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Definition of Increasing the Fibre Capturing Surface of Saw Teeth of Cotton Ginning Machine through Mathematic Modelling

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Abstract

Theoretical and the experimental researches executed in Uzbekistan and abroad explored some ways of a substantiation of a rational profile of a tooth of a saw and its fibre capturing ability. Despite that, untill now, optimum parameters of a saw gin which provides high quality ginning without harming the quality of cotton fibre have not been found. Considering the stated above in the given job the influence of the changed form of saw teeth on fibre-capturing area is examined. The analytical formulas for the additional area promoting to double the fibre capture quantity by saw teeth are received.

Keywords: Factor of Proportionality, Radius of a Saw, Fibre, Gin, Teeth, Linear Speed, New Profile

1. Introduction

It is known, that productivity of saw gin depends on the structure of teeth or on other parameters of saw gin. On defined selection of saw teeth's profile or other parameters, it is possible to achieve the maximum capture of fibre. It promotes the increase of the productivity of a saw gin. Theoretical experimental researches in Tashkent textile institute noted some ways of substantiating the rational profile of saw teeth and its fibre capturing capacity.

On **Figure 1** the circuit of meeting saw teeth with cotton roll in the zone of seed combing developed by G.I. Boldinskiy is given. A centrifugal force influences on fibre seized by saw teeth trying and forces the fibre to escape from the teeth. At the same time another force—friction force influences on fibre which helps to hold the fibre at front lines of the saw teeth [1,2].

Defining the corner, at which the fibre is held on saw teeth, by ψ, we can write following formula:

$$\phi = \gamma - \psi \quad (1)$$

where γ—a front corner of a tooth ϕ—corner between a radial surface of a saw and surface of shift of a fibre.

For defining the corner ϕ, an equation is developed on the movement of the element of fibre, descending from a tooth of a saw, in relation to mobile axes OXY:

$$\frac{m\mathrm{d}^2 y}{\mathrm{d}t^2} = -cv^2 \cos\phi - \frac{mv^2}{R}\sin\phi + N + me_k \quad (2)$$

Here
m—Weight of descending element of a fibre;
c—Coefficient of proportionality;
v—Speed of saw teeth;
R—Radius of a saw;
μ—Coefficient of internal friction of a fibre;
N—Reaction;
e_k—Koriolisovo speed-up;
t—Step of teeth;
After this

$$\mathrm{tg}\phi = \frac{mv^2 - \mu cRv^2}{cRv^2 + \mu mv^2} \quad (3)$$

Or

$$\phi = \mathrm{arctg}\frac{mv^2 - \mu cRv^2}{cRv^2 + \mu mv^2} \quad (4)$$

2. Materials and Methods

This **Table 1** shows the values of parameters in **Figure 1** [3,4].

This **Table 2** shows the values of parameters in **Figure 2**.

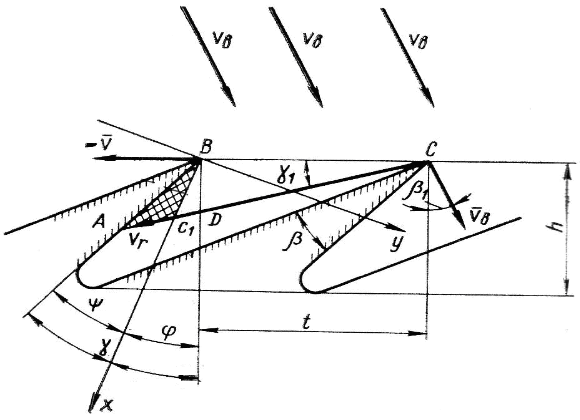

Figure 1. Schematic diagram and parameters of saw teeth developed by G.I.Boldinskiy.

