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Improving the design of sewing machine elements for the environmentally sustainable development of the light industry

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Abstract. Modern tasks of environmentally sustainable development of light industry require continuous improvement of the design of sewing equipment elements. Textile production is one of the key components of the light industry, therefore, innovative developments in the design of sewing equipment elements allow the deployment of green technologies throughout the industry. Moreover, emissions from light industry, as a rule, are easier to reduce precisely from a technological point of view, by improving the design of sewing machine elements and using environmentally friendly textile materials. An analysis of the constructive features of devices for the folding the sewn materials on a sewing machine is given in the article. A constructive scheme and the principle of operation of the improved construction of the ratchet of the device for obtaining various forms of folds of materials are presented. The construction of the folding device with different pitches and shapes of materials on the sewing machine has been recommended. The methods of profiling the curvilinear working areas of the ratchet wheels of the device has been substantiated.

1 Introduction

Environmentally sustainable development of light industry sectors is currently receiving much attention [1-3]. Many authors offer innovative solutions both in the field of improving the design of elements of sewing machines and other auxiliary equipment [4-6], and in the field of using environmentally friendly textile materials [7-9]. Essential for the development of modern sewing technologies is the improvement of the design and design methodology of the ratchet mechanism of the device for the formation of material folds in the sewing machine [10].

The device contains a frame, fastening element to the clamping bar of the sewing machine, a pendulum lever, which is connected at its lower end to the holder, to which the cultivator is attached. The pendulum lever oscillates because of vibrations of the fork lever, the fork lever being bifurcated at its front end to embrace the needle bar screw of the sewing machine to which the device is fastened. A pawl element is fixed on the fork lever, which is

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equipped with a tooth. On the frame, with the possibility of rotation, a ratchet wheel is installed, which is fastens by a pawl on the fork body. The ratchet wheel is provided with deep and shallow recesses, and when the pawl element enters in the shallow recesses of the ratchet wheel, the shoulder strap is not secured to the pendulum lever and therefore does not actuate the latter. When the pawl enters one of the deep recesses of the ratchet wheel, it sets the shoulder of the pendulum lever, sets the milling blade in motion, that is, the fold of material occurs. The number of material folds is equal to the number of deep grooves in the ratchet wheel. The distance between deep recesses is chosen equal. In order to increase the number of material folds, the ratchet wheel is made replaceable [11].

The disadvantage of the construction of the ratchet wheel of the device is the limited possibility of obtaining folds of material in the sewing machine. This construction does not allow changes in the pitch of the folds in the process of grinding materials due to the constant pitch between the deep recesses of the ratchet wheel of the device.

In another known design of a device for folding materials in a sewing machine, the ratchet wheel is also made with a different number of deep recesses of the ratchet wheel (mainly one or two deep recesses) [12].

The disadvantage of this design is also the impossibility of obtaining material folds with different pitches without replacing the ratchet wheels.

Another known design of a device for forming material folds in a sewing machine includes a transmission mechanism with an actuating element in the form of a paper clip that performs a rocking motion, and is kinematically connected with the moving elements of the sewing machine [13].

The disadvantage of the known design is its complexity and the impossibility of obtaining material folds with different varying pitches in the process of stitching materials.

The closest to the proposed technical essence is the ratchet wheel of the device for the folding on the sewing machine [14], which is made of two layers rigidly fastened to each other. In this case, the lower layer is made in the form of a wheel with shallow recesses with the same pitch, and the upper wheel contains deep recesses in the form of a cam for the folding the material. At the same time, the number of recesses in the upper wheel of the ratchet wheel may have one or two deeper recesses, and the pitch between the deep recesses is chosen to be the same.

Disadvantage of this construction is also the impossibility of obtaining folds of material in a sewing machine with different pitches without replacing the ratchet wheels in the process of stitching the materials.

In order to provide folds of material with different pitch between them without changing the ratchet wheels in the process of stitching materials, an improved construction is proposed.

2 Development of an effective constructive scheme for a ratchet wheel of the device on a sewing machine

The essence of the construction is the fact that the ratchet wheel consists of a lower wheel with shallow recesses (teeth) and a rigid wheel with deep teeth. In this case, the pitch between the deep recesses in the upper wheel is made with a variable pitch, and the number of deep recesses and the sequence of changing the pitch between them, which are selected from the shape of the material folds. Thereby, for example, deep grooves in the ratchet wheel are made with grooves, while the pitch between three deep grooves is made increasing, and the pitch between three subsequent deep grooves is made decreasing. The combination of the pitch between the deep grooves of the upper wheel can be different. The ratchet wheel can be made of plastic. The variable pitch between the deep grooves of the top wheel of the ratchet wheel allows the production of folds with different shape pitches.

