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Workloads and Standard Time Norms in Garment Engineering

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ABSTRACT

Possibilities of new methods for measuring loading and standard time norms are presented, as applied in the field of garment engineering. Measurements described are performed on modern measuring equipment designed to measure and perform computer analysis of temporal values of processing parameters in sewing operation and simultaneously record in two planes using a video system. The measuring system described was used to investigate sewing operation for the front seam on a ladies' fashion suit, 52 cm long. For the operation investigated, method of work employing the MTM (Methods Time Measurement) system with analysis of basic movements was selected. The MTM system used shows that normal time for the operation in question is around 429.3 TMU (15.5 s). Investigations of workload imposed on the worker according to the OADM method were done simultaneously, and total ergonomic loading coefficient of K_{er}=0.082 was established, thus determining the time necessary to organise the process of work as 464.5 TMU (16.7 s). Simultaneous measurements of time and dynamic changes of processing parameters, as well as logical sets of movements, are important for defining favourable operation structures, time norms, ergonomically designed systems of work and workplaces in garment engineering, as early as in the phase of designing operations. The investigations described make possible to find optimal distribution of working elements and zones of reach important for ergonomic designing and/or re-designing of workplaces, which results in considerably reduced level of fatigue in work, optimal quality level, higher degree of utilisation of equipment installed and lower manufacturing costs.

KEYWORDS**:** garment engineering, sewing process, standard time of norms, motion timestudy measurement (MTM), workloads

1. Introduction

Processes of garment production belong to the so called »piece-type« of production processes (assembling type), while the work is performed on production lines, including a number of technological operations. Each of them is of a rather short duration, each is highly repetitive, and exerts a considerable psychical and physical strain on the worker. To organize this type of production successfully, and having in mind unbroken material flow, it is necessary to be familiar time norms, as a basis for defining optimal methods of work, more favorable structure of the operation in question, machine utilization ratio, worker load and hourly production.

To be able to establish correct time norms as a basis for organizing production processes, it is necessary to have an overall view of all the factors which have impact on a workplace, such as the level of skill the operator possesses, fatigue, environmental influences, as well as some amount of additional time reserved for personal needs and other time justifiable time losses.

2.1. Defining time norms in sewing operations

Operation of sewing consists of hand, machine-hand and machine sub-operations, which, according to the manner of performance and sequence, constitute its structure (Figure 1).

Regarding the manner of performing, the working process asks for a high degree of movement co-ordination in performing simultaneous movements, as well as a high muscular control and visual concentration in precise matching of the workpiece and guiding it in the course of sewing. Furthermore, the sequence of sets of movements is performed in an extremely short interval of time, and is highly repetitive in the working shift, thus imposing a considerable load on the worker, due to interabdominal pressure, coping with inertial forces, and loading on the lumbar, thorocal and cervical sections of the spine.

Methods of measuring and recording with special stopwatches (Epsiprint - Zeitstudiengärate, Hanhard) and electromechanical stop watches (Clinton Record Timer Fys 25 4M) are used to define basic duration of sewing operations in industrial engineering. These measuring instruments are employed to acquire temporal data on the duration of individual hand machine-hand and machine sub-operations, but they cannot describe tea l conditions in the man-machine system and interrelations in it. Furthermore, these instruments are likely to produce relatively serious recording errors, due to visual-tactile reactions of the person performing the recordings.

In contemporary methods of industrial engineering, elementary time systems are used, the best known being the MTM system (Methods Time Measurement). Using it, a technological operation can be divided down to the level of basic movements necessary to execute it. The MTM system consists of nine basic movements of the fingers, hand and arm; two eye movements and ten basic movements of the foot, leg, trunk and the whole body [1]. The duration of normal execution of an operation is pre-set, following the variables of performing basic movem ents (length, accuracy, dynamics, necessary visual and muscular control in executing basic movements), as well as the possibility of performing simultaneous and combined movements.