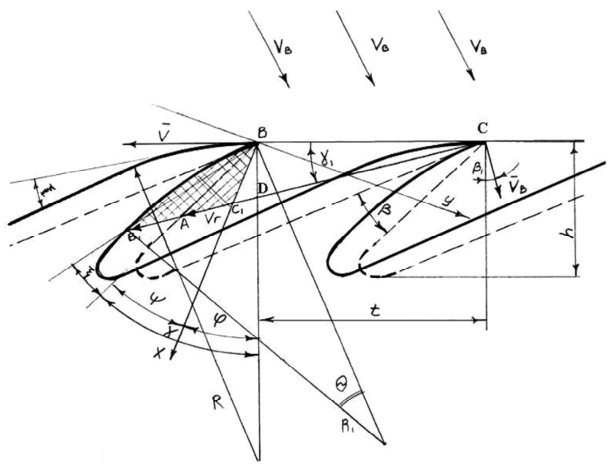

Figure 2. Schematic diagram and parameters of the proposed saw teeth.

Table 1 for Figure 1.

φ	h (mm)	t (mm)	β	γ_1	ΔABC_1 (S4) (mm^2)	ψ
20°	4	4	20°	17° - 18°	3.1	20°

The capturing ability of a tooth is proportional to the area of a triangle ABC_1 which fibre does not leave

$$S_{\Delta ABC_1} = S_{\Delta ABC} - S_{\Delta CBC_1} \tag{5}$$

Table 2 for Figure 2.

$R = R_1$	h	t (mm)	γ_1	θ	ξ	S_{seg} (S_1) (mm^2)	SΔABB_1 (S_2) (mm^2)	SΔABB_1 + S_{seg} (S_3) (mm^2)	SΔABC_1 (S_4) (mm^2)	S_{dop} (S_5) (mm^2)
10	4	4	17° - 18°	25° - 30°	8° - 14°	1 – 1.2	1.2 - 1.6	2.2 - 2.8	3.1	5.3 - 5.9
12	4	4	17° - 18°	25° - 30°	8° - 14°	0.8	1.2 - 1.6	2 - 2.4	3.1	5 - 5.5
14	4	4	17° - 18°	25° - 30^0	8° - 14°	0.6 - 0.75	1.2 - 1.6	1.8 - 2.35	3.1	4.9 - 5.45
16	4	4	17° - 18°	25° - 30°	8° - 14°	0.6 - 0.5	1.2 - 1.6	1.8 - 2.1	3.1	4.9 - 5.2
18	4	4	17° - 18°	25° - 30°	8° - 14°	0.4 - 0.45	1.2 - 1.6	1.6 - 2.05	3.1	4.7 - 5.15
20	4	4	17° - 18°	25° - 30°	8° - 14°	0.4 - 0.42	1.2 - 1.6	1.6 - 2	3.1	4.7 - 5.1

$S_{\Delta ABC}$—The area of a triangle with—applicable indexes;

$$S_{\Delta ABC} = \frac{t^2 \sin\gamma_1 \cos\gamma}{2\cos(\gamma + \gamma_1)} \tag{6}$$

$$S_{\Delta CBC_1} = \frac{t^2 \sin\gamma_1 \cos\phi}{2\cos(\phi + \gamma_1)} \tag{7}$$

Here

γ_1—Corner between vectors of relative speed v_r and tangent to a circle;

$$\gamma_1 = \mathrm{arctg}\frac{v_b \cos\beta_1}{v - v_b \sin\beta_1} \tag{8}$$

v_b—Linear speed of cotton roll in its meeting point with saw;

β_1—Corner between the radius of a saw and vector of speed.

By placing the received figures by formula (6) and (7) on formula (5) we can find the area of capturing surface of saw teeth [1-3,5].

$$S_{\Delta ABC_1} = \frac{t^2 \sin^2\gamma_1}{2} \cdot \frac{\sin(\gamma - \phi)}{\cos(\gamma + \gamma_1)\cdot\cos(\phi + \gamma_1)} \tag{9}$$

To increase the area of capturing surface of saw we offer a new changed profile of saw of saw cylinder. This work examines the influence of the changed form of tooth of saw cylinder on the area of fibre capturing surface (**Figure 2**).

