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Correlation between the Seam Stitch Length of the Sewing Garment and Friction Forces

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In this article the influence of the friction forces on stitch length is analysed. In the course of research, fabrics with different mechanical and structural properties have been used. Internal friction of fabric has been assessed using resonant oscillations. When correlating stitch length with internal friction of fabric it has been established that internal friction influences the stitch length. With minor internal friction of fabric stitch length is unstable and may vary by up to 0.5 mm. As internal friction of fabric increases, average stitch length stabilises or varies within the limits of 0.1 mm. In order to assess quality of the sewing garment it is important to establish how deformation of the sewing garment changes both in the course of sewing and when some time passes after sewing. This is the internal friction that determines relaxation time of the sewing garment and at the same time variation of stitch length after sewing. With minor internal friction of fabric relaxation time of the sewing garment is short (~10 min). When fabrics with higher internal friction are sewn together relaxation time is longer (up to 60 – 240 hours). It has been established that different external forces lead to different feeding conditions of fabric. If external friction force is minor stitch length has no tendency of constant variation, i.e. it may either increase or decrease within the limits of 0.1 mm – 0.3 mm. If external friction force is considerable, stitch length is higher and in the same fabric, under different directions featuring different friction force stitch length may differ by up to 0.4 mm. The lower is the external friction force of fabric, the more considerable decrease of the stitch length is observed when increasing pressing force. It was found as well that the higher is the external friction force of fabric, the lower influence on stitch length variation is made by two-sided load of the sewing garment.

Keywords: stitch length, fabric, internal friction force, resonance oscillations, relaxation time, external friction force.

INTRODUCTION

One of the quality indicators of sewing garments involves stable stitch length within individual seam sections. High-quality of the seam is influenced by behaviour of the sewing garment both in the process of sewing and after sewing. Forces acting upon the sewing garment are varying. A toothed plate moves in an elliptical trajectory, therefore, pressing and friction forces vary within a certain range. Besides, the area of the pressed and stretched sewing garment exceeds the stitch length. In this case, the same part of the sewing garment is affected by force which increases (before feeding by stitch length) and decreases (going off from under the pressing foot) [1 – 6].

Subject to the internal friction of the sewing garment fabric determined by weave, properties of threads, sewing direction, etc., different behaviour of fabric is obtained in the sewing process. After assessing the internal friction of the sewing garment fabric and after defining its relation with the variation of stitch length of the seam in time, the relaxation process may be evaluated partially.

In the process of sewing, the sewing garment undergoes different loads which may act in the sewing direction or in the direction opposite to sewing. This also may depend upon the size and mass of the sewing garment. When sewing a garment with higher mass, it may slip in respect of a toothed plate. After sewing the larger part of the sewing garment, i.e. after the main mass of the sewing garment "passes" the transportation mechanism, the sewing garment is affected by the inertial force in the direction of sewing. The beginning of the seam may be affected by the forces of one direction, whereas the end of the seam may be affected by the forces of another direction. Besides, in the process of sewing, the human factor is observed as well: the sewing garment may be stretched, stayed, etc. by a tailor.

One of the main factors of the sewing garment influencing also the stability of stitch length along the seam is its feeding in the process of sewing. Feeding conditions depend very much upon the external forces affecting the sewing garment: external friction of the sewing garment; load, pressing force, inertial force, etc. acting upon the sewing garment [7 – 9]. The aforementioned factors also influence the quality of the stitch formation process. Therefore, it is very important to determine the influence of various factors upon stitch length and look for techniques in order to stabilise stitch length along the seam.

The aim of this paper involves research of the interaction between seam stitch length of the sewing garment and friction forces affecting this length.

METHODOLOGY

During the investigation, 100 % PES fabrics of plain and twill weave were analysed. Plain weave fabric was examined in the directions of warp, weft and in the bias

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direction of 45°, whereas twill weave fabric was studied in the directions of warp, weft and in the bias directions of 45° and 135°. Two-sided load of the sewing garment was changed within the limits of 0.2, 0.5, 0.98, 1.47, 1.96, 2.45, and 2.94 N. During experiments, sewing was performed by one-needle lockstitch sewing machine UNICORN. Using this machine it is possible to fix stable rotational frequency of the main shaft which was changed within the limits of 200, 1100 and 2100 min^{-1}, presser foot force 45 N and 85 N respectively. Digital image of the sewn specimens was transferred to a computer where seam stitches are measured using special software [8 – 10]. Friction force between fabric and a pressing foot, between fabric and a needle plate was obtained using a tensile testing machine [9 – 14]. Internal friction (tgδ) was determined against amplitude – frequency properties [11, 12]. The stitch length was measured then and there after the sewing and later after 10, 60 and 240 minutes. The change of the stitch length was related with internal friction of the sewing fabric (tgδ).

