Analysis of input angles of fibrous masses of exhaust steam devices

Nurilla Dadakhanov[1,*] and *Rustam* Karimov[1]

[1]Namangan Engineering-Technological Institute, Namangan, Uzbekistan

Abstract. In existing spinning systems when processing natural, artificial and synthetic fibers into yarn, the main task of the technological process is to obtain sliver, roving and yarn that is uniform in structure and properties by folding and drawing. The article proposes a theoretical analysis of the entry angles of the fibrous masses of the exhaust steam of an exhaust device. The entry angles of the fibrous masses of the existing and new design of the pressure roller with reduced diameters were compared.

1 Introduction

An increase in the production volume of the main types of textile products and a significant increase in labor productivity determine the need for further improvement of textile equipment and an increase in its production volumes [1-5].

The ring spinning machine is the main technological equipment for spinning cotton, flax and viscose fibers. Therefore, increasing the productivity and quality of the output of this machine has a very effective effect on increasing the productivity of labor and spinning production equipment in general.

Currently, in cotton spinning, both carded and combed systems are mainly used continuous ring spinning machines. New spinning machines of modern production have more powerful drafting devices, increased spindle speed, they are more reliable in operation and convenient in operation. Leading machine-building enterprises of the world are conducting research in search of improving ring spinning machines and its individual parts, increasing its reliability and productivity, quality of products.

In existing designs of drafting devices and devices, improved control over the movement of fibers is achieved in various ways, for example, by installing additional straps, rollers, clutches, guides, trays, etc. A common drawback of this design is that by correcting one drawback, others are promoted, for example, the design of the assembly becomes more complicated or maintenance is difficult, etc.

Currently, yarn production throughout the world is carried out in two ways: ring and spindleless (rotor, rotor-mechanical and azromechanical) spinning methods. But if we take into account the demand of the world market, where there is increasing interest in lighter fabrics, which are produced from yarn of low linear densities obtained on ring spinning machines, then the development of this method is also very promising. Another urgent task is to expand production, produce products at the level of world standards, and increase their

* Corresponding author: nurilla28@mail.ru

 https://doi.org/10.1051/e3sconf/202454905010

competitiveness. Therefore, in the production of yarn of small and medium linear densities, there will be a need for a ring spinning machine [6-13].

2 Methods

In existing spinning systems when processing natural, artificial and synthetic fibers into yarn, the main task of the technological process is to obtain a ribbon, roving and yarn that is uniform in structure and properties by folding and drawing. It is well known that the cause of unevenness of the drawn product in the draft zone is poor control of floating fibers in the drawing devices.

Theoretical and experimental studies show that uncontrolled (floating) fibers are the cause of product unevenness, and the strength of the sliver on the flow arc is the cause of breakage. Therefore, in this section, technical solutions of various firms and individual scientists will be considered in order to find the optimal solution to the above tasks.

The world's leading machine-building enterprises are conducting research in search of improving ring spinning machines and its individual parts, increasing its reliability and productivity, and improving the quality of products.

The contact area of the roller with dynamic interaction with the sliver receives the possibility of small circumferential and radial displacements relative to the static position. The dynamic analysis of the considered mechanical system shows the possibility of the appearance of modes of unstable rotation of the bead if the frequencies of the radial and circumferential vibrations of the contact area are equal or exceed one another by 2 times. Initially, small deformations of the bead take on large values, which leads to a violation of the stationarity of the technological process of stretching.

At textile enterprises of ring spinning machines, one - and two-belt drawing devices are most widely used. They allow good control of the “floating” fibers during the drawing process. In order to improve the quality of products on ring spinning machines by reducing uncontrolled fibers in the drawing area and reducing thread breakage in the inflow arc of the exhaust cylinder of the drafting device, on the basis of the existing designs of the drafting devices, we have developed a new design of the drafting device.

3 Experiment

Theoretical and experimental research shows that uncontrolled (floating) fibers cause unevenness in the product, adjusting the drawing process by moving the clamping line can reduce the unevenness.

The movement of the fibers is transmitted from the organs of an exhaust device of any design through friction. With this method of transmitting motion between fibers, slippage is possible. The speed of individual fibers may differ from the speed of the end effector. The fibers, while moving in the exhaust device, change speed from V_1 (supply pair) to speed V_2 (exhaust pair) and back several times. The place where the fiber transitions to a new speed is not strictly defined for all the fibers that make up the fibrous product, and the zones of influence on the fibers of adjacent groups of organs that have different speeds do not have precise boundaries.

