access® software tool, for which hierarchical cyclical structuring of motion sets and basic motions for processing and storing within relational databases had been previously carried out.

Declarations

S.Kirin: Collection and analysis of the study data, paper writing

D.Kralj: Analysis of the study data, software design, paper writing.

A. Hursa Šajatović: Supervising, paper writing.

Ethics approval According to the ethics committee, there was no ethical approval necessary for the here presented study. The recorded data was properly anonymized and participants cannot be identified using the here presented data.

Consent to participate All of the participants were recruited on their own will and were informed that they could stop the study session for any reason at any given time.

Consent for publication All authors give their consent for publication of the here presented work.

Conflict of interest The authors declare no competing interests.

All methods were carried out in accordance with relevant guidelines and regulations.

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Figures

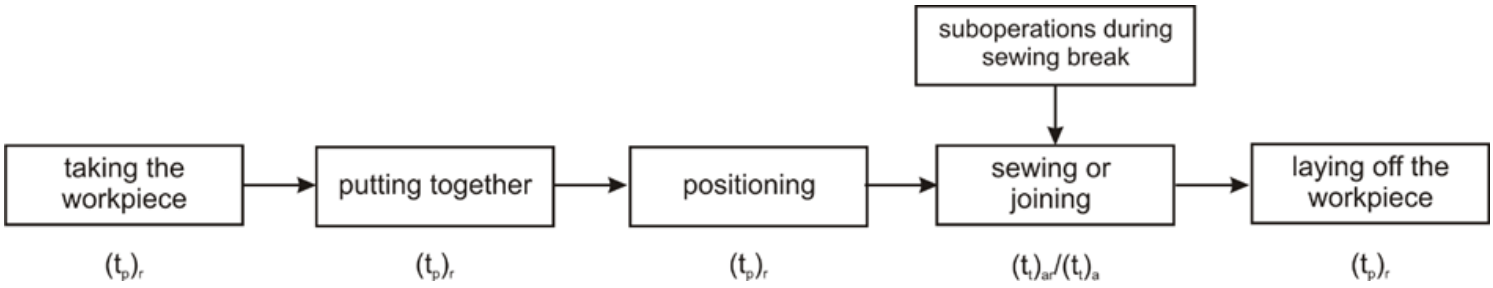

Figure 1

Classification of the technological sewing operation into suboperations [7, 17]

