

Renata Krasowska,
Iwona Frydrych,
Marian Rybicki

Technical University of Lodz,
Department of Clothing Technology
ul. Zeromskiego 116, 90-924 Łódź, Poland
e-mail: mkwiat@mail.p.lodz.pl

Possibilities for Modelling Control Conditions of the Thread by Disc Take-up in the Lockstitch Formation Zone

Abstract

We present a course of needle take-up demand in the zone of lockstitch formation by the needle and the bobbin hook, as well as a course of thread control by the take-up for selected machines with different types of thread take-ups. The classical (crank-rocker) take-up and single-axial disc take-up are distinguished. The possibility of shaping the thread control curve with a disc take-up by changing the number and position of its operating points has been established. The diverse character of changes to the thread overfeed in the feeding zone of the machines indicates the need to establish a set of criteria assessing the correctness of the selection of this overfeed. For determining the thread control curve by disc take-up, software was used to shape this curve.

Key words: lockstitch, lockstitch machine formation zone (STS), thread demand in STS, thread controlling by the take-up.

Introduction

The peculiarities of the machine stitch formation process require consideration of a mechanism to control the motion of the thread, because the thread length needed for the stitch link formation process changes over a range constituting a multiple of its length in this link. This demonstrates that different barriers (stationary and mobile) affecting the thread, including barriers belonging to the thread take-up system, have a destructive character (Figures 2 and 3).

The diversity of thread take-up constructions in sewing machines is principally determined by the category of a tool inserting a thread into the stitch link (needles, bobbin hooks, interlacers) and the structure of this link, where stitches of open and closed interlacements can be distinguished [1 - 3]. In the latter case, the needle thread take-up plays a special role, due to the need for it to interact with the bobbin hook [2].

The needle thread take-up mechanism in lockstitch machines has changed over the years, largely due to the altered efficiency requirements of sewing machines [2]. The following solutions may be listed: an operating point trajectory constituting an arc of a circle (cam, slotted lever), a trajectory with no dead centre (crank-rocker with the working point mounted on the connector; this is the take-up widely used in lockstitch machines, Figure 2) and multi-barrier solutions of rotational motion with a common centre of rotation. The single-axial disc take-up (Figure 3) belongs to the latter group, but for some unknown

reasons is not used in current sewing machines. It is of particular interest due to the relatively small fatigue wear of thread, as found in preliminary studies carried out in the Department of Clothing Technology [5].

Mechanisms of thread take-ups in lockstitch sewing machines are characterised by an absence of regulation points. Examples of solutions of stitch-forming mechanisms, such as a differential feed, in which a stitch can be limited (or in other words shortened), demonstrate the important role of regulation points in adjusting the mechanism to the properties of textiles used in the thread stitch formation process. Thus, it appears advisable to investigate the effects of introduction of regulation points changing the action of the take-up on the thread into the take-up structure, thus making the take-up more modern in comparison with the solutions currently used.

In the literature, there are no studies assessing the take-up with respect to the load of thread in the stitch formation process and the relation of these loads to stitch properties [1, 4]. Thus, it is necessary to develop a set of criteria to assess the correctness of operation of the take-up in the group of stitch-forming mechanisms. The results of investigations into the stitch formation zone, i.e. the space in which a stitch formation process occurs, as found in the literature available [1, 6] do not contain any reference to the thread take-up. First of all, this refers to lockstitch machines, where the thread take-up plays a complex role due to the necessary connection with the bobbin hook and the dynamics of stitch

tightening (drawing an interlacement into the material). This significantly affects the stitch formation process, and in particular the accompanying disturbances, which can lead to the excessive breakage of thread and to unfavourable properties of the stitch.

It results from the above that the introduction of the take-up into a space called a stitch formation zone shapes this space, and likewise the phenomena occurring in this zone and the functional properties of the thread stitch.

Investigations of the action of the take-up on the thread should be preceded by an assessment of the demand of the needle and the bobbin hook for thread and the thread feed by the take-up [7].

