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Development of Resource-Saving Structure and Methods of Calculation of Parameters of Composite Cooling Wedge of a Knitting Machine

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ABSTRACT. It has been developed an effective design of the composite curling wedge which plate is mounted on a rubber pad in a knitting machine. It is given the principle of looping with using recommended design of the kulirniy wedge. It is compiled a mathematical model of oscillations of the plate. On the basis of the numerical solution of the problem there were obtained graphical dependences of the parameters, and basing on the made analyzes there were recommended the values of the parameters of the kulirniy wedge.

KEYWORDS: Knitting machine, kulirniy wedge, composite, rubber pad, vibrations, stiffness, dissipation, looping, frequency, amplitude, mass.

I.INTRODUCTION

To obtain a high-quality knitted fabric when looping, an important role plays kulirniy wedge. In the well-known design of a circular knitting machine the kulirniy wedge has stepped profile of a rectilinear outline. This profile is conditioned by requirements of the looping process and needed trajectory of the needle's path. The process of sticking, the most important operation of the looping process, takes place due to the interaction of the heel of the needle bar with the kulirniy wedge and repetition of the wedge's profile by a needle, since the needle is connected to the needle bar motionlessly.

Wedges of various profiles are rigidly installed in the cylinder's locking system, forming a complex groove, along which, as the cylinder rotates, the needle bar, which is seating in tight contact with the needle, is moving. The interaction of wedges with needle bar occurs through the heel of the latter [1, 2]. The disadvantage of this design of the kulirniy wedge is its low operational reliability and durability, due to the intense wear of its working surface during the execution of the wedging process. In addition, the rectangular profile of the kulirniy wedge leads to blows of the needle bar heels on it and frequent breakage of the latter due to this. The reason for the blows is an instantaneous change in the direction of the speed of the needle bar when it moves from one straight line segment to another. The beating of the needles' heels are extremely undesirable for knitting machine. All this together leads to a breakdown of the rhythmic process of the looping process, to frequent downtime of the process equipment and to a decrease in its useful time ratio (UTR).

II. EFFECTIVE COMPOSITE KULIRNIY WEDGE WITH AN ELASTIC ELEMENT.

To improve the process of looping, the working surface of the kulirniy wedge is made curved. With a curved wedge profile, it is possible to avoid an instantaneous change in the speed of the needle bar and create a so-called unstressed mode of interaction between the wedge and needle bar, which reduces the risk of breaks in the heels of the latter.

The main disadvantage of this design is the technological difficulties in its production, which leads to the high cost of its manufacturing, as well as the danger of accelerated wear of the wedge's working surface at performing a chopping operation is still kept, which causes low reliability and durability indicators. Therefore, it was proposed new design of a kulirniy wedge [3] which allows to improve the kulirniy wedge's operational reliability and durability by reducing the risk of intense wear of its working surface and possible breaks in the heel of the needle bar when it interacts with the wedge at performing the chopping operation.

The given design is shown in Figure 3.2 a, where 1-kulirniy wedge, 2-sheet profile and 3-rubber. As you can see from Fig. 3.2a, the working surface of the kulirniy wedge 1 is made of rubber 3-1-1.2 mm thick and sheet profile 2 of spring steel 65G 1.0-1.2 mm thick. The combination of the elastic properties of the spring steel and the viscoelastic properties

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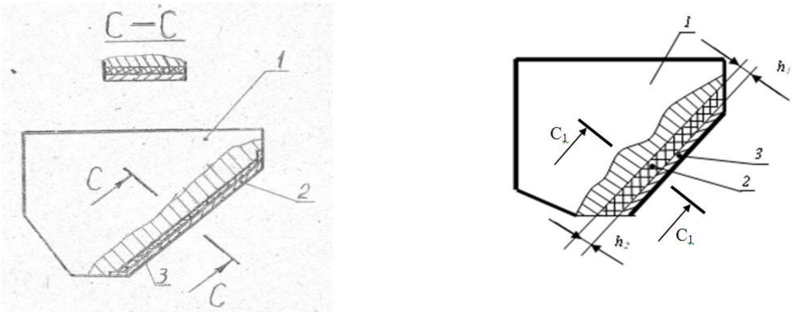
Vol. 6, Issue 3, March 2019