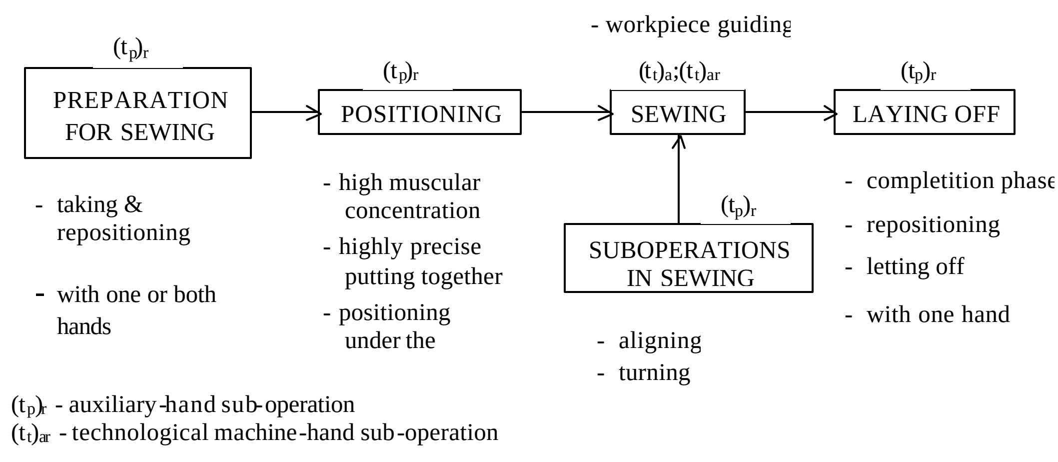

Figure: 1 Sewing operation structure

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The application of the MTM system makes the work method description quite clear, with accurately defined normal duration, while the regularities and the concept are defined by which a worker of average mental and physical abilities, possessing average level of skills, performs the movements involved in a logical sequence. This method can also be used to define time norms and design workplaces in garment engineering as early as the phase of designing manufacturing processes and production systems [2, 3].

2.2. Defining the level of worker load in the man-machine-environment system

Due to repetitiveness of the operations involved in the process of work, physical and psychic fatigue results because of static and dynamic loads imposed on the muscular system of the worker, unfavorable working posture and necessary degree of concentration involved. The fatigue is manifested as reduced accuracy, preciseness and, consequently the quality of performing the operation in question. It is thus necessary to let the worker take a break in the course of the operation, and include this possibility into the time norm structure, using the fatigue coefficient (K_n). Fatigue coefficient in working processes is defined according to the mass of the work piece and takes into account bodily posture in performing the operation. In the course of the work, worker is exposed to various influences from the environment, and according to the REFA system, it is defined by the coefficient of environmental influence (K_a), which depends upon the temperature, relative humidity, as well as upon the degree of pollution, due to dust, vapors and unpleasant odours.

Presenting the level of worker load according to the REFA system, by fatigue coefficient (K_n) and environment impact (K_a), is not appropriate for presenting worker loads in garment industry processes. V. Verhovnik and A.Polajnar [4] have defined a method of analyzing the load of working environment (the OADM method) exerted on workers in garment industry. The method analysis and grades the loads at workplace, on the basis of physical (static and dynamic) and thermal loads, visual control necessary, loads due to the presence of aerosols, gases, vapors, noise, vibration and monotonous character of work. These loads are also presented by indices, as well as by the duration of being exposed to a particular factor. According to the method, working load is presented by the ergonomics coefficient (K_{er}). This coefficient, together with the time analysis of the operation or sub-operation in question done by the MTM analysis of the basic movements, can help in pre-determining real time norms, which should be used as a basis for the organization of manufacturing processes in garment industry.

3. Measuring equipment and measurements

Modern measuring equipment, developed in the Department of Clothing Technology, Faculty of Textile Technology, University of Zagreb, has been used for measuring time component of processing parameters in garment manufacturing operations, as well as for a simultaneous bi-plane video recording, the video system being used for investigating logical sets of movements at work. Using measurements, data processing and analysis of the results obtained, together with implementing the system of sets of logical movements at work, it is possible to define a more favorable structure of the operations in question, better time norms, ergonomically more acceptable designs of production systems and workplaces, and optimal methods of work [5].

