Włodzimierz Więźlak
Joanna Elmrych-Bocheńska

Department of Clothing Technology
Faculty of Engineering and Marketing of Textiles
Technical University of Łódź
ul. Żeromskiego 116, 90-924 Łódź, Poland
E-mail: jboch@p.lodz.pl

Process of Lockstitch Tightening and Optimisation of Thread Working Conditions. Part II. The Trial of Optimising the Interlacement Location in the Stitch Link

Abstract
The high level of destruction of the sewing thread after the sewing process is the main utility disadvantage of using a thread in a lockstitch sewing machine. Using the stitch tightening model presented in the first part of this paper [1], a procedure for optimisation has been devised which allows the sewing process' technological conditions to be shaped in such a way as to obtain the lowest possible level of thread destruction in the stitch formation zone. This theoretical modelling of stitch tightening conditions has been verified in sewing trials. As part of the conducted research, the real interlacement location in the stitch link and the degree of the thread's strength loss related to it after the sewing process were determinated.

Key words: *sewing machine, sewing thread, lockstitch, stitch tightening, interlacement.*

The stitch formation process in the sewing machine presents a cycle of consecutive stages, defined by the cooperation of the machine's working elements. This cooperation aims at control of the sewing thread, leading to the creation of stitch links. The correct course of the process requires the sewing thread to be loaded by adequate tensions, both static and dynamic; this is the cause of the undesirable changes in the thread's tensile characteristics after the sewing process, particularly in the case of the needle thread in the lockstitch machine. The destruction of the thread in the stitch formation zone may result in disruptions to the production process (such as machine outages connected with the need to remove broken threads) and also a significant reduction in the use-durability of the clothing.

The level of thread destruction after the sewing process may be minimised by appropriately selecting the values of the technological parameters, and consequently by shaping the conditions in which the lockstitch interlacement is placed inside the needle channel. In the first part of this paper [1], we presented a model of the stitch tightening process which enabled the assessment of interlacement location in the needle channel under specified technological conditions.

The optimisation procedure connected with modelling the stitch tightening conditions, and consequently the decrease in minimisation of the thread strength after sewing, relies on establishing the ratio of the needle-thread and bobbin-hook-thread restraining forces, upon which the stitch interlacement will be placed in the location described by the following conditions [3, 5]:

1. $u \in (0.2; 0.3)$ – the optimisation of the interlacement placing factor[1)] connected with the minimisation of the loading in the stitch formation zone, and
2. $P_z \rightarrow \min$ – the minimisation of thread loading within the single cycle of lockstitch creating.

If the level of the restraining force of the bobbin-hook-thread was assumed a priori, the problem discussed is then based on determining the level of the second static force, i.e., the needle-thread restraining force, which would be optimal for the given stitch formation conditions.

It should be pointed out that the interlacement location assessment by the coefficient u, which is a criterion of the optimisation procedure presented, is of a theoretical nature. For reasons of methodology, the real interlacement placing coefficient m is used while assessing the interlacement location in the experimental conditions; it will appear later in this paper.

The prediction of the interlacement placed in the needle channel, according to the procedure presented in the first part of this paper [1], which was carried out for many values of the needle-thread restraining force, is a basis for building a nomogram, which enables the optimum level of needle-thread tension to be selected. It should be noted that the needle-thread restraining force value is assessed in intervals. This concerns the assessment (also in intervals) of the most favourable interlacement location in the stitch link, resulting from the wide diversity of conditions (as we described in previous chapters) under which the stitch tightening process proceeds, and from the parameters which shape this process.

The optimisation nomogram presented as an example in Figure 1 was devised on the basis of the data included in Table 1 of [1]. According to the chart, it may be stated that under the realisation conditions of the stitch-tightening process given in Table 1, most favourable is accepting the needle-thread restraining force at the level of $Ph_i \cong 3 \div 4.4$ N. At the same time, it can be predicted that in the case of $Ph_i < 1$ N, the stitch interlacement remains below the plane of the sewn package, so the stitch will be untightened.