In this paper, we present a preliminary assessment of movement of the thread due to the motion of the needle, bobbin hook and the take-up.

Demand of the needle and the bobbin hook for thread and thread feed by the take-up

The design of any type of take-up mechanism is based on the course of the demand for thread in a stitch formation cycle (Figure 1), where we can distinguish the demand for thread forced by the needle motion (part of the curve in Figure 1 which is limited by points 1 and 5) and the bobbin hook motion (part of the curve limited by points 5 and 6).

The curves of the thread feed by the take-up against the demand of the needle and

bobbin hook for thread are presented in Figures 2 and 3. An excess of thread fed by the take-up in relation to the demand, shown in the figures, is necessary because of the length stitch (S) that can be regulated, a variable thickness of the textile package (h) subjected to treatment, and the conditions of passing the thread through the hook system. A lack of this excess will lead to thread breakage.

The comparison of Figures 2 and 3 confirms the diversified character of changes in the thread excess in the phase of feeding by the take-up (part of the curve $f_2(\varphi)$ limited by points A and B). This happens because the stoppage in the crank-rocker mechanism (Figure 2) cannot be taken into account while the needle forms a loop (part of the curve $f_1(\varphi)$ between points 4 and 5 – Figure 1). As far as the demand/feed relationship is concerned, it is stated in the literature that an excess of thread at the moment when the bobbin hook drops off the loop (see 6 in Figure 1) should constitute between 10 and 20% of the thread at this moment. For the machines studied, this excess is 14.4% for the Pfaff machine and 15.6% for the Juki DLM-52 machine. Thus, the two amounts of excess are similar, and are contained in the assumed range.

It seems advisable to undertake studies on the shaping of the curve of thread feed by the disc take-up; this can be attained by selecting the number and position of working points. This can contribute to the decrease in the stitch breakage and the improvement of the stitch quality.

The possibility of analytically describing the thread control by the disc take-up will be used to develop variations in the take-up differing in the thread control curve. This will be an important step towards determining a set of criteria assessing the correctness of the take-up operation for different sewing properties of textiles. Consequently, this may lead to the introduction of regulation points of the take-up.

Modelling

1. The topic of the research is the take-up of needle thread in the lockstitch machine (rotary, multi-barrier), in which we can distinguish constant and moving barriers. The barrier position (Figure 4) is described successively by a distance from the centre of the disc rotation and an angle between a

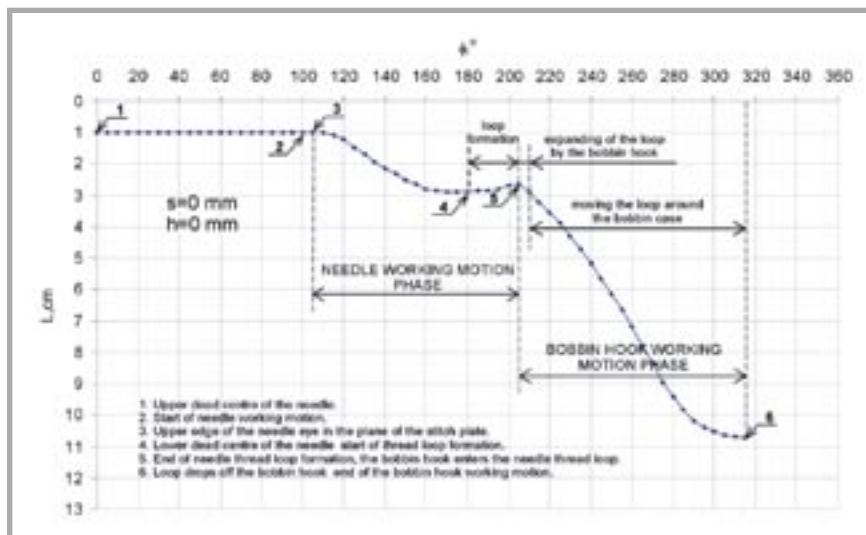


Figure 1. Demand for thread caused by the motion of the needle and the bobbin hook (Pfaff 953 machine).