The clamping line passing through the axes of the cylinder and the roller should be closer to the plane. The contact patch has the shape of a rectangle when the tension of the friction force field is uniform, and the clamping line has a smaller diameter of the cylinder and roller and greater rigidity of the elastic coating [6-8].

Calculations were carried out for the design of an exhaust device of the SKF type, as well as those modernized by us [9].

4 Results and discussions

Press roller drawing device is widely used in textile machinery. Rollers are the main working parts of the machine, performing basic functions. In many machines, roller modules are asymmetrical, that is, they have an asymmetrical process of interaction between a layer of material and pairs of rollers.

Currently, there are no works devoted to the theoretical analysis of the angles of entry of asymmetric fibers between the roller and the tension cylinder during the stretching process. There are studies on the height and width of the twisting triangle, but there is no comprehensive approach that takes into account all possible types of asymmetry at the same time.

When moving a homogeneous layer of elastic fibrous material in front of the roller, a wedge is formed, making it difficult to retract the layer into the roller and the grooved cylinder. When determining the conditions for drawing in an uneven layer, one should take into account the wedge angle caused by the unevenness and the angle formed due to the deformation of the pulled material [10]. Strip grip is noticeably improved at friction coefficients above 0.25. When the radii of the rolls are equal, a mechanism of the smallest size is obtained; with a decrease in the radius of at least one of the rolls, the gripping conditions noticeably worsen, and the best gripping conditions are observed between the roller and the belt [11].

The author of the work [12] claims that when studying the vibrations of the roller, we still assume that the cylinder is smooth. However, the actual drawing pair consists of a roller with an elastic coating and a grooved cylinder. Depending on the pitch of the grooves and the width of the depression, the contact area will fluctuate by alternating protrusions and depressions, causing additional vertical vibration of the roller with a frequency equal to the product of the number of revolutions of the cylinder and the number of grooves.

For the purpose of further development of theoretical concepts, let us consider a significantly asymmetrical pair-rolling module shown in Fig. 1. Here the rollers are located relative to the vertical at an angle of β_1, the lower shaft is stationary, the upper one is movable. Both rollers are driven, the diameters of the rollers are not the same ($R_1 \neq R_2$), the rollers have elastic coatings with stiffnesses c_1 and c_2. Consequently, the friction coefficients of the material layer with the rollers are not equal to ($f_1 \neq f_2$). The material layer is uniform, has an initial thickness of δ_1 and is inclined downward at an angle of γ_1 to the axis O_1y' (center lines), distance between rollers h_1.

According to the conditions of steam of the roller and the cylinder module, we study in two positions: the first is the moment of contact of the front end of the layer of material with the rollers; the second is the moment the front end of the material layer touches the line of centers. Let's analyze the contact angles in the first position. Let the layer of material brought to the rollers touch them in cross-section A_1A_2 (see Fig. 1). From Fig. 1 it follows that:

$$R_1 + h_1 + R_2 - O_1B_1 - B_1B_2 - B_2O_2 = 0, \quad (1)$$

$$A_1B_1 = A_1D_1 + A_2B_2. \quad (2)$$

From right triangles $\Delta A_1B_1O_1, \Delta A_2B_2O_2, \Delta A_1D_1A_2$ we find:

$$O_1B_1 = R_1 \cos(\alpha_1 + \beta_1), A_1B_1 = R_1 \sin(\alpha_1 + \beta_1);$$

$$O_2B_2 = R_2 \cos(\alpha_2 - \beta_1), A_2B_2 = R_2 \sin(\alpha_2 - \beta_1);$$

$$B_1B_2 = A_2D_1 = \delta_1 \cos\gamma_1, A_1D_1 = \delta_1 \sin\gamma_1.$$

Taking into account these expressions, equalities (1) and (2) will take the following form:

$$R_1 - R_1 \cos(\alpha_1 + \beta_1) + R_2 - R_2 \cos(\alpha_2 - \beta_1) + \delta_1(1 - \cos\gamma_1) + h_1 - \delta_1 = 0, \quad (3)$$

$$R_2 \sin(\alpha_2 - \beta_1) = R_1 \sin(\alpha_1 + \beta_1) - \delta_1 \sin\gamma_1. \quad (4)$$

