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Modification of the Classical Needle Bar and Thread Take-Up Lever Mechanism in Sewing Machines

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Abstract
One of the most important mechanisms used in sewing machines is the needle bar and take-up lever mechanism. Being almost the same in nearly all classical sewing machines, this mechanism enables sewing by allowing movement of the needle and pulling of the thread for stitch formation. This study deals with the design of a new modified thread take-up lever mechanism which can be used as an alternative to the classical mechanism. The dimensional design of the mechanism was made by taking into consideration the limitations of sewing mechanics.

Key words: *needle bar and take-up lever mechanism, sewing machines, kinematic analysis, four-bar mechanism.*

Introduction

The needle bar and thread take-up mechanism used in classical sewing machines consists of a slider crank mechanism and four-bar mechanism driven by the same crank. The sewing process occurs in the synchronised motions of these and other mechanisms in the machine. The slider crank mechanism moves the needle carrying the upper thread, while the four bar mechanism moves the take-up lever eye, which performs the task of supplying and pulling the thread. There are many studies in literature about the mechanism. Ogawa suggested a six-link mechanism instead of the four-bar mechanism [1]. In reference [2], a computer simulation of the classical needle bar and thread take-up mechanism was made and the results presented with graphs. Interactions between loop formation and movements of the mechanism were examined. Similar modelling and simulations have also been carried for different textile machines [3, 4]. In stitch formation, thread take-up plays a significant role. Synchronisation of needle, fabric and thread supply motions is very important. The thread take-up mechanism should meet the thread demand of the needle to prevent unfavourable properties of the stitch[5].

Classical needle bar and thread take-up lever mechanism

In the classical mechanism that is used in household and industrial sewing machines, movement of the needle is provided by the slider crank mechanism; the thread take-up mechanism is a four-bar mechanism. Both mechanisms are driven by crank 2 (***Figure 1***), fixed to the flywheel in the main drive shaft; however, since there is a constant angle between them, as seen in ***Figure 2***, the cranks of the two mechanisms do not rotate at the same phase. The position graph of the slider (6) carrying the needle in the slider crank mechanism as well as normalised (by ω_2 = 1 rad/s) velocity and acceleration graphs are given in ***Figure 3***.

The take-up lever eye E, whose path is seen in ***Figure 2***, is fixed to the coupler (3) of the four-bar mechanism. During the formation of a loop, the eye pulls or tugs the upper thread vertically.

Therefore the vertical movement of the eye is important (vertical movement amount is approximately 60 mm), whereas its horizontal movement is insignificant [1, 6]. The position, velocity and acceleration expressions of the vertical movement of point E are as follows:

$$r_{Ey} = r_2 \sin\theta_2 + r_3 \sin\theta_3 + + CE \sin(\theta_3 - \gamma) \quad (1)$$

$$V_{Ey} = r_2\, \omega_2 \cos\theta_2 + r_3\, \omega_3 \sin\theta_3 + + CE\, \omega_3 \cos(\theta_3 - \gamma) \quad (2)$$

$$a_{Ey} = - r_2\, \omega_2^2 \sin\theta_2 + + \omega_3^2[r_3 \sin\theta_3 + CE\sin(\theta_3 - \gamma)] + + \alpha_3[r_3 \cos\theta_3 + CE\sin(\theta_3 - \gamma)] \quad (3)$$

where r_2 = AB, r_3 = BC, and the angular position, velocity and acceleration of link 3, respectively, θ_3, ω_3 and α_3 can

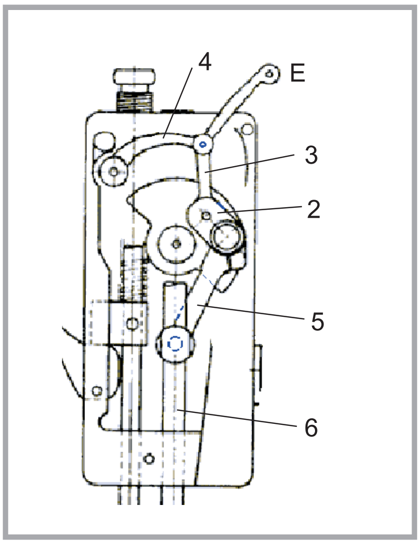

Figure 1. *Classical needle bar and thread take-up lever mechanism on a sewing machine [1].*