of the rubber provides a damping effect on the working surface of the wedge 1 when the heel of the needle bar hits it and it leads to the absorption of impact energy and reduction of its force, which significantly reduces the possible heel failures. In addition, in the period of "quiet" operation regime of the "heel needle bar - kulirniy wedge" pair, rubber 3 provides the necessary flexibility of the contact area, significantly reducing the amount of wear on the rubbing surfaces. The possibility of varying within wide limits of the materials of rubber 3 as a viscoelastic cushion and sheet profile 2 give the ability to control the oscillation value of the kulirniy plate 2. The disadvantage of this design is that the disturbing force is increasing during the kulirniy period. In this case, the plate 2 along the entire length will oscillate with a certain angular displacement. This can lead to disruption of the looping process (Fig. 1).



where, a- a cylinder wedge with a constant thickness of the elastic support;
b- kulirniy wedge with variable thickness of the elastic support

Fig. 1. Composite kulirniy wedge with an elastic element of circular knitting machine

To eliminate the angular displacements of the kulirniy plate, it is recommended to choose the thickness of the elastic support as variable (see Fig.1b). This design provides the necessary vibrations of the plate 2 and the corresponding depreciation in the process of cooling. The working thicknesses of the rubber and steel layers create the prerequisites for optimizing the conditions for the interaction of the wedge 1 with the needle bar.

For ensuring steady loading of the plate of the composite kulirniy wedge of the knitting machine, we recommended a new design of the kulirniy wedge. The circuit design is shown in Figure 1b. The design of the composite curving wedge of a circular knitting machine consists of the body 1 of the kulirniy wedge, a wedge-shaped elastic support (rubber) 2 with the curved side of the plate 3. The curved plate 2 is made of 65g steel sheet with a thickness of 1.0 - 1.2 mm, an elastic support (rubber) 3 has a variable thickness. In this case, the thickness values at the edges of the elastic support have a ratio $h_1 / h_2 = 0,25$corresponding to the interaction force, where h_1 is the thickness of the upper base of the elastic support; h_3 - thickness of the lower base.

The proposed design of the wedge works in the following way. The heel of the needle bar begins to act on the plate 3 of the kulirniy wedge in the right upper part. At the same time, due to the compression of the elastic support 2 (rubber) in the zone of smaller thickness, the force of action of the heel is absorbed (depreciated). At this, the minimum deformation of the elastic support 2 occurs. Due to the deformation of the elastic support 2 practically there is no damage to the heel of the needle bar and the wear of the surface of the plate 3 of the wedge is significantly reduced. With further interaction of the heel of the needle bar with the plate 3 of the kulirniy wedge towards the greater thickness of the elastic support 2, the interaction force increases and therefore the compression force and thereby the deformation of the elastic support 2 in this zone will also increase. In this zone, usually the wear of the surface of the plate 3 of the kulirniy wedge will be maximum (increasing in a curvilinear pattern). But, due to the greater depreciation of the support in this zone, the wear will also be small.

The advantages of the proposed kulirniy wedge design compared to the basic one are obvious: this is a high operational reliability and durability by both creating a damping effect of the working surface to absorb the impact forces between the wedge and the needle bar, and increasing the flexibility of this surface by the optimal combination of the elastic properties of spring steel and viscoelastic properties of rubber, taking into account the variability of its thickness. In addition, the use of composite kulirniy wedges makes it possible to replace only worn sheet plates, and not the entire wedge as a whole as before [4–8].