One of the main factors determining the variation of stitch length is variable sewing speed. Although, when sewing fabrics sewing speed remains stable for some time, in the beginning and in the end of the seam sewing speed is variable. Besides, after detachment of a pressing foot the sewing garment undergoes inertial motion due to the certain motion speed applied.

In order to stabilise stitch length of the sewing garment two-sided load of the sewing garment was applied. Fig. 1 presents a diagram of sewing garment feeding and acting forces.

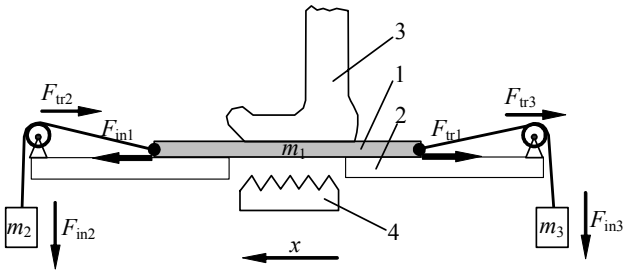

Fig. 1. Diagram of sewing garment feeding and acting forces: 1 – sewing garment, 2 – needle plate, 3 – presser foot, 4 – toothed plate; m_1, m_2, m_3 – masses of elements of the sewing garment and loads; F_{in1} – inertial force of the sewing garment; F_{in2}, F_{in3} – inertial forces of load elements, F_{tr1} – friction force between the sewing garment and a needle plate and presser foot, F_{tr2}, F_{tr3} – friction forces acting in fair – leads, x – axis

If after feeding, the sewing garment undergoes the inertial movement forces acting upon the sewing garment may be expressed as follows:

$$m_1 \ddot{x} = - F_{tr1} - F_{tr2} - F_{tr3} + F_{in2} + F_{in3}, \quad (1)$$

where $F_{tr1} = m_1 g f_1$, $F_{tr2} \approx m_2 g f_2$, $F_{tr3} \approx m_3 g f_3$, $F_{in1} = m_1 \ddot{x}$, $F_{in2} = m_2 \ddot{x}$, $F_{in3} = m_3 \ddot{x}$,

f_1 is the coefficient of sliding friction between the sewing garment and a needle plate and presser foot, f_2, f_3 are the coefficient of sliding friction present in the bearings of guiding rollers, g is the free fall acceleration.

After putting expressions of forces into the equation we obtain the following:

$$(m_1 + m_2 + m_3)\ddot{x} = - g[m_1 f_1 + f_2 (m_2 + m_3)], \quad (2)$$

where $f_2 = f_3 = f$ or

$$\ddot{x} = - g \frac{m_1 f_1 + f(m_2 + m_3)}{m_1 + m_2 + m_3} = -a_0, \quad (3)$$

where a_0 is the acceleration of the slowing movement of the sewing garment.

When initial inertial motion speed v_0 of the sewing garment (feeding speed of the sewing garment) is known, time of its slowing movement is obtained as follows:

$$t = \frac{v_0}{a_0}. \quad (4)$$

Taking into account the fact that final speed of the sewing garment is equal to zero, i.e. the sewing garment after feeding stops completely, we obtain the following:

$$x = -a_0 \frac{t^2}{2}. \quad (5)$$

After putting expression (4) into equation (5) we get the following:

$$x = \frac{v_0^2}{2g} \frac{m_1 + m_2 + m_3}{m_1 f_1 + f(m_2 + m_3)}; \quad (6)$$

$m_2 = m_3 = m$, therefore:

$$x = \frac{v_0^2}{2g} \frac{m_1 + 2m}{m_1 f_1 + 2fm}. \quad (7)$$

If no sewing garment load ($m_2 = m_3 = 0$) was applied, the sewing garment path would be expressed as follows:

$$x = \frac{v_0^2 g}{2 f_1}. \quad (8)$$

In this case, the sewing garment path x (Fig. 1), thus stitch length $L = x$ would increase as speed of the sewing garment grew. When for the sewing garment the aforementioned load ($m_2 = m_3 \neq 0$) is applied, the inertial motion path of the sewing garment, thus stitch length depend upon the friction force caused by load. With growing speed v_0 of the sewing garment it is possible to choose such mass of load elements as to maintain stable stitch length.

