

# The influence of warranty and deformation of the saw blade on the wear of grids in gin machines

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**Abstract.** The article discusses the problem of grate wear in saw blades, caused by uneven contact with the saw blade due to its warping and deformation under load. The results of a theoretical analysis of the forces acting on cotton fiber with a non-central position of the saw blade relative to the inter-grid gap are presented. The dependence of the fiber tension on the grip angle of the grate, which is directly related to the wear of the grate and the displacement of the saw blade, is substantiated. The war page of the saw blade, reaching 0.95 mm, and its deformation under the influence of a load from 0.81 to 0.92 mm with a force of 10 N were experimentally determined. It was established that, due to the uneven rigidity of the deformed disk, variable lateral forces act on the grate in the range 10.8-12.3 N per 1 mm of deformation. The identified factors of warping and deformation of the saw blade are the causes of uneven wear of the grates, which negatively affects the quality of ginning raw cotton. The results of the study are important for improving the design of saw gins.

## 1 Introduction

Modern high-performance saw gins are complex automated units of continuous operation, including a feed unit, a saw cylinder, a grate, a seed comb and other functional elements. In different countries, scientists are conducting active research to improve the ginning process. Much attention is paid to optimizing the parameters of saw teeth, raw rollers, the design of working chambers and factors affecting the performance of gins [1-2]. At the same time, a relatively smaller number of works are devoted to the influence of the design and condition of the grate on the performance of the ginning process [3].

In this study, the main emphasis is placed on the analysis of the interaction of the saw cylinder with the grate, since wear of the grate due to the incorrect position of the saws in the inter-grid gap leads to disruptions in the ginning process and premature failure of the grate. Optimization of the geometric parameters of interacting elements is intended to increase the service life of the grate bars [4].

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Thus, improving the design of saw gins, especially in terms of the interaction of the saw cylinder and the grate, is of great practical importance for increasing the efficiency of cotton processing.

Displacement of the saw blade from the central position in the grate gap of the gin. One of the key factors determining the accuracy and quality of ginning is the deviation of the saw blades from the ideal flat shape. According to technical standards, this deviation (warping) should not exceed 0.5 mm. However, in practice, during the production of saw blades, high residual stresses arise, leading to significant deformation and warping. The amount of warpage of real saw blades can reach 1.5-2 mm or more [5].

Displacement of the saw blade from the central position in the inter-grid gap leads to uneven tension on the fibrous material as it is pulled through this gap. As a result, various defects are formed on the fibers - cuts, breaks and other damage. For a more detailed analysis, let's consider the forces acting on the fiber when the saw blade is in an off-center position.

Distortion of the saw blade shape is one of the main factors that negatively affects the uniform loading of the fibrous material and leads to its damage during the ginning process. Therefore, it is important to study the nature of disc deformation and the resulting force effects on the fiber.

In this situation, the tension in the fiber is unevenly distributed along its length. One part of the fiber is closer to the grate, and the other is further from it. As a result, the angles between the fiber sections in relation to the saw are different. As stated earlier, this can lead to fiber defects. Let us assume that the fiber has already separated from the seed in the raw roller, but has not yet passed through the gap. In this case, additional wear of the fiber occurs due to contact interaction with the grate [6].

## 2 Materials and Methods

Let us formulate an equation to determine fiber tension in this context. Let us assume that the fiber is subjected to pressure from the green roller on one side with a force  $F'$ , and on the other side with a force  $F''$ . We also take into account the friction force between the saw and the grate, which we denote as  $F'''$ . In this case, the tensile strength of the fiber will be determined as follows:

$$T1 = F' + F'' + F''' \quad (1)$$

Let us express the friction force between the grate and the fiber as:

$$F_{tr1} = \mu_1 P_0 L_1 \quad (2)$$

$$F_{tr2} = \mu_1 P_0 L_2 \quad (3)$$

Where  $P_0$  is the specific pressure force on the fiber.

$\mu_1$  - coefficient of friction between the grate and the fiber, as well as the saw and the grate.

$L_1, L_2$  - fiber length.

Fiber tension can be expressed through Euler's formulas

$$F' = F_{mp1} e^{\mu_1 \alpha} = p_0 L_1 e^{\mu_1 \alpha_2} \quad (4)$$

$$F'' = F_{mp1} e^{\mu_1 \alpha} = p_0 L_2 e^{\mu_1 \alpha_1} \quad (5)$$

In view of the close distance between the grates, we accept  $\alpha$ , as 90°, then in this case, (4) and (5) will take the form:

$$F' = F_{mp1} e^{\mu_1 \alpha_1} = \mu_1 p_0 L_1 e^{\frac{\mu_1 \pi}{2}} \quad \text{And} \quad F'' = F_{mp2} e^{\mu_1 \alpha} = \mu_1 L_2 e^{\frac{\mu_1 \alpha_2}{2}}$$

But the presence of pressure force between the saw and the grate can be expressed in the following form:

$$F''' = \mu_1 Q \quad (6)$$

where Q is the lateral pressure on the surface of the grate, depending on the rigidity of the saw.