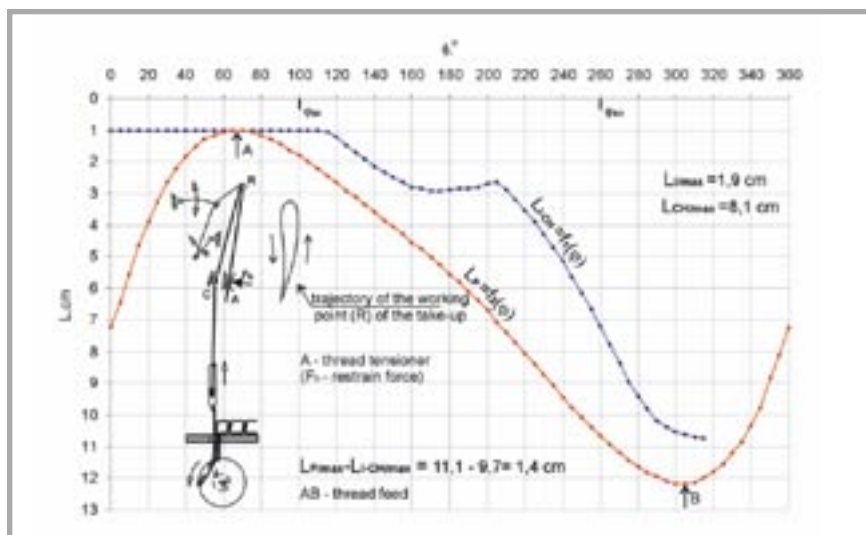


Figure 2. Thread control by a crank-rocker take-up against the thread demand caused by the needle and bobbin hook motion (Pfaff 953 machine; $s=0$ mm, $h=0$ mm).

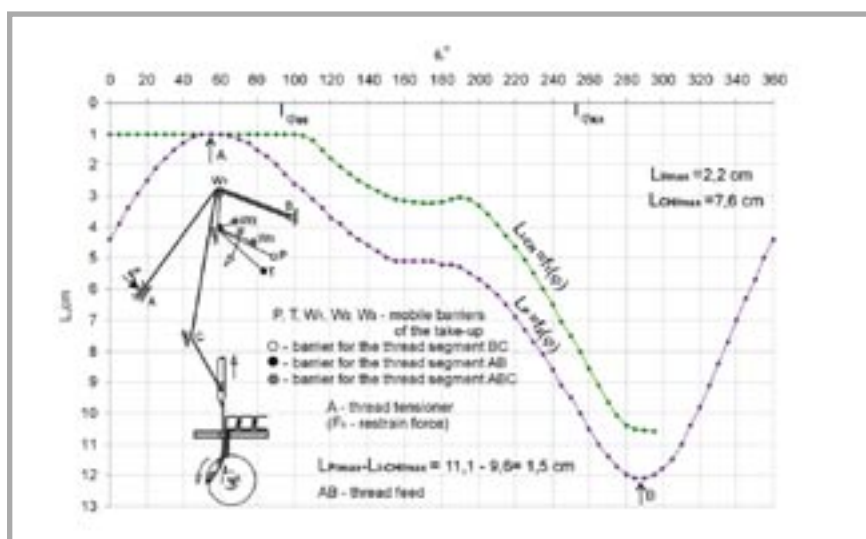


Figure 3. Thread control by the single-axial disc suspender against the demand for thread caused by the needle and bobbin hook motion (Juki DLM-52 machine; $s=0$ mm, $h=0$ mm).

line of needle acting, and a line going through the disc and barrier centre.

- In the group of the constant barrier, a thread tensioner (A) (Figure 4.1) and a distributor (B) (Figure 4.2) can be distinguished, which divide the thread distance in the take-up acting zone into branches lying on the right and left sides of the take-up (Figure 4.3) and thread guide (C) (Figure 4.2) controlling the thread outside the take-up acting zone.