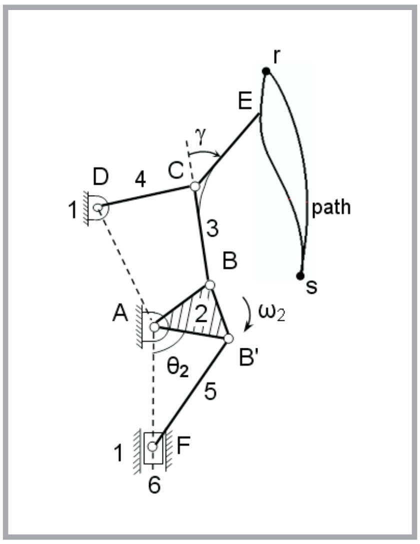

Figure 2. *Schematic of the classical needle bar and take-up lever mechanism.*

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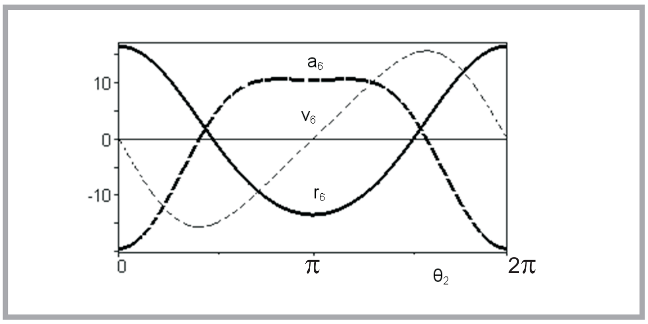

Figure 3. Movement, velocity and acceleration diagrams of the needle bar.

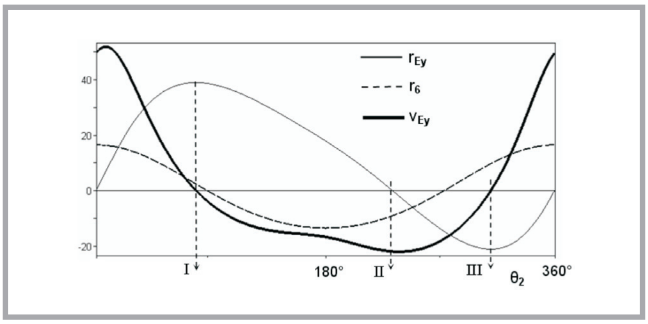

Figure 4. Vertical displacement and vertical velocity diagrams of the take-up lever eye of the classical mechanism and needle displacement.

be found from kinematic analysis of the four-bar mechanism [7].

Position and normalised ($\omega_2 = 1$) velocity diagrams of the vertical movement of the eye are given in ***Figure 4*** together with the position of the needle. These graphs show typical motion diagrams of the classical needle and thread take-up mechanism of a sewing machine in use (JUKI DDL5550), hence the mechanism meets the demand for thread in the stitch formation. Here, in the 1st position (I), the take-up lever eye is in the upper dead position (point *r* in ***Figure 2***) and its velocity is zero. At this moment, the feed dog's teeth catches the fabric and moves it forward by one stitch length. Then the lever eye begins to move downwards, releases the upper thread that it carries, the feed dog then gives up the fabric and goes down. In the meantime, the hook under the sewing plate begins to form a loop by pulling the upper thread. Meanwhile, the needle is moving downwards. In the 2nd position (II), the needle has risen a little from its own lower dead position; the eye E is moving downwards and loop formation of the upper thread is continuing. While the hook rotates, the lever supplies the upper thread, which is necessary to rotate around the hook. In the 3rd position (III), the eye has reached the lower dead position (point *s* in ***Figure 2***) and its velocity is zero. In the meantime, loop formation has been completed and the upper thread has been released after being separated from the hook. Then, the eye moves rapidly upwards, as can be seen from the diagram, and tightens the sewing loop by pulling the upper thread that it carries. The amount of thread that it pulls is slightly more than that required for tightening the loop; this excess amount is pulled over the bobbin and is as long as is required for sewing the stitch. The eye E rises as far as the upper dead point and the aforementioned procedures are repeated.