Then formula (6) will take the form:

$$T = \left( p_0 e^{\frac{\mu_1}{2}} (11,34L_1 + L_2 e^{\alpha_2}) + Q \right) \mu_1 \quad (7)$$

The tensile force of the fiber must satisfy the following conditions:

$$[\sigma_{fib}] < \frac{T}{S} \quad (8)$$

Where S is the cross-sectional area of the fiber;

$$[\sigma_{fib}] - \text{permissible breaking load.}$$

From formula (7) it follows that the amount of fiber tension depends on the coverage angle, and the coverage angle, in turn, depends on the degree of wear of the grate and the position of the saw relative to it. For the grate, to which the saw is moved closer, the coverage angle increases, which increases the likelihood of fiber breakage.

It is known that the deviation of the coordinates of the side surfaces of the saw and the grate from the nominal values causes a displacement of the saw blade inside the inter-grid gap. In this case, a situation is possible when on one side the gap completely disappears, and on the other, a tension is formed in which the curved saw comes into contact with the side surface of one of the grates and wears it out during rotation.

Theoretical studies carried out to assess the contact pressures during the interaction of cotton fiber with the working edge of the gin grate have shown that the tensile forces of the fiber strand with a central saw position in the inter-grid gap are approximately 1.5 times less than with an off-central arrangement [7].

### 3 Results and Discussion

The saw blade touching the side surfaces of the grate leads to the appearance of a normal force that pushes the saw blade away from the grate. The amount of this pressing force will depend on the rigidity of the saw blade.

An off-center position of the saw blade in the inter-grid gap during the ginning process causes the appearance of additional pressing force. This occurs due to the difference in gaps between the opposite sides of the saw blade, which leads to the strand of fibers passing into the gap between the saw and the grate to press out the disk.

In this regard, it is of interest to study the dependence of the force acting on the grate on the deformation (warping) of the saw blade. Since the saw blade has a certain warpage, the gap between the saw and the grate changes when the saw rotates. Accordingly, the magnitude of the lateral force acting on the grate will also change depending on the warpage of the saw blade.

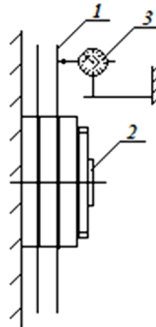
For a detailed study of the dependence of the force acting on the grate on the deformation of the saw blade, it is of great importance to study the magnitude of the runout

(radial displacement) of the saw blade and the magnitude of its elastic deformation at various points under the influence of normal load.

To conduct such studies, a special experimental stand was developed. As you describe, saw 1 was attached to saw shaft 2 of this stand (Figure. 1).

This made it possible to recreate conditions as close as possible to the actual operation of the gin, and to measure the run out of the disk, its deformation under load, and also to study the influence of these factors on the change in the gaps between the saw and the grate.

The experimental data obtained provide valuable information for optimizing the design of the gin and reducing the wear of its parts by reducing unwanted contacts of the saw with the grate due to its deformation and run out.



**Fig. 1.** 1-saw; 2-shaft; 3-indicator.

To study the run out of the saw blade, the circle was divided into eight segments. An indicator was installed on a special stand; its tip measured the radial vibrations of the disk at its edge. Deviations of points on the lateral surface of the disk were measured and entered into Table 1.

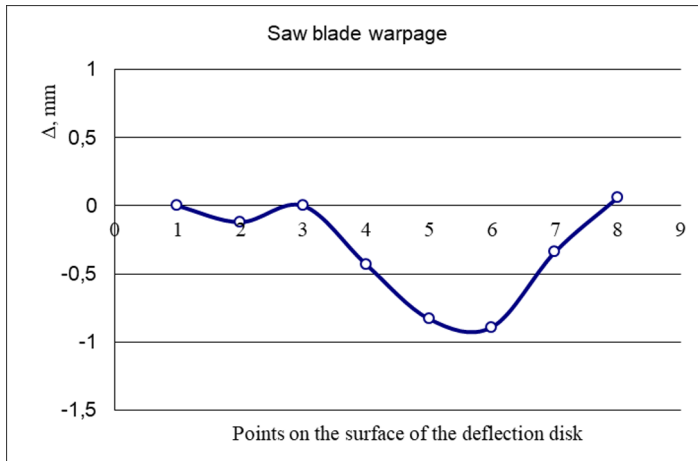
**Table 1.** Experimental results

Points on pov. disc deflection	1	2	3	4	5	6	7	8
Saw blade runout, mm	0	-0.12	0	-0.43	-0.83	-0.89	-0.34	0.06

From the data in Table 1 it follows that the maximum deviation of points on the side surface of the saw blade from the ideal cylindrical shape was 0.95 mm. Based on the measured deviation values at 8 points around the circle, a curve was constructed showing the war page (deviation from flatness) of the saw blade, shown in Figure 2.

Analysis of this curve shows that it has three maxima or "tops". This means that during one full revolution of the saw blade, the points on its side surface approach the grate three times and then move away from it three times. In other words, during one revolution of the saw, the amount of load transmitted through the strand of fibers to the side surface of the grate changes three times.