The profile of a tooth resembles an arch, on which the corner of tooth's tip will be about 25° - 30°.

Vв—Speed of a particle of cotton roll at the moment of its meeting with saw tooth;

V—Linear speed of the end of a saw tooth;

θ—The central corner of an arch BB_1;

ξ—Corner between a tangent carried out arc and straight line shoulder of teeth structure;

β_1—Corner between the radius of saw and direction of movement of light fibre approaching saws;

φ—Corner of friction of fibre on fibre;

γ—Front corner of tooth.

The tooth of a saw will seize a fibre which is kept in a triangle ABC_1, and also in an additional triangle ABB_1 and a segment described by arch BB_1. The area of the triangle $S_{\Delta ABC_1}$ is determined by well-known formula:

$$S_{\Delta ABC_1} = \frac{t^2 \sin^2 \gamma_1}{2} \cdot \frac{\sin(\gamma - \phi)}{\cos(\gamma + \gamma_1) \cdot \cos(\phi + \gamma_1)} \quad (10)$$

As we see, fibre capturing ability of saw teeth is determined by the areas of triangles ABC_1 and ABB_1, and also the segment BB_1. Last two areas are additional to the basic area of a triangle ABC_1.

The area of a triangle ABB1 is determined as follows:

$$S_{\Delta ABB_1} = ?$$

From a triangle ΔBB_1C under the theorem of sine we can define CB_1:

$$CB_1 = t \frac{\cos(\gamma + \xi)}{\cos(\gamma + \gamma_1 + \xi)} \quad \text{then}$$

$$S_{\Delta BCB_1} = \frac{1}{2} BC \cdot CB_1 \sin \gamma_1 = \frac{1}{2} t^2 \frac{\cos(\gamma + \xi) \sin \gamma_1}{\cos(\gamma + \gamma_1 + \xi)} \quad (11)$$

The additional area of a triangle $ABB1$:

$$S_{\Delta ABB_1} = S_{\Delta BCB_1} - S_{\Delta ABC}$$

$$= \frac{t^2}{2} \cdot \frac{\cos(\gamma + \xi) \sin \gamma_1}{\cos(\gamma + \gamma_1 + \xi)} - \frac{t^2 \sin \gamma_1 \cos \gamma}{2 \cos(\gamma + \gamma_1)}$$

$$= \frac{t^2 \sin \gamma_1}{2} \cdot \left(\frac{\cos(\gamma + \xi) \cos(\gamma + \gamma_1) - \cos \gamma \cos(\gamma + \gamma_1 + \xi)}{\cos(\gamma + \gamma_1 + \xi) \cdot \cos(\gamma + \gamma_1)} \right) \quad (12)$$

$$BB_1 = ?$$

Now we pass to definition of the area of a segment BB1, chord which is determined under the formula:

$$BB_1 = t \frac{\sin \gamma}{\cos(\gamma + \gamma_1 + \xi)} \quad (13)$$

The central corner of a segment

$$\theta = \arccos A$$

where:

$$A = \frac{t^2 \sin^2 \gamma - 2R^2 \cos^2(\gamma + \gamma_1 + \xi)}{2R^2 \cos^2(\gamma + \gamma_1 + \xi)} \quad (14)$$

Then the area of a segment:

$$S_{seg}^{BB_1} = \frac{\pi R^2 \theta}{360^0} = \frac{\pi R^2 \arccos A}{2\pi} = \frac{R^2}{2} \arccos A \quad (15)$$

Thus, the additional areas promoting the increase of fibre capture by saw tooth is determined by the formula:

$$S_{dop} = S_{seg} + S_{ABB_1} = \frac{R^2}{2} \arccos A +$$
$$+ \frac{t^2 \sin \gamma_1}{2} \left(\frac{\cos(\gamma + \xi) \cos(\gamma + \gamma_1) - \cos \gamma \cos(\gamma + \gamma_1 + \xi)}{\cos(\gamma + \gamma_1 + \xi) \cdot \cos(\gamma + \gamma_1)} \right) \quad (16)$$

From the formula (16), it can be seen that the area S_{dop} mainly depends on corners γ, γ_1 and ξ.

