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Determination of Working Methods and Normal Times of Technological Sewing Operation using MTM System

Določitev metod dela in časovnih normativov operacij tehnološkega šivanja s sistemom MTM

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Abstract

Working processes in the technological sewing process are performed on machine systems characterized by machine-manual work, where the worker and the machine work simultaneously. Such a work system requires a great deal of responsibility in terms of quality, quantity, and the accurate and timely execution of tasks, which requires the quick and accurate response and extremely good psychomotor and visual skills of workers. This paper presents the process of determining the working method and normal times for the technological operation of runstitching women's blouse collars, which includes the design of an ergonomically designed workplace, the selection and technical equipment of the universal sewing machine and the determination of the optimal work method and normal times using the Methods-Time Measurement (MTM) system. The research results obtained indicate that the technical equipment of a universal sewing machine has a significant impact on the structure of the technological sewing operation and the working method, i.e. the number of auxiliary manual technological suboperations. Improving technical equipment, i.e. increasing the number of automated functions used on a universal sewing machine, reduces the number of auxiliary manual suboperations, reduces the time required to perform the technological operation and increases work productivity.
Keywords: technological operations of garment sewing, work method, determination of normal times, MTM system

Izvleček

Delovni proces v tehnološkem postopku šivanja se izvaja na strojnih sistemih, za katere je značilno strojno-ročno delo, pri čemer delavec in stroj delata sočasno. Takšen delovni sistem zahteva veliko odgovornosti glede kakovosti, količine ter natančnega in pravočasnega izvajanja nalog. To zahteva hitre in natančne reakcije ter izredno dobre psihomotorične in vizualne spretnosti delavcev. V članku je predstavljen postopek določanja metode dela in normiranih časov tehnološke operacije šivanja ovratnika ženske bluze. Ta vključuje zasnovo ergonomsko oblikovanega delovnega mesta, izbiro tehnološke opreme univerzalnega šivalnega stroja in določitev optimalne metode dela in normiranega časa z metodo merjenja časa (sistem MTM). Rezultati raziskave kažejo, da tehnična oprema univerzalnega šivalnega stroja pomembno vpliva na strukturo tehnološkega postopka šivanja in na način dela, tj. na število pomožnih ročnih tehnoloških podo-

peracij. Izboljšanje tehnološke opreme in posledično povečanje števila samodejnih operacij na univerzalnem šivalnem stroju zmanjša število pomožnih ročnih podoperacij in čas izvajanja tehnološke operacije ter poveča produktivnost dela.
Ključne besede: tehnološke operacije šivanja oblačil, metoda dela, določanje normirnih časov, sistem MTM

1 Introduction

The garment industry is labour-intensive and represents the final stage of textile processing. It is responsible for the overall quality of clothing, not only in the area of production, but also in terms of the quality of basic and built-in parts.

For many years, the production of clothing has been focused on small production series of models, different colours, patterns and clothing sizes, high production quality, short delivery times, and the reduction of all production costs. For the successful business of the garment industry, modern production processes are organized according to the Quick Response (QR) strategy, the task of which is to respond quickly to market demand, and the Just-in-Time (JIT) technology strategy aimed at the prudent planning of production time. The JIT strategy organizes technological preparations for the faster placement of clothing on the market, and operations on the principle of profit-making on the basis of cost reduction [1, 2].

According to the organization of the work process, technological sewing operations are considered an assembly (piece) type of work process with a linear method of workplace installation. At their workplaces, workers perform technological operations of similar characteristics, leading to a higher degree of utilization of machines and devices, the improved transport of materials and workpieces through the production line, the reduction of production times, and thus production cycles. This in turn, leads to an increase in the production capacity of each workplace, production lines and systems [3, 4]. Research on the structure of working hours over the course of one working day (450 minutes) in the technological sewing process indicates that the worker spends 20 to 30% of their time for technological machine-manual sewing suboperations $(t_t)_{ar}$ and 60 to 70% of their time for auxiliary manual suboperations $(t_p)_r$, while about 10% (45 minutes) of time is spent on non-productive activities [5, 6].

According to the performance structure, the technological sewing operation comprises the following suboperations: taking the workpiece, assembly, positioning, suboperations during sewing breaks and putting down the workpiece as well as the technological machine-manual suboperations of sewing (Figure 1) [7, 8].

Technological sewing operations have short execution cycles of 15 to 60 seconds, a high degree of repetitiveness with a considerable psychophysical workload on the worker caused by a static sitting load, a high degree of eye focus, short manual movements and the frequent performance of combined and simultaneous movements. An ergonomic and functionally designed workplace and the determination of optimal work methods with corresponding time norms are required for the successful performance of the technological operation. This will facilitate the favourable structure of the technological operation, with the increased use of machines and increased hourly production, while reducing the psychophysical workload on workers, increasing productivity and production quality and reducing production costs [9, 10].