Consequently, due to warping of the disk, the value of the contact load acting on the grate through the fibers is not constant, but changes cyclically with a threefold frequency at each revolution of the saw.

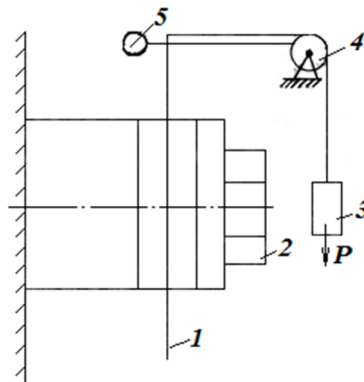


**Fig. 2.** Saw blade warpage

A cyclically changing, alternating load caused by warping of the saw blade can lead to displacement of the removable element (segment) of the grate from its nominal position. The magnitude and amplitude of oscillations of this cyclic load depend on the degree of deformation of the saw blade.

To study the dependence of saw deformation on the applied load, a special experimental stand was used (Figure 3). At this stand, the saw blade was loaded using a load 3 suspended on a thread thrown through a block 4. The amount of deflection of the disk under the action of the applied load was measured by indicator 5, which was installed on a special stand next to the saw.

Thus, the application of a controlled radial load to the saw blade was simulated on the bench and its elastic deformation caused by this load was recorded. The experimental data obtained make it possible to establish the relationship between the magnitude of the applied force and the deflection of the disk.



**Fig. 3.** Scheme of a stand for studying the deformation of a saw blade under load.

To determine the amount of deformation of the saw blade under load, measurements were taken at the same eight points around the circumference as when studying the deviations of the end surface from the nominal shape.

The same reference point on the disk that was used when measuring the warpage of the disk without load was chosen as the initial reference point.

The results of experimental studies to determine the deformation of the saw blade at eight control points under the action of an applied radial load are presented in Table 2.

This approach made it possible to analyze not only the overall value of the disk deflection, but also the nature of the deformation along the circumference, identifying local maxima and uneven deformation at different points. This data is necessary for further calculation of changes in gaps between the saw and the grate under load.

**Table 2.** Saw deformation under external load

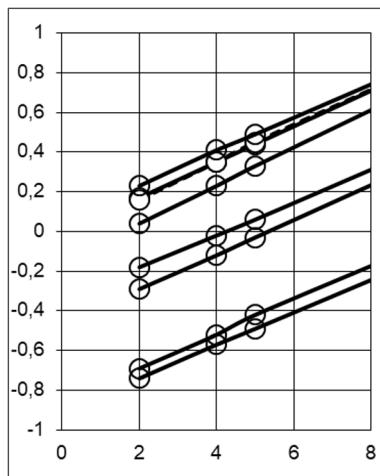
Load, N.	Displacement in points, mm							
	1	2	3	4	5	6	7	8
2	0.17	0.04	0.16	-0.29	-0.69	-0.74	-0.18	0.23
4	0.35	0.23	0.35	-0.12	-0.52	-0.57	-0.02	0.41
5	0.44	0.33	0.45	-0.03	-0.42	-0.49	0.06	0.49
10	0.89	0.8	0.89	0.41	-0.01	-0.08	0.48	0.91

Based on the results of experimental studies, the rigidity of the saw blade was assessed at various points along its circumference. For this, the formula was used:  $J = P / \Delta_n / \text{mm}$ , where

P – load,  $\Delta$ – deformation of the disk under the influence of load R.

Based on the table data, graphs were constructed depending on the movement of points on top. Based on the experimental data from Table 2, which contains the values of deformations at 8 points under different loads, graphical dependences of the displacement (deflection) of each of these points on the surface of the saw blade on the magnitude of the applied radial load were constructed. These graphs are presented in Figure 4.

These graphs and calculated values of rigidity at control points make it possible to evaluate the unevenness of the disk deformation around the circumference and analyze the influence of the load on the change in the gaps between the saw and the grate in different sections. The capacity of the saw depending on the load (Figure 4).



**Fig. 4.** Dependence of saw blade deformation on load.

Analysis of data from the table and graphs in Figure 4 shows that the rigidity (degree of deformation) of points on the surface of the saw blade depends on its warpage. This means that due to the unevenness of rigidity at different points due to the warpage of the disk, the amplitude of cyclic fluctuations in the load on the grate will increase.

## 4 Conclusion

The conducted studies have established that the off-central location of the saw in the gap between the grate during operation of the gin leads to the appearance of a lateral force acting on the grate. The magnitude of this lateral force depends on the rigidity of the saw blade, and when the saw was deformed by 1 mm, it ranged from 10.8 to 12.3 N at different points around the circumference.

The maximum deformation of the saw blade under the action of a radial load of 10 N reached 0.92 mm, and the minimum - 0.81 mm. This confirms the significant unevenness of deformation along the perimeter of the disk. The experimental data obtained make it possible to quantify lateral forces and deformations, which is important for optimizing clearances and reducing the wear rate of gin grates.

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