Investigations of the structure and process parameters of sewing operation

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Abstract

Original measuring equipment is presented, together with the systems aimed at investigating process parameters of the operation structure and establishing optimal working methods to evaluate properly real working conditions of the man-machine system in garment engineering and technologies. The measuring equipment consists of the system for measuring and storing data on process parameters and bi-plane system of video recording. The system for measuring and data storage is equipped with four sensors, which measure rotation speed of the main shaft, arm movements in the taking and laying-off zones, as well as the movements of pedal regulator, used to manage and control the overall sewing dynamics, all in a simultaneous and contactless manner. Bi-plane system of video recordings is used to record simultaneously the working movement systems (working methods) at the workplace analysed. The operation of seam sewing on the front part of a ladies' costume is analysed on a designed workplace, using the above described measuring equipment and system of measuring. The whole cycle of recording the technological operation included 10 consecutive executions, while the operation is performed by an operator of an average level of skill (K_{PZ} = 1,00, coefficient of proficiency*). On the basis of process parameter measurements, employing computer processing of the signals from the sensors, graphs are obtained for the technological operation structure, with the duration of individual suboperations indicated, and also showing the changes occurring in the course of sewing caused by pedal regulator movements (which manage and control the overall dynamics of sewing and the function of the processing microcomputer of the sewing machine. Bi-plane video recording system is used to investigate the working method employed, basic movements and optimal logical sets of movements, as well as the cyclograms of the movements, used to define spatial and temporal values. The results obtained are compared with the system of synthetic normal time (MTM) and indicate negligible discrepancies.*

Key words: garment engineering, sewing operation, process parameters, bi-plane video recording

1. Introduction

Process parameters and the aspects of their interaction should be known and obvious if technological operations of garment sewing for a particular situation are to be determined. Most of the measurements performed to this end used to be done by hand, with stopwatches or some other simple measuring equipment. As individual technological operations are of extremely short duration, it is rather awkward to perform measurements and write down the results by hand, not to mention the subsequent analysis of the results obtained, which is a time-consuming and tiring job. To overcome this problem, the researchers of the Department of Clothing Technology, Faculty of Textile Technology, University of Zagreb, have developed a special equipment for the purpose of measuring garment sewing process parameters, based on computer aided measurements and processing the data gathered. The system can perform simultaneous measurements of a number of parameters: sewing speed, average sewing speed, maximum sewing speed, number of stitches, sewing acceleration, etc.[1; 2].

2. Process parameters of garment sewing

Process parameters of garment sewing operations exhibit characteristic technological values, which can be measured in the course of sewing. They are divided into three groups, based upon the characteristics of the operation of garment sewing [3]:

- total time of the operation as a whole and individual suboperations of garment sewing,
- stitching speed, and
- contour length and the curvature of the seam-connected parts.

The values of some processing parameters, such as garment sewing total time, are comparatively easy to determine, by simply measuring the time needed to perform the operation. Duration of particular technological suboperations, despite being extremely short, can be measured using computers and adequate converters.

Maximum and average stitching speed are the values of the sewing process parameters, which depend upon the average stitching speed.

The relation between process parameters of garment sewing operation and contour length of the seam-connected parts is most accurately shown during the acceleration of sewing and stitching. Acceleration is related to contour length of the seam in question and to the number of stitches the machine employs in machine-manual technological procedures of garment sewing.

2.1 The impact of operation type and technological equipment on process parameters of garment sewing

Technological processes of garment manufacture (cutting, sewing and finishing) consist of a number of different types of technological operations. The exact number and the type of technological operations to be used depend on the type, construction and the purpose of the article of clothing to be produced. The technological operations differ by [4-6]:

- the form and the length of the seam,
- the function of the seam and the place where it is positioned on the article of clothing,
- the numbers of fabric layers to be sewn,
- the length of the sewing stitch to be made,
- quality requirements,
- material feeding methods and modes.

The type of technological operation implemented heavily influences stitching speed. Long and straight seams allow for higher stitching speeds than short and curved ones. In addition to seam length, its function and position on the article of clothing must be taken into account. These two parameters may result in extremely different stitching speeds at equally long seam contours. The length of the stitch is still another important parameter: shorter stitches make higher speeds possible. [4].

