An Application of Six-Bar Linkage to the Thread Take-Up Lever in a Sewing Machine

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In the last report, an unsolved problem in the analysis of six-bar linkage mechanisms was studied.

In this paper, as the result of the investigation on the synthesis of C-type, the author found a new type of the thread take-up lever used for the sewing machine, employing six-bar linkage which has turning pairs only and whose free end performs an ideal thread take-up motion. Thus a most noiseless operation has been attained.

1. Introduction

Formerly, the author treated the unsettled problem\(^{(1)(2)}\) about the synthesis of 6-bar plane linkage mechanisms, and in this paper, he will report a research on trial production by adapting this synthesis to the actual machines. Generally, the displacement curve obtained from the 4-bar plane linkage mechanism is monotonous\(^{(5)}\), and as for the locus loop (C-loop) described by a point on the middle link too, there are many cases when it is difficult to expect a varied displacement by the structure of the machines.

For example, as the thread take-up mechanism of the sewing machine which is treated in this paper, up to this time, two kinds of mechanism have been used, one is a cam type engaged of the cylindrical cam and the swinging follower link (Fig. 1), and the other is a link type using the 4-bar link mechanism.

Although the cylindrical cam is worked so as to give a displacement curve which matches the thread take-up movement, it is the higher pair in the mechanical point of view and so, a certain kind of noises is not avoidable. As the 4-bar linkage is a mechanism with the lower pair, it is already recognized that it has few noises compared with the former, but the thread take-up displacement curve of the point C on the middle link is inferior to the ideal cam type as seen from Fig. 3.

That is, there are the following defects:

1. It is loose to pull the thread, as the area of the rising loop shows 115 degrees against 97 degrees of the cam type.
2. It cannot make a resting place.

Therefore, it is necessary to adjust the thread take-up spring in proper quantities for the thread. Then, the author synthesized by taking up such type as to give a middle resting point on the 6-bar link mechanisms.

2. Synthesis of 6-bar linkage mechanism

2-1 Decision of type

The mechanical type which can easily obtain the ideal displacement curve obtained by the cam type take-up mechanism on Fig. 3 is the mechanism of C-type.

It is clear by the model of the displacement curve\(^{(5)}\), in C-type, C-2-2 is suitable.

2-2 Synthesis

On the synthesis of C-type mechanism, the rotating center of the swinging follower link \(P_{sa}\) and its swinging angle \(\varphi\), and the rotating center of the driving link \(P_{sa}\) and its rotating angle \(\theta\) are
given. In this case, when the loops connected with corresponding positions on the swinging link of the pair point $P_r$ on the driving crank coincide with the locus loop (C-loop) described by a point on the middle link of the 4-bar linkage $t-p-u-s$, the fixed rotation centers $P_u$ and $P_3$ of this 4-bar linkage are fixed on the swinging link $s$ and the 6-bar link mechanism in which the describing point $P_r$ on the middle link $p$ coincides with the pair point $P_r$ on the driving link $r$ is synthesized. But, fundamentally, the synthesis of the 4-bar linkage $t-p-u-s$ becomes a problem. Moreover, on the structure of the sewing machine body, the length of the follower link $s$ cannot be permitted to take a large value as the thread take-up lever. That is, they are given as follows: $s \leq 60 \text{mm}$, the total swinging areas of $\varphi$ is $67^\circ$, the length of the driving crank $r=12 \text{mm}$, the fixed point $P_r$, $P_u=q=33 \text{mm}$.

And, on the displacement curve of Fig.3, 1 ($\theta=328^\circ$) and 3 ($\theta=65^\circ$) decide the down and up dead points, 5 ($\theta=180^\circ$) and 6 ($\theta=210^\circ$) decide the resting points, and 2, 4 and 7 decide the inclination of the loop, and they are noted as the important points.

First of all, decide the positions of the rotating center $P_1$ of the driving crank $r$ and the swing center $P_3$ of the follower link $s$ as seen from Fig.5.

Describing the relation between the rotation angle $\theta$ of the driving link $r$ and the swinging angle $\varphi$ of the follower link $s$, the symmetrical positions $P_{1r}^1$, $P_{1r}^2$, $P_{1r}^3$, ..., $P_{1r}^6$ for the position 0 of the positions 1, 2, 3, ..., 7 of the pair point $P_r$ on the driving link are plotted on the follower link $s$.  

![Diagram](image)
The loop $C^0$ connected with those points is a locus loop described by a point $P_{Qr}$ on the middle link $p$ of the 4-bar link mechanism $t-p-u-s$. It is thought that this loop changes by the relative position of the assigned position of the rotating circle of the driving link and the swinging sector of the following link.

Now, as seen from Fig.6, the angular displacement $P_{Qr}P_{Qs}$ \( \gamma \) (\( \gamma \) takes positive value in the clockwise rotation around $P_{Qr}$ with $P_{Qr}P_{Qs}$ as the original axis) from $P_{Qr}P_{Qs} = q$ which is the distance between the two fixed points $P_{Qr}$ and $P_{Qs}$ and the length $r$ (length of the driving link) from the fixed point $P_{Qr}$ are shown by the polar coordinates. Then, the $C^0$-loop described on the swinging link $s$ changes according to the values of $q$, $r$ and $\gamma$.

