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ANALYSIS OF THE REVERSING MECHANISM OF LIGHT INDUSTRY EQUIPMENT

С.О. Кошель, Г.В. Кошель. **Аналіз реверсивного механізму обладнання легкої промисловості.** Для створення надійних та високоефективних, енергозберігаючих машин легкої промисловості необхідно проводити дослідження динамічних процесів руху ланок механізмів, з яких вони складаються. Особливо таким дослідженням необхідно приділяти увагу для машин, механізми якого мають цикловий характер дії. Під час виконання технологічної операції в машинах легкої промисловості з періодичним цикловим рухом робочих органів виникає нерівномірність руху головного валу внаслідок руху ланок механізму з певними прискореннями та з урахуванням періодичного характеру дії технологічних навантажень, що змінюються за величинами та за напрямками. Нерівномірний характер руху спричиняє до появи додаткових навантажень в кінематичних парах механізмів, механічних коливань в механічних системах передачі руху, призводять до появи вібрацій та порушень в позиціонуванні робочих органів, впливає на технологічний процес роботи обладнання. Рівномірний та стабільний натяг ниток є запорукою якісного виконання технологічної операції петлеутворення. Фактором, що впливає на технологічний натяг ниток під час роботи обладнання також є додаткові динамічні навантаження, що є особливо важливим для технологічного обладнання з наявністю реверсивного робочого ходу, тому що саме в таких механізмах величини кутових прискорень ланок та лінійні прискорення їх окремих точок можуть набувати критично допустимих величин. Забезпечити рух робочих органів машини за необхідним законом за час циклу роботи, для якого натяг ниток буде оптимально необхідним, можна, якщо правильно підібрати тип механізму, що надає їм рух. Метою роботи є проведення структурно-кінематичного дослідження механізму реверсивного руху голкового барабану трикотажного автомату, які б надали обґрунтування щодо оптимального підбору типу механізму для такого обладнання. Отримано підтвердження покращення умов операції петлеутворення для трикотажного автомату з кулісним механізмом реверсивного ходу в порівнянні з шарнірно-важільним за рахунок зменшення амплітуд зміни кутових прискорень руху коромисла приводу голкового барабану для положень головного валу, під час яких виконується технологічна операція в'язання.
Ключові слова: механізм реверсивного ходу, кінематичне дослідження, кутове прискорення, динамічні сили

S. Koshel, G. Koshel. **Analysis of the reversing mechanism of light industry equipment.** To create reliable and highly efficient, energy-saving machines for light industry, it is necessary to study the dynamic processes of movement of the links of the mechanisms of which they are composed. Especially such studies should be given attention for machines, the mechanisms of which have a cyclic nature of action. During the execution of a technological operation in light industry machines with a periodic cyclic movement of the working bodies, an uneven movement of the main shaft occurs. This is caused by the movement of the links of the mechanism with certain accelerations and taking into account the periodic nature of the action of technological loads, which vary in magnitude and direction. The uneven nature of the movement leads to the appearance of additional loads in the kinematic pairs of mechanisms, mechanical vibrations in the mechanical transmission systems of motion, leads to the appearance of vibrations and violations in the positioning of the working bodies, affects the technological process of the equipment. Uniform and stable tension of the threads is the key to a high-quality performance of the loop formation process in knitwear. Additional dynamic loads affect the technological tension of textile threads during equipment operation. These loads are caused by the accelerated movement of the links of the mechanism, which is especially important for technological equipment with the presence of a reverse working stroke of its links. In such mechanisms, the values of the angular acceleration of the links and the linear acceleration of their individual points can acquire critically permissible values. It is possible to ensure the movement of the working bodies of the machine according to the law for which the tension of the threads will be optimally necessary. To do this, you need to choose the right type of mechanism that sets them in motion. The aim of the work is to conduct a structural-kinematic research of the mechanism of the reversible movement of the needle drum of a knitting machine, which will justify the selection of the required type of mechanism for such equipment. The confirmation of the improvement of the conditions for the formation of loops when knitting on a knitting machine with a reversible needle drum movement, made on the basis of a rocker mechanism, has been obtained.
Keywords: reverse motion mechanism, kinematic research, angular acceleration, dynamic forces

Introduction

For mechanical technological processes of light industry, the key to high-quality performance of technological operations is a controlled, uniform and stable tension of threads, which are fed into the working area of technological equipment for further processing. Especially important is the part of the operating cycle of the main shaft of the process equipment, during which the working bodies of the machine perform operations of forming products. For example, when performing the operation of nail-

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ing the weft thread to the edge of the fabric on looms in its manufacture or the operation of looping, which is characteristic of the equipment of garment and knitwear production.