The optimisation procedure presented above has been verified by means of experimental research [2]. Below, one of the research variants, conducted for three kinds of sewing threads (Saba No 150, Epic No 140, Astra No 120), is characterised. The verification carried out involved the following stages:

- Working out the optimisation nomogram for the given conditions of realising the stitch creation process.
- Determining the optimum level of the thread restraining force, for which the following condition is fulfilled: $u \in (0.2; 0.3)$. Setting the determined force value on the sewing machine[2)].
- Carrying out the sewing process under the following accepted technological conditions:

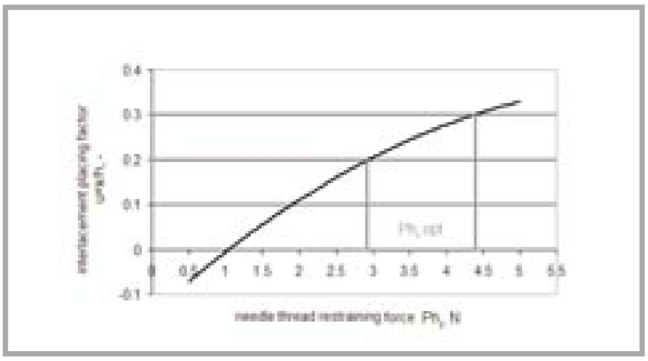

Figure 1. The optimisation nomogram for the needle-thread restraining force built for the hypothetical conditions (i.e. those given as an example) of the technological process.

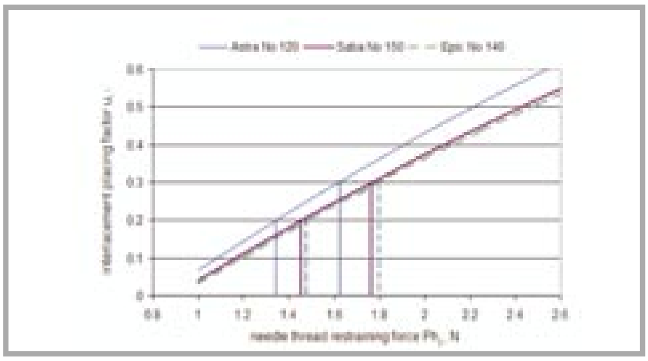

Figure 2. Optimisation nomograms for threads used in the experiment.

- sewing machine; DB2-B373-913 from Brother Exedra
- textile material; CO/PES woven fabric, 3 plies
- rotary speed of the sewing machine; $n = 2100$ rpm
- stitch length; $s = 2.5$ mm
- restraining force of the bobbin-hook-thread; $Ph_i = 0.21$N
- restraining force of the needle thread; assessed according to the optimisation nomogram.

- The assessment of the interlacement placing in the stitch link, carried out by measurements of the thread demands and calculating the value of the interlacement placing coefficient m.
- The assessment of the thread strength after the sewing process, made by tests using a tensile tester.

The experiment also included carrying out the sewing process under the same technological conditions of the restraining force levels of the needle-thread and the bobbin-hook-thread under which the terminal stitch structures were created, that is, the stitch interlacement was located near the bottom or upper plane of the material package sewn. The values of the interlacement placing coefficient and of the breaking force obtained by tensile tests, as determined for the terminal stitch structures, presented the point of reference for the stitch phase forms which were analysed.

Optimisation nomograms for the three kinds of sewing threads we considered are presented in Figure 2. As those threads have similar parameters, the predicted optimum restraining force value, determined from the charts, takes a similar value for each case. Within the optimum range of the interlacement placing factor u, the differences in the terminal values, which designate the most favourable range of the needle-thread restraining force values (regarding the thread working conditions) do not exceed the level of 0.2 N.

The terminal values of the restraining force Ph_i may be precisely determined on the basis of the trend-line equations calculated for the courses obtained. In the case of the threads examined, the equations take the following formulas:

- Astra No 120:
  $u = -0.0309\ Ph_i^2 + 0.4552\ Ph_i - 0.3562$
- Saba No 150:
  $u = -0.0268\ Ph_i^2 + 0.4114\ Ph_i - 0.3423$
- Epic No 140:
  $u = -0.0244\ Ph_i^2 + 0.3997\ Ph_i - 0.3400$

Considering the condition $u \in (0.2; 0.3)$, the equation presented above gives us the following terminal values of the needle-thread optimum restraining force:

- Astra No 120: $Ph_i \in (1.35 \div 1.62)$ N
- Saba No 150: $Ph_i \in (1.46 \div 1.76)$ N
- Epic No 140: $Ph_i \in (1.48 \div 1.80)$ N

For each of the experimental variants, the values of elementary demands of the needle and bobbin hook were determined; this was done for the structures taken as optimum, as well as for the terminal structures. On the basis of the values obtained, the interlacement placing was evaluated by calculating the real interlacement placing coefficient[3)] m.