Modified new needle and take up lever mechanism

In the classical mechanism, the slider crank mechanism which moves the needle and the four bar mechanism which moves the thread are driven by the same crank attached to the flywheel fixed to the main drive shaft (***Figure 1***). Over the 360 degree rotation of the drive shaft, the planes of motion of the cranks of the two mechanisms need to be different so that they will not get overlapped. To this end, a construction was designed in which the coupler of the slider crank is at the top, crank 2 is below it and the coupler belonging to the four-bar is at the bottom (***Figure 5,*** see page 110). Such a structure causes excess occupation of space in the right axial direction to the plane of motion as well as pressure on the ball bearings due to the bending moment. The mechanism was modified as in ***Figure 6*** (see page 110) in order to remove these inconveniences to a certain extent and simplify the construction. Without making any modification on the slider crank mechanism, coupler 5, to which the take-up lever eye was attached, was connected to joint C on the extension of link 3. Thus, since links 3 and 5 will never overlap in any position during their movement, their planes of motion can be the same. Coupler 5 is linked to flywheel 2 with the joint at point G. In this way, the complicated assembly in the classical mechanism is simplified.

The vertical position equation of eye E, from ***Figure 6***, can be denoted as follows:

$$r_{Ey} = -r_2 \cos\theta_2 + a \cos\theta_5 + r_3 \cos\theta_3 + d \cos\theta_3 + e \sin\theta_3 \quad (4)$$

where, a = BG, b = DK, c = AK and point E's right distances to point C are d = CH and e = HE. θ_5 and θ_3 are the angular positions of links 5 and 3, respectively, which can be easily obtained from the position analysis of the mechanism:

$$\theta_5 = \arcsin(r_2 \sin\theta_2 / r_5) \quad (5)$$

$$\theta_3 = 2\arctan\left(\frac{B + \sqrt{B^2 - AC}}{A}\right) \quad (6)$$

$$A = r_4^2 - u^2 + k^2 + r_3^2 - 2u\, r_3,$$
$$B = k\, r_3,$$
$$C = r_4^2 - u^2 + k^2 + r_3^2 + 2u\, r_3,$$
$$u = b + r_2 \cos\theta_2 - a \cos\theta_5,$$
$$k = c + r_2 \sin\theta_2 + a \sin\theta_5.$$

The velocity and acceleration expressions of point E are obtained from a kinematic analysis of the mechanism:

$$V_{Ey} = r_2\, \omega_2 \sin\theta_2 + a\omega_5 \sin\theta_5 + \omega_3 (e\cos\theta_3 - r_3 \sin\theta_3 - d\sin\theta_3) \quad (7)$$

$$a_{Ey} = r_2 (\omega_2^2 \cos\theta_2 + \alpha_2 \sin\theta_2) + a (\omega_5^2 \cos\theta_5 + \alpha_5 \sin\theta_5) - r_3 (\omega_3^2 \cos\theta_3 - \alpha_3 \sin\theta_3) - d (\omega_3^2 \cos\theta_3 + \alpha_3 \sin\theta_3) - e (\omega_3^2 \sin\theta_3 - \alpha_3 \cos\theta_3) \quad (8)$$

where, ω_3 and α_3 can be found with kinematic analysis [7].

