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ANALYSIS OF CINEMATIC PARAMETERS OF CENTRAL CURVED SEWING MACHINE MECHANISM

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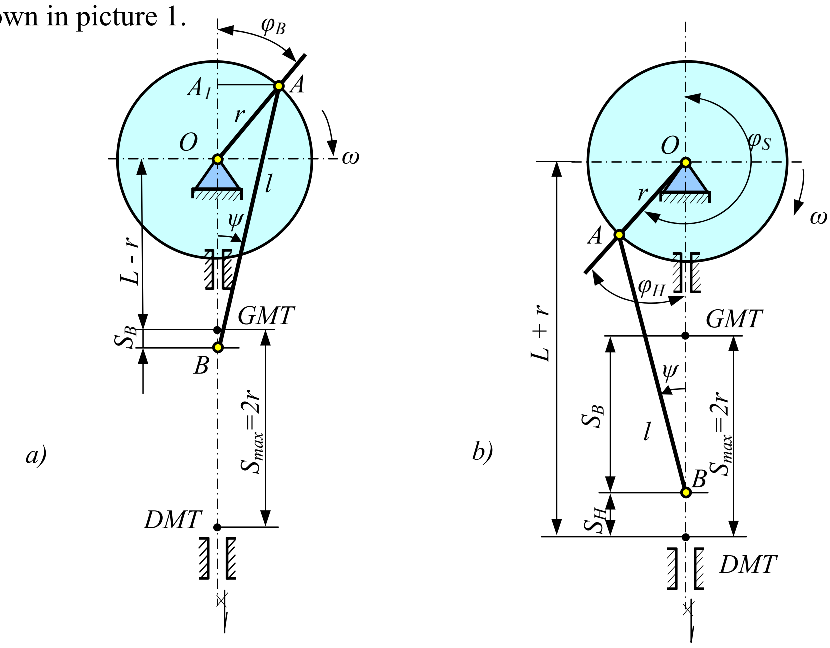
ABSTRACT
The mechanism for starting of needle holders still being analyzed. In order to get the analysis of alteration of the force during penetration of needle through material to be soon it is necessary to make cinematic and dynamic analysis of the mechanism for starting of needle holder. Through the cinematic and dynamic analysis we will pass on to the analysis of forces between needle and material with direction of optimization of parameters which influence this process.
Keywords: sewing, central curving, cinematic machine, dynamic analysis, between, needle, parameters, influence

1. INTRODUCTION
In order to get the rectilinear needle movement on the vertical plane in the sewing machine mechanism, it is necessary to make a kinematics analysis of the mechanism itself. It is usual to apply the mechanism with the simplest construction. In this paper we shall make the analytic solution for velocity and acceleration of needle conducting holder but also analytical and graphical solution of velocity and acceleration changes of needle conducting holder. The analysis of kinematical parameters is necessary because of calculation of inertial force which is the reason for dynamical load of sewing machine mechanism.

2. CENTRAL CURVIED MECHANISM
In the analysis we use the simplest curving mechanism for needle conducting holder for the machine type 22-A, as shown in picture 1.



$$\lambda = \frac{l}{r}$$

Picture 1. Curving mechanism of needle conducting holder

Rotation of crankshaft $\overline{OA}$ can be defined by angle φ_B and movement of needle conducting handler can be defined by S_n, starting point is GMT. On the base of we h ΔOAB ave:

$$BO + r\cos\varphi_B - l\cos\psi = 0 \tag{1}$$

As it is known [2] $BO + r\cos\varphi_B - l\cos\psi = 0$ so it is

$$S_B + (l - r) + r\cos\varphi_B - l\sqrt{1-\lambda^2\sin^2\varphi_B} = 0$$

$$S_B = (r - l) - r\cos\varphi_B + l\sqrt{1-\lambda^2\sin^2\varphi_B} \tag{2}$$

We got a periodical function which is inappropriate for the use. If we separate it into identical harmonic Fourier's sequence of trigonometric sequence the finding of Fourier's sequence coefficient goes with approximate methods of elliptic integrals. Identical harmonic sequence is divided in binominal

$\sqrt{1-\lambda^2\sin^2\varphi_B} = 1 - \lambda^2\sin^2\varphi/2 - \lambda^4\sin^4\varphi_B/8 - \lambda^6\sin^6\varphi_B/16 - 5\lambda^8\sin^8\varphi_B 128 - ...$