Changing the value of $\gamma$ variously for $q = 33$ mm and $r = 12$ mm and describing $C^0$-loop which connects the points $P_{Qr0}$, $P_{Qr1}$, $P_{Qr2}$ \( \cdots \), $P_{Qr9}$ by the method of Fig.5, the various loops which are shown in Fig.7 are obtained.

1~7 on the loop are abbreviations of $P_{Qr0}$~$P_{Qr9}$ and the aspect of the closed loop transformation is shown by the change of $\gamma$.

In the vicinity of $\gamma = 25^\circ$ and $-55^\circ$, the closed loop collapses and the respective points 1, 2, \( \cdots \), 7 stand in an opening loop.

This means that it comes and goes in a part of C-loops, and for the best condition it uses a part of C-loop as $z_{\text{max}}$, $z_{\text{min}}$ on C-type mechanisms.

When the best condition, that is, $\gamma = -55^\circ$, and examining on the case of $r = 12$ mm, the influence of the loop based on the slight changes of $q$ is shown in Fig.8.

Here the following condition is best: $q = 33$ mm, $r = 12$ mm, $\gamma = -55^\circ$.

The next problem is to synthesize the 4-bar linkage $t-p-u-s$ which has this loop as a part of C-loop.

For this synthesis, we adopt the synthesis of the 4-bar linkage mechanism which the author proposed earlier. The 4-bar linkage of Fig.10 is synthesized by turning the figure of classification of which number is 133 in the classification figure (Fig.6) of C-loop and using the method of superimposition as shown in Fig.9. That is, $P_{Qru0}$ and $P_{Qru9}$ are on C-loop exactly and they are in the

![Fig. 7](image1)

![Fig. 8](image2)

![Fig. 9](image3)

![Fig. 10](image4)
vicinity of the important points $P_{ar}^3$, $P_{ar}^6$ and $P_{ar}^9$.

The 6-bar linkage mechanism synthesized by such a method is shown in Fig. 11.

The displacement curve becomes nearly equal to one of the cam type thread take-up lever shown in Fig. 12. The 6-bar linkage thread take-up lever produced on trial is shown in Fig. 13.(b)

3. On the prevention of the thread breaking in back sewing of the 6-bar link thread take-up lever

In the sewing machine, the effort has been made to tighten the thread.

This means that the rising up displacement curve should be better as it is shown on Fig. 1.

In this respect, the 6-bar link mechanism is as good as cam type as it has a smaller range of 1-3 compared with the 4-bar link.

On the other hand, the thread breaking and, especially, one which is caused by the back sewing mechanism, poses a problem. The 4-bar link mechanism is apt to suffer frequent thread breaking, especially in the case of back sewing. This tendency seldom appears in the case of ordinary cotton thread, but it has high frequency in the case of silk thread.

Through the investigation of the causes of the thread breaking which happens in the case of back sewing, it is found that a swelling just like a snake that has swallowed an egg appears in the top thread in about 60 mm upper part from the surface of the needle plate several rotations before thread breaking as seen in Fig. 14. This is a return of the local thread breakings. Once this swelling appears, it never restores to its former state and it approaches slowly to the seam according to the advance of sewing. When this part reaches the shuttle, it
does not form a complete thread loop, and is hooked by the edge of the shuttle, which causes a thread breaking, or by idle striking of the shuttle, the thread breaks by twinning round the needle without passing through the shuttle.

Moreover, a break is caused under the unusual tension when the thread passes through the needle hole. As this swelling relates to the twist of the thread, through the back and forth sewing examination went in the spot numbers of the twist plies within the 10 mm thread length of the upper part (the thread take up lever side) from the needle hole at the arm shaft rotation angle $\theta=100^\circ$ was measured as shown in Fig.15.

The results are shown in Fig.16 (a). The average spot numbers of the silk thread are 20 spots per 10 mm, but on the 4-bar link, when it is an advancing sewing, the sewing spots suddenly increase to about 26 spots according to the increase of the sewing length but, thereafter, the spots number does not increase over 26 even if the sewing length increases. On the contrary, in the case of back sewing, the twist, at first, returns suddenly and advances to about 13 spots per 10 mm but, thereafter, comes to be cut growing continuously.

This is on account of after appearance of the phenomenon of "swelling" which is shown before and caused by the advancement of the undoing of the twist of the thread by drawing action. On the contrary, on the 6-bar linkage, in spite of great variation of the first spot numbers with the advance and back sewing as seen in (b) of the same figure, it stabilizes at about 300~400 mm of the sewing length and becomes parallel straight lines for $x$-axis and does not cause a thread breaking.

Through precise observation of the twisting state of the thread, it is found that, in the case of the needle going down in the direction of the arrow on Fig.17, the thread always touches the two points A and B for the needle hole and the thread at the touching point is collapsed and pulled toward the direction of arrow, losing the usual roundness. The thread moves along the needle hole curved surface according as it goes down the needle.

In the case of advancing sewing (a), the point A' of the front view (i) moves to the point B' of the plane figure (ii) and the point A'' to B''.