The measuring system (Figure 2) consists of two independent parts for measuring and acquisition of processing parameter times, as well as a bi-plane system of video cameras. The measuring system is equipped with four measuring sensors, which measure the duration of rotation and rotational speed of the main shaft, simultaneously and in a non-contact manner, employing IR reflection (Fig. 2/5); arm movements in a limited part of the working area within the work piece taking zone (Figure 2/3) and work piece laying-off zone (Figure 2/4) (employing active microwave sensors). Special sensors determine the shift of the pedal regulator (Figure 2/6), which controls and directs the dynamics of the sewing process in general [6]. The workplace is simultaneously and synchronously recorded by a bi-plane video system, in a side view (Fig. 2/l) and ground plan (Figure 2/2) position in the course of performing the working process [7].

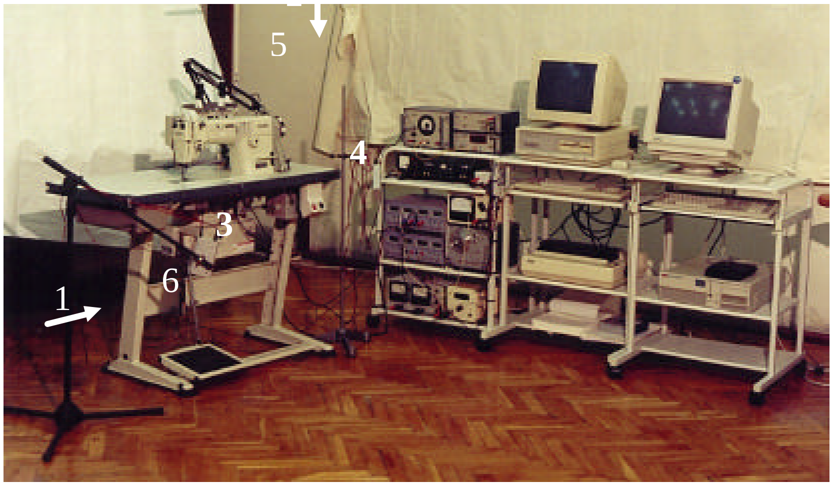

Figure 2 Linking of sewing machine to measurement equipment: side video camera (1); upper video camera (2); movement detector for taking the work piece (3); movement detector for laying-off the work piece (4); IR converter for measuring the rotation speed of main sewing machine (5); movement detector for lifting and lowering pressure foot (6); measurement equipment (7).

The measuring equipment mentioned can also be used, besides investigations in the field of garment engineering, to investigate processes in the fields of mechanical engineering, electrical engineering, graphic technology, as well as in all the processes where machine elements are circularly driven.

Marks were positioned symmetrically on the body of the female worker, for the purpose of analysing the parameters of basic movements. Marks were used to analyse the rotation and flexion of the head, back and shifting the sight (10) for movements of limbs (24), and there were additional 18 marks intended for analysing the movements of the legs and feet.

The figure 3 shows bodily posture of the female worker, with the distribution of marks, in the course of sewing the second segment of a seam.

The technological operation was performed on a designed workplace, following a predetermined working method using the MTM system (Tab. 1), where the operation selected is performed in three sub-operations.

In the **first sub-operation**, employing a simultaneous movement of the left and the right hands, the worker simultaneously lays-off the work piece from the previous cycle with her right hand, while taking and transporting the new work piece into the central zone of the sewing machine using her left hand. In the **second sub-operation**, the worker uses both her hands to position the angles of the work piece under the sewing machine needle. The **third sub-operation** includes sewing the first segment of the seam, 30-35 cm long. A break in sewing follows, in which the patterns on the fabric are adjusted and made parallel, after which the second segment of the seam is sewn, 17-22 cm long.

