Finding the Optimal Setting of the Sewing Needle Transfer Mechanism Using Simulation Software

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Abstract

The paper is concerned with an analysis and optimisation of the needle transfer mechanism by means of the software Pro/Engineer Wildfire 4 with the aim to obtain a reduction of needle wear. An optimisation of parameters of the setting mechanism that influence the moment of release of the needle during its transfer from one needle bar to the other has been carried out. As a result the optimal setting of the needle transfer mechanism was found. Modifications of the design of the needle transfer mechanism were proposed which are leading to improved force effects in the gripping of the needle. The results have been experimentally verified by the long-term operation of a functional model.

Keywords: hand stitch sewing, optimization of sewing mechanism, dynamic analysis

1. Introduction

The efforts of sewing machine manufacturers are focused on reducing time of the sewing cycle and improving productivity. Further important requests are quiet run, low vibrations, long life and easy maintenance [1]. The Deco 2000 Hand Stitch sewing machine and its needle transfer mechanism are operated in the speed range between 100 and 250 rpm. The needle bar performs a rectilinear reverse movement obtained by a cam mechanism. It uses the floating needle system, developed by AMF Reece, to produce a "true hand stitch" as represented in figure 1.

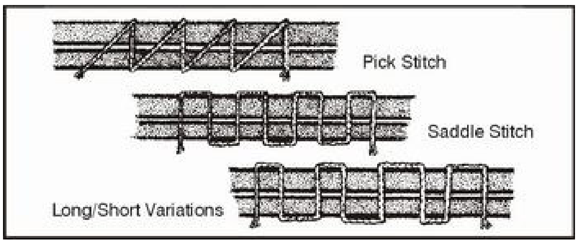

Fig. 1 - Hand stitch types
(http://www.amfreece.com/features.asp?prod=deco%202000&lang=eng)

The machine uses a double pointed needle, with an eye in the middle, as represented in figure 2. By the use of two needle bars, one above and one below the work plate, a length of thread is passed through the material on every stitch, reproducing the seamstress work, accurately and at an incomparable speed.

Fig. 2 - Double pointed needle
(http://www.amfreece.com/features.asp?prod=deco%202000&lang=eng)

However, in case of high operating speeds, machines produce high level of vibrations. In order to reduce the vibration and noise a new functional model of the drive needle bars was created. This model consists of a crank mechanism with servo-drive converting the rotary swinging motion into rectilinear reverse movement [3]. The model is capable of reaching speeds up to 300 rpm. However, there is higher wear and frequent breaking of the needle. The aim of this work is the optimization setting of the needle transfer mechanism, proposing improvements leading to wear needle reduction. An experimental work was carried out in order to verify the asset of the selected concept.

2. Analysis of the Needle Transfer Mechanism

The needle transfer mechanism is part of a system capable of imitating the handmade stitch. It is necessary to ensure the transfer of the floating needle between two needle bars operating above and below the machine bed. The needle bar is schematically represented in figure 3.

The floating needle is held by collets (12) inside the needle bar. The collets consist of two balls, which are due to contact force springs (11,

15) pushed into the tapered conical hole in the shell (2). This can be seen in figure 1-A.

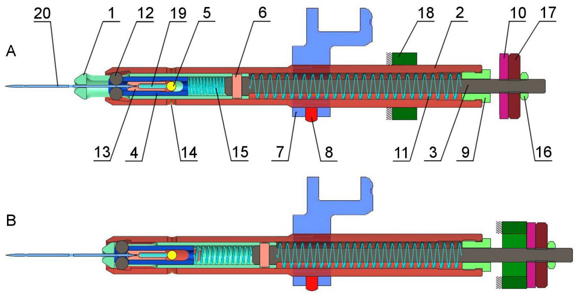

Fig. 3 - Cross-section of the needle bar [2]

The balls move in the axial direction together with the cylinder (4), which forms their cage. Cylinder (1) is connected to the rod (3) using pin (6). Release of the collets is activated in a point when the collets mechanism (1, 3, 6) impacts to the machine frame (18). This situation occurs before the needle bar reaches the dead point. The shock produced by the impact is absorbed by the rubber pad (10). After the impact the shell of needle bar (2) continues its movement towards the lower dead point. The collets mechanism, which is not moving at this stage, stops the cage with balls. The Shell finishes the process of needle transfer. The balls are then released in the enlarged area of the conical hole. This can be seen in figure 1-B. Size of opening collets is controlled by nuts (16, 17).