Thus, the paper analyses the variation of stitch length taking into account such as internal and external friction force of the sewing garment, feeding, speed and looks for techniques in order to stabilise stitch length applying load.

INVESTIGATION

When correlating stitch length with internal friction of fabric it has been established that internal friction influences stitch length [11]. Internal friction also determines relaxation time of the sewing garment and at the same time affects variation of stitch length after sewing (Fig. 2). It was obtained that with minor internal friction of

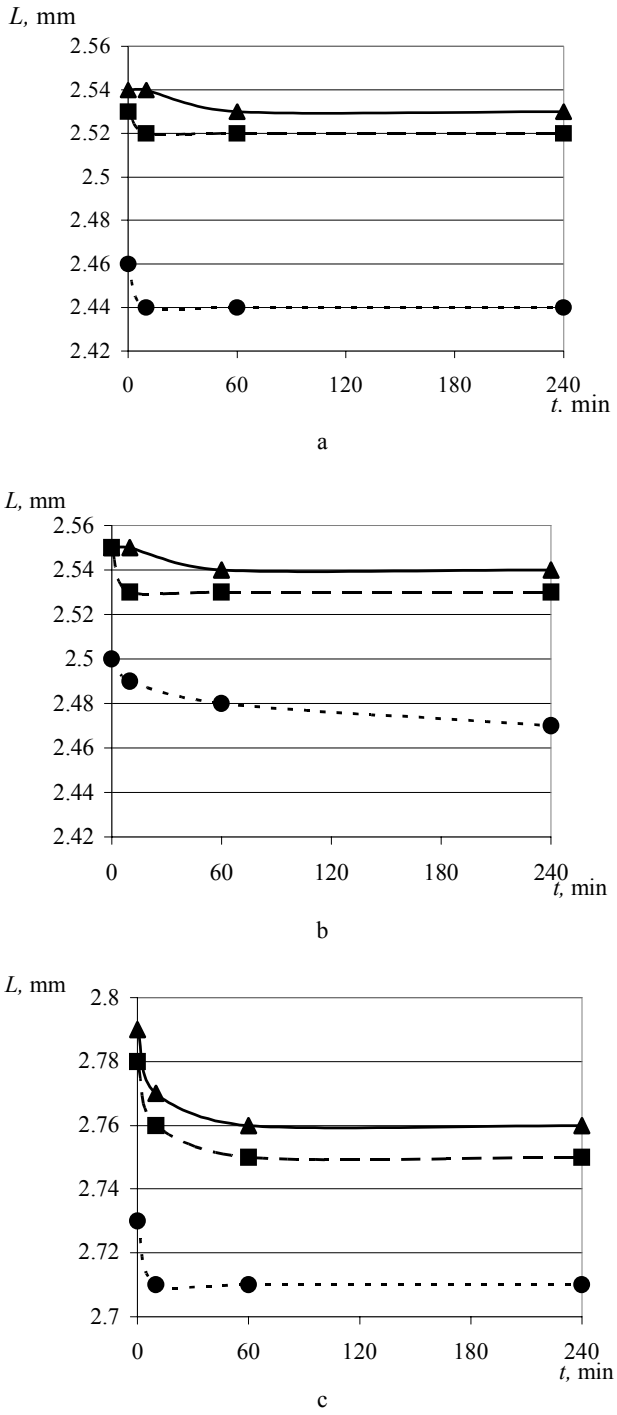

Fig. 2. Dependence of plain weave fabric the stitch length $L(x)$ upon internal friction (tgδ) and time t, when rotational frequency of the main shaft is the following: a – 200 min^{-1}, b –1100 min^{-1}, c) 2100 min^{-1} (– – – – 0.03, —— – 0.033, ---- – 0.037)

fabric (tgδ = 0.01 – 0.03) relaxation time of the sewing garment is short, i.e. about 10 min. When fabrics with higher internal friction are sewn together (tgδ exceeds 0.03) relaxation time is longer (up to 1 – 4 hours). In the course of the relaxation process of the sewing garment, stitch length changes negligibly (up to 0.03 mm). The influence of sewing speed on relaxation of the sewing garment is also observed: when sewing speed is 200 min^{-1} stitch length eventually after sewing shortens by ~0.01 mm, whereas when sewing speed is higher (2100 min^{-1}) the change of stitch length may be up to 0.03 mm. It is seen that internal friction of fabric influences stitch length, but very negligibly within the limits of 0.01 mm – 0.03 mm. The aforementioned investigations should be important when sewing fabrics together by longer stitches (5 mm – 10 mm).

