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Dependence of Stitch Length along the Seam on External Friction Force Theoretical Analysis

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At joining of clothing details different defects may be observed. One of the most obvious defects is stitch length unevenness along the seam. The maximum stitch length unevenness along the seam is known to be obtained by sewing at different speed. This paper concerns with the theoretical research of fabric load and external friction forces that have influence on change in stitch length along the seam. It was demonstrated that the inertial motion path, after its detachment from the toothed plate, of the fabric is determined by sewing speed, mass of the fabric and load, and friction conditions. The carried out calculations illustrate that at a low ratio between the fabric mass and load mass, influence of the ratio between the friction coefficients of the sewing garment and load on change in length is different: when the ratio between friction coefficients is below 1, increase of the mass ratio leads to higher change in stitch length; when the ratio of friction coefficients is above 1, increase of the mass ratio leads to lower change in stitch length; when the mass ratio fluctuates within greater limits, a tendency of stitch length change variation is not subject to the friction ratio, and change increases in all cases. It was established that greater influence on stitch length change in made by friction conditions. With the increasing ratio of the aforementioned friction coefficients, the stitch length may decrease down by 80 %.
Keywords: fabric, stitch length, stitch length change, sewing garment load, friction coefficient.

INTRODUCTION

When joining sewing details by threads various defects often are observed. Due to different tension of upper and lower threads, variable sewing speed, a seam shrinks, individual stitches can be not formed. Furthermore, upon the influence of various factors, one of the main defects, i. e. stitch length unevenness is observed. In exposed details of the sewing, this defect shall be unnoticeable by an eye. It was established that sewing by a stitch longer than 1 mm and looking from a distance of 25 cm, change of 0.1 mm in its length is observed. Such stitches are especially noticeable when sewing by contrasting threads [1].

It was determined that stitch length may vary subject to the properties of the fabrics being sewn together [2 – 6]. Experimental results evidently proved that the mean stitch length decreases as the fabric tensile stiffness grows. The rotational speed of the main shaft of sewing machine also has a great influence on the process [2].

In the other case the seam parameter is related to fabric deformation and internal friction of the fabric. The obtained results proved that internal friction of fabric determines the behaviour of the sewing and alterations of stitch length, especially [3].

The highest influence upon movement of a lower layer with respect to an upper layer has the type of a pressing foot. It is shown that the fabrics with different setting, thickness and composition materials are characterized with different external friction. Analysis of the stitch length shows that different friction forces cause the variation of the stitch length in range of 10 % – 20 % [6]. In many cases the stitch length is defined by the parameters of a sewing machine [1, 7, 8]. From the latter ones, variation of rotational frequency of the main shaft shall be mentioned. The maximum stitch length unevenness along the seam is known to be obtained by sewing at different speeds. The greater is rotational frequency of the main shaft, the higher is stitch length along the seam. Besides, stitch length is influenced by pressing force of the sewing, friction between the fabric and a needle plate, etc. [10 – 14].

The stability of stitch length is influenced greatly by the feeding conditions of the fabric and forces acting at the moment of stitch formation. Sometimes, the extent of pressing force is changed [4 – 5]. In this case, stopping of the sewing is arranged additionally. In other cases, tensioning of a needle or shuttle thread is changed, a pressing foot (with castors, Teflon base, etc.) able to reduce friction is applied [4]. One of the factors having influence on stitch length along the seam is load of the fabric [15]. In this case, feeding conditions of the sewing are changed and at the same time the sewing is under the action of additional forces. Obviously the stitch length is under the influence of the properties of fabric, thread and the parameters of sewing machine.

The aim of this paper concerns theoretical research of fabric load and external friction forces that have influence on change in stitch length along the seam.

METHODOLOGY

To stabilise stitch length of the sewing, two-sided load of the fabric was applied. Figure 1 presents a diagram of the sewing feeding and acting forces.