The tension of the threads in the working area of the technological equipment is due to the physical and mechanical properties of the processed material, the technological parameters of the products during their formation, the parameters of the adjustment of the technological equipment and so on. A factor that affects the technological tension of the threads during the operation of the equipment is also additional dynamic loads, the appearance of which is caused by the accelerated movement of the links of the mechanism, namely certain points. If the accelerated movement of the points of the working bodies of the machine is observed during the working cycle of the mechanism, such circumstances can significantly affect the tension of the threads in the working area of the machine, the quality of the technological operation and the quality of the product as a whole.

To ensure the movement of the working parts of the machine according to the required law during the work cycle, for which the tension of the threads will be optimally necessary, you can, if you choose the right type of mechanism that gives them movement. Especially important is the correct selection of the type of mechanism that would ensure the reversible course of the process equipment. It is in such mechanisms that the values of the angular accelerations of the links and the linear accelerations of their individual points can become critically acceptable values. This choice of the optimal type of mechanism is made on the basis of analysis of the results of previously conducted structural and kinematic studies of possible variants of the mechanism.

In the context of the above, structural and kinematic studies of the reverse mechanism of light industry equipment are relevant.

Analysis of basic research and publications

The analysis of the mechanisms of the existing technological equipment requires first of all their structural and kinematic researches. Such studies allow to determine the sequence of solving the problem and to obtain the values of kinematic parameters required for further dynamic and other special calculations. In the publications of professional publications of recent years in a number of works the problems of structural-kinematic analysis of mechanisms [1, 2], and also the problems which decision demands performance of graphic constructions [3, 4], analytical researches [5], use of modern computers computer programs for engineering research [6, 7], which are solved for the mechanisms of sewing [8 – 10] and knitting equipment of light industry [11].

The aim of the study

The aim of the work is structural and kinematic studies of the mechanism of reverse movement of the needle drum of a knitting machine, which would provide a justification for the optimal selection of the type of mechanism for such equipment.

Presentation of the main material

Consider a flat hinge-lever mechanism of the second class, which provides reversible movement of the needle cylinder in the warp knitting machine (Fig. 1).

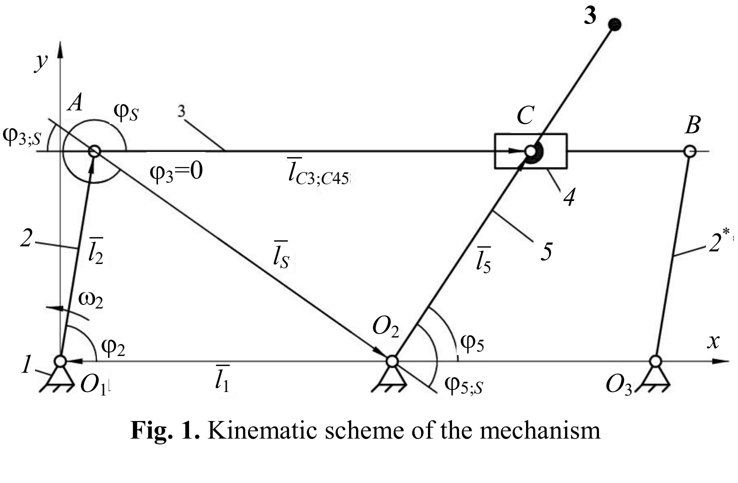

Fig. 1. Kinematic scheme of the mechanism

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The mechanism consists of a leading link *2*, which is connected to the riser *1* and other slave links: rocker arm 2^*, *5* and connecting rods *3*, *4*, including the link *3*-link, *4*-rock stone. The point “**3**” in the diagram indicates the place of attachment of the toothed sector, which provides reversible movement of the needle cylinder of the knitting machine.