Systems of predetermined normal times are based on the principle that the work process can be broken down to the level of basic motions, which can determine work methods and production time. The most commonly used systems of predetermined normal times are: Motion Time Analysis (MTA), Work Factor (WF), Methods-Time Measurement (MTM), Basic Motion- Time (BMT) study, Dimensional Motion Times (DMT) and Master Clerical Data (MCD). These systems are also referred to in literature as synthetic time systems.

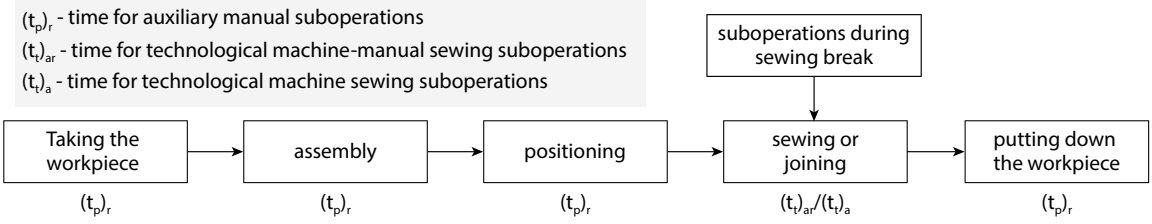


Figure 1: Structure of the technological sewing operation [7, 8]

Available on the market today are software solutions that are used for the quick and easy determination of normal times using predetermined motion time systems, and for the better organization of production process, the calculation of prices and offers, workflow optimization, etc. The MTM organization has developed several software solutions [11] such as TICON, the standard software for industrial engineering, and MTM-EasyTime, which are based on the MTM-1 system. The MTM Association Benelux [12] upholds the professional standards of training and research. That organisation developed the following MTM-software: TiCon© (Time Control), as support software for MTM-building block-systems (UAS, MEK, SDB, MTM-1 and MTM-2), EAWSdigital (Ergonomic Assessment WorkSheet) and ProKondigital (Productiegeoriënteerde Konstructie). In addition, the TMU CALCULATOR® (MTM Software / MTM App) processes predetermined time systems such as MTM-1 [13].

Workplace design includes adjusting the seat height, the height and size of the work surface, foot pedal position, and the distance of the seat from the edge of the work surface to the physical measurements of the worker. This results in a favourable working posture with the anterior flexion of the spine of up to 15° and the anterior flexion of the head and neck of up to 30°, with additional eye travel of up to 10°, which ensures a vision field with a viewing angle of ±1°. In this way, the high visual acuity required to accurately perform the technological sewing operation is achieved [14, 15].

This paper presents an ergonomically designed workplace for the technological operation of runstitching women's blouse collars. Working methods for performing that technological operation, taking into account the technical equipment of the universal sewing machine, were developed and described. Two levels of technical equipment of the universal sewing machine were considered:

Level 1: non-equipped universal sewing machine (manual seam beginning and end seam bartacking, manual cutting of thread); and level 2: universal sewing machine with programmed functions of tucking the beginning and end of seam, needle positioning in the specified position and the automatic cutting of thread.

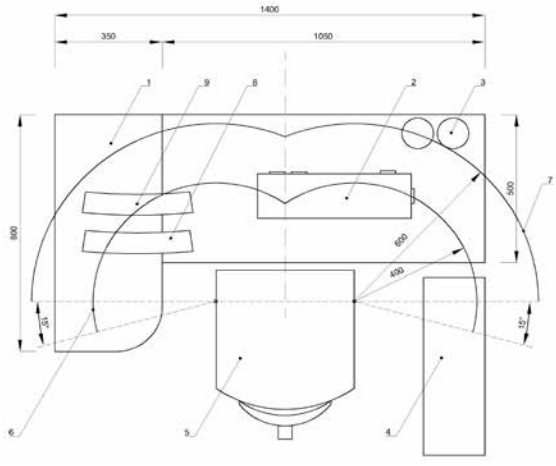
Working method analysis and the determination of time norms of the technological operation of runstitching women's blouse collars were performed using the MTM system.

2 Materials and methods

In the experimental part of this paper, working methods for the technological operation of runstitching women's blouse collars were defined and designed, depending on the technical equipment of the sewing machine. For this purpose, a workplace was designed, a universal sewing machine was selected, and the working method and performance time were determined using the MTM system, while the RAV and ZAK methods were used to determine the normal time of the machine-manual sewing suboperation.