The kind of garment to be sewn and the shapes of the cutting parts define the types of operations to be used, from which seam contour and seam length are derived. These two parameters are of key importance, as material feed modes and average stitching speeds depend upon them. Seam length and the shape of seam contour also influence the number and the type of technological operations to be employed.

Process parameters also depend on equipment available – it is not the same whether an operation is performed by an universal sewing machine, an automatic sewing machine or by a sewing aggregate. Motor drives and feed devices are also very important, as well as additional devices for feeding layers, movement detectors, operation sensors, etc. These instruments can reduce the number of operations and their duration as well.

The influence of the sewing machine on the stitching speed can be derived from the general influence of the equipment on the sewing process parameters. This influence is most comprehensively expressed by the sort and type of the sewing machine used, its additional equipment and auxiliary devices, as well as by the nominal speed of the machine, which directly effects the stitching speed. The type of the sewing machine used and its auxiliary equipment effect stitching speed indirectly, as they define the method of work to be used and the resulting structure of the sewing operation to be performed. Sophisticated sewing machines available today allow for sewing at very high speeds, but it does not necessarily mean these sewing machines are more efficient, as preparatory operations can sometimes be extremely time- and effort-consuming. Top stitching speeds depend on the length of the seam contour and on the fabric feed method employed.

2.2 Requirements of workplace design in sewing processes

With a properly organised workplace, and taking into account the capabilities of operators, an optimal interaction of the operator, the machinery and the material can be established. Workplace design includes the development and improvement of technological processes, working methods, working conditions and machines with devices and instruments [7].

The purpose of workplace design is to reduce time losses, stresses and strains imposed on workers, and, on the other hand, to upgrade the quality and human conditions of work.

Four groups of factors are crucially important in workplace design: technological, technical, ergonomic and economic factors [8].

2.3 Determining total time on the basis of process parameter measuring

Total time of a technological operation can be measured using various electronic measuring instruments, connected to the sewing machine on one hand and to a personal computer on the other. The use of a computer and measuring equipment makes it possible to measure a number of process parameters, as well as to store results and process them with great precision and considerable speed. Converter is also an important element of every measuring system. It offers a faster and safer data transfer to the computer.

Specialised equipment for measuring the values of garment sewing process parameters has been developed at the Department of Clothing Technology, Faculty of Textile Technology, University of Zagreb. This equipment is based on computer measurements and measuring data acquisition. It is capable of simultaneous and contactless measurements of a number of parameters, such as sewing speed, average sewing speed, maximum sewing speed, sewing acceleration and the number of stitches in a seam [9].

2.4 Determining total time using video cameras

Determination of the duration of a garment sewing operation can also be performed using a video camera. Video system for the purpose includes a video camera, a video recorder and special software packages for further analysis of the material recorded.

The video camera is positioned at a precisely defined spot, which must not be changed during the recording. The video camera has an in-built timer, to be used to control the duration of the recording and to insert data notations. The technological operation recorded can be stored on the videotape. In addition, process parameters in the course of technological operation of garment sewing can be measured using suitable measuring equipment [10].

3. Investigation methodology

3.1 Measuring system and equipment

Original measuring equipment has been developed in The Department of Clothing Technology, Faculty of Textile Technology, as well as a measuring system intended for sewing operation process parameter measurements, able to evaluate properly real conditions of the man-machine system [3; 11].
Measuring system (Fig 1) consisting of two parts:
a) equipment for measuring and storing process parameter data, and
b) bi-plane video recording system
has been used to investigate temporal structure of performing the operation in question.