In the set of moving barriers placed on the rotating disc, barriers located on the right and left sides (right – P & left – L), as well as barriers acting on both branches – W₁, W₂ and W₃.

- The changes in thread length in the take-up acting zone are due to the barriers of type P, L and W rotation movement.
- Conditions of thread control by take-up (replacement l, speed v and acceleration a) depend on the moving and constant barrier position of the take-up.

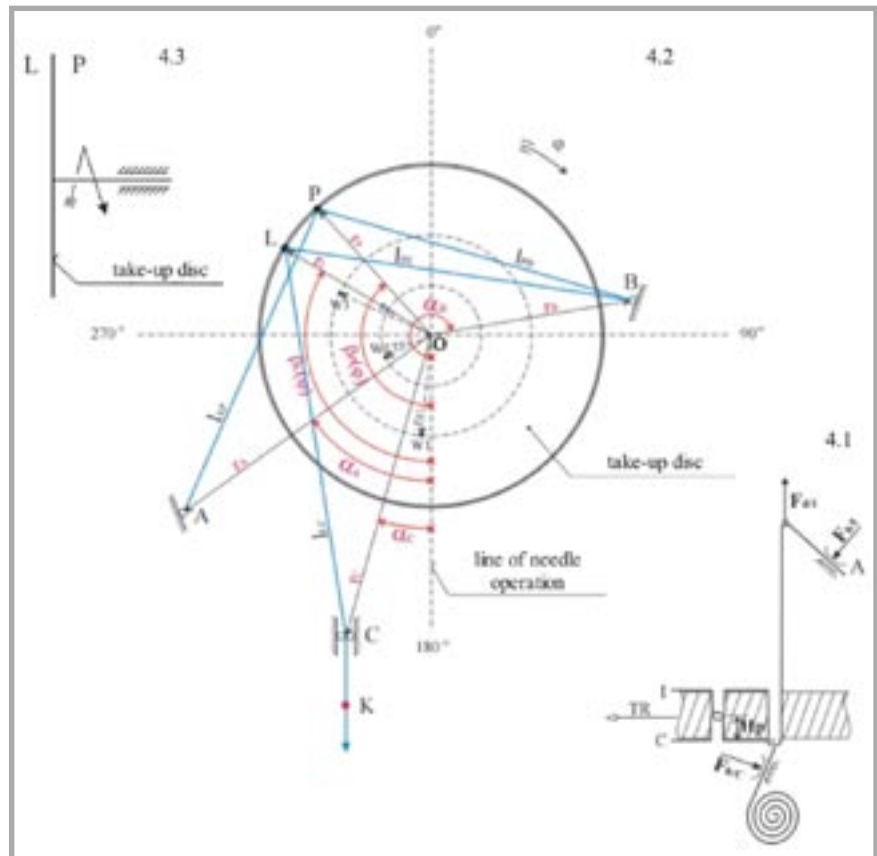


Figure 4. Characteristics of the thread length in the multi-barrier disc take-up acting zone at the moment of stitch tightening.

Then the analytical description of non-stretchable thread length changes, for example, the phase of the stitch tightening formation according to Figure 4.2 can take the following form:

$$l(\varphi) = l_{AC}(\varphi) = l_{AP}(\varphi) + l_{PB}(\varphi) + l_{BL}(\varphi) + l_{LC}(\varphi) \quad (1)$$

$l(\varphi)$ - max for knot interlacing of thread of stitch in the position H_p (Figure 4.1)

where the particular lengths are presented by Equations (2 - 5).