The design scheme and the equation of the oscillatory motion of the kulirniy plate on an elastic support with nonlinear stiffness. When machine is operating and the interaction of kulirniy wedge occurs, the latter makes a complex

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Vol. 6, Issue 3, March 2019

oscillatory motion. To reduce the shock pulse, the plates were installed by means of an elastic element - rubber with a variable thickness. It is known that rubber is mainly characterized by elastic - dissipative properties. Therefore, choosing the type and brand of rubber with different elastic and dissipative properties and thickness, it is possible to adjust the amplitude and frequency of natural oscillations of the plate of the knitting machine's kulirniy wedge.

It should be noted that with an increase in the dissipation coefficient of the elastic element, it is possible to reduce the decay time of the plate's natural oscillations. By controlling the stiffness characteristics of the rubber, the necessary amplitude-frequency characteristics of the plate's natural oscillations are provided. In order to simplify the problem, we have adopted a computational scheme of oscillations of the kulirniy wedge's plate on an elastic base with nonlinear stiffness in the form of a single-mass oscillatory system. This design scheme is presented in Figure 3.3.

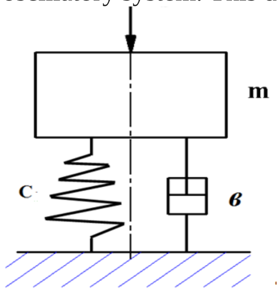

Fig. 2. The design scheme of oscillations of the plate of the kulirniy wedge on an elastic base with nonlinear stiffness

To compose a mathematical model of oscillations of a plate of a kulirniy wedge on an elastic base, we will use the Lagrange equation of 2-kind. Then we have

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{x}}\right)-\frac{\partial T}{\partial x}+\frac{\partial \Phi}{\partial \dot{x}}=\frac{\partial \Pi}{\partial x}-F_i \tag{1}$$

where: x - the generalized coordinate (movement of the kulirniy wedge's plate); T is the kinetic energy of the system; P is the potential energy of the system; Φ - dissipative function of Rayleigh; Fi - components of the generalized force.
In this case, the differential equation of plate motion on the elastic base of the kulirniy wedge is obtained in the form

$$m\ddot{x}+в\dot{x}+cx+c_1x^3=F_в \tag{2}$$

where, m-mass of the kulirniy wedge's plate; c, c1 are the stiffness coefficients of the elastic support; в-coefficient viscous resistance of the elastic support.
In the resulted differential equation, the disturbing force Fв is a complex function. When knitting machine operates, the heels of the needles act cyclically with a high frequency on the plate of the wedge. Depending on the class of the knitting machine, the number of simultaneously interacting heels of the needle bars with the kulirniy wedge's plate varies within certain limits [9, 10]. Therefore, the disturbing force acting on the kulirniy wedge's plate can be represented

$$F_в = F_u + iF_{cp}$$

where, Fu is an impulsive force at the beginning of the interaction of the heel of the needle bar on the plate of the kulirniy wedge; Fcp-average value of the interaction force of the heel of the needle bar in the working area (along the length of the plate) with the plate; i is the number of heels of needle bar at the same time along the length of the kulirniy's wedge plate.

III. ANALYSIS OF OSCILLATIONS OF THE KULIRNIY PLATE WITH A VARIABLE IMPACT OF THE NEEDLE BAR HEELS.

In knitting machines, kulirovaniye accompanied by variable interactions of the needle bars with wedges. In this case, the amplitude and frequency of oscillations of the plate on an elastic base are important. Analyzing the work of the recommended composite kulirniy wedge, it can be noted that the elastic base of the kulirniy wedge's plate significantly reduces the amplitude of oscillations in the first period after the pulse impact of the heel of the needle bar, and also increases the reliability of the machine due to the damping of the plate's vibrations.