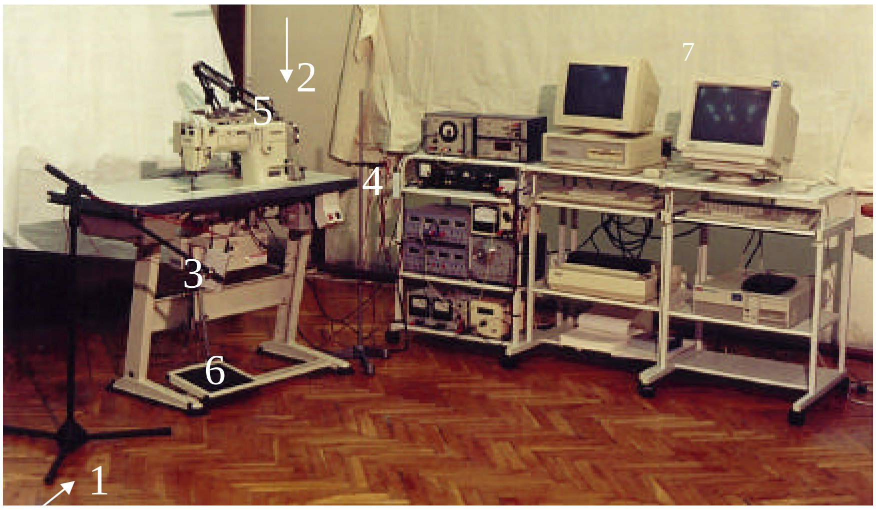

Figure 1: Linking a sewing machine to measurement equipment: side video camera (1); upper video camera (2); movement detector for taking the workpiece (3); movement detector for laying the workpiece off (4); IR converter for measuring the sewing machine main shaft rotation speed (5); movement detector for lifting and lowering pressure foot (6); measuring equipment (7); [10].

Sensor-computer system for measuring and storing the recorded data on process parameters is equipped with four sensors, able to measure continuously and without need for a contact, the following: main shaft rotation speed (5), hand movement in a limited work space of the workpiece taking zone (3) and workpiece laying-off zone (4), the pressure foot shifts, through which overall sewing dynamics is regulated and controlled (6). Employing measuring converters, the measuring data from the above four sensors are stored into the computer, and plotted separately or on the same diagram, employing the technique of superposition. Computer data processing offers the possibility of determining real sewing speed, as well as the overall and individual total times for each suboperation (taking, setting, carrying, positioning, laying-off) which together constitute sewing operation structure.

Video recording system consists of two video cameras, which simultaneously record the working movement systems (methods of work) at the workplace, in two planes – vertical and horizontal. This results in continuous and comparable recordings of all the postures and limb and body movements of the operator in the course of sewing, given as ground plan and side view representations. Cameras are synchronised with each other and calibrated, while computerised processing of video recordings obtained simultaneously gives the ground plan and side view representations of the movement flow and succession in the course of work.
For the purpose of comparative investigations of the man-machine system as well as for the purpose of establishing optimal working methods, marks are positioned on the body of the operator, made of special stickers in a phosphorescent colour. Marks are symmetrically distributed along the body of the operator. For the purpose of analysing head and neck rotation and flexion, as well as shifting the eye (10), body movements and curvature of spinal column (10), and limb movements, 24 marks are positioned on the arms and 18 on the feet and legs. Marks are clearly visible in horizontal and vertical recordings, and are used to define logical sets of movements, cyclograms of movement, on the basis of which spatial and temporal values of the movements, angles and axes of body dynamical movements, important for biomechanical investigations of human body in working processes, are defined. Slowed-down recordings (5-15 frames per second) are used in video recording analysis to determine optimal working methods, while current time data are obtained employing a time generator, with the accuracy of $\pm$ 0,01 s.

Individual pieces of equipment are mutually complement and compatible, constituting original measuring equipment for investigating interactions of man and machine in garment manufacturing operations.

3.2 Measuring procedures and results

The structure and process parameters of sewing operation for the front parts of a ladies' costume, on an engineered workplace (Fig. 2) were investigated. The workplace was designed following anthropometrical measures of the operator, sitting height defined, while working positions of taking (7) and laying-off (5) were positioned in an ergonomically acceptable range.