If after feeding the fabric moves decelerating in the direction of axis x, forces acting upon the fabric may be

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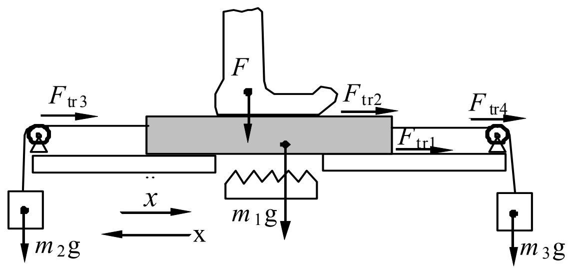

Fig. 1. Diagram of the sewing feeding and acting forces: m_1, m_2, m_3 – masses of the fabric and load elements, F_{tr1} – friction force between the fabric and a needle plate, F_{tr2} – friction force between the fabric and a pressing foot, F_{tr3}, F_{tr4} – friction forces acting in guiding pulleys, F – pressing foot force acting upon the fabric, $\ddot{x}$ – acceleration of the sewing, x – direction of the movement of the fabric

expressed as follows:

$$-(m_1+m_2+m_3)\ddot{x} = -m_2 g + F_{tr1} + F_{tr2} + F_{tr3} + F_{tr4} + m_3 g \, . \quad (1)$$

When masses of load elements are equal, i. e. $m_2 = m_3$, acceleration of the fabric will be the following:

$$\ddot{x} = -\frac{F_{tr1}+F_{tr2}+F_{tr3}+F_{tr4}}{m_1+m_2+m_3} = -a_0\,, \quad (2)$$

where:

$$F_{tr1} = f_1(m_1 g + F), \quad (3)$$

$$F_{tr2} = f_2 F\,, \quad (4)$$

$$F_{tr3} \approx f_3 m_2 g\,, \quad (5)$$

$$F_{tr4} \approx f_4 m_3 g\,, \quad (6)$$

where f_1 is the coefficient of friction between the fabric and a needle plate, f_2 is the coefficient of friction between the fabric and a pressing foot, f_3, f_4 are the coefficients of slip friction present in the bearings of guiding pulleys, g is the free fall acceleration, a_0 is the acceleration of the slowing movement of the fabric.

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

$$v_0 - a_0 t = 0\,, \quad (7)$$

where v_0 is the initial motion speed of the sewing after shifting feeding, t is the slowing movement time.

When initial speed v_0 of the sewing is known, time of its slowing movement is figured out as follows:

$$t = \frac{v_0}{a_0}\,. \quad (8)$$

From equations (2) and (8), the following is obtained:

$$t = \frac{v_0(m_1+m_2+m_3)}{F_{tr1}+F_{tr2}+F_{tr3}+F_{tr4}}\,. \quad (9)$$

Motion path of the fabric, which is the same, like stitch alteration, is calculated:

$$x = a_0\frac{t^2}{2}\,. \quad (10)$$

From equations (9) and (10), the following is obtained:

$$x = \frac{v_0^2(m_1+m_2+m_3)}{2(F_{tr1}+F_{tr2}+F_{tr3}+F_{tr4})}\,. \quad (11)$$

After putting (3), (4), (5), (6) into (11) and taking that $f_1 = f_2$ and $f_3 = f_4 = f$, and $m_2 = m_3 = m$, the following is figured out:

$$x = \frac{v_0^2(m_1+2m)}{2[g(f_1 m_1 + 2fm) + 2f_1 F]}\,. \quad (12)$$

It is known that initial movement speed of the sewing is:

$$v_0 = \zeta n\,, \quad (13)$$

where ζ is the proportionality coefficient, which in this case is equal to 0.07, n is the rotational frequency of the main shaft, min^{-1}.

We may see that the inertial motion path (change x in the stitch length) of the fabric (after its detachment from the toothed plate) is determined by sewing speed, mass of load and the fabric, pressing force but also by the fabric friction conditions (ratio f_1 with f).

CALCULATION RESULTS AND DISCUSSIONS

Calculations were carried out by evaluating sewing speed, changing the fabric friction conditions and load mass.

Figure 2 illustrates theoretical dependence of stitch length change x upon the ratio between the masses of the fabric m_1 and load m under varying friction conditions at constant sewing speed ($n = 1600\ min^{-1}$). When numerical value of ratio m/m_1 is 0.02 (m = 10 g, m_1 = 500 g), ratio of respective friction coefficients has almost no influence on change x (Fig. 2, a). In this case, under variation of ratio f_1/f within a rather wide range (from 0.333 to 2) change x is maintained stable. However, with increase of mass ratio m/m_1 significant friction influence is observed. When ratio of friction coefficients is $f_1/f < 1$, increase of ratio m/m_1 also leads to greater change x. When $f_1/f = 1$, change x stabilises and varies very negligibly. Decrease in change x is observed when ratio of friction forces exceeds 1. When $f_1/f > 1$, a stronger tendency of stitch length x decrease is observed. Similar variation tendencies in change x are also observed when mass ratio m/m_1 fluctuates from 0.05 to 2.5 (m change from 10 g to 500 g, m_1 = 200 g) (Fig. 2, b). When mass ratio m/m_1 ranges from 10 to 50 (m change from 10 g to 500 g, m_1 = 10 g) (Fig. 2, c), different variation of change x is observed. In this situation, irrespective of numerical value of ratio f_1/f, change x increases in all cases. It was noticed that the less is ratio f_1/f, the greater is change x with increase of m/m_1.