When correlating external friction force with load of the sewing garment (Fig. 3), we see that the stitch length depends upon the following parameters. If external friction force of fabric is law (up to 14 N), stitch length decreases considerably as load increases. Difference between the stitch lengths when sewing without load and with 2.9 N load is ~0.6 mm. When sewing in the direction where the external friction force of fabric is approximately 16 N, this difference decreases approximately up to 0.3 mm. Thus, the higher is the external friction force of fabric, the lower influence on the stitch length is made by load.

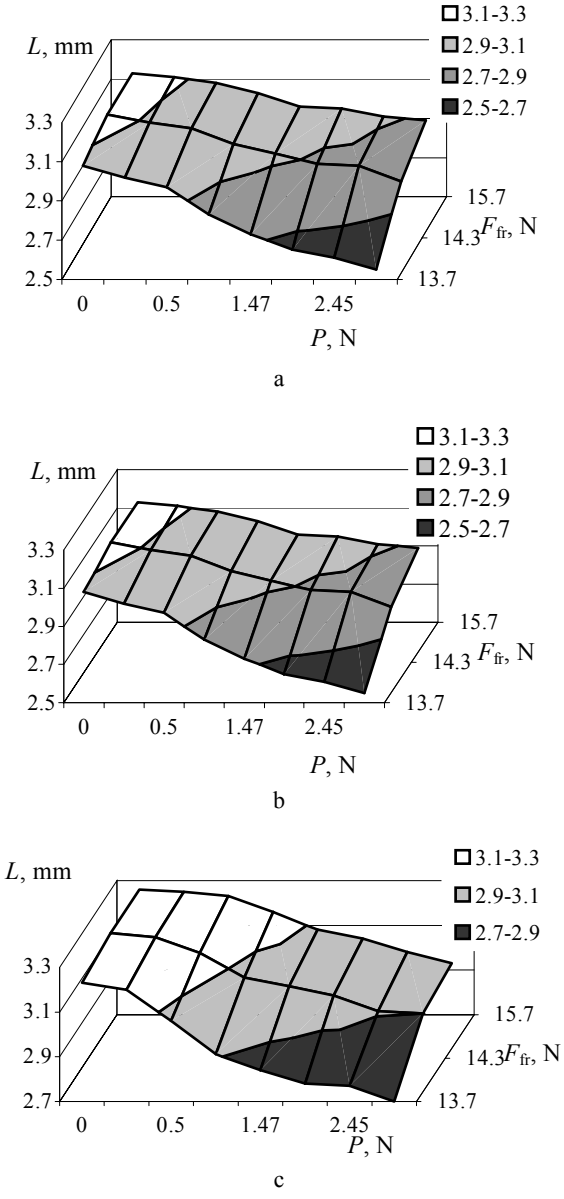

Fig. 3. Dependence of the stitch length L upon external friction force of fabric F_{fr} and two-sided load P, when pressing force is 45 N and rotational frequency of the main shaft is the following: a – 200 min^{-1}, b – 1100 min^{-1}, c – 2100 min^{-1}

In all cases, it was obtained that two-sided load influences stitch length irrespective of the extent of pressing force. Increase of two-sided load leads to decrease of stitch length. When sewing at different pressing forces, stitch length varies within the limits of 0.1 mm. Increase of load may lead to decrease of stitch length up to 0.6 mm.

One of the outer factors influencing the process of sewing involves pressing force acting upon the sewing garment. Failure to select proper force between a pressing foot and the sewing garment may cause such defects of the seam as waviness, uneven stitch length, feeding of layers in the sewing garment, etc. The presented results (Fig. 4) demonstrate that irrespective of external friction force of fabric, stitch length is always shorter when sewing at higher pressing force. In all cases, it was obtained that two-sided load influences stitch length both at 45 N and 85 N pressing forces. Increase of two-sided load leads to decrease of stitch length. When sewing at different pressing forces stitch length varies within the limits of 0.1 mm. Increase of load may lead to decrease of stitch length by up to 0.6 mm. After investigations performed with other fabrics, a similar tendency of stitch length variation taking into account pressing force, load and external friction force of the sewing garment was established.