Figure 3: Bodily posture with marks in the course of sewing the second segment of the seam

Figure 4 shows characteristic body posture in the method of work presented for the structure of the sewing operation analysed. It was obtained by analysing a video recording made by side view camera (Fig. 1/2).

This sequence of movements is optimal, as it enables handling bigger samples and includes simultaneous movements of both left and right hands, with adequate and ergonomically favourable bodily posture. The sets of basic movements used make possible achieving a well-balanced rhythm of performing and lower degree of fatigue.

The MTM system is used for scientific investigations of technological operation structure and adequate time duration of associated hand sub-operations. Problems usually occur in defining machine and machine-hand times of particular sewing segments that constitute the operation. A mathematical model has been devised on the basis of systematic investigations of machine and machine-hand times, which indicates mutual dependence of the following three factors: sewing time (t_i), main shaft rotation speed selected (v_{max}) and the number of stitches constituting the seam (B_u). The model was verified experimentally on technologically acceptable pre-programmed sewing machine speeds (1000 - 4700 rpm) and number of stitches (3-300) [8]:

$$t_i = \exp\left[0.1239 - 0.3558 \ln v_{\max} + \frac{478.89}{v_{\max}} + 0.7668 \ln B_u + \frac{2.56}{B_u}\right]$$

The overall cycle of recording the operation consisted of 15 subsequent operations, performed by a female worker possessing an average level of skill ($K_{PZ} = 1.00$), of an average tallness (160 cm) and average static and dynamic anthropometric bodily measures.

4. Results and discussion

The technological operation of sewing a front bust seam on a ladies' fashion suit, 52 cm long, performed on a designed workplace on an universal sewing machine BROTHER DB2-B755, equipped with a processing microcomputer designated F-100. An optimal method of work, with appropriate normal duration (Table 1) was defined using the MTM analysis of the basic and possibility of performing simultaneous and combined movements.

The overall normal time necessary to perform the operation described is 429.3 TMU (15.5 s). Machine-hand times in the structure of the sub-operation III are defined following the mathematical model [8] for a pre-programmed maximum sewing speed of 4000 rpm and feed rate of 2.0 mm is 87.9 TMU (3.2 s) for the first sewing segment (30-35 cm) and 69.7 TMU (2.5 s) for the second one (17-22cm).

Using the OADM method in investigations, this work can be described as a light physical work (oxygen consumption 0.5-1.0 l/min, with energy consumption of 175 W and brief static loads of lesser intensity). Sight is exposed to considerable loads and high visual concentration is necessary in the course of the sub-operations II and III. Due to the brevity of individual cycles (15.5 s) and high repetitiveness, psychic fatigue (which can be attributed to monotony mostly) is also considerable. The work is performed in the temperature range between 20.0 and 24.0^0 C, and noise intensity is 70 dB(A), with possible peak loads up to 90 dB(A). Depending upon the time of being exposed to the above factors, and supposing a working shift of 7.5 h, the ergonomics coefficient for the technological operation in question is K_{er} = 0.082, or 8.2%. Investigations show that the time norm is 464.5 TMU (16.7 s), with an adequate hourly production of 205 cycles/h.

The series of movements described is optimal, consisting at the same time of simultaneous movements of left and right arm, with ergonomically acceptable body posture. The sets of basic movements implemented result in an even rhythm of performing the job and lower fatigue.

5. Conclusion

The kind of investigation of operation structure in garment industry described here indicate that the implementation of the MTM system and the OADM method make the definition of an optimal working method (with adequate time norms) possible, such that can be already used in the procedure of technological process and workplace designing. Furthermore, these methods are used in optimising the existing production systems, in educating the workers while practising the operations, for making preliminary costs estimations etc. The data obtained are precise and reliable, and can be applied to the workers possessing average level of skills, which is quite important for a successful organisation of manufacturing processes in garment industry.

