Investigation of two-dimensional unsteady motion of deformable raw roller during saw ginning

Fazliddin Sirojiddinov[1], *Botir* Mardonov[2], *Ilkhom* Abbazov[3*] and *Bobir* Sharopov[3]

[1]Kattakurgan branch of Samarkand State University, Samarkand, Uzbekistan
[2]Tashkent Institute of Textile and Light Industry, Tashkent, Uzbekistan
[3]Jizzakh Polytechnic Institute, Jizzakh, Uzbekistan

Abstract. In this article, based on the analysis of research conducted by scientists in many fields on increasing the productivity of sawing gin, the requirements for sawing gin to improve the workability of gin, increase fiber quality, and reduce energy consumption, as well as its separation into technological parts, and a single conclusion, collecting the conducted research it was mentioned that it should be released. It is explained the requirements for cotton ginning equipment in cotton ginning cluster enterprises and the need to carry out the innovative approach of sawing gins, dividing each technological process into separate technological parts to fulfill these requirements. The technological process of the sawmill consists of a complex of 9 technological parts.

1. Introduction

In Uzbekistan grown 2 types of cotton. *Gossypium hirsutum*, also known as upland cotton or Mexican cotton [1], is the most widely planted species of cotton in the Uzbekistan, constituting some 90% of all cotton production there.
Gossypium barbadense, also known as extra-long staple (ELS) cotton, is a species of cotton plant [2] that has been cultivated to have extra-long staple fibers - longer than 34 mm (1 3/8"), that are associated with high quality products. To grow, it requires full sun and high humidity and rainfall. For that this cotton grows South region in Uzbekistan.
Quality indices values of cotton varieties in cotton picking season on Table 1.

Table 1. Quality indices values of cotton

#	Variety	MIC	Staple	UHML	STR	UI	RD	b	SFI
		Unit	32/inch	inch*100	gf/tex	%	%	%	%
1.	S 6524	4.6	35.7	111.9	32.9	83.8	77.2	8.7	6.6
2.	Bukhara 102	4.5	36	112.8	31.8	83.2	79.1	9.1	4.9
3.	Bukhara 6	4.4	36.3	113.3	32.7	83.8	79.6	8.9	4.5
4.	Bukhara 8	4.4	36.4	113.4	32.7	83.7	79.6	8.9	4.7
5.	An-Bayaut 2	4.5	35.3	110.7	30.8	83.1	78.3	8.9	7.6
6.	Namangan 77	4.6	35.7	111.6	31.8	83.5	77.9	8.9	5.9
7.	Andijan 35	4.7	35.3	110.8	31.7	83.5	76	8.8	7.7
8.	Khorezm 127	4.7	35.7	112.2	31.2	82.9	79.4	8.6	8.4
9.	Omad	4.5	36.1	113.6	30.6	82.4	78	9.2	5.7
10.	S 4727	4.7	35.7	112.3	31.0	82.8	78.3	8.7	4.7
11.	Mehnat	4.6	35.7	112.2	31.2	82.9	79.1	8.5	8.5
12.	Andijan 36	4.6	35.9	112.6	30.5	83.5	76.4	8.9	8.6
13.	S 6541	4.6	35.3	111.0	31.3	82.4	80.1	8.5	8.2

*Corresponding author: ilhom.abbazov.86@mail.ru

14.	Sulton	4.6	35.6	111.7	31.4	83.2	77.7	9.1	5.6
15.	Ibrat	4.6	35.7	112.2	31.3	82.9	79.0	8.7	8.9
16.	Andijan 37	4.6	35.8	112.4	31.6	82.9	75.2	8.6	10.4
17.	Beshqakhramon	4.5	36	112.4	31.8	83.1	78.6	9.1	4.7
18.	Porloq 1	4.5	37.8	118.8	32.5	83.5	77.8	9.0	4.9
19.	Porloq 2	4.4	38.7	121.5	34.1	84.0	79.3	8.4	4.9
20.	Porloq 3	4.4	38.6	121.7	33.1	83.2	78.8	8.9	5.9
21.	Porloq 4	4.6	38.4	120.5	33.3	84.8	78.3	8.8	4.1

The quality characteristics of all Uzbek varieties meet the requirements of the world market.
The main production of cotton is cotton fiber. For that cotton fibers classification doing by quality of cotton fiber in the world [3].
The standart O'z DSt 604:2001 «Cotton fiber. Technical conditions». This standard about the staple length and linear density type of cotton fibers by the lowest index. The cotton fibers consists to 9 types by standard O'zDSt 604:2001.