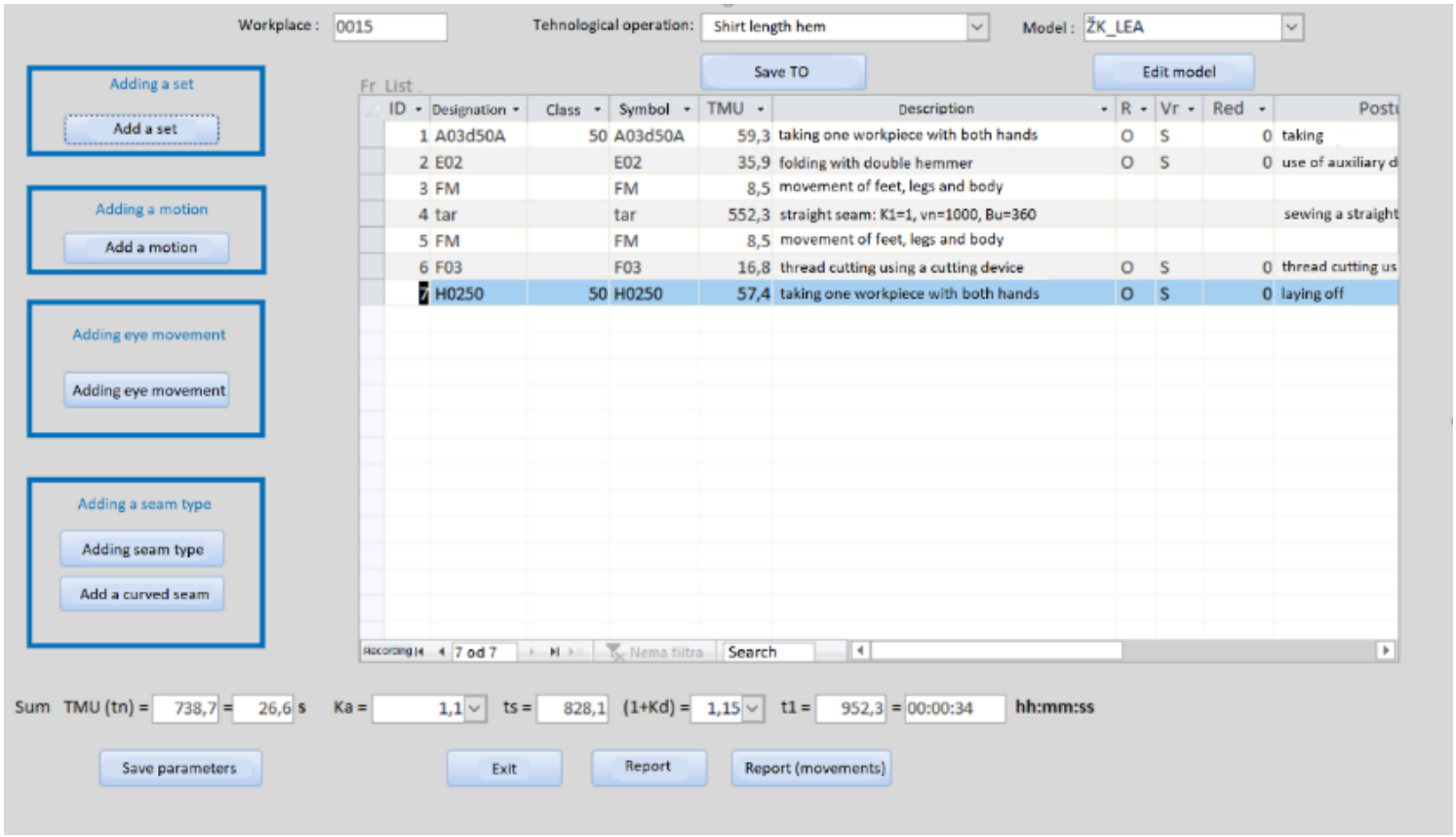

Figure 2

Form designed for inputting sets of motions and fundamental movements required for technological sewing operations