Assuming that the angles $\alpha_1, \alpha_2, \beta_1, \gamma_1$ are small, we can write equations (3) and (4) in a simplified form:

$$R_1(\alpha_1 + \beta_1)^2 + R_2(\alpha_2 - \beta_1)^2 + \delta_1\gamma_1{}^2 + 2(h_1 - \delta_1) = 0, \quad (5)$$

https://doi.org/10.1051/e3sconf/202454905010

$$\alpha_2 - \beta_1 = \frac{R_1}{R_2}(\alpha_1 + \beta_1) - \frac{\delta_1}{R_2}\gamma_1. \tag{6}$$

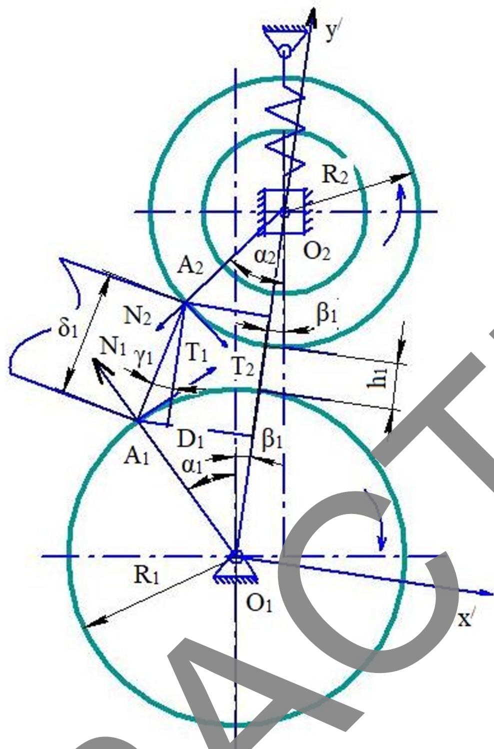

Fig 1. Scheme of the steam felling module

After substitution $\alpha_2 - \beta_1$ from equality (6) and simple transformations, equation (5) takes the form:

$$R_1(R_1 + R_2)(\alpha_1 + \beta_1)^2 + 2R_1\delta_1\gamma_1(\alpha_1 + \beta_1) + {\delta_1}^2\gamma_1^2 + R_2\delta_1{\gamma_1}^2 + 2R_2(h_1 - \delta_1) = 0,$$

Solving this quadratic equation, we find:

$$\alpha_1 + \beta_1 = \frac{\delta_1\gamma_1}{R_1+R_2} + \sqrt{\frac{2R_2(\delta_1-h_1)}{R_1(R_1+R_2)} - \frac{R_2\delta_1(\delta_1+R_1+R_2)\gamma_1^2}{R_1(R_1+R_2)}}. \tag{7}$$

After adjusting formula (7), giving the formula for determining the angle α a simpler form:

$$\alpha_1 = \sqrt{\frac{2R_2(\delta_1-h_1)}{R_1(R_1+R_2)}} - \frac{(R_1+R_2)\beta_1-\delta_1\gamma_1}{R_1+R_2}. \tag{8}$$

Taking into account expression (8) from equality (6), we find the formula for determining the angle α_2:

$$\alpha_2 = \sqrt{\frac{2R_1(\delta_1-h_1)}{R_2(R_1+R_2)}} - \frac{(R_1+R_2)\beta_1-\delta_1\gamma_1}{R_1+R_2}. \tag{9}$$

Having added expressions (8) and (9), after transformations we find the sum of the contact angles $\alpha_1$and α_2:

$$\alpha_1 + \alpha_2 = \sqrt{\frac{2(R_1+R_2)(\delta_1-h_1)}{R_1R_2}}. \tag{10}$$

Next, we will study, taking into account the forces acting on the material layer, how the contact angles change. For this purpose, let us consider the diagrams of forces acting on a layer of material in cross section A_1A_2 (see Fig. 1).