Using dependence: $\sin^n\varphi_n = \left[2^{n-1}\left(\sqrt{-1^n}\right)\right]^{-1}\cdot$

$\cdot\left[\cos n\varphi_n - K_1\cos(n-2)\varphi_B + K_2\cos(n-4)\varphi_B - ... + (1)^{(n-2)/2}K_{(n-2)/2}\cos 2\varphi_B + (-1)^{n/2}K_{n/2}0{,}5\right]$

Where is: $K_i = n(n-1)(n-2)...[n-(i-1)]/1\cdot 2\cdot 3 ... i.$

i.e. it is:

$\sqrt{1-\lambda^2\sin^2\varphi_B} = \left[1 - \lambda^2/4 - 3\lambda^4/64 - 10\lambda^6/(16\cdot 32) - 5\cdot 35\lambda^8/(128\cdot 128) - ...\right] +$

$+\left[\lambda^2/4 + 4\lambda^4/64 + 15\lambda^6/(16\cdot 32) + 5\cdot 56\lambda^8/(128\cdot 128) + ...\right]\cos 2\varphi_B -$

$-\left[\lambda^4/64 + 6\lambda^6/(16\cdot 32) + 5\cdot 28\lambda^8/(128\cdot 128) + ...\right]\cos 4\varphi_B +$

$+\left[\lambda^6/(16\cdot 32) + 5\cdot 8\lambda^8(128\cdot 128) + ...\right]\cos 6\varphi_B - \left[5\lambda^8/(128\cdot 128) + ...\right]\cos 8\varphi_B + ...$

By inserting of last expression in the sequence (2) we get the movement of needle conducting holder S_B. Instead of endless Fourier's sequence we consider the final number of its particles. They also very accurately present the function we are interested in. But in case that we expel all the particles which contain λ^9 and more, with enough precision for practise, we will get with $\lambda \le 0{,}8$ that it is

$$S_B = r\left\{1 - \left[\lambda/4 + 3\lambda^3/64 + 10\lambda^5/(16\cdot 32) + 5\cdot 35\lambda^7/(128\cdot 128)\right]\right\} - r\cos\varphi_B +$$
$$+ r\left[\lambda/4 + 4\lambda^3/64 + 15\lambda^5/(16\cdot 32) + 5\cdot 56\lambda^7/(128\cdot 128)\right]\cos 2\varphi_B \tag{3}$$

In rough calculation from the equation (3) if we overlook all addends that have λ^3 and more, we will get the equation for the calculation of moving of needle conducting holder from its up standstill (UP)

$$S_B = r(1 - \lambda/4) - r\cos\varphi_B + (r\lambda\cos 2\varphi_B)/4 \tag{4}$$

If it is necessary to determine the angle of rotation φ_B of the main shaft when the needle will lower from GTM to S_B, we do the exchange:

$$\cos 2\varphi_B = 2\cos^2\varphi_B - 1 \tag{5}$$

We will get the square equation: $\cos^2\varphi_B + 2\cos\varphi_B/\lambda + (2/\lambda - 2S_B/(r\lambda) - 1) = 0$

From which base we get the angle:

$$\cos\varphi_B = 1/\lambda - \sqrt{1/\lambda^2 - \left(2/\lambda - 2S_B/(r\lambda)\right) - 1} \qquad (6)$$

The plus sign before root is left out since it doesn't give the realistic solution. If we want to determine the movement of the needle conducting holder from down standstill (DMT) we will have:

$$S_N = S_{max} - S_B = 2r - S_B \qquad (7)$$

In picture 1. we can see that and with including it into equation (3) we have:

$$\begin{aligned} S_N = {} & r\left[1 + \lambda/4 + 3\lambda^3/64 + 10\lambda^5/(16\cdot 32) + 5\cdot 35\lambda^7/(128\cdot 128)\right] - \\ & - r\cos\varphi_N - r\left[\lambda/4 + 4\lambda^3/64 + 15\lambda^5/(16\cdot 32) + 5\cdot 56\lambda^7/(128\cdot 128)\right]\cos 2\varphi_N \end{aligned} \qquad (8)$$