At the appropriate selection of these corners, the optimum additional area of fibre capture by saw teeth is achieved.

3. Numerical Results and Discussion

Figure 3 shows changes of the central corner θ arches BB_1, in dependence of a corner ξ between a tangent of the spent bow-shaped and direct back of a profile of teeths [6,7]. The red line on a schedule figure means changes $\theta = \theta(\xi)$ at $R = 20$ cm. The yellow line on a figure shows changes $\theta = \theta(\xi)$ at $R = 10$ cm. We take corner radius from the given schedule $R = 10$ cm because at this value the tooth height will be equal h =4mm and a tooth step t = 4mm. At these data the most optimum value is $\theta = 25^\circ$ - 30° at $\xi = 14^\circ$. If we accept optimum value $\theta = 25^\circ$ - 30° and $\xi = 14^\circ$ and radius $R = 20$ cm that leads to increase of a step and tooth heights. It leads to seed jamming in a backlash between teeth. As a result it will lead to intensive crash of seeds between tooth of a saw and a grid-iron saw gin. From this follows that the central corner θ arches BB_1 should be in $\theta = 25^\circ$ - 30° limits and not exceed these values. Change of the additional area of a segment depending on a corner ξ pi various radiuses of curvature of a new profile of teeth. Optimum value of the area of a segment is $S_{seg} = 0.01$ cm^2 which corresponds $R = 10$ cm, $\xi = 14^\circ$.

In **Figure 3** when the maximum value of ξ eqauals to 14° and when the maximum value of θ equals to 30°, the level of teeth capturing fiber reaches its maximum de-

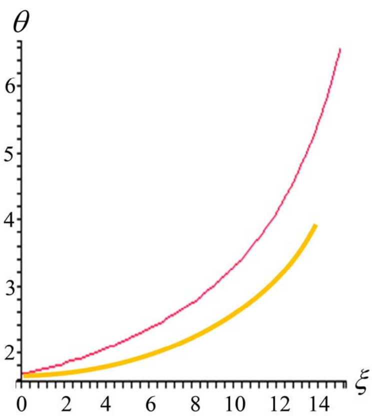

Figure 3. Variance of central corner θ versus corner ξ.

gree.

In **Figure 4**, the area of S_{seg} (S_1) has been determined at different radiuses according to the value of ξ.

In **Figure 5**, the area of $S_{\Delta ABB_1}$ (S_2) triangle has been found at different radiuses according to the value of ξ.

In **Figure 6**, in order to find $S_{dop}(S_3)$, we have added the area of S_{seg} (S_1) to the area of $S_{\Delta ABB_1}$ (S_2) triangle.

Since we know the area of $S_{\Delta ABC_1}$ (S_4) triangle, we have added the area of S4 to the area of S3 and as a result, we have determined the area of capturing fiber of new profiled teeth based on the mathematic modeling and graphics (**Figure 7**). There are 100 micron fibers in the area of $S_{\Delta ABC_1}$. Using the new teeth profile, we can increase the amount of fiber.

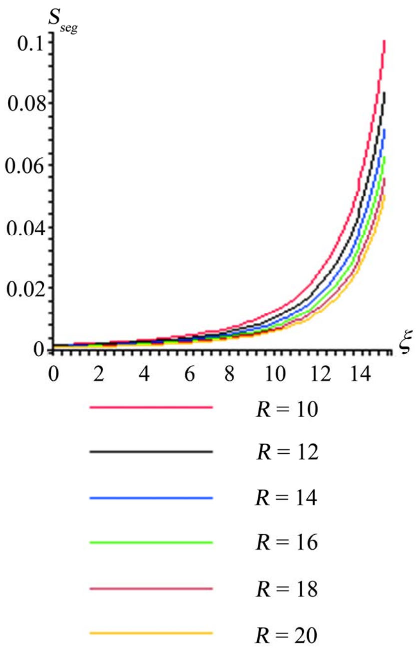

Figure 4. Variance of the area S_{seg}(S_1) versus corner ξ.