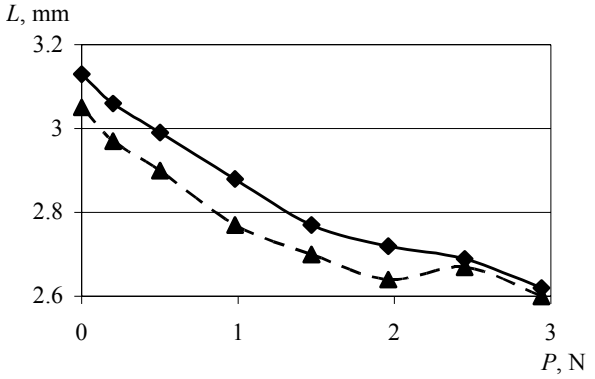

Fig. 4. Dependence of the stitch length L upon two-sided load P and pressing force, when rotational frequency of the main shaft is 1100 min^{-1} and external friction force of fabric is 13.7 (—— – 45 N, – – – – 85 N)

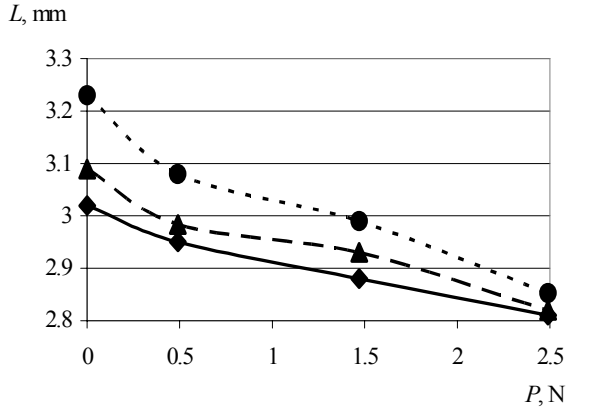

Fig. 5. Dependence of the stitch length L upon two-sided load P and rotational frequency of the main shaft, when pressing force is 45 N and external friction force of fabric is 10.9 N (—— – 200 min^{-1}, – – – – 1100 min^{-1}, ···· – 2100 min^{-1})

In the former investigations, it was established that one of the factors having the greatest influence on the variation of stitch length (up to 0.8 mm) is sewing speed [9 – 14]. Fig. 5 presents the influence of two-sided load on stitch length when rotational frequency of the main shaft is 200, 1100 and 2100 min^{-1}.

It is possible to see that difference between stitch lengths when sewing at different speeds without load may be ~0.3 mm. Increase of two-sided load leads to decrease of difference between stitch lengths obtained when sewing by different speeds. When the sewing garment is affected by the maximum two-sided load of 2.5 N, difference between stitch lengths may be some 0.05 mm. The result is acceptable as this difference is unnoticeable by an eye and such a defect is not subject to evaluation. Two-sided load helps to stabilise stitch length even if sewing speed differs some 10 times.

Thus, we see that proper selection of two-sided load of the sewing garment, evaluation of properties of the sewing garment and adjustment of technological equipment may decrease the variation of stitch length along the seam. This fact improves the quality of both the seam and entire sewing garment.

4. CONCLUSIONS

1. It has been established that the internal friction force of fabric determines relaxation time of the sewing garment and at the same time variation of stitch length after sewing. Stitch length when sewing by lower speed may vary up to 0.01 mm, whereas stitch length when sewing by higher speed (2100 min^{-1}) may vary up to 0.03 mm.
2. Thus, the higher is the external friction force of fabric (~16 N), the lower influence on stitch length is made by load and stitch length varies within the limits of 0.2 mm. When external friction force of fabric is lower (~13 N) stitch length with the increase of load changes up to 0.5 mm.
3. It has been established that with increase of two-sided load of the sewing garment stitch length decreases – increase of load may lead to decrease of stitch length up to 0.6 mm.
4. Irrespective of sewing speed, stitch always is the longest when the sewing garment is not affected by load and sewing is performed in the direction along which the highest external friction force is observed.
5. It has been obtained that proper selection of two-sided load may decrease the influence of the rotational frequency of the main shaft on the variation of stitch length along the seam and on the stabilisation of stitch length.

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