Therefore, it is important to determine the patterns of change in the amplitude of oscillations of the plate displacement as a function of the geometric, force, and elastic-dissipative properties of the system. In this case, the

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Vol. 6, Issue 3, March 2019

dissipative properties of rubber leads to the absorption of part of the energy, that is, a decrease in the amplitude of oscillations. Therefore, we do not take into account dissipation, and will consider the rigidity of rubber as a linear characteristic. Then equation (2) is rewritten taking into account the variable perturbation force in the form:

$$m\ddot{x} + cx = F_в \qquad (3)$$

The kulirniy wedge will be cyclically impacted by the heel of the needle bar. The sequence of impact is shown in Figure 3a. From the oscillograms (see Fig. 3b) of the load during kulirovaniye, taking into account the elastic support, it can be seen that it is to some extent aligned. Therefore, the resulting waveform can be approximated by a harmonic function $|F_0 \sin \alpha t|$ (see Fig. 3c).

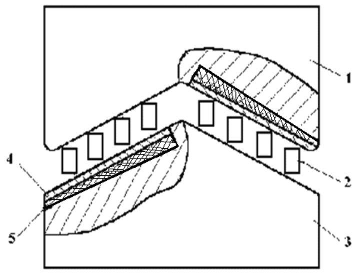
In this case, equation (3) can be represented as:

$$m\ddot{x} + cx = |F_0 \sin \alpha t| \qquad (4)$$

where, α is the oscillation frequency of the disturbing force, F_0 is the amplitude of the disturbing force.

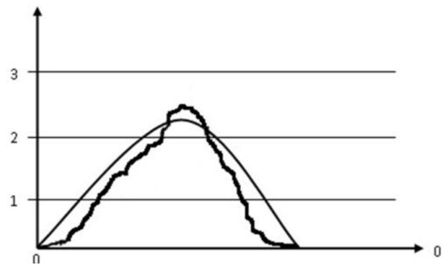
The disturbing force can be decomposed into a Fourier series according to [11, 12].

$$F_в = F_0\left[\frac{1}{\pi} + \frac{1}{2}\sin \alpha t - \frac{\pi}{2}\left(\frac{\cos 2\alpha t}{3} + \frac{\cos 4\alpha t}{15} + \ldots\right]\right. \qquad (5)$$



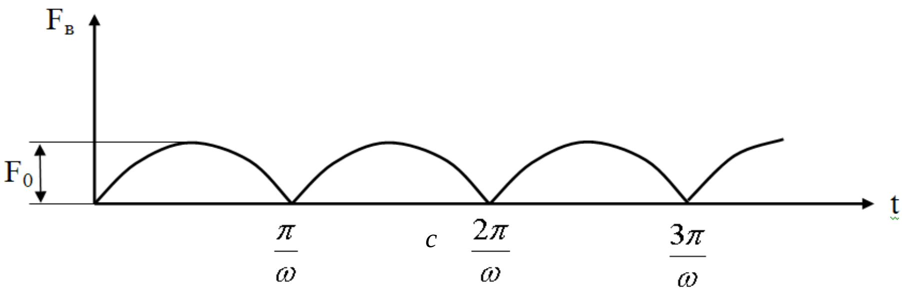
a

where, 1 is the upper wedge; 2 is the heel of the needle; 3 - lower wedge; 4 - elastic plate; 5 - elastic rubber



b

where, 1- oscillographic recording of disturbed force; 2-fitting curve



a -is the approximation of the disturbing force of the action of the needles' heels on the control plate; b - periodic function of perturbation of the heel of the needle bar on the kulirniy plate on the elastic support with a variable thickness; c - Periodic function of perturbation of the heel of the needle bar on the kulirniy plate on the elastic support with variable thickness

Fig. 3. Composite wedges of knitting machine

Using the method of solution (4), taking into account (5), we obtain the law of the movement of the knitting machine's plate in the form:

$$F_в = F_0\left[\frac{1}{\pi c} + \frac{\sin \alpha t}{2m(p_0^2 - \alpha^2)}\right] - \frac{2F_0}{\pi m}\sum_{n=1}^{\infty}\frac{\cos 2n\alpha t}{(2n-1)(2n+1)(p_0^2 - 4n^2\alpha^2)} \qquad (6)$$

ISSN: 2350-0328
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Vol. 6, Issue 3, March 2019