2.1 Designed workplace

A universal BROTHER DB2-B755-403A Mark III sewing machine with a work surface dimension of 500 mm x 1400 mm (Figure 2) was selected. The



1 – work surface of the sewing machine
2 – head of the universal sewing machine
3 – sewing thread stand
4 – stand for putting down the workpiece
5 – industrial chair
6 – normal reach zone
7 – maximum reach zone
8 – lower part of the collar
9 – upper part of the collar

Figure 2: Designed workplace for the technological operation of runstitching women's blouse collars

workpiece bundles were of a medium size (dimensions 36 cm x 7 cm) and were located on the work surface of the sewing machine in the normal reach zone.

The workplace was designed according to the worker's body height (160 cm), while the sitting height (50 cm) was determined according to the popliteal length of the lower leg (43 cm) with an allowance for footwear (2 cm) and the sewing machine's pedal height (5 cm). The distance of the torso from the edge of the work surface was 15 to 20 cm, while the height of the work surface was 10 to 15 cm higher than the thigh thickness. This posture allowed the work to be performed with anterior head flexion in a comfortable posture up to a maximum of 30° with an eye distance of 30 to 40 cm from the central working sewing space, thereby achieving the high visual acuity required for the accurate technological operation. The workpiece or women's blouse collar dimension of 36 cm x7 cm is shown in Figure 3. The runstitching of women's blouse collars was performed in three segments, where segments A and C (7 cm) had 34 stitches in the seam, and segment B (36 cm) had 144 stitches in the seam. The runstitching of women's blouse collars was performed with sewing stitch type 301 and a stitch density of 4 cm.

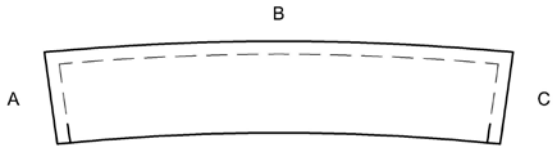


Figure 3: Women's blouse collar (36 cm x 7 cm) with marked sewing segments

The designed working method for the technological operation of runstitching women's blouse collars included taking the workpiece from the first bundle, moving the workpiece to the work zone and releasing it onto the work surface of the sewing machine. The worker reached out and took the workpiece from the second bundle, moved it to the work zone and placed it on the first workpiece (assembly). The worker then performed positioning under the machine sewing needle while simultaneously lifting the presser foot. The worker sewed the first segment (Figure 3, segment A) with seam beginning bartacking. After sewing the first segment, the worker turned the workpiece to change the sewing direction, aligned the workpiece and sewed the second segment (Figure 3, segment B). The workpiece was turned again due to the change of the sewing direction, and the third segment (Figure 3, segment C) was sewn with the seam end bartacking and the thread was cut off. After sewing, the worker moved the workpiece to the movable stand located on the right.

2.2 Sewing machine

A universal BROTHER DB2-B755-403A Mark III sewing machine was selected for the technological operation of runstitching women's blouse collars. It is a single needle, double lockstitch sewing machine. The workpiece is moved by the bottom feed. The sewing machine is equipped with process microcomputer model F-100 which, with the help of a built-in servomotor and other additional devices, enables the programmed performance of complex segments of technological processes. The most important automatic functions are needle positioning above or in the throat plate, the automatic tucking of the beginning and the end of the seam, automatic thread cutting, and the automatic lifting of the presser foot at the end of the sewing segment or technological operation, with the possibility of programming the nominal stitch speed of the sewing machine. For research purposes, the sewing machine was programmed using a process microcomputer, where two levels of equipment were selected.

Level 1 (technically non-equipped universal sewing machine):

- the lifting and lowering of the presser foot were performed using a knee lever mechanism;
- the tucking of the beginning and end of the seam was performed using a manual lever mechanism according to the worker's experience with an unequal number of stitches;
- the machine sewing needle was in an unspecified position after the break or end of sewing; and
- the thread was cut off after the sewing process using scissors and the workpiece was putting down.

Level 2 (technically equipped sewing machine):

- the electromagnetic lifting of the presser foot was determined according to the function of the pedal movement;
- the tucking of the beginning and end of the seam was programmed to 3 stitches;
- the machine sewing needle was set in its programmed position; and
- the automatic cutting of the thread was performed using a mechanism activated by the pedal movement.

2.3 Methods-Time Measurement (MTM-1) system

By studying various working methods, through the systematic filming of a large number of trained workers in various production processes, and using detailed analysis and methods of motion studies based on the breakdown of work to the level of basic movements, H.B. Maynard, G.J. Stegemerten and J.L. Schwab established the basic MTM-1 system, which can be used for assembly processes [16].

