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METHOD FOR DETERMINING THE NORMAL TIMES OF MACHINE-HAND SUBOPERATION IN SEWING SEAMS WITH TWO RADII OF CURVATURE

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Abstract: *This paper describes the methods for determining the normal times of machine-hand technological suboperations in sewing curved seams with two radii of curvature, based on systematic research and measurements during the performance of machine-hand suboperations in sewing. For that purpose measurements were performed in the laboratory of the Department of Clothing Technology at the Faculty of Textile Technology, University of Zagreb, using modern measurement equipment, as well as the recording technology of the process of sewing clothes in a real production process. After that, the video recordings were analyzed and the times of performing the sewing suboperations were extracted. Based on the measured data a mathematical model and a computer program to calculate relevant parameters in joining work pieces with two radii of curvature BIR were established.*
Key words: *garment technology, normal times, machine-hand suboperations, curved seam, mathematical model*

1. INTRODUCTION

W. Möller performed investigations of finding mathematical expressions for the determination of normal machine-hand suboperations in sewing based on the correction of nominal stitching speeds of sewing machines. Besides the parameters of maximum stitch speed in sewing, this author included the values of the machine operator's reaction capability during the manual control of the work piece, and the time associated with the activation of the foot pedal during starting and stopping the electric drive motor (Möller, W., 1986). For the calculations of normal machine-hand suboperations he established the following expression:

$$t_{ar} = \frac{l_s \cdot G_u \cdot 1667}{v_n} \cdot \frac{R_p}{R_{maks}} + D \quad (1)$$

where: R_p- necessary reaction capabilities; R_{max}- maximum reaction capabilities; D- attachment for the activation of the pedal regulator and transient phenomena of acceleration and braking the electric motor

He also established the expression for the so-called effective stitching speed (2) in which he corrected the sewing speed of the sewing machine by the coefficient of the ratio between the maximum and necessary number of reactions.

$$v_{ef} = \frac{v_n \cdot R_{maks}}{R_p} \quad (2)$$

where: v_{ef} - effective sewing speed, min^{-1}

He determined the necessary reaction capabilities depending on the radius of the seam curvature, joining accuracy and seam guidance method, Figure 1. Reaction abilities of workers are necessary so that the seam trajectory, which deviates from the necessary sewing line, is guided by correcting so as to achieve the desired position with given accuracy (Krowatschek & Ludemann, 1974). Necessary reaction capabilities are determined from the influencing parameters of the deviation of the seam trajectory from the imaginary sewing line and joining accuracy according to the formula:

$$R_p = \frac{deviation}{joining\ accuracy} \quad (3)$$

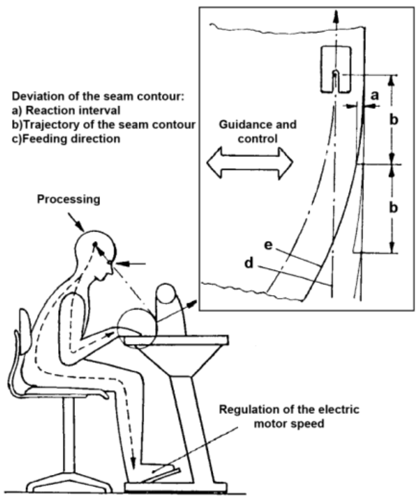

Fig. 1. Man-machine system as a control circuit

The maximum number depends on the maximum stitching speed and specific stitch density (Möller, W., 1978). Due to seam curvature and a certain accuracy with which the seam should be joined, the number of required reactions will become greater than the maximum number of reactions. Therefore, the machine operator has to reduce the stitcing speed and is not able to take advantage of technological possibilities of the sewing machine when operating at maximum stitching speeds, and sewing will be longer. The first part of expression (1) is the formula for the machine operation with a factor of 1667 to convert the minutes calculated in TMU units. The sewing time calculated in the first part of expression (1) represents the original sewing time to be prolonged due to necessary reactions of the machine operator. That time is prolonged as the ratio between Rp and Rmax. According to Möller, prolongation of sewing time will be longer with increasing seam curvature and necessary greater accuracy of joining and as a consequence sewing will be performed using machines with a higher stitching speed and a lower specific density of machine stitches in the seam. Addition D in equation (1) consists of 9 TMU required to activate the sewing machine pedal and 5 TMU as average values for starting and stopping the rotor of the sewing machine electric motor.

2. MEASURING SYSTEM AND EQUIPMENT

Operations of sewing straight and curved seams were recorded under laboratory and in-plant conditions. Measuring has developed, calibrated and tested special measuring equipment and method (MMPP) used to determine machine-hand time necessary to perform particular sewing sub-operations (Firšt Rogale. & Dragčević, 2001).