The two balls (12) have to fit into the recess located on the needle in the process of catching the needle. If the mechanism is incorrectly configured, the balls grab the needle in the wrong place and crush the sides of the needle (Fig. 4) causing severe damage.

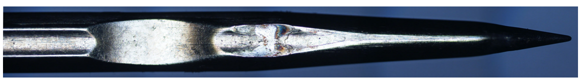

Fig. 4 – Effect of grabbing the needle in the wrong place

The collets grab the needle in an optimal place when the plane passing through the centre of the balls coincides with the plane passing through the centre of the recess on the needle. Optimal transfer of the needle depends on the setting of opening collets and on the setting distance between needle bar shells in the lower dead point of the needle transfer. These two parameters are closely related and are hard to find in operation. A simulation software ProEngineer/Mechanica has been used. The value of the opening collets is not measurable in practice; therefore the value of the distance between cylinders (1) in the lower dead point of the needle transfer will represent this value.

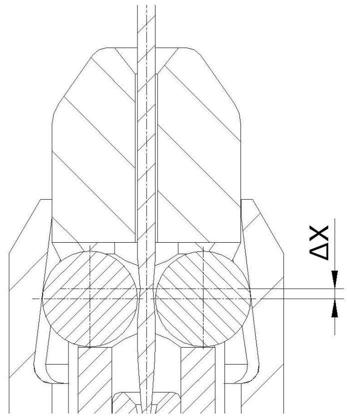

Fig. 5 - Deviation of planes passing through the centres of the balls and recess on the needle

First, an analysis of the current setting of the needle transfer mechanism on the functional model with these parameters was carried out: distance needle bar shells $LS_0 = 22{,}9$ mm, distance cylinders (1) $LR_0 = 8{,}3$ mm, stiffness of spring (19) $C_0 = 1{,}86$ N/mm. Results of the analysis: deviation of planes passing through the centres of the balls and recess on the needle in the first contact of the balls with the needle $\Delta XA_0 = 0{,}5$ mm; deviation of planes passing through the centres of the balls and recess on the needle in the steady state $\Delta XB_0 = 0{,}13$ mm; maximum contact force between the balls and the needle $F_0 = 135$ N. The results are shown in Figure 6. With this setting excessive wear and frequent needle breaks occur.

3. Optimization of the Sewing Needle Transfer Mechanism

Further analysis examined the influence of parameter settings to transfer a needle. The aim of the first sensitivity analysis was to find the optimal setting of distance between needle bar shells. Extreme values of the analysis resulted from the needle bar geometry. When approaching shells to the needle bars to a distance bellow 22 mm there is contact between the needle cylinder (13) and the pin (5). When the distance between needle bar shells has exceeded 22,9 mm, then the contact force between the balls and needle is soaring, whose cause is catching the needle in the wrong place. The deviation of central planes of the balls and recess on the needle decreases with the approaching of the shells. The contact force between the balls and the needle decreases too. The behaviour of the monitored variables is shown in figure 6. From the analysis these two potential areas for the setting of distance between needle bar shells, 22,1 mm and 22,3 mm were obtained.