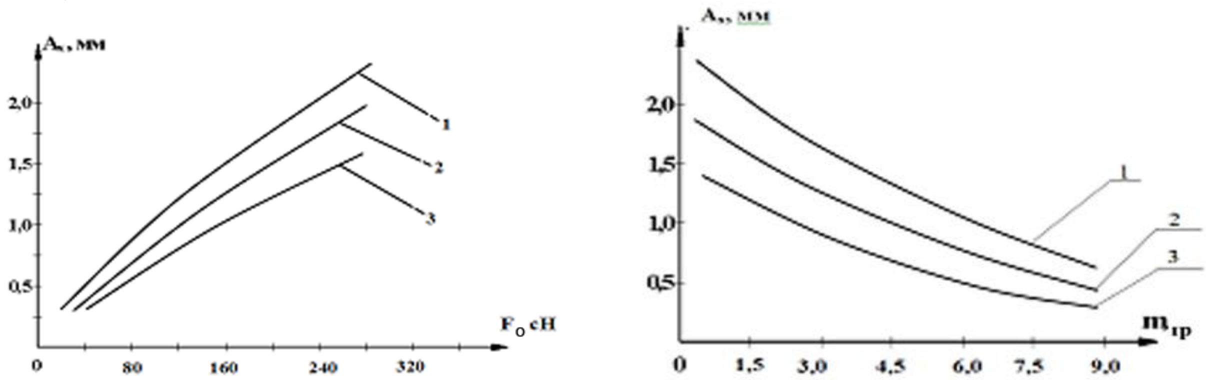
Full movement of the kulirniy plate of the loop-forming system, taking into account its own weight, will be:

$$x_0 = x + \frac{m_g}{c} \qquad (7)$$

Then in a final form the common decision of a task on determining of kulirniy plate's movement has an appearance:

$$X_1 = \frac{mg}{c} + F_0\left[\frac{1}{\pi c} + \frac{\sin\alpha t}{2m(p_0^2-\alpha^2)}\right] - \frac{2F_0}{\pi m} + \left[\frac{\cos 2\alpha t}{3(p_0^2-4\alpha^2)} + \frac{\cos 4\alpha t}{15(p_0^2-16\alpha^2)} + \frac{\cos 6\alpha t}{35(p_0^2-36\alpha^2)}\right] \qquad (8)$$

Solution of a task and analysis of results. Numerical calculations were conducted at the following values of parameters: $m = 4{,}0\cdot 10^{-3}$ kg, $c = 320$ cH /mm, $g = 9{,}8$ m/c2, $F_0 = 230$ cH. From the received equation (8) it is convinced that with increase in the revolting force the amplitude of kulirniy plate's fluctuations sharply increases. With increase in rigidity of an elastic support (rubber) in a compound kulirniy wedge the amplitude of fluctuations decreases and has nonlinear character. With increase in amplitude of the revolting periodic force of Fo from 40 cH to 300 cH amplitude of fluctuations of a plate of a kulirniy wedge increases from 0,34 mm to 2,31 mm for rubber with rigidity of 1200 cH /mm, and for rubber with rigidity 200 cH /mm amplitude of fluctuations increases from 0,3 mm up to 1,51 mm (see fig. 4a).



1 - при C =1200 cH/мм; 2 - при C = 650 cH/мм; 3 - при C =200cH/мм

1– при Fo = 155 cH; 2– при Fo = 110 cH; 3-при Fo = 75 cH

Fig. 4. a-Graphic changes of amplitude of fluctuations of a compound kulirniy wedge's plate depending on amplitude of the periodic revolting force of a needle bar heel, b - Graphic dependences of change of fluctuations' amplitude as specified mass of a kulirniy wedge's plate of the knitted machine

In the figure 4b graphic dependences of change of amplitude of fluctuations of a compound kulirniy wedge's plate depending on its presented specified weight. Depending on a class of the knitted machine the number of heels being at the same time and interacting with a plate changes over a wide range.