Table 2. Weediness and moisture content of cotton in varieties, %

Variety of Cotton	1st class		2nd class		3rd class	
	Weediness 3, %	Moisture W, %	Weediness 3, %	Moisture W, %	Weediness 3, %	Moisture W, %
I	3,0	9,0	10,0	12,0	16,0	14,0
II	5,0	10,0	10,0	13,0	16,0	16,0
III	8,0	11,0	12,0	15,0	18,0	18,0
IV	12,0	13,0	16,0	17,0	20,0	20,0
V	-	-	-	-	22,0	22,0

Accepted for all varieties of cotton weediness must be (2-3%), moisture must be (9%)

Table 3. The norms of qualitative indicators by the type of cotton fiber

Type of fibers	staple length, **mm**	linear density, **m-tex**	STR **For sort (I) and (II), gf/tex**
1a	40,2	125	more than 29,0
1b	39,2	135	
1	38,2	144	
2	37,2	150	
3	35,2	165	
4	33,2	180	23,0-27,0
5	31,2	190	
6	30,2	200	
7	29,2	more than 200	

Uzbek cotton is necessary to note that the new upland/middle staple transgenic variety "Porloq" is characterized by high yield, fiber strength and the best performance for the world textile industry. "S-6524", "Namangan-77", "Bukhara-6", "Bukhara-8", "Bukhara-102", "Omad", "Sultan", "An-Bayavut" and other varieties of Uzbek cotton fiber are highly demanded among the world consumers and occupy now the main planting areas in the Republic. By improving agricultural techniques, the introduction of new varieties over the past 10 years there has been a steady trend in the increase of the share of "Oliy" and "Yaxshi" classes. If in the harvest of 2005, the Uzbek cotton share of "Oliy" and "Yaxshi" classes was only 67%, in the harvest of 2014 it was 96%. Measures taken by the Uzbek government, which introduced discounts due to higher micronaire on the domestic market and prohibition from sowing of varieties with high micronire, allowed to decrease the share of fibre with high micronaire already in 2001. At present cotton fibre of season 2014 by the micronaire index meets the requirements of the state standard and international market. Cotton fibre volume with micronire index higher than 4.9 decreased from 16.66 % in 1999 to 0.6 % in 2014. Apparently, there is explicit redistribution of cotton fibre types IV and V: the share of type V decreased more than four times until the season of 2014 – from 81.5 % to 17.2 %, while the share of type IV increased more than three times- from 15.7 % to 68.2 %. At the same time 37 code fibre has grown by 14.5 %. The main volume of cotton fibre manufactured in cotton season 2014 falls to staple code 36. Pie chart of staple length distribution on slide points to the presence of 19.36% cotton volumes of the Republic in a length code (code35) in season 2014. The share of code 36 was 67.77 % in season 2014, the share of code 37 was 19.36 %. The share of fibre in the range of price discount is not significant [4-7]. Thus, the share of fibre code 34 was only 0.05 % in season 2014. Impartial per bale evaluation of cotton fibre length indices in the laboratories of Uzbek Centre "SIFAT" according to international system and a new cotton standard is among such important factors of improving of cotton fibre type as careful selection of cotton varieties, qualitative preparation of planting seeds, improved agrotechnics in cotton growing farms and maintenance of optimal schedule of storage and processing of seed–cotton at the ginneries. Uzbekistan cotton fibre is famous for its strength. Only 9,28 % of cotton fibre of the Republic lies within a base range according to international norms (26.5 and less gf/tex). 85.80 % of fiber lies within the range of 28.7 and higher, for which there is premiums in the world market. Insignificant volume of 4.92 % lies within the range of 26.5 and lower. 15.29 % of fibre in the Republic lies in the base range of Uniformity index 80.0-82.0. 83,1% of cotton fibre lies within the range of premiums (82.1 and higher). Insignificant fibre volume of 1.71 % lies within the range of 79.9 and low. Data about quality of a cotton fibre in cotton seasons indicates that implemented reforms in criteria and methods of cotton fibre quality evaluation, 33rd system of its payment, processing technology of seed cotton, putting into practice the measures for improvement of cotton varieties and stimulation of profitable varieties production were showen by positive tendencies in change of competitive properties of Uzbek cotton fibre. Taking into account the previous experience, the Holding Company "Uzpaxtasanoatexport" takes a series of practical measures to further improve the competitiveness and attractiveness of Uzbek cotton fiber.