Table 1: Investigation of sewing operation employing the MTM system (1 TMU = 3,6 • 10^{-2} s)

MTM – WORK ANALYSIS					List No.: 1
Object of manufacture		**Operation: Sewing the breast seam on ladies' suit**			
Date: 12.15.1999					
Prot. No.	**Left hand movement description**	**Symbol**	**TMU**	**Symbol**	**Right hand movement description**
1.	**PREPARATION FOR SEWING (Fig. 4/1)**				
1.1.	**Take and transport the new upper part to the working zone**			**Lay-off the workpiece from the previous cycle**	
1.1.1.	Reach for the upper part	R55B	23.7	M80Bm	Lay-off the workpiece (Fig. 4/2)
1.1.2.				(T90S)	Rotate hand
1.1.3				(RL1)	Release the workpiece (Fig. 4/3)
1.1.4.				**Take and transport the new lower part**	
1.1.5.			26.9	mR80B	Reach for the lower part
1.1.6.	Grasp the upper part (Fig. 4/5)	G5/G2	5.6	G5/G2	Grasp the lower part (Fig. 4/4)
1.1.7.	Reach with fingers	R8A	13.3.	M30B	Transport the lower part into the working zone
1.1.8.	Grasp the lower part	G5	0	RL2	Release the lower part onto the working zone
1.1.9.	Move fingers forwards	M8A	5.1	G5	Support the lower part
1.1.10.	Release fingers	RL2	0		
1.1.11.	Reach with fingers	R8A	5.5		
1.1.12	Grasp the upper part	G5	0	**x5**	
1.1.13.	Reach with fingers	M8A	5.1		
1.1.14.	Release fingers	RL2	0		
1.1.15.	Transport the upper part	G1B / M60C	28.7		
		S = **156.3 TMU (5.6 s)**			
2.	**POSITIONING UPPER AND LOWER PARTS**				
2.1.	Position the upper part	P1SE	5.6	P1SE	Position the lower part
2.2.	Transport the workpiece to the needle (Fig. 4/6)	M4C	4.5	M4C	Transport the workpiece to the needle
2.3.	Feet movement	FM	8.5		
2.4.	Position the workpiece under the needle	P1SE	5.6	P1SE	Position the workpiece under the needle
2.5.	Feet movement	FM	8.5		
		S = **32.7 TMU (1.2 s)**			
3.	**SEWING THE SEAM**				
3.1.	**Sewing the first segment**				
3.1.1.	Feet movement (Fig. 4/7)	FM	8.5		
3.1.2.	Sew the seam (30-35 cm)	t_{ar}	87,9	G5	Guide the workpiece in sewing
3.1.3.	Feet movement	FM	8.5		
		S = **104.9 TMU (3.8 s)**			
3.2.	**Breaking with alignment (Fig. 4/8)**				
3.2.1.	Release the workpiece	RL2	2.0	RL1	Release the workpiece
3.2.2.	Align the workpiece	R20A	7.8	R20A	Align the workpiece
3.2.3.	Grasp the workpiece	G1B	3.5	G1B	Grasp the workpiece
3.2.4.	Align the edges of the upper and lower parts	P2SE	16.2	P2SE	Align the edges of the upper and lower parts
		S = **29.5 TMU (1.1 s)**			
3.3.	**Sewing the second segment (Fig. 4/9)**				
3.3.1.	Feet movement	FM	8.5		
3.3.2.	Sew the seam (22-17 cm)	t_{ar}	69.7	G5	Guide the workpiece in sewing
3.3.3.	Feet movement	FM	8.5	RL2	Release the workpiece
3.3.4.	Grasp the workpiece (Fig. 4/10)	RL1	10.0	R20B	Reach for the workpiece
3.3.5.	Return the hand to a balanced position	R20E	9.2	G1B	Grasp the workpiece
		S = **105.9 TMU (3.8 s)**			
		The movements of right hand from 1.1.1. to 1.1.2 follow			
	Total time needed for the operation = 429.3 TMU (15.5 s)				