The basic MTM-1 system provides a detailed description of working methods and an analysis of manual operations up to the level of basic motions. The MTM-1 system consists of nine basic motions of fingers, hands and arms (Reach – R, Move – M, Turn – T, Crank – C, Apply Pressure – AP, Grasp – G, Release – RL, Position – P, Disengage – D), two eye motions (Eye Focus – EF, Eye Travel – ET) and ten motions of the feet, legs and body (Foot Motion – FM, Leg Motion – LM, Sidestep – SS, Turn Body – TB, Bend – B, Stoop – S, Kneel – K, Sit – SIT, Stand up – STD, Walk – W). The times for basic motions are summarized in tables, depending on the variables of motions (length, case and type of motion, mass, size and shape of the object to be handled, etc.), and their combination results in the required time of a suboperation or technological operation. The times listed in the tables are given for the average trained worker of normal mental, psychological and physical abilities, and represent normal time (t_n). The time unit of the MTM system is TMU (Time Measurement Unit), which is 0.00001 hours or 0.036 seconds. Up to 400 minutes are required for the analysis of technological operations and suboperations up to the level of basic motions using the MTM-1 system, and to describe one minute of the work process [17, 18].

Primarily arm, hand and finger motions are used in the technological sewing process: reach (R), grasp (G), move (M), release (RL), position (P), turn (T) and apply pressure (AP). Also used are eye motions: eye focus (EF) and eye travel (ET), as well as body, leg and foot motions: foot motions (FM) and leg motions (LM) [17, 19].

2.4 Determination of machine-manual sewing times

When performing machine-manual technological sewing suboperations and guiding the workpiece, it is necessary to maintain three degrees of freedom of movement: seam distance from the edges of the workpiece, alignment of the workpiece and monitoring the seam curvature for a seam allowance of ±1 mm [18]. The time of machine-manual sewing suboperations depends on nominal stitch speed, seam curvature, specific stitch density, total length of the sewn seam, number of segments and the equipment of the sewing machine with auxiliary devices. Mathematical models obtained through the systematic investigation of sewing process parameters using the patented measuring equipment for measuring process parameters (MMPP) developed at the University of Zagreb, Faculty of Textile Technology in the Department of Clothing Technology were used to determine the machine-manual normal times of the technological sewing suboperation of straight and curved seams [20, 21]. The applied mathematical models give the dependence of the normal times of machine-manual suboperations on the variable values of process parameters:

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

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

$$t_{arRAV} = \{B_u[0.227 - 0.025\ln(v_n)] + 0.334\}\,K_1 \quad (1)$$

$$t_{arZAK} = \{[B_u[0.227 - 0.025\,ln(v_n)] + 0.334]\cdot K_1\,[3.12 - 0.30\,ln(r_z)]. \quad (2)$$

A computer program [22, 23], which is used to calculate the normal time of the machine-manual sewing suboperation in different time units (s, TMU, min, h), was developed for these mathematical models.

3 Results and discussion

A workplace was designed (Figure 2) for the technological operation of runstitching women's blouse collars on the above-described universal sewing machine, while the working method was defined and designed, and an analysis of the suboperation to the level of motion using the MTM system was performed. The time of machine-manual technological sewing operations was determined using the RAV and ZAK methods. In the case of the technically non-equipped sewing machine (level 1),

the technological operation of runstitching women's blouse collars comprised the following technological suboperations:

1. an individual taking the workpiece from the first bundle with one hand, moving it to the other hand and releasing it in the central work zone, and an individual taking the workpiece from the second bundle with one hand and moving it to the other hand;
2. assembly;
3. positioning under the needle (lifting the presser foot using the leg motion (LM) and lifting the sewing needle into the upper position with the right hand using the wharf of the main shaft);
4. sewing the seam in three segments by aligning the edges after sewing segments A and B, and by tucking the beginning and end of the seam using the seam bartacking mechanism lever;
5. cutting of the thread with scissors;
6. putting down the workpiece.

Table 1 presents an analysis of technological suboperations to the level of motions using the MTM system for the technically non-equipped universal sewing machine (level 1).