It may be seen that variation of the ratio between the masses of the fabric and load may reduce stitch length change by 40 % or even by 60 % in individual cases. Thus, it would be possible to reduce stitch length increment by increasing sewing speed, i. e. stitch length stabilisation is possible in this case.

Figure 3 illustrates theoretical dependence of change x under varying friction conditions.

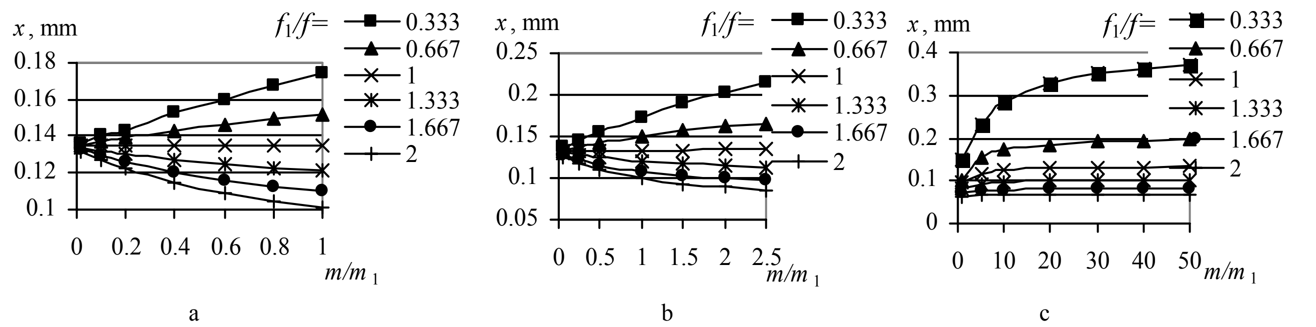

Fig. 2. Theoretical dependence of stitch length change *x*, mm, upon the ratio between the mass of the fabric and load when: a – m/m_1 = 0.02÷1.0; b – m/m_1 = 0.05÷2.5; c – m/m_1 = 1÷50

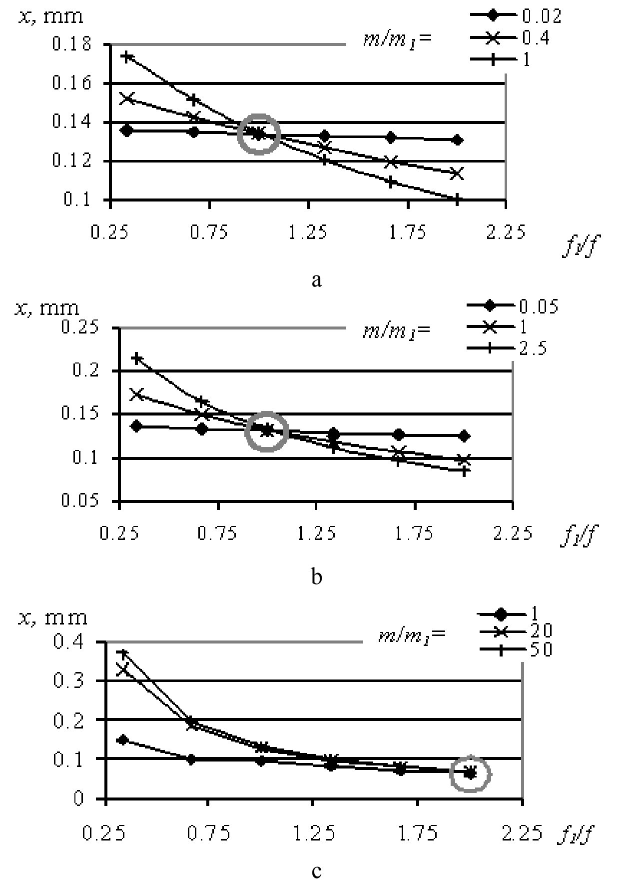

Fig. 3. Theoretical dependence of stitch length change *x*, mm, upon the ratio between the friction coefficients of the fabric and load when: a – $m/m_1 = 0.02 \div 1.0$; b – $m/m_1 = 0.05 \div 2.5$; c – $m/m_1 = 1 \div 50$