The coefficient m is the main tool for evaluating the stitch structures obtained in the experimental research. Assuming that the lockstitch terminal structures (m_{min} and m_{max}) are described by the following conditions:

- the structure of the minimum share of needle-thread m_{max} (the stitch interlacement located by the upper material plane): $li_{min} \cong s$ and $lc_{max} \cong 2\ h + s$,
- the structure of the maximum share of needle-thread m_{min} (the stitch interlacement located by the bottom material plane): $li_{max} \cong 2\ h + s$ and $lc_{min} \cong s$,

we may construct a chart which represents the theoretical changeability area of the stitch-phase forms [6]. Furthermore, this area is verified by considering the values of the stitch shape coefficient[4)] γ calculated empirically, consequently obtaining the real changeability area of the phase-forms, which is illustrated in Figure 3.

The theoretical interlacement placing factor u precisely expresses the interlacement location with respect of the height of the needle channel (parameter h); however, it is not possible to determine its value by experiments. On the other hand, in the case of the real interlacement placing coefficient m, the interpretation of the result allows us to assess (on the first approximation) whether the interlacement is located below or above the central position. For the needs of the optimisation procedure, the assumption may be taken that the assessment of the interlacement central position by the coefficient $m = 1$

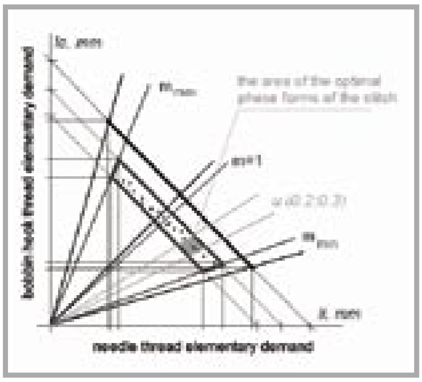

Figure 3. The theoretical and real area of the optimum phase-forms of the stitch [2].

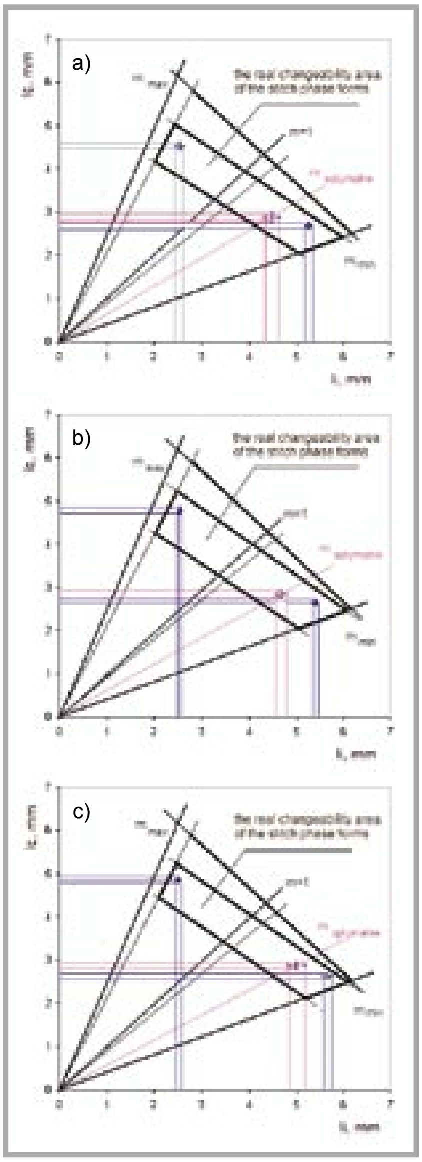

Figure 4. The theoretical and real changeability area of the stitch phase-forms, together with the plotted structures examined in the experiment; a) Saba No 150, b) Epic No 140, c) Astra No 120.

corresponds with the theoretical factor value $u = 0.5$. Therefore, the area of the stitch optimal phase-forms, described by the condition $u = (0.2; 0.3)$, should be sought within the range of $m = (m_{min}; 1)$. The stitch structure of the needle-thread maximum share corresponds with the value of the theoretical factor $u = 0$ (Figure 3), and the determination of the value m_{min} presents the necessary conditions to assess whether the stitch-phase form created under the experimental conditions belongs to the area presumed as the optimum.