Therefore at researches of variations the specified mass of a kulirniy wedge's plate was chosen within 1,5÷9,0 gr. It is known that increase in mass of a kulirniy plate leads to reduction of amplitude of fluctuations of a plate on the elastic basis. So, at m=1,05 gr, Ax =2,45 mm at Fo =350 cH, and at m=9,0 gr, Ax =0,71 mm.

Respectively, at m=1,05 gr, Ax =1,24 mm and at m=9 gr, Ax =0,41 mm at Fo=125cH. The law of change of amplitude of fluctuations of kulirniy wedge's plate is caused by some change of own frequency at a variation of mass of a plate on the elastic basis. Researches on determining of the maximum movement of a kulirniy plate at a variation of coefficient of rigidity of an elastic support are important. The received regularities of change from increase coefficient of rigidity of an elastic support are presented in the figure 5.

ISSN: 2350-0328
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Vol. 6, Issue 3, March 2019

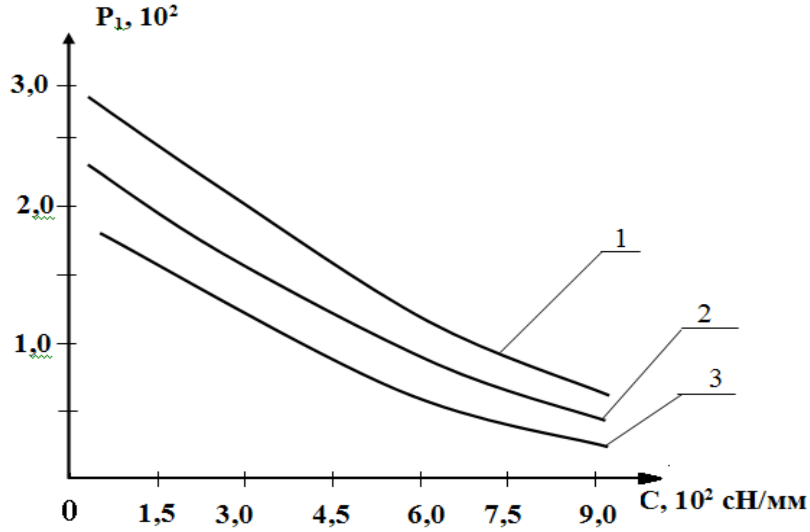

Fig. 5. Dependences of change of maximum values of a kulirny plate's movement from increase in coefficient of rigidity of an elastic support

The analysis of results shows that with increase in rigidity of an elastic support the influence of the kulirniy plate's specified mass decreases. So, at plate weighing of $3{,}5{\cdot}10^{-3}$ kg the movement $X_{\max}$ makes 2,77 mm at $c{=}3{,}5{\cdot}10^{2}$cH/mm and at weighing of $5{,}5{\cdot}10^{-3}$ kg, $c{=}9{\cdot}10^{2}$cH/ mm, the maximum movement of a kulirniy plate makes 0,43 mm, i.e., the difference makes at T = $3{,}5{\cdot}10^{-3}$ kg, $\Delta X_{\max} = 0{,}92$ mm and at T = $5{,}5{\cdot}10^{-3}$ kg, $\Delta X_{\max} = 0{,}36$ mm, where, 1 – at m = $3{,}5{\cdot}10^{-3}$ kg, 2 – at m = $4{,}5{\cdot}10^{-3}$ kg, 3 – at m = $5{,}5{\cdot}10^{-3}$ kg.

It is explained by the fact that with increase in coefficient of rigidity of an elastic support amplitude of the variable which is working out the equation (5) is decreased that leads to the general reduction of movement of a kulirniy plate of the knitted machine.

For ensuring necessary amplitude of fluctuations of a kulirniy plate on the elastic basis 0,8÷1,2 mm the recommended values are C=350÷500 cH/mm and m=2,6÷4,5gr.

IV. CONCLUSION.

The new resource-saving scheme of a compound design of a kulirniy wedge with an elastic element of the knitted machine is developed. The problem of fluctuations of a kulirniy plate on the elastic basis is solved, necessary parameters of system are recommended.

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