Synchronisation of the classical mechanism must be achieved in this newly designed mechanism for smooth operation of sewing. First of all, the amount of vertical movement in the path of the take-up lever eye must be the same. In order to meet this condition, a preliminary design was made using the Cinderella [8] geometry package. Here the dimensions of the slider crank were maintained exactly as they were. The dimension BG = a was taken to be 12 mm in order to keep it at a minimum by taking into consideration the practical construction of joints B and G. Apart from this there

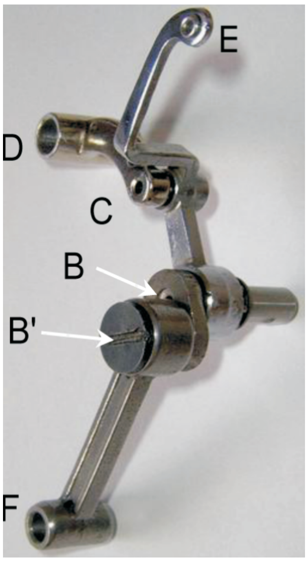

Figure 5. Take-up lever mechanism.

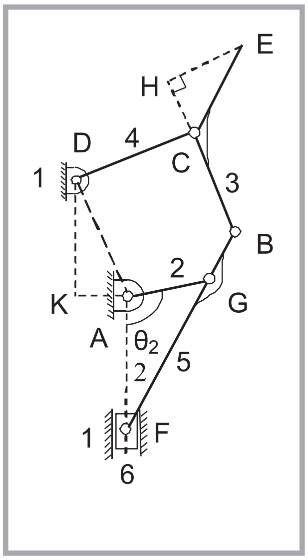

Figure 6. *Schematic of the new modified take-up lever mechanism.*

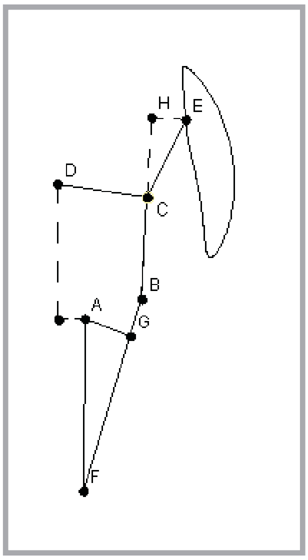

Figure 7. *Schematic of the new take-up lever mechanism pre-designed by geometry software.*

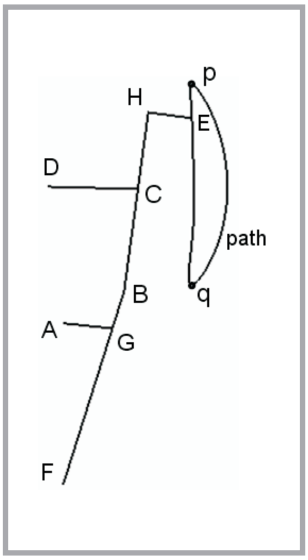

Figure 8. *Scaled schematic of new mechanism designed.*

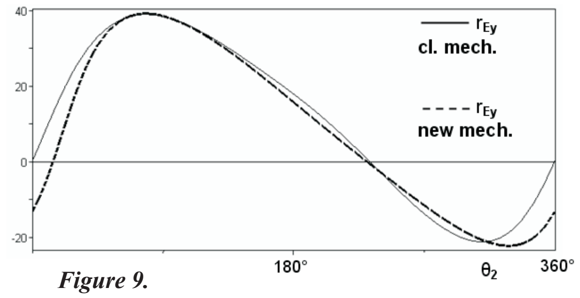

Figure 9.

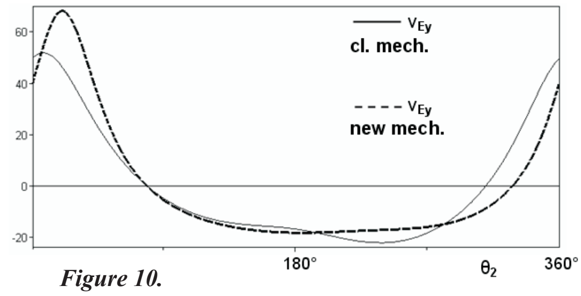

Figure 10.