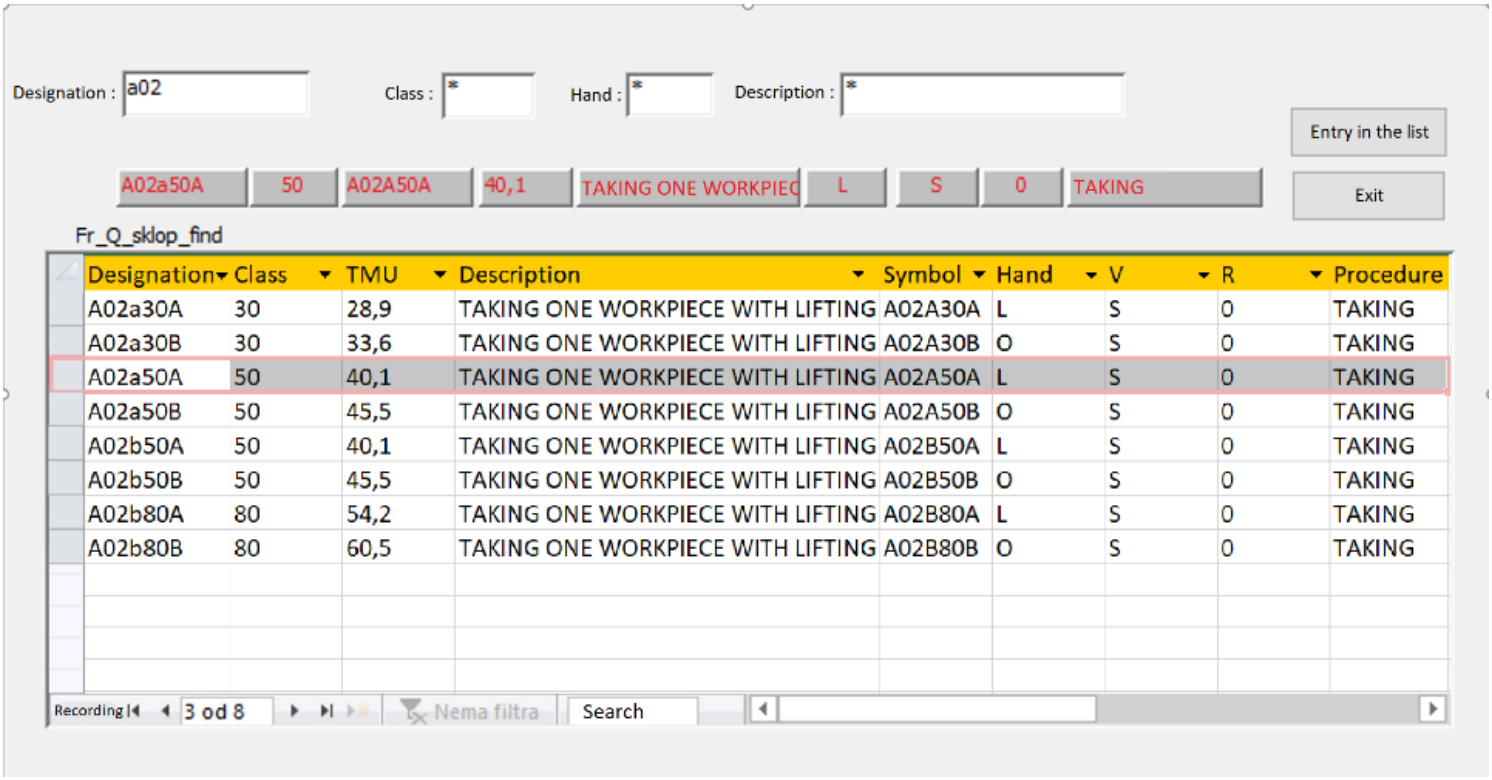

Figure 3

Searching, selecting and adding defined sets of motions

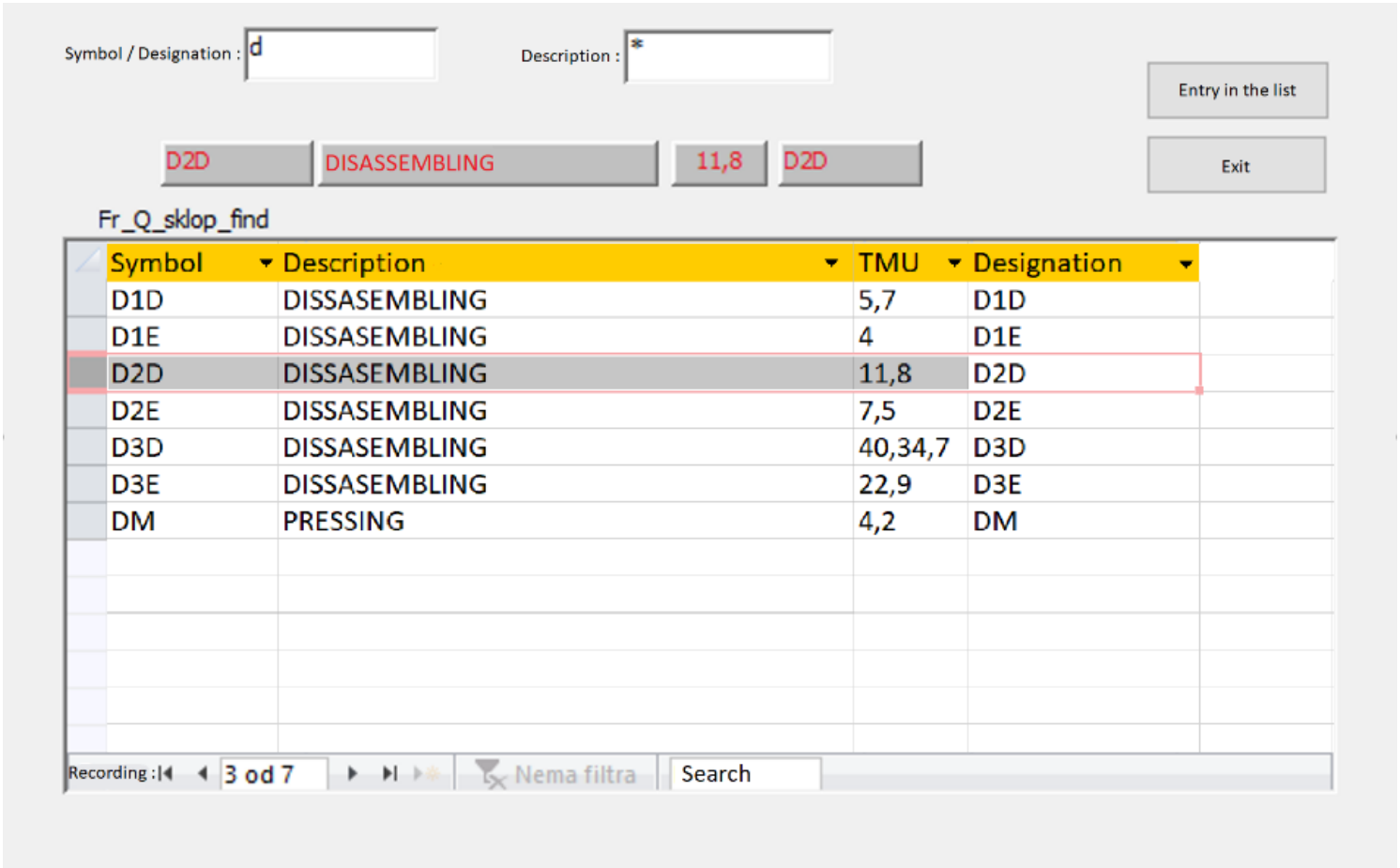

Figure 4

Searching, selecting and adding basic movements

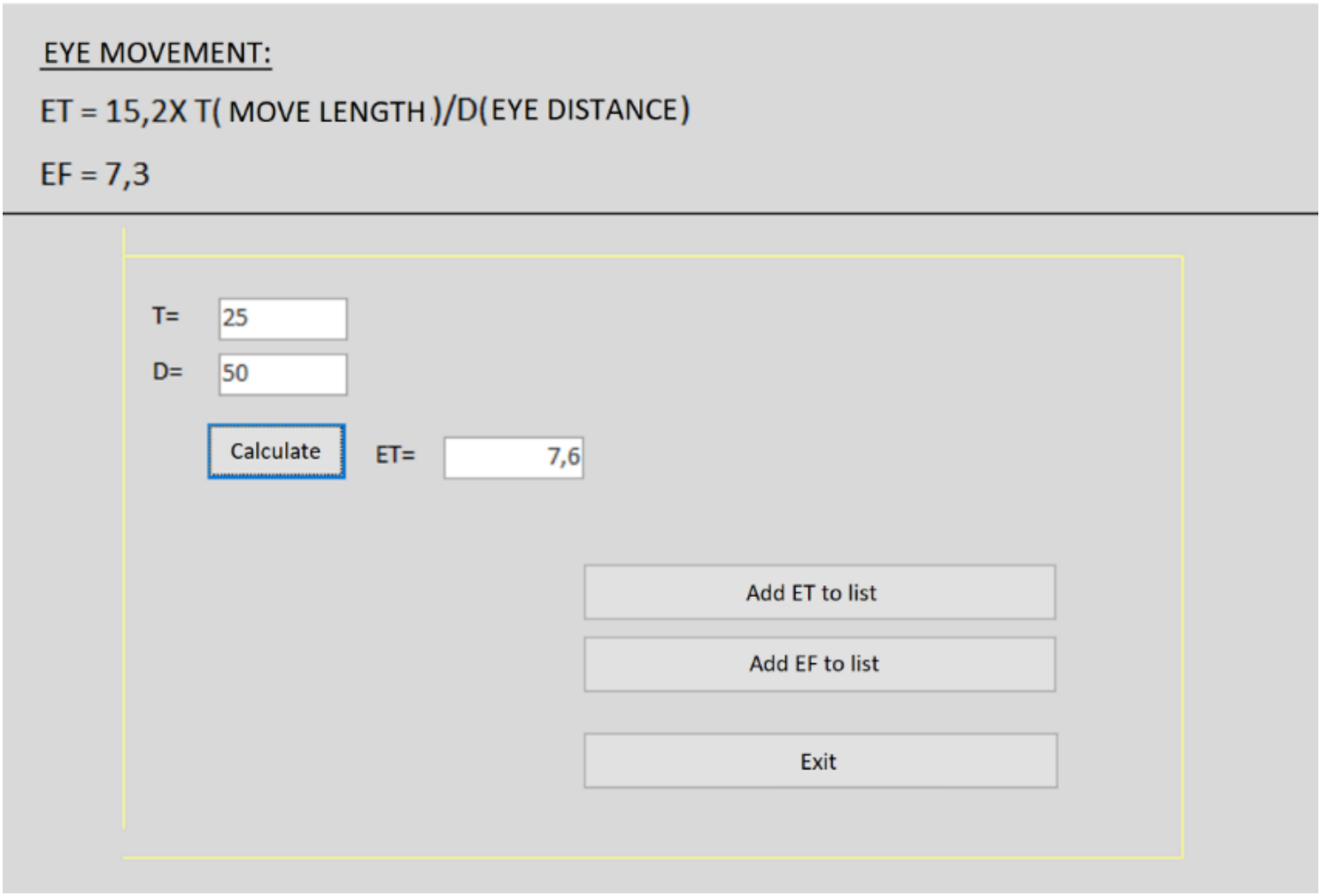