As it is seen (Fig. 3), influence of friction on stitch length change is similar in all cases – increase of friction ratio f_1/f results in decrease of change *x*. It was obtained that a decrease range of change *x* depends upon the mass ratio. When mass ratio m/m_1 varies within the smallest range (from 0.02 to 1), change *x* may vary from 0.0006 mm to 0.08 mm (Fig. 3, a). Similar variation tendencies in change *x* are also obtained when mass ratio m/m_1 fluctuates from 0.05 to 2.5 (Fig. 3, b). In this case, change *x* varies from 0.01 mm to 0.15 mm. It may be seen that increasing the ratio between friction coefficients and having a greater mass ratio, change *x* may range within considerable limits. Analysis of the aforementioned conditions allowed establishing the point ($f_1/f = 1$) at which equal change *x* is obtained irrespective of mass ratio m/m_1. When mass ratio m/m_1 varies within a wide range ($1 \div 50$), change *x* also varies within a wide range (~0.15 mm – 0.4 mm) (Fig. 3, c) subject to friction ratio f_1/f. In the latter case, the point at which equal change *x* ($f_1/f = 2$) is obtained was also established.

Also, was determined that greater influence on stitch length change have the friction conditions (Fig. 4). With the increasing ratio of the aforementioned friction coefficients, stitch length change may decrease down by 80 %.

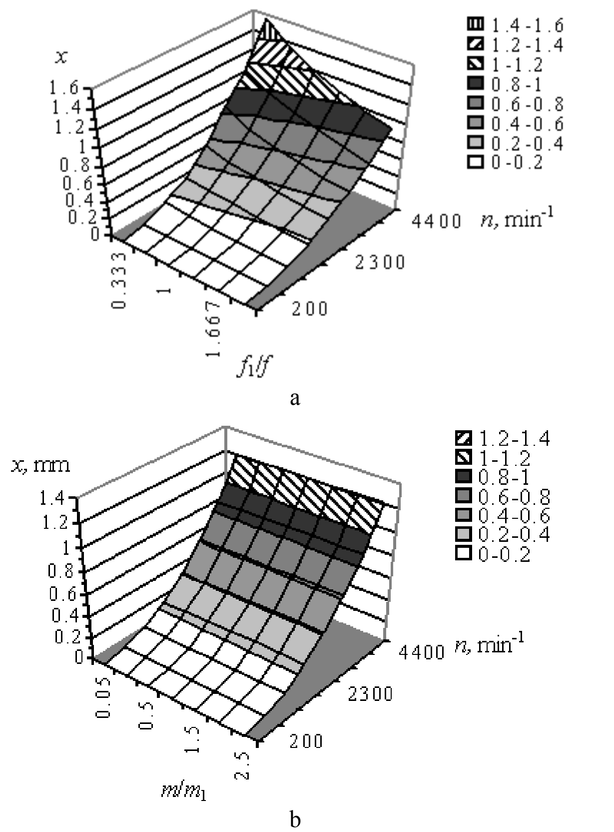

Fig. 4. Theoretical dependence of stitch length change *x*, mm, upon rotational frequency of the main shaft when: a – $m/m_1 = 1.0$; $f_1/f = 0.333 \div 2$; b – $f_1/f = 1.0$; $m/m_1 = 0.05 \div 2.5$

For example, at the minimum friction ratio (0.333) and sewing speed of 1600 min^{-1}, change *x* makes some 0.2 mm. Speed increase up to 2300 min^{-1} results in change increase up to 0.3 mm. After friction increase up to 2, change regains its previous value, i. e. 0.2 mm.

Comparison of theoreticaly calculations with the data of the experiments carried out [5, 15] has demonstrated that the obtained results are similar. Experiments have shown that actual stitch length when sewing at 2300 min^{-1} speed and 200 min^{-1} respectively varies from 0.3 mm to 0.5 mm. Theoretically calculated stitch length change is ~0.3 mm. Both experiments and calculations have demonstrated that growing rotational frequency of the main shaft leads to a longer stitch.

Changing of pressing force of a pressing foot in the process of sewing has resulted in higher friction between the fabric and a pressing foot and between the fabric and a needle plate. In this case, the experimentally obtained stitch length decreases with growing pressing force, thus with growing outer force [4]. A similar tendency has also been demonstrated by theoreticaly calculations where stitch length has been inclined to decrease with growing outer friction force.

During experiments, other factors related to the sewing machine, fabric and human factor also operate. However, variation tendencies of theoreticaly and experimental results remain similar.