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Ratchet wheel of the device for the folding on the sewing machine is made in the form of a composite wheel 1, including the upper wheels 2 with deep recesses 5, height h, and the lower wheel 3 with shallow recesses (teeth) 4. Wheels 2 and 3 are rigidly fastened to each other, and can be made of plastic, which have a common hole 6 for passing through the attachment axis to the device drive (Figure 1).

The construction works as follows. During the operation of the device, the pawl tooth (not shown in the figure) gears with shallow recesses (teeth) 4 of the lower wheel 3, there is no gearing of the lever shoulder on the pendulum lever (not shown in the figure) and, therefore, it does not set the latter in motion. When the pawl gears one of the deep grooves 5 of the upper wheel 2, it leads to the gearing of the shoulder of the pendulum lever and ensures the movement of the milling blade (not shown in the figure), and the material is folded. In this case, the pitch between the folds of the material depends on the pitch between the deep grooves 5 of the upper wheel 2. The ratchet wheel 1 is made with different pitch between the deep grooves 5 and has the ratio:

$$t_{\varphi_3} > t_{\varphi_2} > t_{\varphi_1} \tag{1}$$

where, $t_{\varphi_1}, t_{\varphi_2}, t_{\varphi_3}$ are the values of the angular pitch in the upper wheel 2 along its circumference.

In this case, the pitch of deep recesses 5 is made increasing along the circumference of the ratchet wheel 1.

In order to obtain folds with different pitches, the angular pitch between the deep recesses 5 of the upper wheel 2 are respectively selected to be different. For example, Figure 3 shows a diagram of a ratchet wheel 1 with six deep grooves 5 with the corresponding values of the angular pitches:

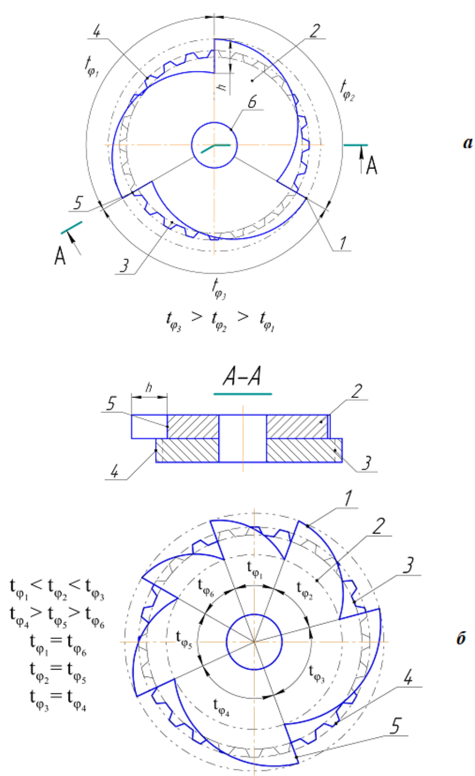

Fig. 1. The ratchet wheel of the device for folding the material on the sewing machine. a - a wheel with three working areas; b - a wheel with six working zones.

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3 Method and results of the formation of profiles of the working areas of the ratchet wheels of the device

In order to obtain various shapes and folds of sewn materials on a sewing machine, it is important to profile the curvilinear areas of the ratchet wheel of the device. For this, a graphical method for profiling cam mechanisms has been used [15, 16].

Figure 2 shows the forms of the working areas of various ratchet wheels obtained by a graphical design of the cams (ratchet wheels). At the same time, they have the following relations:

for “*a*” option:

$$\varphi_1 + \varphi_2 + \varphi_3 = 2\pi; \quad \varphi_1 < \varphi_2 < \varphi_3; \quad \Delta y = R_1 - R_2 \tag{2}$$

where, $\varphi_1, \varphi_2, \varphi_3$ are angles of the working areas of the ratchet wheel in “*a*” option;

Δy is wheel transgression height;