Table 1: Working method and the analysis of technological suboperations to the level of motions using the MTM system for the technically non-equipped universal sewing machine (level 1)

No.	Left hand movement description	Symbol	TMU	Symbol	Right hand movement description
1					
1 TAKING THE WORKPIECE					
1.1	Reach for the bundle	mR30B	8.5		
1.2.	Grasp the workpiece	G5/G2	5.6		
1.3.	Lift the workpiece	M10Bm	4.3		
1.4.	Move to the central work zone	mM30B	8.5		
1.5.			5.6	G3	Grasp the workpiece
1.6.	Release the workpiece	RL1	2.0	(RL1)	Release the workpiece
1.7.	Reach for the bundle	mR35B	11.4		
1.8.	Grasp the workpiece	G5/G2	5.6		
1.9.	Lift the workpiece	M10Bm	4.3		
1.10.	Move to the central work zone	(mM35B)	11.7	R10A G5/G2	Reach for the workpiece in the left hand and grasp it
1.11.	Extend the arm along the workpiece	R10E	6.8		
		ΣTMU (s)	**74.3 (2.68)**		
2 ASSEMBLING THE EDGES OF WORKPIECES BY CHANGING THE GRIP					
2.1.	Move the workpiece to the corner	M7C	6.4	(M7C)	Move the workpiece to the corner
2.2.			5.6	P1SE	Precisely put on the first corner
2.3.	Contact grasp	(G5)	3.2	R4E	Pull the index finger from under the workpiece
2.4.	Pull along the edge of the workpiece to the other corner	R35B	14.2		
2.5.	Grasp	G1B	3.5		
2.6.	Precisely move to the other corner	M5C	5.2		
2.7.	Precisely put on the other corner	P1SE	5.6		
2.8.	Pull the index finger from under the workpiece	R4E	3.2		
2.9.	Additional grasping	G2	5.6	(G2)	Additional grasping
		ΣTMU (s)	**52.5 (1.89)**		

No.	Left hand movement description	Symbol	TMU	Symbol	Right hand movement description
3 POSITIONING THE WORKPIECE					
3.1.	Move to the presser foot	M10B	6.8	(1/2 LM)	Lift the presser foot using the knee lever
3.2.			11.3	R40A	Reach for the main shaft
3.3.			5.6	G5/G2	Grasp the main shaft
3.4.			8.4	M6B/AF	Turn the main shaft
3.5.			0.0	RL2	Release the main shaft
3.6.			14.1	R40E	Return the hand to the workpiece
3.7.	Move to the needle	M6C	5.8		
3.8.	Position under the needle	P1SE	5.6		
3.9.			3.6	(1/2 LM)	Lower the presser foot using the knee lever
		ΣTMU (s)	**61.2 (2.20)**		
4 TUCKING THE BEGINNING OF THE SEAM					
4.1.			9.5	R30A	Reach for the lever
4.2.			0.0	G5	Grasp the lever
4.3.	Activate the pedal	FM	8.5	(M4A/AF)	Push down on the lever
4.4.			0.0	RL2	Release the lever
4.5.			11.7	R30E	Return the hand to the workpiece
		ΣTMU (s)	**29.7 (1.07)**		
5 SEWING THE FIRST SEGMENT					
5.1.	Sew segment A	t_{ar}	60.6		
		ΣTMU (s)	**60.6 (2.18)**		
6 POSITIONING THE NEEDLE INTO THE LOWER POSITION, TURNING, ALIGNING					
6.1.	Deactivate the pedal	(FM)	11.3	R40A	Reach for the main shaft
6.2.			5.6	G5/G2	Grasp the main shaft
6.3.			8.4	M6B/AF	Turn the main shaft
6.4.			3.6	1/2 LM	Lift the presser foot using the knee lever
6.5.	Turn the workpiece	M25C	13.4	(R30E)	Return the hand to the workpiece
6.6.	Kinematic reaction	t_{rr}	4.0		
6.7.			3.6	1/2 LM	Lower the presser foot using the knee lever
6.8.			2.0	RL1	Release the workpiece
6.9.	Contact grasp	(G5)	11.3	mR35E	Reach the hand to another place
6.10.			2.0	G1A	Grasp the workpiece
6.11.			11.4	M6C/ P1SE	Parallel placing and joining
		ΣTMU (s)	**76.6 (2.76)**		
7 SEWING THE SECOND SEGMENT					
7.1.	Activate the pedal	FM	8.5		
7.2.	Sew segment B	t_{ar}	108.1		
		ΣTMU (s)	**116.6 (4.20)**		
8 POSITIONING THE NEEDLE INTO THE LOWER POSITION, TURNING, ALIGNING					
8.1.	Deactivate the pedal	(FM)	11.3	R40A	Reach for the main shaft
8.2.			5.6	G5/G2	Grasp the main shaft
8.3.			8.4	M6B/AF	Turn the main shaft