In Figures 2 to 5, the following was taken into consideration:

- | | |
|--------------------------------------|----------------------------------------------|
| A (r _A , α _A) | L (r _L , α _L) |
| B (r _B , α _B) | α _A = C ₁ |
| C (r _C , α _C) | α _B = C ₂ |
| P (r _P , α _P) | α _C = C ₃ |
| β _{P/0} = C ₄ | at β _P (φ) = β _{P/0} + φ |
| β _{L/0} = C ₅ | β _L (φ) = β _{L/0} + φ |
| β _{W1/0} = C ₆ | β _{W1} (φ) = β _{W1/0} + φ |
| β _{W2/0} = C ₇ | β _{W2} (φ) = β _{W2/0} + φ |
| β _{W3/0} = C ₈ | β _{W3} (φ) = β _{W3/0} + φ |
- and:
- | | |
|----------------------|----------------------|
| AP – l _{AP} | PB – l _{PB} |
| BL – l _{BL} | LC – l _{LC} |

Differentiating Equation (1) in relation to time, we obtained the speed of changing the thread length in the take-up acting zone, presented by Equations (6 - 10).

Differentiating Equation (6) in relation to time, we obtained the acceleration, presented by Equations (11 - 15).

Figure 4, and the analytical relationships corresponding to it do not consider removing the thread from the thread tensioner.

$$l_{AP}(\varphi) = \left[r_A^2 + r_P^2 - 2r_A \cdot r_P \cdot \cos(C_4 - C_1 + \varphi) \right]^{1/2} \quad (2)$$

$$l_{PB}(\varphi) = \left[r_P^2 + r_B^2 - 2r_P \cdot r_B \cdot \cos(C_2 - C_4 - \varphi) \right]^{1/2} \quad (3)$$

$$v(\varphi) = v_{AC}(\varphi) = v_{AP}(\varphi) + v_{PB}(\varphi) + v_{BL}(\varphi) + v_{LC}(\varphi) \quad (6)$$

$$v_{AP}(\varphi) = \frac{\omega \cdot r_A \cdot r_P \cdot \sin(C_4 - C_1 + \varphi)}{\left[r_A^2 + r_P^2 - 2r_A \cdot r_P \cdot \cos(C_4 - C_1 + \varphi) \right]^{1/2}} \quad (7)$$

$$v_{PB}(\varphi) = -\frac{\omega \cdot r_P \cdot r_B \cdot \sin(C_2 - C_4 - \varphi)}{\left[r_P^2 + r_B^2 - 2r_P \cdot r_B \cdot \cos(C_2 - C_4 - \varphi) \right]^{1/2}} \quad (8)$$

$$l_{BL}(\varphi) = \left[r_L^2 + r_B^2 - 2r_L \cdot r_B \cdot \cos(C_2 - C_5 - \varphi) \right]^{1/2} \quad (4)$$

$$l_{LC}(\varphi) = \left[r_L^2 + r_C^2 - 2r_L \cdot r_C \cdot \cos(C_5 - C_3 + \varphi) \right]^{1/2} \quad (5)$$

$$v_{BL}(\varphi) = -\frac{\omega \cdot r_L \cdot r_B \cdot \sin(C_2 - C_5 - \varphi)}{\left[r_L^2 + r_B^2 - 2r_L \cdot r_B \cdot \cos(C_2 - C_5 - \varphi) \right]^{1/2}} \quad (9)$$

$$v_{LC}(\varphi) = \frac{\omega \cdot r_L \cdot r_C \cdot \sin(C_5 - C_3 + \varphi)}{\left[r_L^2 + r_C^2 - 2r_L \cdot r_C \cdot \cos(C_5 - C_3 + \varphi) \right]^{1/2}} \quad (10)$$

Equations 2, 3, 4, 5, 6, 7, 8, 9, and 10.