Table 4. Comparison of physical and mechanical properties of cotton

#	Properties	Cotton
1.	Length (mm)	25-45
2.	Fineness (dtex)	1.2-2.8
3.	Dry tenacity (cN/dtex)	1.9-3.1
4.	Wet tenacity (cN/dtex)	2.2-3.1
5.	Dry breaking extension (%)	7-10
6.	Moisture regan (%)	8.5
7.	Density (g/cm3)	1.5-1.54

2. Technological part

In the cotton industry are applied saw ginning - which are the main technological machine for processing of raw cotton, designed for the separation of fiber from the seed. Ginning machines in cotton industry are applied - which are the main technological machine for processing of raw cotton, designed for the separation of fiber from the seed.Ginning is the mechanical process for separating cotton into its constituents namely lint (Cotton Fibre) and Cotton Seed. The Seed Cotton that comes from the field has to be subjected to various treatments in the ginning factories depending upon its inherent characteristics such as trash contents, moisture contents, length of the fibre, variety of seed i.e. fuzzy or black, method of seed cotton transportation, storage practices, handling practices inside the ginning factories and finally subjected to ginning process for separation of fibre and seed before packing into bales etc. Ideally the quality of the constituents i.e. cotton fibre and cotton seed before ginning and after ginning must be more or less same however it is seen that substantial damage is caused to quality parameters during processes in the ginning factories [9-11].

3. Theoretical part

Experience in operating the saw gins shows that qualitative and quantitative indicators of the saw ginning largely depend on raw speed and roller the force of interaction in the contact zone with the raw roller the saw cylinder. In this raw roller in the chamber makes a rotation around an axis which in turn can make a motion in the plane through the axis of the roller and perpendicular to the surface of the cutting cylinder. Law of motion of the roller and the raw values of contact force depends on many technical factors, in particular on the composition and mass of the raw roller and the contact conditions it with the saw cylinder. Therefore, in general, move the roller and the course of the process ginning interrelated and should be treated as a single technological object. The study of such an object requires the creation of the model described by complex mathematical equations. Therefore, in practice, various simplified models that take into account the most dominant elements in the law of motion of the raw roller and ginning. In particular, it is taken into account the constancy of the speed of rotation of the raw roller and a fixed axis of rotation. It does not take into account the dependence of the length of the contact zone of the mass and composition of the material and the roller of time. In this connection it should be noted that, for a more detailed study of ginning to assess the impact of major

factors (the shape and velocity of the raw roll, the degree of fibrous and the number of bare seeds in the raw roll, etc.) on the technological characteristics of the genie, it is necessary to use models close to real situations.
Using the model of the elastic foundation of Winkler ("spring model"), for two contacting cylindrical bodies with an elastic hull of thick, form the first equation of the rotational movement of raw roll around a fixed axis. Normal and shear stresses in the contact area according to this model is determined by the formulas [13, 14].

$$q_x = \frac{K_q}{h} u_x\,,\ q_y = \frac{K_p}{h} u_y\,,$$

where K_q and K_p - Base module for the tangent shear and compression of the normal and tangential and normal displacements of points on the surface in the contact area.
where K_q и K_p - modules are the basis for the tangent shear and normal compression, u_x and u_y tangent and normal displacements of surface points in the contact zone. The values of K_q and K_p are related to the reduced modulus of elasticity $E_x = \dfrac{E_1 E_2}{(1-\nu_1^2)E_2 + (1-\nu_2^2)E_1}$ (E_i, ν_i - modulus and Poisson's ratio for the raw material roll ($i = 1$) and material of saw cylinder ($i = 2$ which take $E_2 >> E_1$) formulas (a -arc length of contact) [2]

$$\frac{K_q}{h} = \frac{1.1}{a}\frac{E_1}{1-\nu_1^2}\,,\ \frac{K_p}{h} = \frac{1.35}{a}\frac{E_1}{1-\nu_1^2}\,,\ a = \sqrt{2R\delta}$$

where δ- value convergence centers adobe roller and saw cylinder, $R = \dfrac{R_1 R_2}{R_1 + R_2}$ - reduced radius.