R_1, R_2 are radii of the ratchet wheel outer and inner circumference;

for “*b*” option:

$$\varphi_1 + \varphi_2 + \varphi_3 = 2\pi; \quad \varphi_1 = \varphi_3 \tag{3}$$

for “*c*” option:

$$\varphi_1 + \varphi_2 + \varphi_3 + \varphi_4 + \varphi_5 = 2\pi; \tag{4}$$

or in general form:

$$\sum_{i=1}^{n}(\varphi_1 + \varphi_2 + \cdots + \varphi_i) = 2\pi; \quad \varphi_1 < \varphi_2 < \varphi_3 < \cdots < \varphi_n; \tag{5}$$

for “*d*” option:

$$4\varphi_1 + 2\varphi_2 = 2\pi; \quad \varphi_2 = 2\varphi_1 \quad \Delta y = R_1 - R_2 \tag{6}$$

It should be noted that the profiles of the ratchet wheels for the working areas in the above options have different radii for each point of the curved profiles. Therefore, the design of curved surfaces of the working areas of the ratchet wheel can be carried out analytically according to the data of the coordinates of the curved profiles [17, 18].

It is recommended to make curved surfaces with constant zone radii to obtain folds of materials of special shapes. Figure 3 shows a general view of the ratchet wheels:

a – with a profile of constant radius R_1 in φ_2' area;

b – with a profile of constant radius R_2 in φ_1' area;

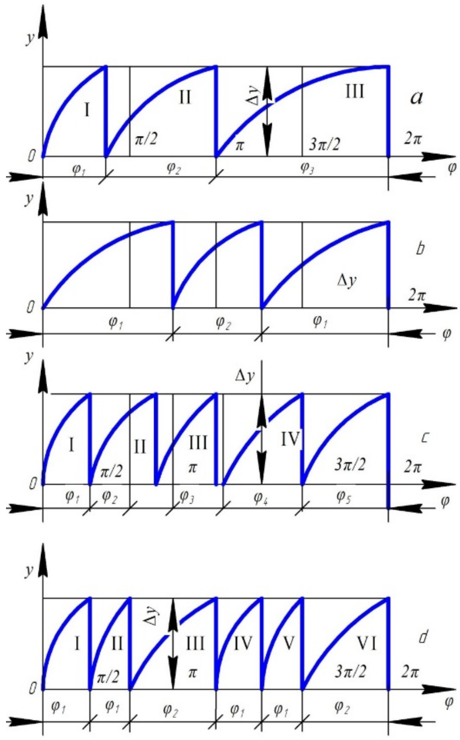
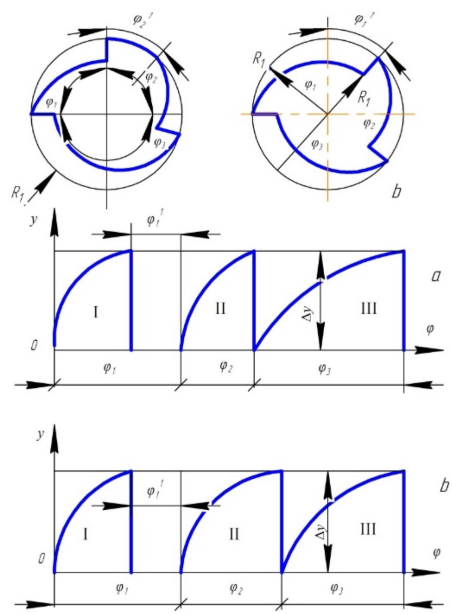


Fig 2. Variants of ratchet wheel shapes with different working zones.



a – $at\ R_1 = const$ in φ_2' area;
b – $at\ R_2 = const$ in φ_1' area.

Fig. 3. Ratchet wheels with constant radii of working area profiles (a, b) and their approximations.

In order to obtain specific phases of the folds of the sewn materials, it is possible to make options of the ratchet wheels of the device for folding the materials on a sewing machine by choosing the numerical values of the parameters $\varphi_1, \varphi_2, \dots, \varphi_n$ and R_1, R_2.

4 Conclusion

Thus, the presented analytical calculations and simulation results make it possible to improve the design of sewing machine elements for the environmentally sustainable development of the light industry. The construction of the folding device with different pitches and shapes of materials on the sewing machine has been recommended. The methods of profiling the curvilinear working areas of the ratchet wheels of the device has been substantiated. It is important to note that the apparel manufacturing sectors are distributed over a much larger number of production sites and companies operating in light industries than the clustered production facilities in heavy industries. This complicates the introduction of new structural elements and the deployment of clean technologies across all sectors of the light industry. However, the advantages of new designs of sewing machine elements allow to some extent to influence those technological changes that contribute to the greening of clothing production and accelerate this process so that the light industry enters the path to achieving zero emissions by 2050.

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