INTERNATIONAL MULTIDISCIPLINARY JOURNAL FOR RESEARCH & DEVELOPMENT
SJIF 2019: 5.222 2020: 5.552 2021: 5.637 2022:5.479 2023:6.563 2024: 7,805
eISSN :2394-6334 https://www.ijmrd.in/index.php/imjrd Volume 11, issue 06 (2024)

INCREASING THE EFFICIENCY OF THE LINTING PROCESS USING ABRASIVE BLASTING OF SAW TEETH

Z. A. Shodmonkulov (PhD)
Tashkent Institute of Textile and Light Industry

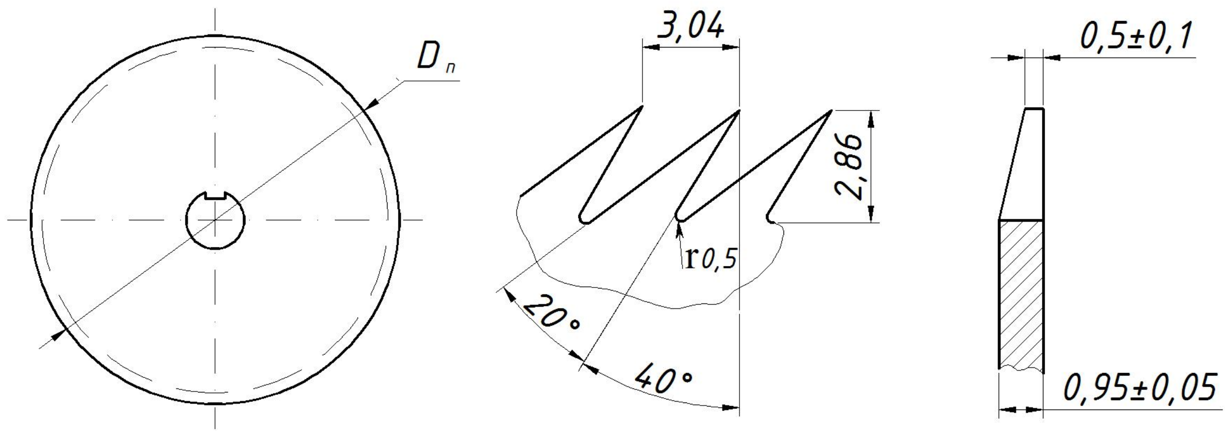
Abstract: The article presents materials on intensifying the linting process - removing the remaining short fibers from cotton seeds after ginning. Abrasive blasting of the side surfaces of saw blade teeth with abrasive particles made of black silicon carbide contributes to the formation of a favorable height and pitch parameter of surface roughness, capable of additional cutting of fibers in addition to the tip of the tooth, which leads to increased linting productivity. The state of the microprofile of the treated surface was studied using high-resolution atomic force microscopy.
Key words: Lintering, saw blade tooth, roughness height and pitch, abrasive blasting, fibers, fiber diameter, microprofile

After the ginning operation, a fibrous coating remains on the cotton seeds, consisting of relatively short fibers, the number of which depends on the breeding and industrial variety of raw cotton. Thus, for medium-fiber varieties, the amount of fibrous material is 11...16% of the seed weight, and for fine-fiber varieties - 3...5% [1]. The fibrous material remaining on cotton seeds consists of fibers with a length of 1...1.5 to 25...26 mm. In this case, fibers with a length of 6 mm or more are classified as linters, and fibers with a length of less than 6 mm are referred to as delint or short-staple linters. The total mass of lint, expressed as a percentage of the initial mass of seeds, is defined as the complete or total pubescence of the seeds.

Linters are designed for mechanically removing linters from cotton seeds and belong to cotton processing machines with a forceful effect on the processed product during a continuous operating cycle. The main working body in the 5 LP linter unit is a working body in the form of a saw cylinder with discs of the same name [2].

When linting, the teeth of the saw blade (Fig. 1,a) cut into the formed and continuously rotating seed roller. At the next stage of contact interaction, the fibrous cover remaining after ginning occurs and is scraped off from the cotton seeds. Considering the value of lint as a raw material in various industries, the issue of intensifying the linting process is relevant, and at the same time maintaining the quality indicators of lint is the most important task in the modern cotton ginning industry.

It should be noted that the basis of linting is the work of scraping the linter with the tip of the tooth, and linting productivity was previously associated only with the geometric parameters of the saw blade teeth (Fig. 1, b). The linting process as a whole depends on the degree of capture of the linter and its further transportation, determined by the front edge of the saw tooth. As noted by the author [3], non-participation of the side surfaces of the saw teeth in the process of scraping the linter leads to an increase in the residence time of the seeds in the chamber, which increases the density of the seed roller and reduces the throughput (productivity) of the linter for seeds. Activation of the side surfaces of saw teeth to intensify the linting process is possible if you first create a microprofile on their working surfaces capable of capturing fibers during the rotational movement of the saw blades relative to the seed roller.



a) b)

Rice. 1. Linter saw with diameter Dn (a) and tooth profile with dimensions of geometric parameters (b)