The results of the experiments with the charts of the stitch structure changeability area are presented in Figure 4. In each of the experimental variants analysed, the stitch structures obtained on the basis of the optimising procedure are characterised by the interlacement located in the bottom of the needle channel (according to the estimation by the interlacement placing coefficient *m*), which fulfils the assumptions of the procedure devised. At the same time, in the case of the stitch-phase-forms described as optimum, the creation of excessive stitch structures along the seam length has not been noted. Nevertheless, such structures have been recognised in selected links of the limited stitch phase-form which was created by the minimum share of the bobbin-hook-thread (the minimum value of the needle-tread restraining force). It can thus be stated that the procedure devised ensures the appropriate changeability area for the stitch phase-forms, connected with the lack of stability of the stitch formation zone fed by the needle-thread in the consecutive working cycles of the machine.

The breaking force values for threads taken from the seam were measured for the stitch structures determined on the basis of the optimisation nomograms, as well as for the limited structures which were taken for comparison. In order to determine the thread destruction level under the given technological conditions of the sewing process carried out, the results obtained were linked to the breaking strength value determined for the thread before sewing. The breaking force average values obtained during the tensile stretching tests, together with their changeability area, are presented in Figure 5.

The analysis of the percentage assessment of the thread strength loss after sewing in relation to the un-sewn thread (Figure 6) shows that in the case of the structure described as minimum, the thread strength decreases; this is caused by the action of the stitch forming tools

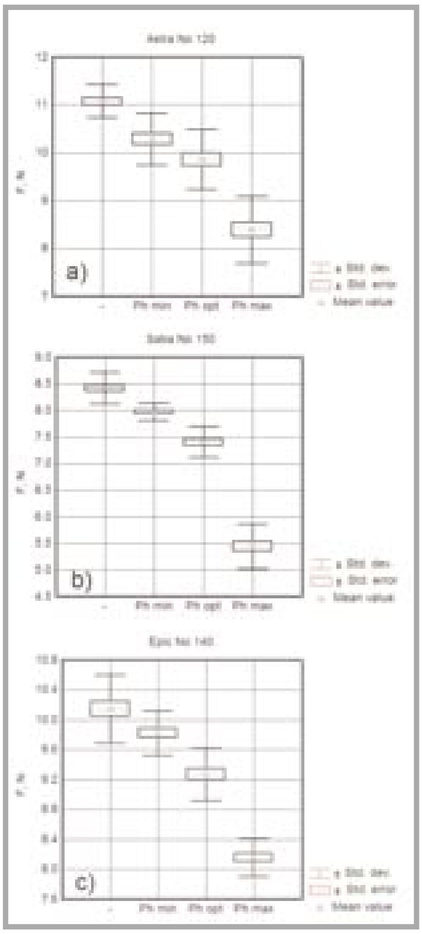

Figure 5. The comparison of the average values and the changeability area of the breaking force values, obtained during the verification experiments for the three kinds of sewing thread.

during the sewing process, and the losses are within the range of 3.2 ÷ 7.7%. Such values, adequately for the types of thread examined, correspond with the thread destruction by reduction of the stitch tightening stage, and present a point of reference for the values assumed as optimum. In the case of the structure determined on the basis of the optimisation nomogram, the strength losses are at the level of about 8.6 to 12.1%; this means that they fall within the acceptable limits