Figure 5

Selection, calculation and addition of eye movements

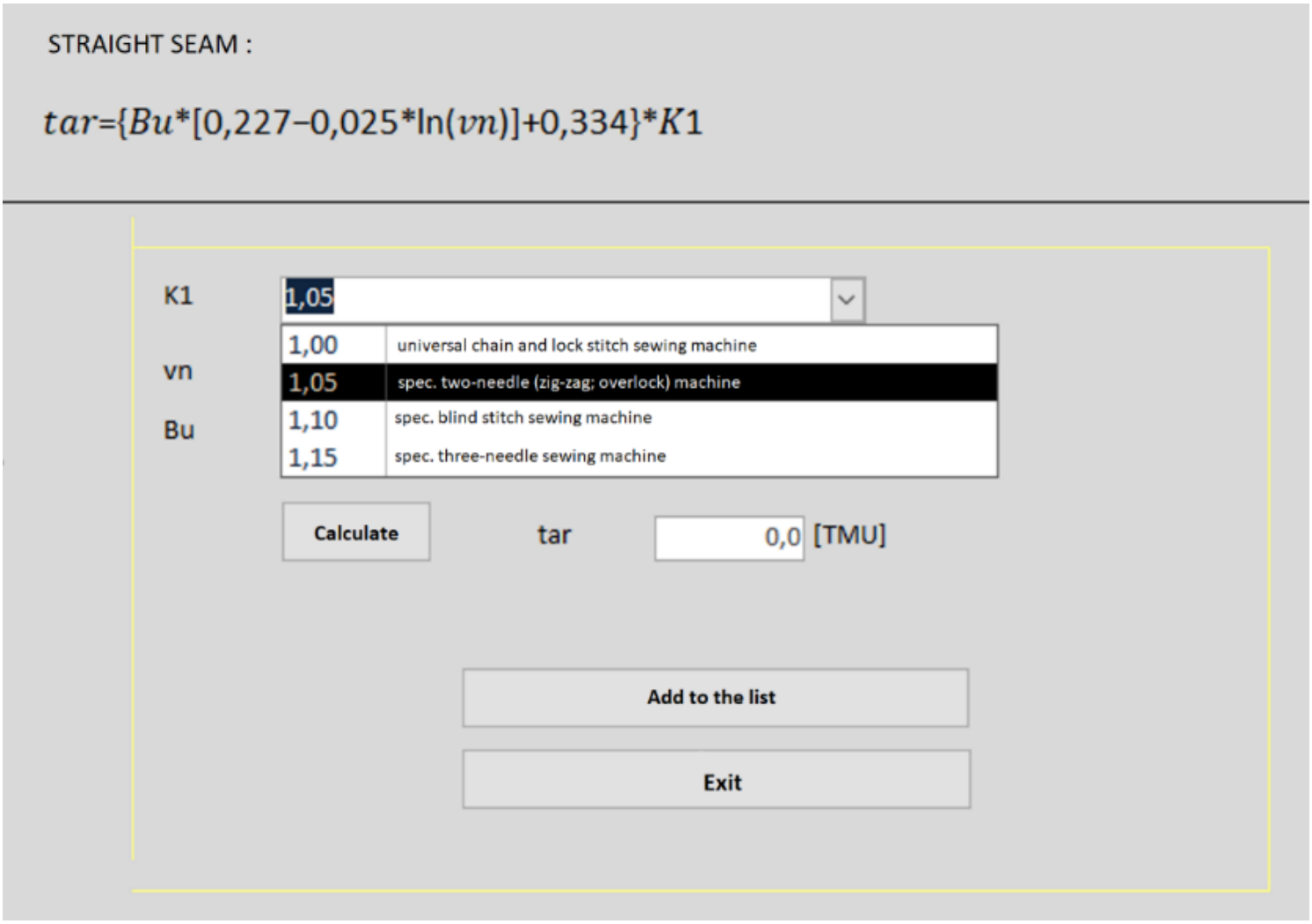

Figure 6

Calculation of the sewing time for straight seams using the RAV method

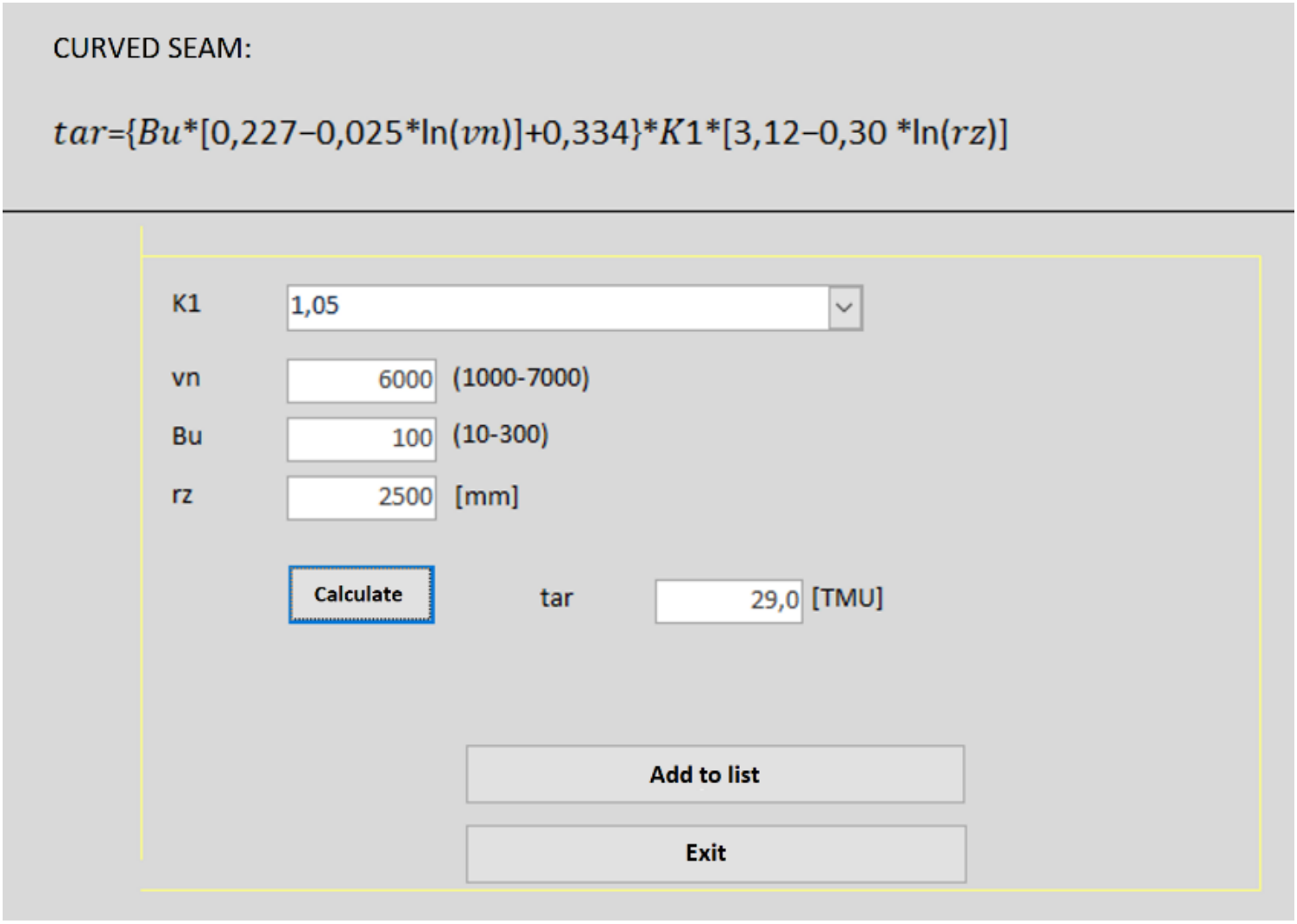

Figure 7

Calculation of the sewing time of a curved seam using the ZAK method

List

RM: 0015 Techn. operation: Hem of the shirt length Model: ŽK_LEA

DESIGNATION	CLASS	SYMBOL	TMU	DESCRIPTION	HAND	TYPE	RED	PROCEDURE
A03d50A	50	A03d50A	59,3	taking one workpiece with both hands	0	S	0	taking
E02		E02	35,9	folding with double hemmer	0	S	0	use of auxiliary d
FM		FM	8,5	movement of feet, legs and body				
tar		tar	552,3	straight seam: K1=1, vn=1000, Bu=				sewing a straigh
FM		FM	8,5	movement of feet, legs and body				
F03		F03	16,8	thread cutting using a cutting device	0	S	0	thread cutting u
H0250	50	H0250	57,4	laying off the workpiece with both hands	0	S	0	laying off

(Ka= 1,1 ; (1+Kd)= 1,2)

tn = 738,7 (TMU) ts= 828,1 (TMU) t1= 952,3 (tmu) = 00:00:34 (hh:mm:ss)