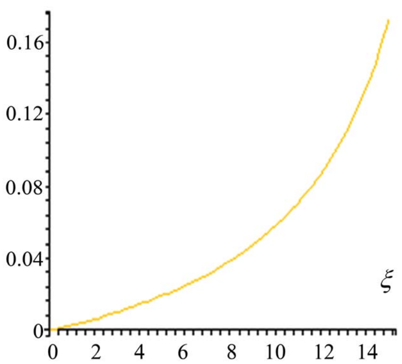

Figure 5. Variance of the area $S_{\triangle ABB1}$ (S_2) versus corner ξ.

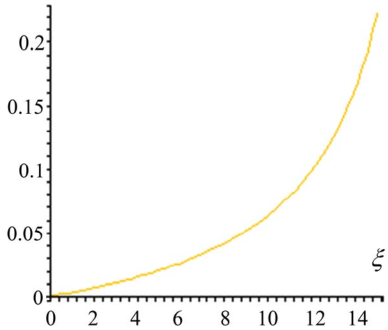

Figure 6. Variance of the area S_{dop}(S_3) versus corner ξ.

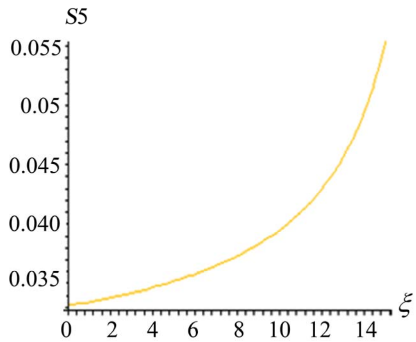

Figure 7. Variance of the area of capturing fiber of the new profiled teeth (S_5) versus corner ξ.

4. Conclusions

Theoretical and the experimental researches executed at Tashkent Textile institute by B. A. Levkovich, N. G. Gulidov, G. I. Boldinskiy and G. I. Miroshnechenko and analytical formulas (10) for definition of the area of capture of a fibre by saw tooth are offered. Values of area $S_{\Delta ABC_1}$ calculated under the standard data of saw gin equal $S_{\Delta ABC_1}$ = 0.031 cm^2 which contains 100 mkr fibres. If to consider a new profile of a tooth of saw gin offered by us it will increase the useful area of capture of fibre. At the expense of a bow-shaped profile of a tooth it will generate the additional areas in the form of triangle $S_{\Delta ABB_1}$ and segment S_{seg}. On **Figure 3** optimal values of the central corner of an arch $\theta = 4^\circ$ and value of a corner between a tangent of the spent bow-shaped and direct back of teeth $\xi = 14^\circ$ are identified. Within this data the areas of additional triangle $S_{\Delta ABB_1}$ = 1.2 mm^2 and segment S_{seg} = 1 mm^2 are calculated and as a result an additional area is received:

$$S_{dop} = S_{ABB_1} + S_{seg} + S_{ABC_1} = 1.2 + 1 + 3.1 = 5.3 \text{ mm}^2 .$$

The given figures in **Table 2** show that the area of fibre capturing surface of saw tooth widened two times. The highest figure of the area of the surface is achieved at R = 10. Proportionally, at R = 20 the area of segment decreases and fibre capturing capacity also decreases.

Through this additional area, 200 - 250 mkr of fibre is achieved. Thus the offered new profile of a tooth of a saw gin will increase fibre capture 2 - 3 times.

The values have been checked and prepared in Maple 9.5. Drawings have been prepared and projected through T-Flex CAD programm using the calculated values.

Stemming from these facts, it can be concluded that the application of the offered new design of a saw on cotton processing industry will increase the productivity of ginnng, and also will bring to saving of power resources.

5. References

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