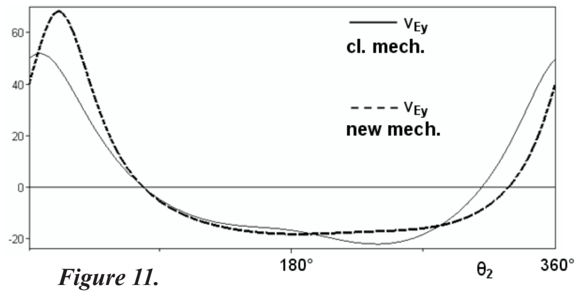

Figure 11.

Figure 9. *Vertical movement diagrams of the take-up lever eye of the classical and new modified mechanism.*

Figure 10. *Vertical velocity diagrams of the take-up lever eye of classical and new modified mechanism.*

Figure 11. *Vertical acceleration diagrams of the take-up lever eye of the classical and new modified mechanism.*

are six dimensional parameters that need to be determined: b, c, d, e, BC = r_3 and DC = r_4. These dimensions were altered appropriately in the geometry package, and thus an attempt was made to obtain an approximate path at point E that meets the above condition (***Figure 7***). This program can be used interactively, and when the dimension is changed, the change in the coupler curve (the path of point E) can be seen instantly.

The shape of the path is not important, what is important is the kinematics of the vertical movement of eye E [1]. In the vertical movement of the point, firstly the upper dead position (point p in ***Figure 8***) must appear at the same crank angle in the classical mechanism (position number I in ***Figure 4***). Moreover, the vertical velocity component is zero. The vertical velocity and position values at the same crank angle in position II in ***Figure 4*** should be satisfactory in the new mechanism too. Values of positions I and II are approximately satisfactory in the approximate solution in ***Figure 7***. On the other hand, position III, in which eye E is in the lower dead position, occurs 10 degrees later in comparison to the classical mechanism. The lower dead position (point q in ***Figure 8***) is not a critical position in terms of sewing mechanics and upper thread is in a released state in this position. Therefore the occurrence of this position 10 degrees later does not pose a problem. The vertical velocity component in the lower dead position is zero. When the crank angles in these three positions and the vertical position values of the eye are calculated from the approximate solution in ***Figure 7*** and the velocity value in position II is calculated from the kinematic analysis of the classical mechanism and substituted in ***Equations 4*** and ***7*** as initial estimations, then six nonlinear equations with six unknowns are obtained. The dimensions are obtained after the nonlinear equation set is solved using a mathematical package.

A scaled drawing from the results of the new mechanism obtained and the coupler curve of point E are shown in ***Figure 8***. After a kinematic analysis, the position diagram of the vertical movement of point E is presented in ***Figure 9***, and normalised ($\omega_2 = 1$) velocity and acceleration diagrams are given in ***Figures 10*** and ***11***, together with those belonging to the classical mechanism. As can be seen in the position diagram, point E reaches the lower dead point a little late in the new mechanism (approx. 10°), whereas a good coincidence is observed in the other sections. Since the new mechanism takes as reference the classical one in use, then it meets the demand for thread in the stitch formation.

The positive peak of velocity before the upper dead position is nearly 20% greater in comparison to the classical mechanism. The same increase is also observed in the positive peak of acceleration, resulting from the fact that the eye, which reaches the lower dead point later, moves more rapidly in order to reach the upper dead point. The velocity and acceleration have lower values in the other sections and their diagrams are in proper order.

Conclusions and discussion

A new mechanism of a more simplified structure was obtained by modifying the classical needle bar and thread take-up mechanism. Kinematic analysis revealed that the new mechanism was in conformity with classical lockstitch sewing mechanics. Besides this, it is much smaller in size compared to the classical mechanism, that is, it covers a smaller space. The increase in the peak value of acceleration may increase the tension on the thread slightly at the aforementioned crank angle coupled with an increase in the number of revolutions. However, this increase is both short-lived, as can be seen in ***Figure 11***, and occurs just before point E reaches the upper dead point. This increase does not pose a problem as the upper thread is free at this position (***Figure 9***).

In conclusion, the new mechanism has a potential use in household and industrial lockstitch sewing machines as an alternative.

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