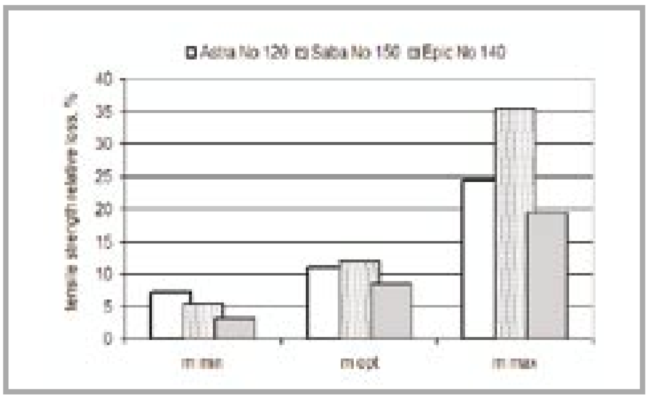

Figure 6. Comparison of the relative values of the thread strength loss after sewing with relation to the un-sewn thread.

of 15% accepted by publications in the literature. On the other hand, the structure described as the maximum projects the thread destruction level under conditions when the stitch interlacement during the stage of the stitch tightening is pulled to the sewn package's upper plane. So, the extreme thread destruction under the given technological conditions may reach the level of 19.6 to 35.5% (adequately to the thread examined), if the lockstitch structure is not modelled.

Summary

- On the basis of the experimental research results presented herein, it can be stated that under the given technological conditions of the sewing process, the optimisation procedure which we devised allows the lockstitch structure to be shaped in the most favourable way for the subsequent use of the seam created.
- The procedure proposed enables the sewing process parameters to be selected in such a way that the process discussed does not cause a thread destruction at a level higher than 15%, whose value of the thread strength loss after sewing is acceptable.
- The stitch structures obtained as the result of the optimisation procedure at the same time ensures an appropriate changeability area for the interlacement location, connected with the lack of stability of the stitch formation zone fed by the needle-thread [7, 8]. At the same time, the potential maximum level of the needle-thread's destruction which might arise by not using the optimisation tools was determined by experiments.

Editorial notes

1) The theoretical factor of the interlacement placing u is calculated as the ratio of the interlacement distance from the sewn material lower plane x (expressed in absolute units) to the entire stitch link height h: $u = x/h$ [3].

2) As the assessment of the optimum value of the needle thread restraining force is of an interval character, the tensioner settings should thus correspond approximately with the mean value of the range calculated from the nomogram.

3) The interlacement placing coefficient is determined as a ratio of the elementary demand of the bobbin-hook-thread (l_c) to the elementary demand of the needle-thread (l_i): $m = l_c/l_i$ [3].

4) The stitch shape coefficient γ expresses the relation of the theoretical and the real thread demands in the stitch link; coefficient γ is determined from the equation: $2s + 2h = \gamma\,(l_i + l_c)$, where s – the length of the stitch, h – the stitch link height [3].

References

1. *Więźlak W., Elmrych-Bocheńska J., 'Process of the lockstitch tightening optimisation of the thread working conditions. Part I. Dynamic model of the phenomenon'; Fibres and Textiles in Eastern Europe, No. 4 (58) 2006.*
2. *Elmrych-Bocheńska J., 'Minimisation of the thread destruction during the impact-character inserting of the interlacement in the needle channel' (in Polish); – Ph.D. Thesis, Technical University of Łódź, 2004.*
3. *Więźlak W., 'On some possibilities of optimisation lockstitch sewing machine working conditions' (in Polish); Odzież [XXXIV], 1984, no. 7, p. 192-196.*
4. *Siejka K., Wpływ położenia przeplotu na zrywność nici szwalnych na stębnówce (The influence of the interlacement location on the sewing thread breakage in the lockstitch machine); Odzież, 1987, nr 9, s. 260-263 (in Polish).*
5. *Garbaruк V.P., 'Rasčet i konstruirovanie osnovnyh mehanizmov čelnočnyh švejnyh mašin'; IzdateÍstvo Mašinostroenie, Leningrad 1977, p. 230.*
6. *Więźlak W., Neue Erkenntnisse zur Dynamik der Stichbildungsprozesse und deren praktische Nutzung; Textiltechnik 94, 1986, no. 1-2, p. 76-80.*
7. *Orawiec G., 'Recording of feeding by the thread the lockstitch formation zone' (in Polish); Odzież, 1987, no. 9, p.256-259.*
8. *Elmrych-Bocheńska J., The assessment of the changeability area of the lockstitch interlacement placing in the needle channel; Proceedings of the 8th Conference of Faculty of Engineering and Textile Marketing, 2005, Łódź (Poland) 2005.*

Received 24.05.2006 Reviewed 07.06.2006