The initial mechanism (links *1*, *2*) together with two sequentially connected structural groups of the second class of the second order, which include a set of four moving links 2^*, $3-5$ ($n=4$) together with seven kinematic pairs of the fifth class A, B, O_3, O_2, C_3, C_4, C_5 ($p_5=7$) form a mechanism of the second class with the degree of freedom of one and the other leading crank, the structure of which is shown in Fig. 2.

1st class (Links *1*, *2*) ⟶ 2nd class 2nd order (Links *3*, 2^*) ⟶ 2nd class 2nd order (Links *4*, *5*)

Fig. 2. The formula of the structure

A structural feature of the mechanism is the presence of a rocker part formed by links *3* and *4*. Moreover, taking into account the size of the links of the mechanism ($l_2=l_{2*}$) we have that the angular kinematic parameters of links *2* and 2^* are the same, and the connecting rod – rocker *3* moves translationally (flat translational motion of a rigid body).

To study the kinematic parameters, we use the analytical method, namely the method of vector closed circuits. For the contour O_1AO_2 we make a vector equation of its geometric closure:

$$\overline{l_1}+\overline{l_2}+\overline{l_S}=0\,. \tag{1}$$

We design equation (1) on the axis O_1x and O_1y, we have:

$$\begin{aligned} O_1X &: -l_1+l_2\cdot\cos\varphi_2+l_S\cdot\cos\varphi_S=0;\\ O_1Y &: l_2\cdot\sin\varphi_2+l_S\cdot\sin\varphi_S=0, \end{aligned} \tag{2}$$

where l_1, l_2, l_S – the lengths of the corresponding vectors; φ_2, φ_S – the angles of the $\overline{l_2}$, $\overline{l_S}$ vectors, relative to the horizontal axis.

From equations (2) we calculate:

$$\varphi_2=\arcsin\left(\frac{-l_S\cdot\sin\varphi_S}{l_2}\right). \tag{3}$$

We compose a vector equation of geometric closed loop O_1ACO_2:

$$\overline{l_1}+\overline{l_2}+\overline{l}_{C45;C3}=\overline{l_5}\,. \tag{4}$$

We design equation (4) on the axis O_1x and O_1y, we have:

$$\begin{aligned} O_1X &: -l_1+l_2\cdot\cos\varphi_2+l_{C45;C3}=l_5\cdot\cos\varphi_5;\\ O_1Y &: l_2\cdot\sin\varphi_2=l_5\cdot\sin\varphi_5. \end{aligned} \tag{5}$$

We differentiate equations (5) by the generalized coordinate φ_2. After algebraic transformations we find the equation for determining the angular velocity of the rocker arm *5*:

$$\omega_5=\omega_2\cdot\frac{-l_2\cdot\cos\varphi_2}{l_5\cdot\cos\varphi_5}=\omega_2\cdot U_{5;2}\,, \tag{6}$$

where ω_2 – angular velocity of the leading link; l_2, l_5 – the lengths of the corresponding vectors; $U_{5;2}$ – analog value of the angular velocity of the rocker arm *5*.

After double differentiation of equations (5) by the generalized coordinate φ_2 and algebraic transformations, we find the equation for determining the angular acceleration of the rocker arm *5*:

$$\varepsilon_5 = \omega_2^2 \cdot \frac{l_5 \cdot U_{5;2}^2 \cdot \sin\varphi_5 - l_2 \cdot \sin\varphi_2}{l_5 \cdot \cos\varphi_5}, \qquad (7)$$

We use equations (6) and (7) to calculate the angular kinematic parameters of the gear sector “**3**” together with the rocker arm *5*. The results of calculations (Table 1) allowed building a graph of the angular acceleration of the rocker arm *5* from the angle of rotation φ_2 of the leading link reversible movement of the needle cylinder of the knitting machine (Fig. 3).