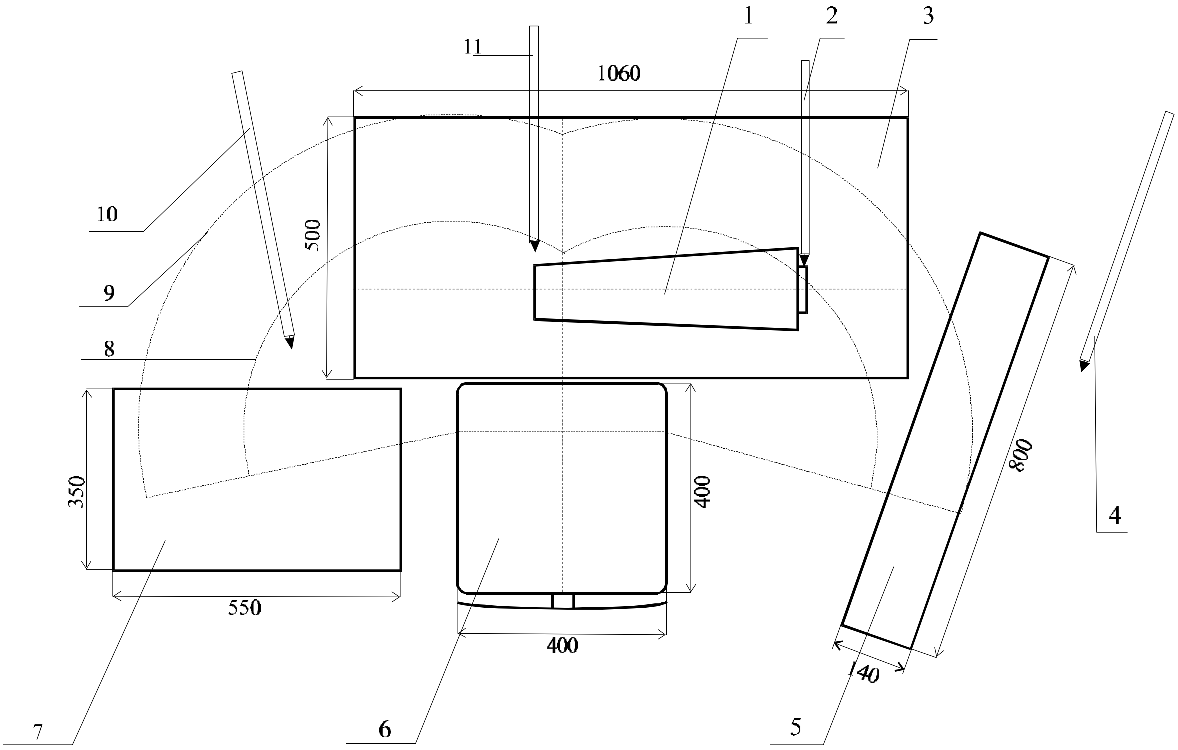

Figure 2: Ground plan representation of a designed workplace, M1:10

Description of the ground plan representation of a designed workplace: sewing machine Brother DB2-B755 (1); infrared measuring converter (2); working area (3); movement detector for laying-off the workpiece (4); frame for laying-off the workpiece (5); industrial chair (6); frame for taking the work piece (7); normal hand reach (40 cm) (8); maximum hand reach (60 cm) (9); movement detector for taking the work piece (10); movement detector for lifting and lowering pressure foot (11).

Sewing operation described here was performed on a modern BROTHER DB2-B755 sewing machine, equipped with a process microcomputer F-100, able to program the nominal stitching speed, number of stitches per a segment, sewing thread cutting-off and sewing needle position.

Polyester thread of the fineness 8.3x3 tex was used in sewing, and the seam was made using the double lockstitch 1.01.01/301.

Fabric samples used to make the ladies' costume were wool/polyester blends (45/55), with the surface mass of 264 gm^{-2}, thickness 0,875 mm, warp/weft density of 30/28 yarns cm^{-1}, manufactured in twill (2/1) weave. Other sewability characteristics were determined employing the contemporary FAST measuring system [12]. Overall recording cycle included 10 successive recordings of the operation. The operation recorded was performed by an averagely skilled operator (K_{pz}=1,00; coefficient of proficiency), using an optimal working method, considering the type, dynamics and succession of basic movements. The working method employed had been previously defined and described employing MTM system (Motion Timestudy Measurement) [13;14].