No.	Left hand movement description	Symbol	TMU	Symbol	Right hand movement description
8.4.			3.6	1/2 LM	Lift the presser foot using the knee lever
8.5.	Turn the workpiece	M25C	13.4	(R30B)	Return the hand to the workpiece
8.6.	Kinematic reaction	t_{rr}	4.0		
8.7.			3.6	1/2 LM	Lower the presser foot using the knee lever
8.8.			2.0	RL1	Release the workpiece
8.9.			4.6	mR8E	Reach the hand to another place
8.10.			2.0	G1A	Grasp the workpiece
8.11.			11.4	M6C/ P1SE	Parallel placing and joining
		ΣTMU (s)	**69.9 (2.51)**		
9 SEWING THE THIRD SEGMENT					
9.1.	Activate the pedal	FM	8.5		
9.2.	Sew segment C	t_{ar}	60.6		
		ΣTMU (s)	**69.1 (2.49)**		
10 TUCKING THE END OF THE SEAM					
10.1.			9.5	R30A	Reach for the lever
10.2.			0.0	G5	Grasp the lever
10.3.			8.5	(M4A/AF)	Push down on the lever
10.4.			0.0	RL2	Release the lever
10.5.			12.8	R30B	Return the hand to the workpiece
10.6.	Deactivate the pedal		8.5	FM	
		ΣTMU (s)	**39.3 (1.41)**		
11 CUTTING OF THE THREAD WITH SCISSORS					
11.1.			3.6	1/2 LM	Lift the presser foot using the knee lever
11.2.			11.3	R40A	Reach for the main shaft
11.3.			5.6	G5/G2	Grasp the main shaft
11.4.			8.4	M6B/AF	Move with pressing
11.5.	Pull the workpiece from under the needle	M10B	6.8		
11.6.			11.4	R25B	Reach for the scissors
11.7.			5.6	G5/G2	Grasp the scissors
11.8.			10.5	M20B	Move the scissors into the work zone
11.9.			5.8	M6C	Move the scissors to the thread
11.10.			(2.0)	(M2A)	Open the scissors simultaneously
11.11.			3.4	AF	Press the scissors blades
11.12.			(2.0)	(M2A)	Cut the thread simultaneously
11.13.			11.2	M25A	Put down the scissors
11.14.			2.0	RL1	Release the scissors
11.15.			10.0	R25E	Return the hand to the workpiece
		ΣTMU (s)	**99.1 (3.57)**		
12 PUTTING DOWN THE WORKPIECE WITH THE RIGHT HAND					
12.1.			6.3	R10B	Take the workpiece
12.2.	Release the workpiece	(RL1)	2.0	G1A	Grasp the workpiece
12.3.			6.8	M10B	Lift the workpiece

No.	Left hand movement description	Symbol	TMU	Symbol	Right hand movement description
12.4.			18.0	M50B	Lay off the workpiece
12.5.			2.0	RL1	Release the workpiece
12.6.			14.7	R50Em	Return the hand to balanced position
		ΣTMU (s)	**49.8 (1.79)**		
TOTAL: ΣTMU (s) = 798.7 (28.75)					

Based on the established working method using the MTM system, the normal time for performing the technological operation of runstitching women's blouse collars for the technically non-equipped sewing machine was 798.7 TMU (28.75 s).

In the case of a technically equipped universal sewing machine, the technological operation of runstitching women's blouse collars comprises the following technological suboperations:

1. an individual taking the workpiece from the first bundle with one hand, moving it to the other hand and releasing it in the central work zone, and an individual taking the workpiece from the second bundle with one hand and moving it to the other hand;
2. assembly;
3. positioning under the sewing needle (lifting the presser foot and the sewing needle by foot movement);
4. sewing the seam in three segments by aligning the edges after sewing segments A and B, and automatic tucking the beginning and end of the seam, and cutting of the thread;
5. putting down the workpiece.

Table 2 presents an analysis of technological suboperations to the level of motions using the MTM system for the technically equipped universal sewing machine (level 2). Some technological suboperations are similar for both working methods (levels 1 and 2 of technically equipped machine). For this reason, Table 2 illustrates the entire MTM analysis for different technological suboperations.