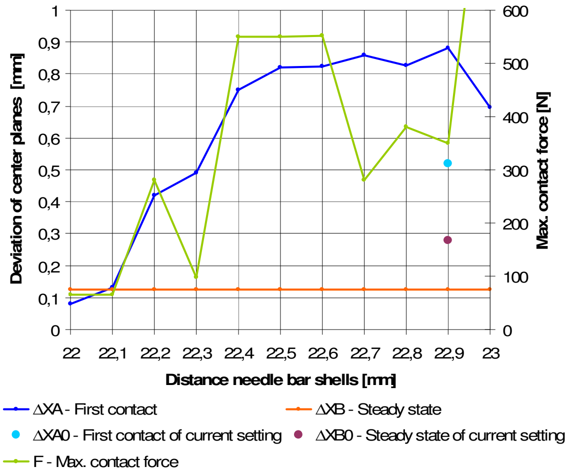

Fig. 6 - Sensitivity analysis of the distance needle bar shells

In the next step the influence of the needle spring (19) stiffness to transfer the needle was examined. In the hand-over point, where both the collets are open, the needle is centered by small springs (19), which define the clearance between the needle cylinder (13) and the pin (5). These springs also help to open the collets; after releasing the collets the spring pushes the needle out of the needle bar. First, the stiffness of the spring was increased to twice the current value. The consequence was the increase of contact forces and delaying the first point of contact between the needle and the balls. On the contrary, by reducing the stiffness of the spring the points of the curves favourably met in a location that corresponds to the distance between needle bar shells of 22,3 mm. The contact force was reduced and especially almost united the centre planes of first contact and steady state, which predicts catching the needle in the desired location. This is shown in figure 7.

The aim of a last analysis was to find appropriate settings of the collets for newfound distance between needle bar shells of 22,3 mm. Settings of collets affect the amount of space between the balls at the moment of the needle transfer.. The space has to be so great that the needle can move through it smoothly. On the contrary, if this space is too large then the collets catch the needle in the wrong place. The balls are closing when the shell is moving. In this movement the balls change its position relative to the needle. The behaviour of the monitored variables is shown in figure 8. Optimal setting of the space between balls is expressed by the value of 1,05 mm.

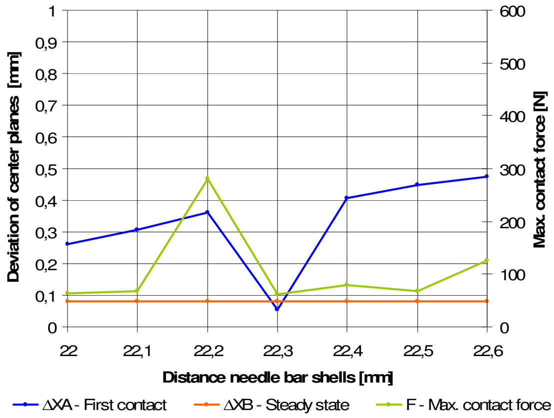

Fig. 7 - Sensitivity analysis of the needle spring stiffness

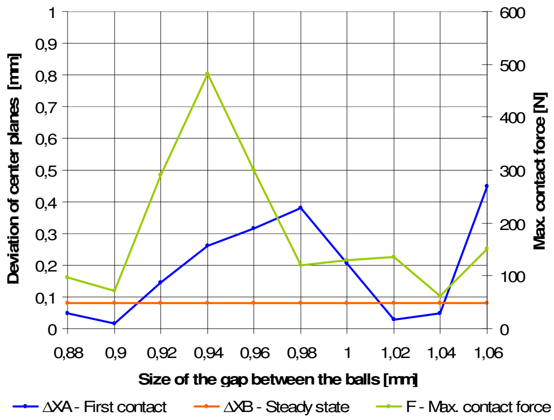

Fig. 8 - Sensitivity analysis of the setting collets

The performed analyzes showed optimal setting of the needle transfer mechanism with the following parameters: distance needle bar shells, $LS = 22{,}3$ mm; distance cylinders (1), $LR = 8{,}9$ mm - this value corresponds to the space between balls, 1.05 mm, stiffness of spring (19) $C = 0{,}84$ N/mm. These parameters correspond to the following values: deviation of planes passing through the centres of the balls and recess on the needle in the first contact the balls with the needle $\Delta XA = 0{,}05$ mm; deviation of planes passing through the centres of the balls and recess on the needle in the steady state $\Delta XB = 0{,}08$ mm; the maximum contact force between the balls and the needle $F = 61$ N.