Therefore, this gives "a thread drawing" between A and B and it moves rotatingly in the direction of the arrow. Therefore, in the case of the right twisting thread, a twist in the thread in the under part of the point A is undone and the thread in the upper part from the point B is twisted.

![Diagram](image-url)
Next, in the case of back sewing (b), it is the same as (a).

The point $A'$ of the front view (i) moves to the point $B'$ of the plane figure (ii) and the point $A''$ of the front view (i) moves to the point $B''$ of the plane figure (ii), and this gives the thread a rotation between $A$ and $B$ and increases the twist in the lower parts from the point $A$ rotating in the direction of the arrow and the twist is undone in the upper parts from the point $B$.

In the case that the thread is twisted counterclockwise, there happens a quite opposite phenomenon to the one described above. In either case, a thread cutting is induced when the thread is drawn by large tension for long time in the needle hole. Then, examining the movements of the thread take-up lever in the division of $\theta=65^\circ$~$120^\circ$ of the upper axis rotation angle, the thread take up lever of the cam type, the 4-bar linkage type and the 6-bar link type show different changes in the distance between the thread hole and the needle hole of the thread take-up lever as shown in Fig. 18.

From these diagrams, it is seen that the descending amounts of the cam type and the 6-bar link type thread take-up levers nearly equal that of the needle hole, but the descending amount of the 4-bar link thread take-up lever is smaller than that of the needle hole. Generally, in the areas of $\theta=40^\circ$~$100^\circ$ to pull out the thread before the thread take-up lever reaches the highest position, that is, where the sheets are stretched by the advance of the thread take-up lever, the upper thread is given much tension.

Therefore, the upper thread comes to be fixed at both ends and the contact force between the thread and the needle will become larger.

On the 4-bar link thread take-up lever, the state of only the needle descending appears in $\theta=65^\circ$~$100^\circ$, so the drawing of the thread in the needle hole is strong. On the contrary, on the 6-bar link type or the cam type, the thread take-up lever and the needle descend in the areas of $\theta=65^\circ$~$100^\circ$ and so it is understood that the drawing of the thread at the needle hole is weak, which constitutes one of the factors for prevention of thread breaking.

4. Examination of vibration and noises

The author made comparative examinations of the vibrations and the noises about the cam type, the 4-bar link type and the 6-bar link type thread take-up levers. In order to observe these influences by the movements of the thread take-up lever, the moving mechanism, the needle rods and the sheet weights except the lever were all removed and the thread take-up lever was fitted to the circle rod which had neither the arm shaft nor the parts of the crank. In observation of the vibration, the
displacement of the electrical capacity changes between the two plate was recorded on the electric oscillograph, and the noise examination was made by the noise indicator (SL-5) and the frequency analyzer. Fig. 19 shows the observing positions of the vibrations and the noises. Fig. 20 shows the relation of the rotating numbers and the amplitudes for the vibration, omitting the details.

From this it is seen that in less than 1500 r.p.m. that is regarded as the working area of the machine, the amplitude of the 4-bar linkage type is largest and that of the cam type is smallest. The 6-bar linkage type is in the middle of them.

The reasons why the cam type has the smallest amplitude is that the cylindrical cam has a fairly big weight and exerts the effect of a flywheel.

It seems that the 6-bar linkage type acts to cancel the force of inertia by each link, but on this point, there is room for more investigation.

Next, on the results of the noise examination, as shown on Fig. 21, the noise of the cam type is much larger than that of the 4-bar and 6-bar link type. This is seen from the fact that the cam type is a higher order pair mechanism, and on the 4-bar link type and the 6-bar link type that have lower order pairs, it is predicted that the noise of the 6-bar link type becomes higher than that of the 4-bar link type with the increase of the rotation number. In both cases, it is understood that the 6-bar linkage type compensates the defects of the 4-bar link type and the cam type.

5. Conclusion

As the result of adapting the synthesis of the 6-bar link mechanism to the sewing machine, the following conclusions have been obtained:

1. The displacement curve of the new thread take-up lever is very much similar to the ideal curve and the area of the rising curve from the down dead point to the upper dead point is 97° in the arm shaft rotation angle, and this is superior to the 4-bar linkage thread take-up lever like the cam type as it gives good tightness of the thread.

2. The conditions of this synthesis are:
   (a) When the position of the starting point P_r of the driving link r was given as the angular displacement $\gamma$ from the distance $q$ between the fixed point P_r and P_ws, it was found that at $\gamma = -55^\circ$ (taken positive the direction of clockwise rotation) it produced a profitable loop for synthesis from the results of examination of the loop which connects the symmetrical points on the position 0 of 1, 2, …, 7 of the position of P_r based on the change of $\gamma$.
   (b) The 4-bar link l-p-a-s that is profitable for $\gamma = -55^\circ$ was decided as the synthesis of the mechanism satisfying a part of C-loop.

3. From the results of the experiments about the thread cutting, vibration and noise with the trial construction of a 6-bar linkage type thread take-up lever, the superiority of the 6-bar linkage type over the cam shaft and the 4-bar linkage type was recognized.

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References

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