At a designed workplace (Fig. 2), following the principles of the above method, a bundle of workpieces was positioned for taking (7) while another one was situated in the operator's lap. By simultaneous movements of both left and right arms, both workpieces were taken and carried to the machine working plate, aligned at the starting angles and positioned under the machine needle. Total seam contour length was 52 cm, and sewing was done in two segments. Seam length of the first segment was 30-35 cm, which is within the boundaries of ergonomically acceptable arm reach, with the help of body front flexion and repeated angles of vision. During the stoppages in sewing, the samples were parallelised and the second segment of the seam was sewn. When sewing was completed, pressure foot was lifted pressing the pedal regulator with the heel, thus positioning the needle in the upper position. The mechanism for thread cutting-off was activated at the same moment. The garment part sewn was taken using right hand and positioned for laying-off (5). This working method is optimal, since it enables the operator to handle bigger samples, while encompassing the movements of both right and left arm, with the body in an ergonomically acceptable position. The sets of basic movements used offer an even rhythm of performance and lower fatigue.

Seam sewing operation was recorded using the measuring equipment for measuring process parameters and bi-plane video camera system. Statistical data processing for 20 consecutive trials of the operation showed that the average duration of the sewing operation, as established by measuring process parameters was 23,87 s (σ = 0,838 s), while the analysis of the video recordings of the movements, following the marks on the operator's body gave 23,65 s (σ = 0,818 s). These results indicate a high degree of coefficient of workplace stabilisation (K_s = 0,12), as well as the fact that the working process was done employing the same method, and using the same optimal logical sets of movements [15].