4. Experimental Verification

The optimal settings and the proposed changes of the needle transfer mechanism have been verified by long-term operation of a functional model. Along with the functional model the original needle transfer mechanism of the hand stitching machine was operated. The sewing machine was adjusted by a specialist prior to testing. The functional model was operated at the speed of 300 rpm. Since the maximum speed of the hand stitching machine is only 200 rpm it was necessary to compare the number of cycles, where one cycle corresponds to one revolution. Using the microscope it was examined and compared the wear of the needles during operation. The needle transfer mechanism and the hand stitching machine were operated for 4 million cycles. The condition of needles at the end of the tests is shown in figure 9.

5. Conclusions

In order to reduce vibration and noise of the sewing machine a functional model of the needle transfer mechanism was created, which is also capable of operating at higher speeds, leading to increased productivity of the sewing process. Downside of this solution was higher wear and frequent breaking of needles. Optimization of the needle transfer mechanism and its settings are managed by a mathematical model that simulated the transfer of the needle. Design changes and modifications in the adjustment mechanism were verified by long-term operation, where the needles wear has been compared to the functional model on a sewing machine. Wear of the needles was captured and examined in the photos that were taken by the help of a microscope. Long-term operation confirmed the correctness of the found optimal settings and proposed changes of the needle transfer mechanism. No needles were broken during the operation. It should be noted that higher dynamic force act on the functional model operated in the speed of 300 rpm than at the hand stitching machine operated in the speed of 200 rpm for the same number of cycles. Even so the needle of the functional model was less worn than the needle on the hand stitching machine at all time of operation.

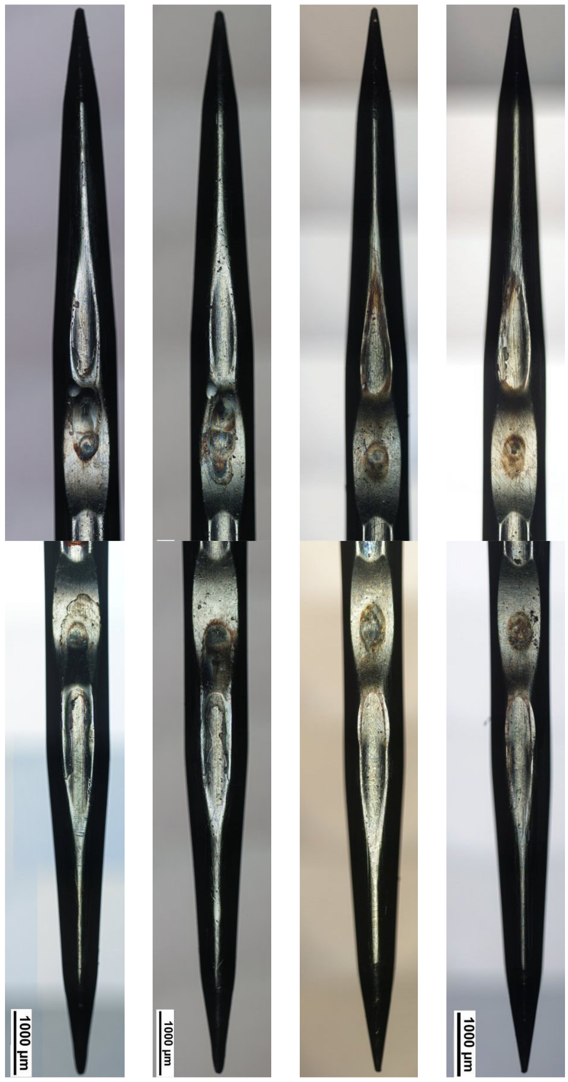

Fig. 9 - Status of needles after long-term operation

References

1. Komárek, J., Design and construction of the drive needle bars of hand stich machine. /Diploma work/, Liberec, TUL 2009.
2. Pejchar, K., Beran, J., Optimalisation of the needle bar mechanism. /Entry in the collection of papers/, Liberec, TUL 2009.
3. Beran J., Pejchar, K., Komárek, J., Analysis and optimisation of the needle transfer mechanism. /ACC Journal/, Liberec, TUL 2010.

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