Figure 8

Basic report on the content and name of a particular technological operation

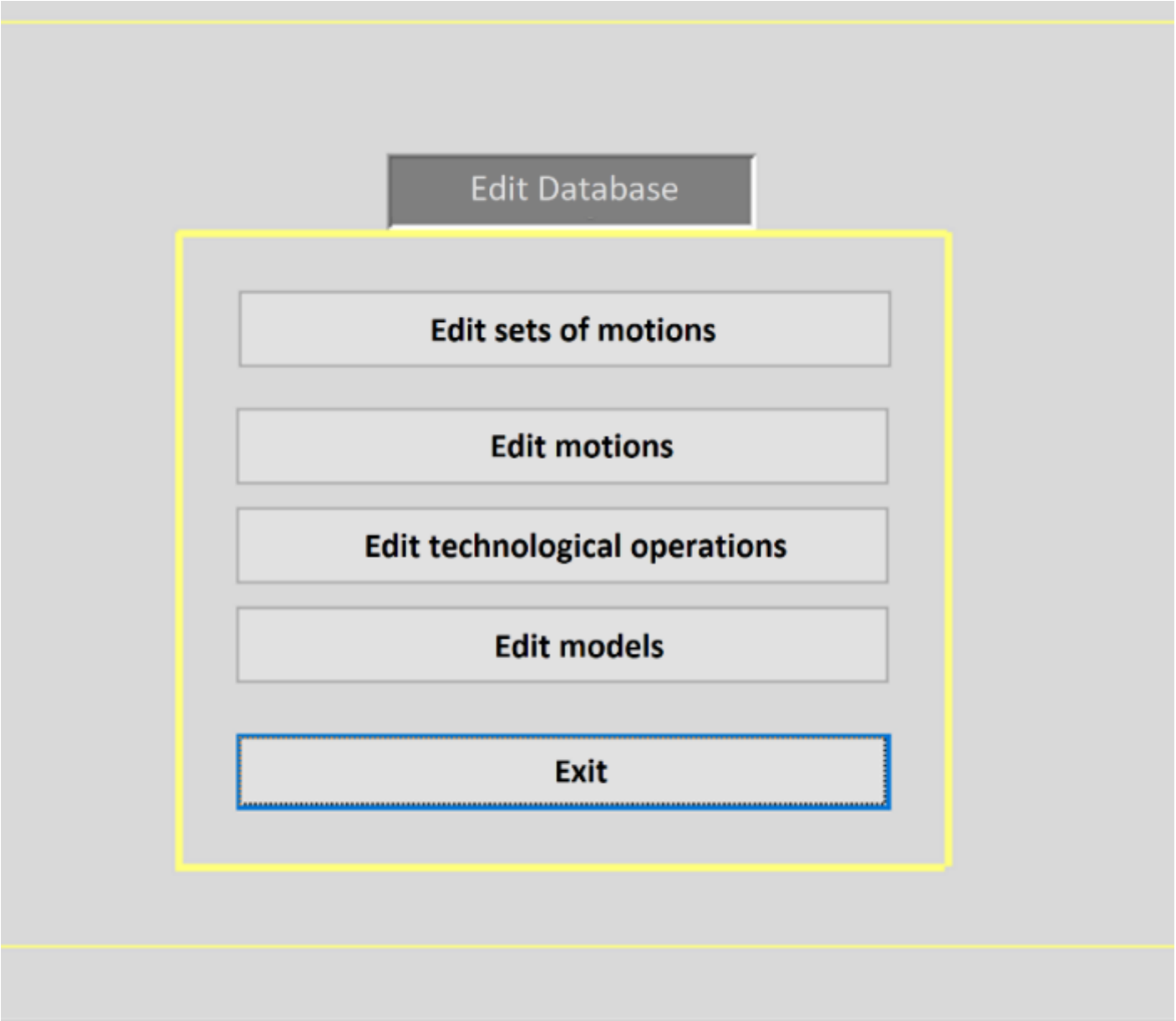

Figure 9

Display of the "Edit database" menu