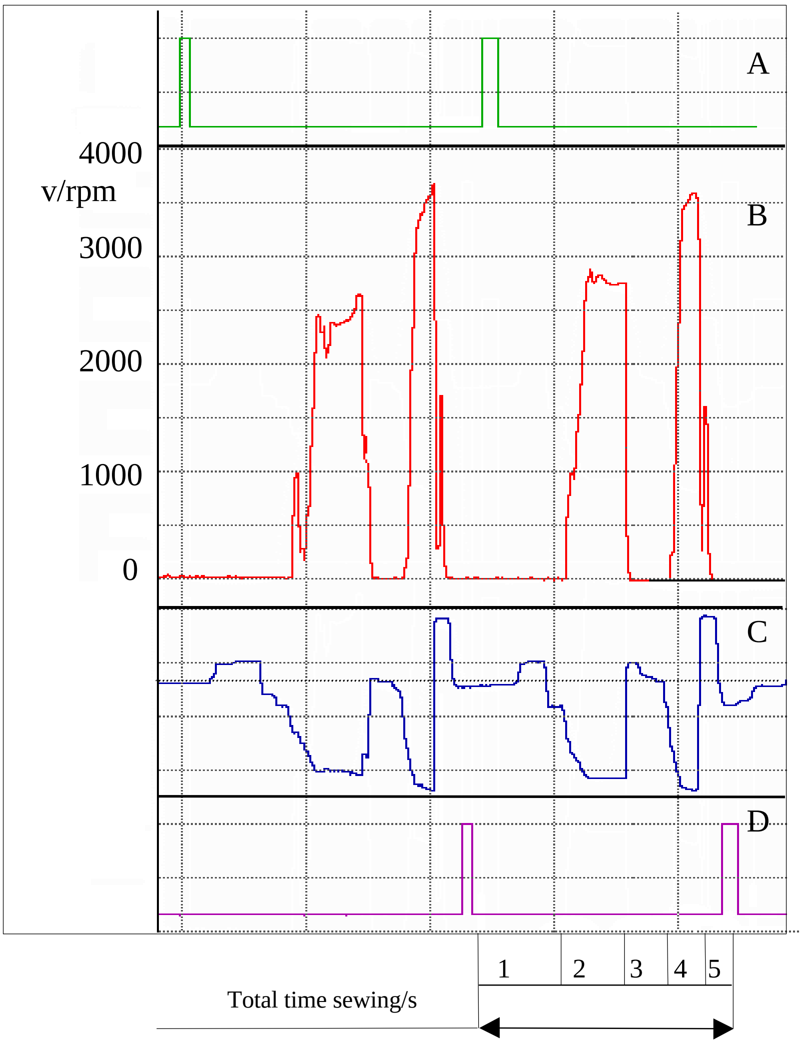

Figure 3: Process parameter measurements by a computerised processing of sensor signals for: taking (A), stitching speed (B), pedal regulator position (C) and laying-off (D) [15].

Figure 3 offers an example of graphic data on process parameter measurement representation obtained through computerised processing of sensor signals for taking (A), stitching speed (B), pedal regulator position (C) and laying-off sensor (D). Employing comparative analysis of these graphs, duration of individual suboperations and sets of movements can be obtained. These movements constitute the structure of the technological operations of: taking, setting, carrying and positioning (1), first seam segment sewing (2), aligning both workpieces during the break in sewing (3) second seam segment sewing and automatic thread cutting-off (4), and finally, laying the workpiece off.

Overall duration of the sewing operation (23.62 s) was established employing the above method. The time necessary for movement sets of taking, setting, carrying and positioning the workpiece (1) was 8.57 s, first seam segment sewing (2) needed 7.11 s, aligning both workpieces during the break in sewing (3) asked for 2.51 s, second seam segment sewing with automatic thread cutting-off (4) 3.97 s, and final laying-off (5) 1.46 s.

Signal for pedal regulator position (C) was a predominant source of data about discrete feet movements that govern and control overall sewing dynamics and the functions of sewing machine process microcomputer. Feet movements included in switching-on and sewing can be seen in the graph under the neutral position, while the movements involved in pressing with the heel part of the foot in switching-on the mechanism for lifting pressure foot (I phase) and mechanism for thread cutting-off (II phase) are shown above the neutral position.

Measurements of operation process parameters result in duration of individual suboperations, while the recordings done using the bi-plane video recording system enables the investigation of the working methods, movements and sets of movements employed to undertake a working process. With this goal in mind, the investigations of logical sets of movements were done by the video recording analysis (5 frames per second), including the adequate sub-durations (± 0,01 s), and following the system of synthetic normal times MTM - Motion Timestudy Measurement. Real lengths of sub-movements for each complete movement (Fig.4) were defined on the video recordings of the operations, employing the grid method and using the marks on the operator's body. Basic notions of this method have been analysed and presented in literature [7,8].

Figure 4: Body posture with marks, in the course of sewing the second segment of the seam (Fig. 3 - segment 4)

According to the MTM system, the succession of movements in performing the operation belongs to the types 2 and 3. The movement of taking the workpiece with laft hand is done employing an optimal set of basic movements (mR55B-G1B/G2-M65B$_{CD}$), while the other workpiece is being taken with right hand simultaneously (mR50B-G1A/G2-M70B$_{CD}$). Parallelisation is done employing another set of movements (M10C-P2SE-R30B-G1A-P1SE), and then the positioning under the sewing needle, employing the set of movements (M6C-FM-P2SE-FM).

According to the MTM system, the duration of the suboperation of taking and positioning the workpiece is 228 TMU (8,23 s), and the analysis of the video recording on screen says it lasts for 8,73 s, while the measuring of process parameters (Fig. 3 - segment 1) results in 8,57 s, which means the discrepancies are minimal.

4. Conclusion

Using the measuring equipment described and the system to measure process parameters and logical sets of movements in a technological operation, proper evaluation of real conditions of the working system man-machine can be made. This measuring system makes possible to consider in detail all the parts of the operation structure used to design optimally both working methods and workplaces.

This investigation has been done as a part of international collaboration between the Department of Clothing Technology, Faculty of Textile Technology, University of Zagreb, Croatia and Textile and Garment Manufacture Institute, Faculty of Mechanical Engineering, University of Maribor, Slovenia, as well as a part of the co-operation in the CEEPUS programme.

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