Table 2: Working method and analysis of technological suboperations to the level of motions using the MTM system for the technically equipped sewing machine (level 2)

No.	Left hand movement description	Symbol	TMU	Symbol	Right hand movement description
1 TAKING THE WORKPIECE – the same as for the level 1 (see Table 1)					
		ΣTMU (s)	**74.3 (2.68)**		
2 ASSEMBLING THE EDGES OF WORKPIECES BY CHANGING THE GRIP – the same as for level 1 (see Table 1)					
		ΣTMU (s)	**52.5 (1.89)**		
3 POSITIONING THE WORKPIECE					
3.1.	Move to the presser foot	(M10B)	8.5	FM	Lift the presser foot using the pedal
3.2.	Move to the needle	M6C	5.8		
3.3.	Position under the needle	P1SE	5.6		
3.4.			8.5	FM	Lower the presser foot using the pedal
		ΣTMU(s)	**28.4 (1.02)**		
4 SEWING WITH AUTOMATIC TUCKING THE BEGINNING AND END OF THE SEAM AND CUTTING OFF THE THREAD					
4.1	Activate the pedal	FM	8.5		
4.2.	Sew segment A	t_{ar}	60.6		
4.3.	Lift the presser foot	FM	8.5		
4.4.	Turn the workpiece	M25C	13.4		
4.5.			2.0	RL1	Release the workpiece
4.6.	Contact grasp	(G5)	11.3	mR35E	Reach the hand to another place
4.7.			2.0	G1A	Grasp the workpiece
4.8.			11.4	M6C/ P1SE	Parallel placing and joining

No.	Left hand movement description	Symbol	TMU	Symbol	Right hand movement description
4.9.	Kinematic reaction	t_{rr}	4.0		
4.10.	Lower the presser foot and activate the pedal	FM	8.5		
4.11.	Sew segment B	t_{ar}	108.1		
4.12.	Lift the presser foot	FM	8.5		
4.13.	Turn the workpiece	M25C	13.4		
4.14.	Kinematic reaction	t_{rr}	4.0		
4.15.	Lower the presser foot and activate the pedal	FM	8.5		
4.16.			2.0	RL1	Release the workpiece
4.17.			11.3	mR35E	Reach the hand to another place
4.18.			2.0	G1A	Grasp the workpiece
4.19.			11.4	M6C/ P1SE	Parallel placing and joining
4.20.	Activate the pedal	FM	8.5		
4.21.	Sew segment C	t_{ar}	60.6		
4.22.	Foot motion	FM	8.5		
4.23.	Reaction time of lifting the presser foot and the needle, and automatic cutting off the thread	t_{aok}	4.0		
4.24.	Deactivate the pedal	1/2 FM	4.3		
		ΣTMU (s)	**385.3 (13.87)**		
5. PUTTING DOWN THE WORKPIECE WITH THE RIGHT HAND – the same as for the level 1 (see Table 1)					
		ΣTMU (s)	**49.8 (1.79)**		
TOTAL ΣTMU (s) = 590.3 (21.25)					

The normal time offor performing the designed technological operation of runstitching women's blouse collars on the technically equipped sewing machine was 590.3 TMU (21.25 s).

The conducted research dealt with the working method and the normal time for performing the designed technological operation of runstitching women's blouse collars using the technically non-equipped (level 1) and technically equipped (level 2) universal sewing machine. In this way, it was possible to compare the structure of the technological operation with the technological suboperations and motions for two different working methods already in the design phase of the production system.

Based on the obtained results, it was determined that the normal time for the technological operation of runstitching women's blouse collars on the technically non-equipped universal sewing machine was 28.75 seconds (798.7 TMU), while the normal time for the technically equipped universal sewing machine was 21.25 seconds (590.3 TMU), meaning that time decreased by 26.1%. According to the above, it can be concluded that the working method and the normal time depend on the technical equipment of the sewing machine, if the same worker works in an equally designed workplace. When performing the technological operation on the technically non-equipped universal sewing machine, the worker performs several auxiliary manual motions, as can be seen from the comparison of the motion sets for both methods (Table 3).

Table 3 shows that on the technically equipped sewing machine with automated functions the following sets of motions are eliminated:

- tucking the beginning and end of the seam;
- positioning the needle into the lower position during sewing break due to the change of the sewing direction; and
- manual cutting of the thread with scissors.

The machine-manual time of the technological sewing suboperation was calculated according to formulas (1) and (2). The resulting times are the same for both working methods and amounted to 8.25 seconds (229.3 TMU) for all three segments. The set of motions for positioning the workpiece differs de-

Table 3: Comparison of the used sets of motions for performing auxiliary manual suboperations in the technological operation of runstitching women's blouse collars on the technically non-equipped and equipped sewing machine