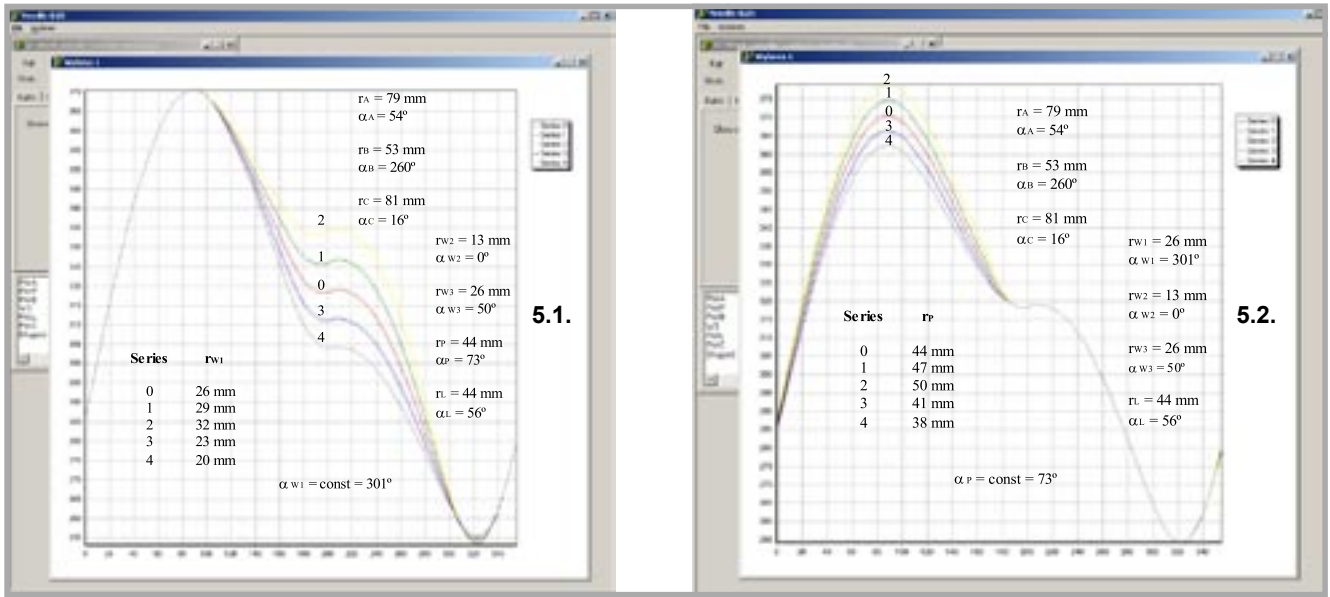


Figure 5. Changes to the conditions of thread control by the disc take-up: 5.1 In the zone of feeding by the thread needle and bobbin caused by the changes of a distance of working point of take-up W_1 from the rotation centre of the take-up disc (r_{W1}), 5.2 In the zone of thread delivering from the bobbin system, stitch formation and feeding by the needle thread caused by the changes of the distance of working point of take-up P from the rotation centre of the take-up disc (r_P).

$$a(\varphi) = a_{AC}(\varphi) = a_{AP}(\varphi) + a_{PB}(\varphi) + a_{BL}(\varphi) + a_{LC}(\varphi) \quad (11)$$

$$a_{AP}(\varphi) = \frac{\omega^2 \cdot r_A \cdot r_P \cdot \cos(C_4 - C_1 + \varphi)}{[r_A^2 + r_P^2 - 2r_A \cdot r_P \cdot \cos(C_4 - C_1 + \varphi)]^{\frac{1}{2}}} - \frac{\omega^2 \cdot r_A^2 \cdot r_P^2 \cdot \sin^2(C_4 - C_1 + \varphi)}{[r_A^2 + r_P^2 - 2r_A \cdot r_P \cdot \cos(C_4 - C_1 + \varphi)]^{\frac{3}{2}}} \quad (12)$$

$$a_{PB}(\varphi) = \frac{\omega^2 \cdot r_P \cdot r_B \cdot \cos(C_2 - C_4 - \varphi)}{[r_P^2 + r_B^2 - 2r_P \cdot r_B \cdot \cos(C_2 - C_4 - \varphi)]^{\frac{1}{2}}} + \frac{\omega^2 \cdot r_P^2 \cdot r_B^2 \cdot \sin^2(C_2 - C_4 - \varphi)}{[r_P^2 + r_B^2 - 2r_P \cdot r_B \cdot \cos(C_2 - C_4 - \varphi)]^{\frac{3}{2}}} \quad (13)$$