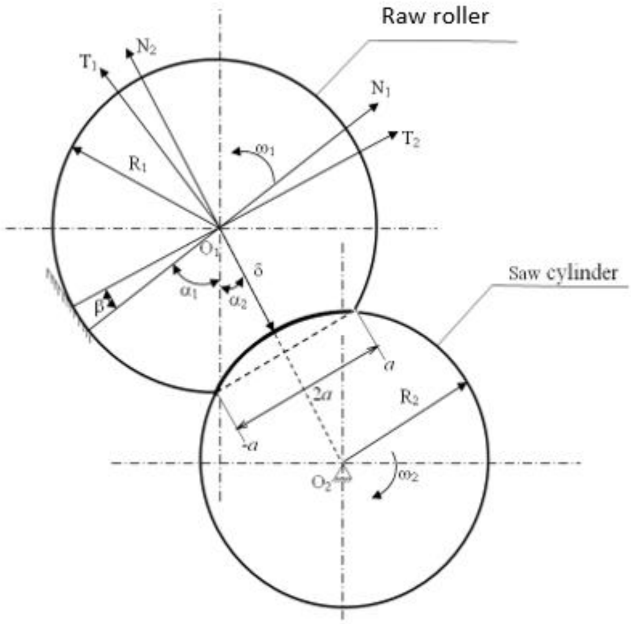


Fig. 1. Contact zone of raw roller with the saw cylinder

Accepted that the raw roller makes movement in the direction normal $\vec{N}_2$ and rotation around the center O_1. The equation of motion along the normal $\vec{N}_2$ written as:

$$m\ddot{\delta} = Amg + BT_2 - N_2 \qquad (1)$$

where

$$A = \frac{\cos(\alpha_1 - \beta) + f\sin(\beta - \alpha_1)}{\cos\beta + f\sin\beta}, \quad B = \frac{\cos(\alpha_1 + \alpha_2) - f\sin(\alpha_1 + \alpha_2)}{\cos\beta + f\sin\beta}$$

$$\beta = \frac{\pi}{2} - \alpha_1 - \alpha_2$$

where N_2 and T_2 - normal and tangential forces at the contact surface with the raw roller the saw cylinder, defined by the formulas [15,16]:

$$N_2 = \frac{\pi\delta E_1 \cdot b}{2}, \quad T_2 = \frac{3\pi E_1 bf\delta\lambda}{8}\left(1 - \frac{\lambda}{2} + \frac{1}{12}\lambda^2\right)$$

$$\lambda = \frac{K_q}{K_p}\frac{R}{f_1\sqrt{2\delta R}}\xi_x, \qquad \xi_x = \frac{R_2\omega_2 - R_1\omega_1}{R_2\omega_2}$$

The equation of rotational motion around the center of mud roller O_1 written as:

$$J_0\frac{d\omega}{dt} = R_1\left(C \cdot T_2 - D \cdot mg\right) \qquad (2)$$

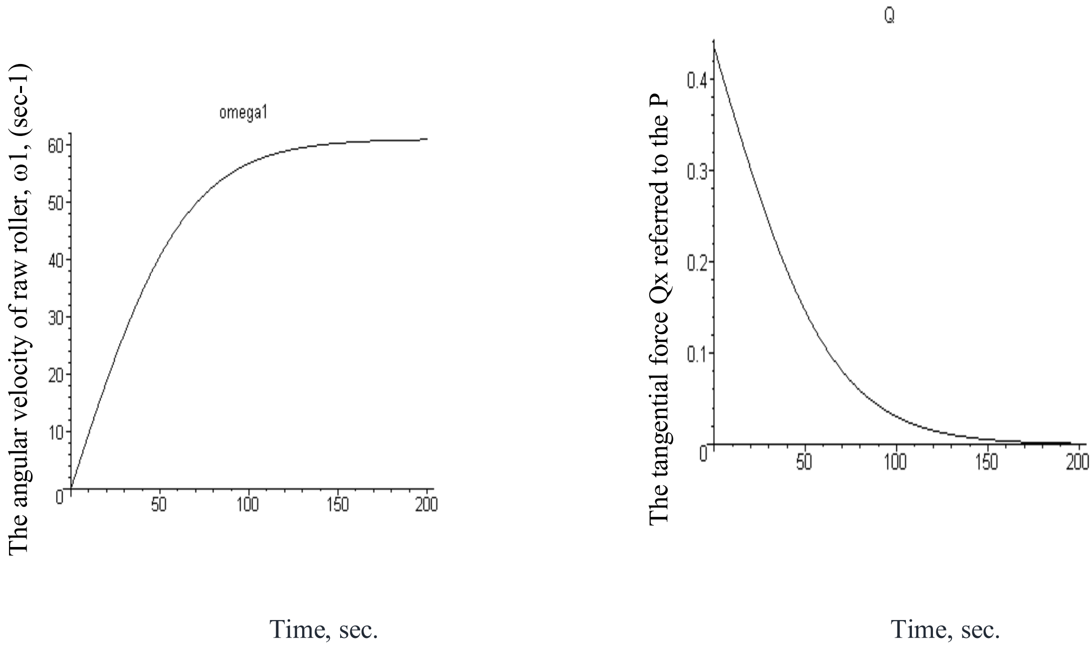
where

$$C = \frac{\cos\beta + f\sin\beta + f}{\cos\beta + f\sin\beta}, \quad D = \frac{f \cdot \sin\alpha_1}{\cos\beta + f\sin\beta}$$

where J_0 - moment of inertia roller.

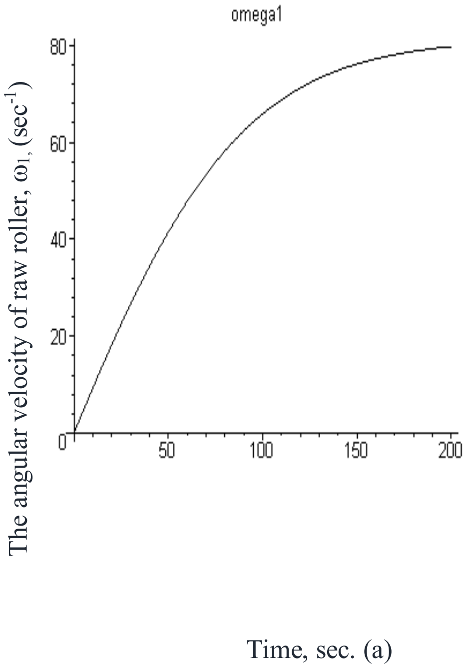
Equation (1), (2) together form a system for determine the movement of raw roller δ and angular velocity ω_1 and integrated with the initial conditions

$$\delta = \delta_0, \quad \dot{\delta} = \delta_0, \quad \omega_1 = 0 \text{ at } \quad t = 0$$



(a) (b)

Fig. 2. Changing the angular velocity of raw roller ω_1 $(\sec^{-1})$ and tangential forces $Q = -Q_x / P$ in time, at $R_1 = 0.2\,m$



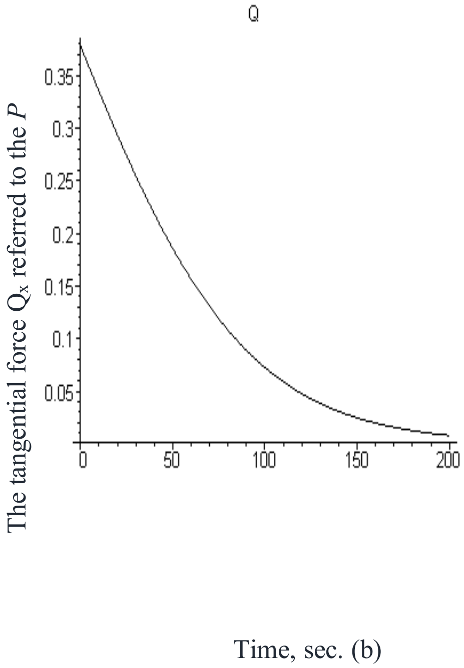


Fig. 3. Changing the angular velocity of raw roller ω_1 $(\sec^{-1})$ and tangential forces $Q = -Q_x / P$ in time, at $R_1 = 0.16m$

4. Conclusions

Figure 2 and 3 show the curves of the angular velocity ω_1 and tangential force (divided by the value P) $Q = Q_x / P$ in the contact zone for two values of frequency ω_2, where it is assumed $R_2 = 0.16m$, $\omega_2 = 76.4\sec^{-1}$, $R_1 = 0.2m$, $m = 71.7кг$, $f_1 = 0.2$, $a_0 = 0.24m$, $P_{00} = 717H$, $P_{10.} = 0.3P_{00}$.

As can be seen from the plots with increasing shear effort Q_x angular velocity of raw roller ω_1 increases (Figure 2,3 (a)), and with increasing time indicators are pointing Q downward (Figure 2,3. (b)).

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