To do this, we will draw up equations for the equilibrium of forces of the material layer at the moment of contact with the rollers:

$$\begin{cases} \sum X' = -N_{1x'} - N_{2x'} + T_{1x'} + T_{2x'} = 0, \\ \sum Y' = N_{1x'} - N_{2x'} + T_{1x'} - T_{2x'} = 0. \end{cases} \tag{11}$$

From the diagram of forces in Fig. 1 we find:

$$N_{1x'} = N_1 \sin(\alpha_1 + \beta_1), T_{1x'} = T_1 \cos(\alpha_1 + \beta_1), N_{1yx} = N_1 \cos(\alpha_1 + \beta_1),$$
$$T_{1y} = T_1 \sin(\alpha_1 + \beta_1), N_{2x'} = N_2 \sin(\alpha_2 - \beta_1), T_{2x'} = T_2 \cos(\alpha_2 - \beta_1),$$
$$N_{2y'} = N_2 \cos(\alpha_2 - \beta_1), T_{2y'} = T_2 \sin(\alpha_2 - \beta_1). \tag{12}$$

Taking into account these expressions, we rewrite system (11) in the form:

$$\begin{cases} N_1 \sin(\alpha_1 + \beta_1) - T_1 \cos(\alpha_1 + \beta_1) = -(N_2 \sin(\alpha_2 - \beta_1) - T_2 \cos(\alpha_2 - \beta_1)), \\ N_1 \cos(\alpha_1 + \beta_1) + T_1 \sin(\alpha_1 + \beta_1) = N_2 \cos(\alpha_2 - \beta_1) + T_2 \sin(\alpha_2 - \beta_1). \end{cases} \tag{13}$$

Let us divide the first equation of this system by the second and transform system (13), expressing friction forces T_1 and T_2 through normal forces N_1 and 4, according to Amonton's law of friction:

$$\frac{\sin(\alpha_1 + \beta_1) - f_1 \cos(\alpha_1 + \beta_1)}{\cos(\alpha_1 + \beta_1) + f_1 \sin(\alpha_1 + \beta_1)} = \frac{\sin(\alpha_2 - \beta_1) - f_2 \cos(\alpha_2 - \beta_1)}{\cos(\alpha_2 - \beta_1) + f_2 \sin(\alpha_2 - \beta_1)}.$$

After a series of transformations, we find:

$$tg(\alpha_1 + \alpha_2) = \frac{f_1 + f_2}{1 - f_1 f_2}.$$

Then, keeping in mind that $f_1 = tg v_1$ and $2f_1 = tg v_2$ (where v_1 and v_2 are the friction angles at points A_1 and A_1, respectively), we finally have:

$$\alpha_1 + \alpha_2 = v_1 + v_2. \tag{14}$$

Thus, at the moment the material layer touches the rollers, the sum of the contact angles is equal to the sum of the friction angles, regardless of the inclination of the upper roller and the material layer.

Taking into account equality (14), expression (10) has the form:

$$v_1 + v_2 = \sqrt{\frac{2(R_1 + R_2)(\delta_1 - h_1)}{R_1 R_2}}. \tag{15}$$

Taking into account expression (15), dependencies (8) and (9) will take the form:

$$\alpha_1 = \frac{1}{R_1 + R_2}(R_2(v_1 + v_2) - (R_1 + R_2)\beta_1 - \delta_1 \gamma_1),$$
$$\alpha_2 = \frac{1}{R_1 + R_2}(R_1(v_1 + v_2) + (R_1 + R_2)\beta_1 - \delta_1 \gamma_1) \tag{16}$$

Let us now analyze the geometric factors in the second position of the front end of the material layer. Let the front end, brought to the rollers of the material layer, touching them in section $A_1 A_2$, travel to section $C_1 C_2$ lying on the line of centers (Fig. 2). During this period the passage of a layer of material between the rollers is accompanied by the lifting of the upper roller by a distance of $\Delta = h_2 - h_1$ and section $A_1 A_2$ passes to section $B_1 B_2$:

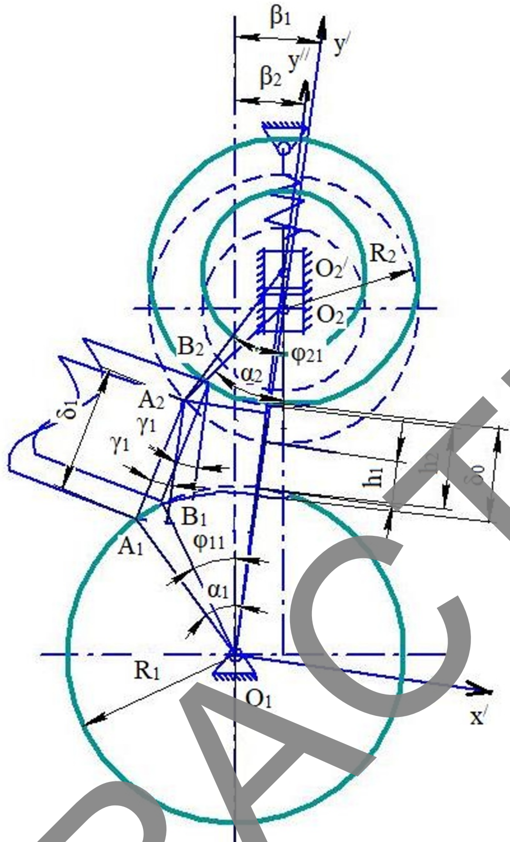

Fig 2. Diagram of the steam-rolling module in the second position front end of the layer of material

In this case, the layer of material and the elastic coating of the rollers will be deformed. Deformation occurs until the vertical component of the elastic force of the material is equal to the pressure of the upper roller. Suppose that at the moment of equality of the above forces, the two-roller module has the following parameters: contact angles of the beginning of the steady-state process ϕ_{11} and ϕ_{11}, the angle of inclination of the upper roller relative to the vertical β_2, the distance between the rollers h_2.

We believe that:

$$h_2 = kh_1, k \succ 1, \tag{17}$$

where k is the proportionality coefficient.

By analogy with formulas (8), (9), (10), taking into account equality (17), we determine ϕ_{11}, ϕ_{21} and their sum:

$$\phi_{11} = \sqrt{\frac{2R_1(\delta_1 - kh_1)}{R_1(R_1 + R_2)}} - \frac{(R_1 + R_2)\beta_1 - \delta_1\gamma_1}{R_1 + R_2},$$

$$\phi_{21} = \sqrt{\frac{2R_1(\delta_1 - kh_1)}{R_2(R_1 + R_2)}} + \frac{(R_1 + R_2)\beta_1 - \delta_1\gamma_1}{R_1 + R_2}, \tag{18}$$

$$\phi_{11} + \phi_{21} = \sqrt{\frac{2(R_1 + R_2)(\delta_1 - kh_1)}{R_1 R_2}}. \tag{19}$$

According to Fig. 2, for the considered steam-rolling module we have where are the friction angles at points and, respectively:

$$\phi_{11} + \phi_{21} = \ \upsilon_{11} + \upsilon_{21}, \tag{20}$$

where v_{11}, v_{21} are the friction angles at points B_1 and B_2, respectively.
Taking into account equality (20), expressions (18) and (19) will take the following form:

$$v_{11} + v_{21} = \sqrt{\frac{2(R_1+R_2)(\delta_1-kh_1)}{R_1R_2}}. \quad (21)$$

$$\phi_{11} = \frac{1}{R_1+R_2}(R_2(v_{11}+v_{21}) - (R_1+R_2)\beta_1 + \delta_1\gamma_1),$$

$$\phi_{21} = \frac{1}{R_1+R_2}(R_1(v_{11}+v_{21}) + (R_1+R_2)\beta_1 - \delta_1\gamma_1). \quad (22)$$

The analysis of the geometric conditions of interaction between the pair of the roller module allows us to determine the angles of contact between the pair of the roller module and two drive rollers. They are in the following order:
according to formula (15) $-v_1 + v_2$;
according to formulas (16) and (17) $-;\alpha_1, \alpha_2, h_2$;
according to formula (21) $-v_{11} + v_{21}$;
according to formulas (22) and (25) $-\phi_{11}, \phi_{21}$.

5 Conclusion

Using the initial data, we check the angle of entry of the product into a pair of rollers ϕ_{11}, ϕ_{21}. Since the thickness of the product depends on the thread number, we will conditionally take it as one thread (Fig. 3): existing: $R_1 = 14mm; R_2 = 14mm; h_1 = 1mm; h_2 = 1{,}5mm; \delta_1 = 3mm; k = 2.$ $\beta_1 = 4^0 = 0{,}0698rad; \gamma_1 = 42^0 = 0{,}6691rad;$ new: $R_1 = 14mm; R_2 = 9mm; h_1 = 1mm; h_2 = 1{,}5mm; \delta_1 = 3mm; k = 2.$ $\beta_1 = 21^0 = 0{,}3584; \gamma_1 = 44^0 = 0{,}6947rad.$