We will get the simplified expression as in equation (3) if we leave out the same particles:

$$S_N = r(1 + \lambda/4) - r\cos\varphi_N - (r\lambda\cos 2\varphi_N)/4 \qquad (9)$$

3. VELOCITY AND ACCELERATION OF THE NEEDLE CONDUCTING HOLDER

All the points of the needle conducting holder have the same velocity and acceleration. It is necessary to know the exact movement of the needle conducting holder, which is connected with technological process of making the prick, determination of velocity and acceleration of the needle conducting holder doesn't require such accuracy that is why we can use simplified expression (4).
In differing by time we get to the velocity of the needle conducting holder:

$$v_B = \frac{dS_B}{dt} = r\sin\varphi_B \frac{d\varphi_B}{dt} - 0{,}5r\lambda\sin 2\varphi_B \frac{d\varphi_B}{dt} \qquad (10)$$

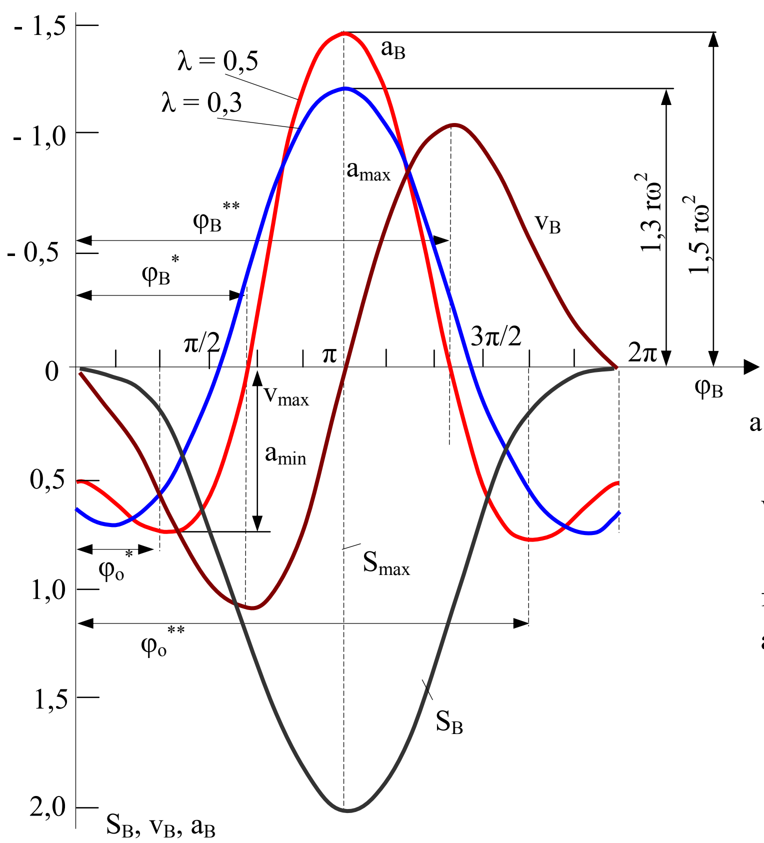
Taking into consideration that $\omega = \frac{d\varphi_B}{dt}$ we get the expression for velocity:

$$\omega = \frac{d\varphi_B}{dt} \qquad (11)$$

We can get acceleration of the needle conducting holder if we search for the first derivation of velocity by time:

$$a_B = \frac{dv_B}{dt} = r\omega^2\left(\cos\varphi_B - \lambda\cos 2\varphi_B\right) \qquad (12)$$

With $\lambda = 0{,}5$ the charts are given for S_B, v_B and a_B in picture 2. and for $\lambda = 0{,}3$, the charts for acceleration a_B is shown.



Picture 2. Change of relocation of S_B, velocity v_B and acceleration a_B of needle conducting holder

4. CONCLUSION

Analysing the mechanism for moving of needle conducting holder, we can notice that the needle pricking of sewn material is achieved somewhere in the middle of the movement S_{max}, when the movement of the needle conducting holder approximately reaches its maximum. We will find the maximum of velocity when we equalize acceleration with zero, so we have $\cos^2\varphi_B - \cos\varphi_B / 2\lambda - 0{,}5 = 0$ from which it is $\cos\varphi_B = \left(1 \pm \sqrt{1+8\lambda^2}\right)/4\lambda$ and the result is φ_B^* and φ_B^{**} angles, $v_{max} = r\omega\left(\sin\varphi_B^* - 0{,}5\lambda\sin 2\varphi_B^*\right)$.