$$a_{BL}(\varphi) = \frac{\omega^2 \cdot r_L \cdot r_B \cdot \cos(C_2 - C_5 - \varphi)}{[r_L^2 + r_B^2 - 2r_L \cdot r_B \cdot \cos(C_2 - C_5 - \varphi)]^{\frac{1}{2}}} + \frac{\omega^2 \cdot r_L^2 \cdot r_B^2 \cdot \sin^2(C_2 - C_5 - \varphi)}{[r_L^2 + r_B^2 - 2r_L \cdot r_B \cdot \cos(C_2 - C_5 - \varphi)]^{\frac{3}{2}}} \quad (14)$$

$$a_{LC}(\varphi) = \frac{\omega^2 \cdot r_L \cdot r_C \cdot \cos(C_5 - C_3 + \varphi)}{[r_L^2 + r_C^2 - 2r_L \cdot r_C \cdot \cos(C_5 - C_3 + \varphi)]^{\frac{1}{2}}} - \frac{\omega^2 \cdot r_L^2 \cdot r_C^2 \cdot \sin^2(C_5 - C_3 + \varphi)}{[r_L^2 + r_C^2 - 2r_L \cdot r_C \cdot \cos(C_5 - C_3 + \varphi)]^{\frac{3}{2}}} \quad (15)$$

Equations 11,12,13,14, and 15.

Analogous relationships can be derived for the whole interval of the angle position of the take-up disc. The number of branches into which the thread distance is divided in the take-up working zone depends on the number of active barriers of the take-up disc.

Displacement of the thread end in the take-up acting zone (point K in Figure 4.2) can be determined in the following way:

$$s = l_{max} - l(\varphi) \quad (16)$$

where:

l_{max} – the maximum thread length in the take-up acting zone,

$l(\varphi)$ – the moment length of thread in the take-up acting zone (Equation 1).

The speed and acceleration of point K can be determined in an analogous way.

In order to assess the influence of the constant (A, B, C) and moving (L, P, W_1 , W_2 , W_3) barrier positions (Figure 4) on the conditions of thread control, a special Take-up disc 1.0 system was elaborated in the Delphi 7.0 environment. This system uses components of the VCL Borland standard library. The application is designed as MDI, which enables simultaneous following the many configurations determined by the position of constant and moving barriers belonging to the thread take-up system.

The Take-up disc 1.0 system enables the calculation of thread lengths for a given configuration of take-up and for any given angle position of the main machine crankshaft (φ). Figure 5.a illustrates the example of thread length changes for selected positions of take-up barrier P, acting on the thread on the right side of the take-up disc (see: Figure 4.3), whereas Figure 5.b shows selected positions of barrier W_1 acting on the thread on both sides of the disc.

Summary

Summing up, it should be pointed out that when describing the task which

the thread take-up should perform in the sewing machine, distinguishing the thread demand by the needle, bobbin and transporter, as well as the thread overfeed in the process of stitch formation (which is done by the take-up in the feeding by the thread phase), is very important. The graphs obtained experimentally and presented in Figure 2 and 3 prove this.

Of special interest is the disc take-up, the construction of which creates possibilities for shaping the thread control curve. This applies to the thread feeding as well as thread selecting, as is presented in Figure 5.

We can predict the creation of take-up configuration with different numbers and positions of moving and constant barriers, followed by an assessment of the acting conditions of these barriers on the thread in the real sewing process. This may lead to introduction of regulation points which depend on thread and fabric properties, for example due to stitch formation conditions.



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Instytut Włókien Chemicznych - Institute of Chemical Fibres
 ul. Skłodowskiej-Curie 19/27, 90-570 Łódź, Poland
 tel. (48) 426 380 300, (48) 426 376 510, fax. (48) 426 376 501
 e-mail: iwch@iwch.lodz.pl