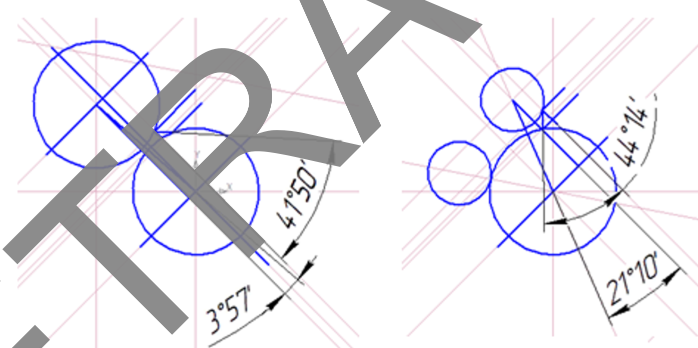

Fig 3. Measuring scheme for existing and new designs pressure pair.

Based on this, we calculate expression (2.50):

existing: $v_{11} + v_{21} = \sqrt{\frac{2(14+14)(3-2\cdot1)}{14\cdot14}} = 0{,}53.$

new: $v_{11} + v_{21} = \sqrt{\frac{2(14+9)(3-2\cdot1)}{14\cdot9}} = 0{,}365.$

existing: $\phi_{11} = \frac{1}{14+14}(14\cdot0{,}53 - 28\cdot0{,}0689 + 3\cdot0{,}6691) = 0{,}262rad = 15^012',$

$$\phi_{21} = \frac{1}{14+14}(14\cdot0{,}53 + 28\cdot0{,}0698 - 3\cdot0.6691) = 0{,}265rad = 15^022'.$$

new: $\phi_{11} = \frac{1}{14+9}(9\cdot0{,}365 - 23\cdot0{,}3584 + 3\cdot0{,}698) = 0{,}122rad = 7^0,$

$$\phi_{21} = \frac{1}{14+9}(14\cdot0{,}365 + 23\cdot0{,}3584 - 3\cdot0.698) = 0{,}482rad = 28^048'.$$

As can be seen from the calculation results, it is difficult to insert the product into the existing pair of expanders, since the contact area with the roller surface is large. In the new one, the contact surface is smaller on one side. Therefore, as indicated in [10], the use of small-diameter rollers reduces the wedge of the entrance zone and facilitates the entry of fibers.

References

1. Dadakhanov N.K., Sidikov A.Kh; Karimov N.M. M 2019 Universum: Engineering 1 **(58)** 34-37
2. Jumaniyazov K.J., Bobojanov X.T., Gafurov J.K. 2009 Textile problems **4** 19-21
3. Saidmuradov M, Abduvakhidov and Muradov A. 2020 The American journal of engineering and technology. **7** 58-64
4. Ruixiang Baia, Weikang Li. 2018 Composites Part A: Applied Science and Manufacturing 529-535.
5. Daffa Bhaskar, Bahejee S., Sengupta A. Indian Text. J **1191** 101(8) 114-120 (2020)
6. Dadakhanov N.K., Boltaboyev B 2019 M UNIVERSUM: Engineering **6 (63)** 50-53
7. Nurilla Dadakhanov. 2022 AIP Publishing. AIP Conference Proceedings **2647** 1
8. Nurilla Dadakhanov et al. 2023 J. Phys.: Conf. Ser. **2573** 012046
9. Grigoreva K. A. et al. 1973 Optimization of spinning line parameters of a cotton spinning machine for high speed spinning (Penza: NIIEKIPMash, 1973), **vol. 5** pp 59
10. Kuznesov G.K. 1994 Textile Industry Technology **2** 67
11. Sherzod Korabayev, Kamol Akhmedov, Saypila Matismailov, Alisher Yuldashev; AIP Conf. Proc. **3045 (1):** 030018 (2024). https://doi.org/10.1063/5.0197289
12. Shavkat Fayzullaev, Sherzod Korabayev, Husanhon Bobojanov, Odiljon Rajapov; AIP Conf. Proc. **3045 (1):** 030039 (2024). https://doi.org/10.1063/5.0197345
13. Avazbek Obidov, Sardor Khamidov, Iroda Muhammadjonova; AIP Conf. Proc. **2789 (1):** 040007 (2023). https://doi.org/10.1063/5.0145601