During analysis of the work of the needle conducting holder mechanism, the change of acceleration a_B is especially interesting, because the inertial forces which are produce in the working process of sewing machine depend on that acceleration. These inertial forces are destructive for the mechanism. We will get the position where a_{max} appears if we equalize derivation of acceleration by time with zero.

$\frac{da_B}{dt} = r\omega^2\left(-\sin\varphi_B + 2\lambda\sin 2\varphi_B\right) = 0$ i.e. $\sin\varphi_B\left(4\lambda\cos\varphi_B - 1\right) = 0$ where there are two solutions:

a) $\sin\varphi_B = 0 \Rightarrow \varphi_B = 0 \text{ i } \pi$

b) $\cos\varphi_B = 1/4\lambda$ which gives meaning to two angles φ_0^* and φ_0^{**}

For $\lambda = 0{,}5$ it is $\varphi_0^* = \pi/3$ $\varphi_0^{**} = 5\pi/3$, then it is $a_{max}^* r\omega^2\left(\cos\varphi_0^* - \lambda\cos 2\varphi_0^*\right)$, and for $\varphi_B = 0$ acceleration reaches its minimum: $a_{min} = r\omega^2(1-\lambda)$.

If $\varphi_B = 0$ then the adequate acceleration will be maximal and will have negative meaning because it is directed to the opposite of velocity: $a_{max} = -r\omega^2(1+\lambda)$, then it is: $a_{min} \prec a_{max}^* \prec |a_{max}|$

On the base of the explained above, we can conclude that the biggest inertial force in the needle conducting holder will be in DMT when the acceleration is negative. As we can to see in picture 2. decreasing of λ during changing of acceleration becomes more even, and it decreases dynamic load of sewing machine, so it is advisable to take λ as smaller as possible.

5. REFERENCES

[1] Karabegović I.: Statika, Mašinski fakultet Bihać, 1998.
[2] Karabegović I.: Teorija mehanizama, Mašinski fakultet Bihać, 1999.
[3] Karabegović I.: Mehanizmi – Praktikum, Mašinski fakultet Bihać, 1999.
[4] Rogale D., Ujević D., Firšt Rogale S., Hrastinski M.: Tehnologija proizvodnje odjeće, Tehnički fakultet Bihać, 2005
[5] Knez B.: Tehnološki procesi proizvodnje odjeće, Tekstilno-tehnološki fakultet Zagreb, 1994.
[6] Karabegović I,, Ujević D., Kovačević S.: Tendencije razvoja međufaznog transporta u tekstilnoj industriji, TMT 2004, Neum BiH
[7] Ujević D., Rogale D., Karabegović I.: Dostignuća i tendencije razvoja šivaćih strojeva prikazani na IBM 2003, Tekstilni dani Zagreb 2004.
[8] Bolić B., Karabegović I., Ujević D.: Prilog analizi sila na šivaćoj igli pri prolazu kroz materijal, RIM 2004, Bihać BiH
[9] В. Н. Гарбарук: Расчет и конструирование основных механизмов челночных швейных машин, Ленинград «Машиностроение» Ленинградское отделение, 1977.
[10] Nestler R. i Arnold J.: Messtechnische Untersuchungen zum Nadeldurstechkraft-verhalten wahrend des Nahprozesses, Bekleidung und Maschenware, 18 (1979) 3, str. 132-136
[11] Gotlih K.: Študij prebodne sile šivalne igle, Oblačilno inženirstvo 1996, Univerza v
[12] Karabegović I., Ujević D., Kovačević S., Bolić B.: Konstrukcija izvedbe strojno šivaćih igala,RaDMI 2004 Zlatibor 31.08-04.09
[13] Ujević D. Knez B.: Utjecaj karakterističnih parametara na probodne sile šivaćih igala, IMCEP 1994. Tehniška fakulteta Maribor
[14] Ujević D.: Utjecaj probodnih sila šivaćih igala u procesu šivanja pletene odjeće, Zagreb, 1997.