The presented results illustrate that with the help of the fabric load and friction stitch length stabilisation is possible by increasing rotational frequency of the main shaft. Variation of the aforementioned conditions may result in a high quality seam under fluctuations of sewing speed.

CONCLUSIONS

1. It was theoreticaly established that at a low ratio between the fabric mass and load mass ($0.02 \div 2.5$), influence of the ratio between the friction coefficients of the fabric and load on stitch length change is different: when the ratio between friction coefficients is below 1, increase of the mass ratio leads to higher change in stitch length, whereas when the ratio between friction coefficients is above 1, increase of the mass ratio leads to lower change in stitch length. When the mass ratio varies within greater limits, a tendency of stitch length change variation is not subject to the friction ratio, and change increases in all cases.
2. It was determined that variation of the fabric load value enables to reduce stitch length change by 40 % or even by 60 % in individual cases.
3. It was theoreticaly obtained that influence of friction conditions on stitch length change is similar in all cases: with the increasing ratio between friction coefficients, stitch length change may decrease down, even by 80 % in individual situations.
4. It was illustrated that variation of the fabric load and friction condition may stabilise stitch length at unstable sewing speed.

REFERENCES

1. **Jucienė, M., Vobolis, J.** Survey of the Lockstitch Quality Effecting Upholstered Furniture *Light Industry - Fibrous Materials: III International Scientific Conference, 17–18. 11.* Radom, Poland, 2005: pp. 328 – 333.
2. **Tartilaitė, M., Vobolis, J.** Effect of Fabric Tensile Stiffness and of External Friction to the Sewing Stitch Length *Materials Science* (*Medžiagotyra*) 7 (1) 2001: pp. 57 – 61.
3. **Tartilaitė, M., Vobolis, J.** The Investigation of Fabrics Internal Friction and Relaxation Processes Interaction in Sewing Garments *Materials Science* (*Medžiagotyra*) 7 (3) 2001: pp. 191 – 195.
4. **Jucienė, M., Vobolis, J.** Influence of Fabric External Friction Force and Certain Parameters of a Sewing Machine upon Stitch Length *Materials Science* (*Medžiagotyra*) 10 (1) 2004: pp. 101 – 104.
5. **Tartilaitė, M.** Determination Methods Investigation of Shuttle Stitch Length and Equipment Development. Summary of Doctoral Dissertation, Technology, Kaunas, Lithuania, 2002.
6. **Tartilaitė, M., Vobolis, J.** The Effect of Sewing Fabrics Parameters upon the Seam Quality *Materials Science* (*Medžiagotyra*) 8 (1) 2002: pp. 116 – 119.
7. **Vaitkevičius, V., Jucienė, M., Punys, J., Vobolis, J.** Computerized Estimation of Seam Quality *Information Technology and Control* 26 (1) 2003: pp. 32 – 36.
8. **Vobolis, J., Jucienė, M., Vaitkevičius, V., Punys, J.** Influence of Selected Machine and Material Parameters on the Stitch Length and its Irregularity *Fibres and Textiles in Eastern Europe* 42 (3) 2003: pp. 51 – 56.
9. **Jucienė, M., Vobolis, J.** Investigation of the Influence of Defects of Sewing Machine V-belt Drive on the Stitch Length *Tekstil* 53 (5) 2004: pp. 219 – 225.
10. **Rocha, M., Lima, M. F., Ferreira, F. N., Araújo, M. D.** Developments in Automatic Control of Sewing Parameters *Textile Research Journal* 66 (4) 1996: pp. 251 – 256.
11. **Briedis, U., Klavinš, A.** The Effect of the Force of Presser Foot to the Stitch Length in Convential Sewing Machines *Proceedings of the International Conference Baltic Textile & Leather,* Kaunas, Lithuania, 2003: pp.111 – 114.
12. **Rogale, D.** Garment Sewing Processing Parameters *International Journal of Clothing Science and Technology* 7 1995: pp. 56 – 60.
13. **Nikolić, G., Šomođi, Ž.** Dynamic Model of Frictional Fabric Transport in a Sewing Machine. DAAAM International Vienna, 2004: pp. 433 – 440.
14. **Nikolić, G., Šomođi, Ž.** Numerical Dynamic Analysis of Fabric Transport in Sewing Process. DAAAM International Vienna, 2003: pp. 325 – 326.
15. **Jucienė, M., Vobolis, J.** Investigation of the Stitch Length Change under the Conditions of Sewing Garment Inertia Motion *Tekstil* 55 (5) 2006: pp. 244 – 248.