Description of the set of motions	Level of the technical equipment of the universal sewing machine	
	Level I	Level II
Taking the workpiece	✓	✓
Assembling the edges of workpieces by changing the grip	✓	✓
Positioning the workpiece	✓	✓
Tucking the beginning of the seam	✓	-
Positioning the needle into the lower position, turning, aligning	✓	-
Tucking the end of the seam	✓	-
Cutting of the thread using the scissors	✓	-
Putting down the workpiece with the right hand	✓	✓

pending on the level of technical equipment of the sewing machine. In the case of the technically non-equipped sewing machine, the presser foot is lifted by the thigh motion and by pushing down the knee lever (1/2 LM). The worker reaches the right hand to the shaft, lifts the sewing needle into the upper position (motions 3.2 to 3.6 in Table 1), and moves the workpiece (M6C) and positions it under the needle (P1SE), and lowers the presser foot (1/2 LM), taking a total of 2.20 seconds (61.2 TMU). In the case of the technically equipped sewing machine, the workpiece is moved to the presser foot (M10B), while the presser foot and the sewing needle are simultaneously lifted by the foot pushing down the pedal (FM). The workpiece is moved (M6C) and positioned under the needle (P1SE), the presser foot is lowered by the foot (FM), taking a total of 1.02 seconds (28.4 TMU), meaning that the time was reduced by 55.5%.

In the case of the technically non-equipped sewing machine, tucking the beginning and end of the seam during the technological sewing suboperation is performed using the bartacking mechanism lever with the following set of motions 4.1 to 4.5 (Table 1), with a total duration of 1.07 seconds (29.7 TMU). In addition, the number of stitches for tucking the beginning and end of seam is programmed using a process microcomputer on the technically equipped sewing machine.

During the sewing break, due to a direction change on the technically non-equipped sewing machine before turning the workpiece, it is necessary to move the needle into the lower position using the wharf, which is done using a right-hand motion. The knee lever is used to lift the presser foot and the motion set for the entire suboperation is 6.1 to 6.5 (Table 1) with a duration of 1.47 seconds (42.3 TMU). In the case of the technically equipped universal sewing machine, the placement of the needle into the appropriate position is programmed using a process microcomputer. The cutting of the thread on the technically non-equipped sewing machine is done using hand scissors and the set of motions 11.1 to 11.15 (Table 1) with a duration of 3.57 seconds (99.1 TMU). The same operation is performed on the technically equipped sewing machine by pushing down the pedal with a foot motion (FM), which lifts the needle and the presser foot into the upper position activating the mechanism for cutting the thread with a duration of 0.60 seconds (16.8 TMU).

The analysed technological operation of runstitching women's blouse collars has a similar working method as technological operations of runstitching the pocket flap or runstitching women's blouse cuffs or men's shirt cuffs. The difference between these technological operations lies in the method of taking and assembling the workpiece because cutting parts are smaller, and the time of machine-manual suboperations, which are calculated according to the formulas for the RAV and ZAK methods as the seam lengths, is also less. When the runstitching of the cuff or the pocket is performed, assembly is performed at the sewing beginning and during the technological sewing operation, and no additional alignment of the workpiece is required.

A comparison of the working methods indicates that the technological operation of sewing (level 1) is per-

formed in the sagittal and frontal planes (tucking the beginning of the seam, positioning the needle into the lower or upper position and cutting of the thread using scissors), thus interrupting the uniform rhythm of performance, which requires a higher degree of movement coordination. In the working method of level 2, the technological sewing operation is performed in the sagittal plane, which enables a uniform rhythm of performance and a reduced workload on workers.

This scientific approach also enables to formulation of logical sets of individual suboperations based on the analysis of basic movements. Combining logical sets formulated and defined using the MMPP method, the optimal working methods of the technological operations with normal times can be determined in advance already in the design phase of the sewing process based on the designed workplace.

4 Conclusion

The application of the MTM system in the technological processes of clothing production facilitates the identification, development and preparation of optimal working methods before production starts, the rationalization of existing procedures and working methods, and the determination of actual norms with respect to working staff and installed equipment.

On the basis of the MTM analysis carried out and the identified suboperations in the structure of the technological operation of runstitching women's blouse collars at the designed workplace using a universal sewing machine, it can be concluded that a higher level of technical equipment of sewing machines enables the following:

- the optimal structure of the technological sewing operation;
- the optimal working method with proper time norms;
- the elimination of some motions in technological suboperations, and the replacement of others with motions that are easier to perform; and
- a reduction in the time required to perform the technological operation and increased labour productivity.

The obtained research results show that a higher level of technical equipment of sewing machines results in a higher degree of utilization of those machines and higher productivity. The research presented in this paper has proven the appropriateness of the use of the MTM system, and the RAV and ZAK methods to determine the optimal working methods and corresponding time norms of the technological operation. This research can be very useful in real clothing production processes because the MTM analysis and defined logical sets of movements for suboperations in the technological process of sewing with performance times can provide prompt normal times for the technological operation. Moreover, the use of MTM software as an application or calculator makes it possible to determine normal time for the technological operation in the production process, and facilitates the calculation of prices and offers, the better organization of the production process, workflow optimization, etc.

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