Table 1

The results of the calculation of angular velocities ω and angular accelerations ε of the links of the rocker mechanism of the needle drum drive

φ_2 deg	ω_5, c^{-1}	ε_5, c^{-2}
0.00	$-4.654\cdot10^{-13}$	0
30.00	$-4.373\cdot10^{3}$	$1.176\cdot10^{7}$
60.00	$-3.142\cdot10^{3}$	$2.452\cdot10^{7}$
90.00	$-4.517\cdot10^{3}$	$4.425\cdot10^{7}$
120.00	$3.142\cdot10^{3}$	$2.452\cdot10^{7}$
150.00	$4.373\cdot10^{3}$	$1.176\cdot10^{7}$
180.00	$4.654\cdot10^{3}$	$3.419\cdot10^{-9}$
210.00	$4.373\cdot10^{3}$	$-1.853\cdot10^{7}$
240.00	$3.142\cdot10^{3}$	$-4.077\cdot10^{7}$
270.00	$1.355\cdot10^{-12}$	$-4.425\cdot10^{7}$
300.00	$-3.142\cdot10^{3}$	$-4.077\cdot10^{7}$
330.00	$-4.373\cdot10^{3}$	$-1.853\cdot10^{7}$
360.00	$-4.654\cdot10^{3}$	$-6.838\cdot10^{-9}$

Comparison of the results of changes in the angular accelerations of the toothed sector of the rocker mechanism of the reverse of the needle drum depending on the position of the main shaft with similar studies of the needle drum drive using a hinge-lever mechanism allowed to make assumptions about improving the loop by reducing the amplitudes of changes in the angular acceleration of the rocker arm with the toothed sector of the drive of the needle drum for the positions of the main shaft, during which the technological operation of knitting.

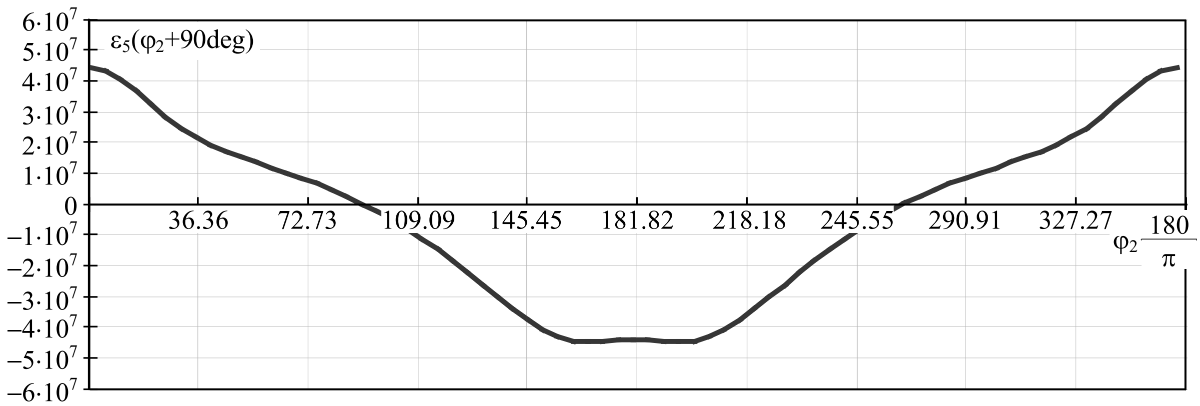

Fig. 3. Graph of dependence $\varepsilon_5 = f(\varphi_2)$

The assumption was experimentally confirmed by tensometric method after studying the change of amplitudes of thread tension in the loop formation zone by the coefficient of non-uniformity of its tension, calculated by the ratio of absolute change of thread tension to its average value for dynamic

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mechanisms of different structures. Thus, for the rocker mechanism of the needle drum drive, the value of the coefficient of non-uniformity of the thread tension is on average three times less than for the hinge-lever mechanism under all other identical technological conditions.

Conclusions

Structural and kinematic studies of the rocker mechanism of the reversible movement of the needle drum of a knitting machine are performed. The analysis of change of amplitudes of tension of threads in a zone of loop formation for dynamic conditions of work of rocker and hinged-lever mechanisms of reverse is carried out. As a criterion for comparative evaluation of the influence of the design of mechanisms on the technological process of looping, the coefficient of non-uniformity of thread tension was adopted. Its value for the rocker mechanism is on average three times less than for the articulated lever, which indicates the need to use in the reversible drive of the needle drum of the knitting machine is the rocker structure of the mechanism.

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