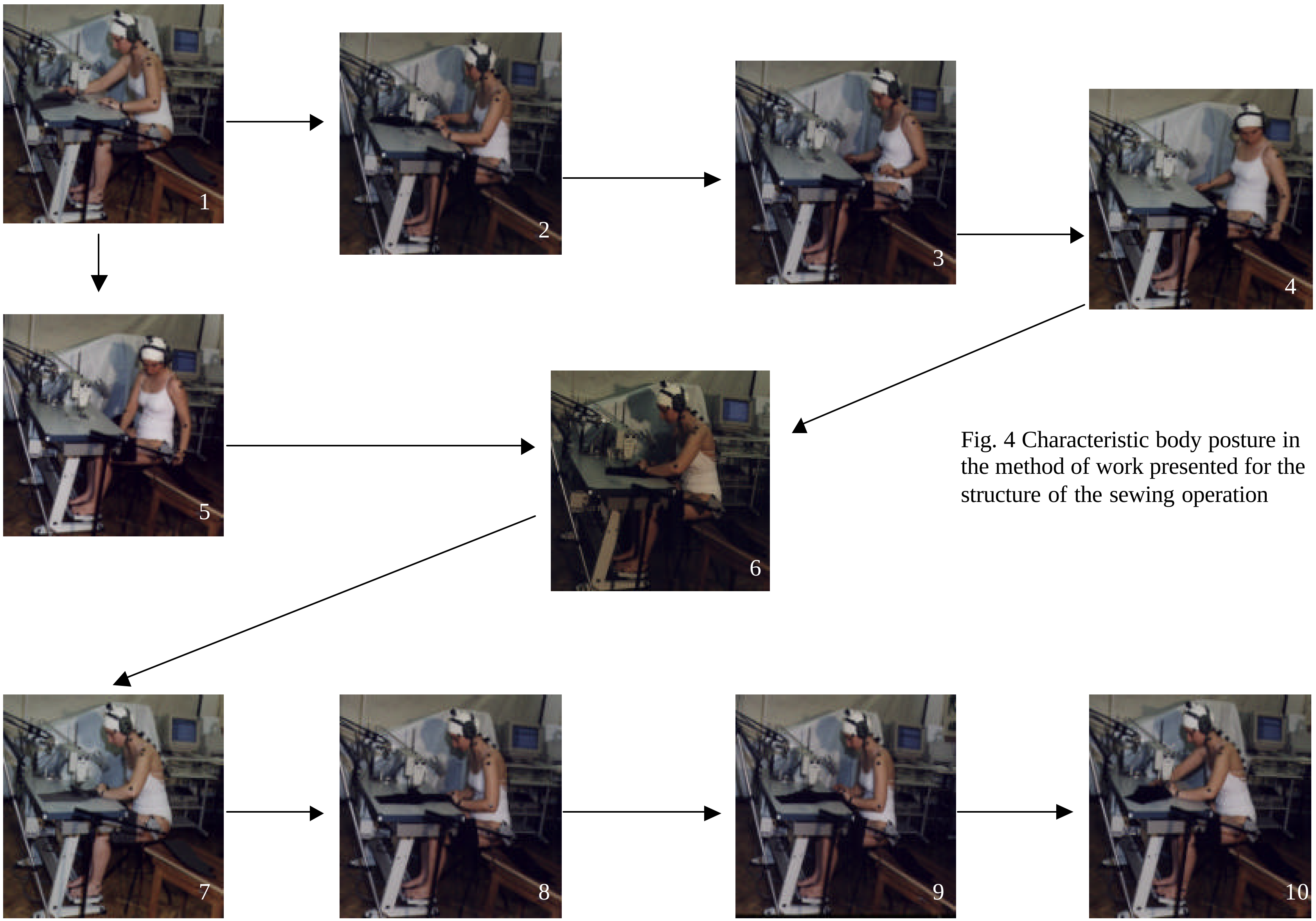

Fig. 4 Characteristic body posture in the method of work presented for the structure of the sewing operation

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