3. RESULTS AND DISCUSION

Based on the studies of reaction capabilities of the sewing machine operator during sewing curved seams, a new method for the determination of normal times of joining work pieces with two different radii of the curvature of the work pieces was created. For this purpose geometrical dependencies of the factors of seam joining with two different radii of the curvature of the work pieces, Figure 2, were determined.

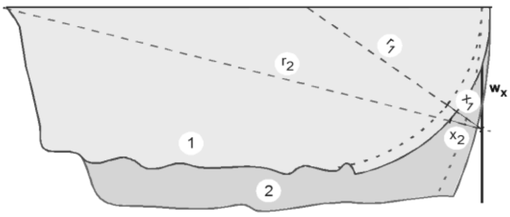

Fig. 2. Geometrical dependence of the factors of seam joining with two different radii of the curvature of the work pieces

In Figure 2 the total deviations x_Σ represent the sum of deviations of the seam trajectory in the upper part of the work piece 1 and in the lower part of the work piece 2:

$$x_\Sigma = x_1 + \left(x_1 - x_2\right) \tag{4}$$

where: x_Σ - total deviation of the necessary and actual seam trajectories or total joining accuracy, respectively [mm]; x_1 - deviation of the seam trajectory of the upper work piece (upper contour) and real seam trajectory; x_2 - deviation of the seam trajectory of the lower work piece (lower contour) and the real seam trajectory; (x_1-x_2) - difference between the seam trajectories in the work pieces

According to Figure 2 a system of equations with three unknowns:

$$w_x = \sqrt{(r_{1,2} + x_{1,2})^2 - r_{1,2}^2} \tag{5}$$

expressed by the radius of curvature of the upper work piece (r_1) or (r_2).where w_x is the distance after which there is a need for reaction

By solving the quadratic equation an expression for calculating the difference x_1 seam trajectory on the upper work piece and the necessary seam trajectory:

$$x = \frac{\left(r_1 - 2\cdot r_2 + 2\cdot x\right) \pm \sqrt{\left(r_1 - 2\cdot r_2 + 2\cdot x\right)^2 + 3\cdot\left(2\cdot r_2\cdot x - x^2\right)}}{3} \tag{6}$$

This determines the expression for the calculation of the deviation of the upper seam trajectory 1, Figure 2, from the real seam trajectory. The deviation of the lower seam trajectory 2 is also determined using the expression (6). This satisfies the condition that the sum of the deviations x_1 and x_2 is equal to the allowable total deviations of the seam contours on both work pieces from the real seam trajectory or to a certain joining accuracy. The above mathematical analysis and elaboration are the backbone of the considerations which are necessary for the establishment of mathematical models and BIR computer program to calculate the time of machine-hand technological suboperations for making seams which have work pieces with two different radii of curvature. The radius of curvature of the seam trajectory of the upper work piece, the radius of curvature of the seam trajectory of the lower work piece, the total deviation of both trajectories, the specific density of seam stitches, the seam length and the nominal sewing speed of the sewing machine that performs sewing represent the input elements of the program.

Output parameters represent the calculated deviations of the trajectories of the upper and lower seam portion from the actual seam trajectory, the required number of reactions of the machine operator to join the upper and lower seam portion, maximum possible reaction, and necessary times to join the seam, whereby the duration to join the upper seam portion (upper contour) and the lower seam portion (lower contour) is separately calculated, while cumulatively calculated is machine-hand time for the technical suboperation of joining this kind of the seam. The program also calculates the effective sewing speed required for joining the upper portion of the work piece, the lower portion of the work piece and the whole seam.

4. CONCLUSION

On the basis of the performed investigations a method was created which is based on the cybernetic model of reaction capabilities of the operator of the sewing machine during joining curved seams with two different radii of curvature of the seam trajectories on the work pieces. This method is based on the initial consideration of the established geometric dependences of the factors of joining seams with two radii of curvature of the work pieces. Since the sum of deviations of the seam trajectories on the so-called upper and lower part of the work piece is defined as joining accuracy, it is necessary to establish a system of three equations with three unknowns whose solutions form the basis for establishing a mathematical model of the method and BIR computer program. For this model and program the input parameters for the radius of curvature of the seam contours of the upper work piece and the lower work piece as well as the total joining accuracy and the density of seam stitches , the length of this seam and the nominal sewing speed of the sewing machine are used. The program offers a number of output calculated parameters such as the calculated deviations of the seam trajectories on the upper and lower part of the work piece from the required seam trajectory, the necessary number of reactions in joining the upper and lower contour and the maximum number of the sewing machine operator's reactions. In addition, the program calculates the time required to perform joining the upper and lower contours of the work piece, total time of sewing, as well as the effective sewing speeds.

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