Fundamental research by acad. R.G. Makhkamov [4] on creating the basis for the process of interaction of solid surfaces with fibrous mass showed the following. In the specifics of the phenomenon of fiber capture by irregularities, the assessment of the relationship between the dimensional characteristics of irregularities and cotton fibers is of great importance. A microprotrusion is capable of capturing a fiber if it falls into a microcavity, which will depend on the ratio of the nominal fiber diameter d with the height Rz and the roughness pitch S. He developed a classification of interaction schemes based on an analysis of the relationships between the geometric parameters of roughness and fiber dimensions (Table 1). As follows from the data presented, the average pitch of irregularities along the vertices S varies over a wide range and depends on the method of machining (cutting with a blade or abrasive tool) even within the same irregularity height Rz. Due to the large range of fluctuations in the pitch of irregularities, we can only state the probability of fibers getting into microcavities: for rough surfaces the probability is greatest, with low roughness the probability is very small, and for Rz = 2-10 μm the possibility of fibers getting into microcavities can be considered equally probable. At the same time, the nominal diameter of raw cotton fiber for medium-fiber varieties is in the range of 20-40 microns with a length of l = 31/32, and for fine-fiber varieties - 7-15 microns, with a length of l = 39/40 and 40/41 mm [1].

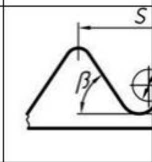
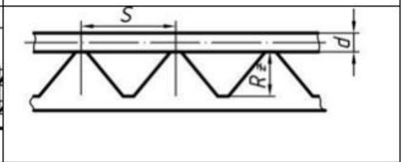
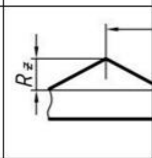
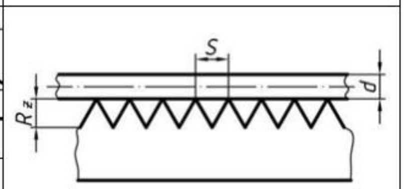
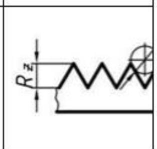
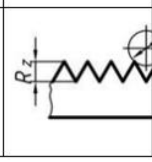
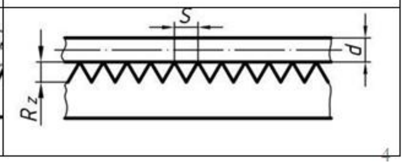
The roughness height Rz, which is one of the standard roughness parameters, allows you to estimate the number of fibers that simultaneously fall into the micro-cavity of the roughness, if theoretically they are located on top of each other in the vertical plane. The number of fibers located simultaneously in the space between irregularities in the horizontal plane depends on the pitch of the irregularities. The angle of inclination of the lateral sides of the irregularities relative to the horizontal plane depends on the methods of machining and is in the range β=1-400. The value of this angle determines the ability of a microprotrusion to capture a fiber when it enters a microcavity.

The other part of the fibers (Table 1), located parallel to the movement velocity vector when interacting with surface roughness, form so-called longitudinal fibers [4]. In contrast to the transverse fibers discussed above, when in contact with irregularities, longitudinal fibers are not captured by microprotrusions in the process of entering microcavities, but only change the actual contact area along the tops of the irregularities. For longitudinal fibers, the probability of their falling into microcavities depends on the ratio of the pitch of irregularities S and the nominal diameter of the fiber d or the stiffness of a single fiber. Even for the case of contact S/d>1, the probability of fiber penetration will be realized if the friction force at the tops of the irregularity approaches zero and the fiber can slide into the microcavity.

Thus, the feasibility of the scientific search for new methods for processing the teeth of saw blades is dictated by the creation of their increased performance and the activation of the side faces of the teeth through the formation of a rational microprofile (a combination of parameters Rz and S). Increased performance of saw blades due to their abrasive and fatigue destruction is ensured by the improved condition of the surface layer of the teeth due to the effect of strain hardening: favorable compressive residual stresses, depth and degree of hardening, dislocation density.

The most promising at present seems to be the processing of saw blade teeth with a flow of free abrasives under compressed air pressure, capable of forming the proper microprofile of the treated surface to enhance contact interaction with cotton fiber in technological machines [5,6].

Classification of interaction patterns between fibers and metal surface irregularities

Uneven height Rz, µm	Step on the peaks S, мкм	Type of processing	Fiber diameter d ,	Attitude S/d	Cross fibers	Longitudinal fibers
10 – 80	50 – 150	blade	20 – 40	$\frac{S}{d} > 1$		
2 – 10	50 – 90			$\frac{S}{d} > 1$		
	12 – 20	abrasive		$\frac{S}{d} = 1$		
0,05 – 2	2 – 11			$\frac{S}{d} < 1$		

Steel 65G has a high elastic limit and fatigue resistance with sufficient ductility [7]. For carbon spring steels, the value of the conditional yield strength σ0.2 must be not lower than 800 MPa, for alloy steel - not lower than 1000 MPa.

Supplied new gin and linter saws must comply with the requirements of OST 27-72-234-81 [8]: diameter of new saws (320±0.25 mm); number of saw teeth: gin saws - 280, linter saws - 330. Radial runout of the outer diameter of the saws relative to the inner diameter should not exceed 0.5 mm. The chamfer should overlap the tooth by no more than 2 mm. A one-sided chamfer on the teeth of linter saws is removed from the exit side of the gear-processing tool - the punch.

The shaping of the tooth profile of new and used gin and linter saws is carried out on special sawing machines using stamping equipment consisting of a punch and a matrix. The presence of a technological gap higher than permissible (0.05...0.1 mm) between the cutting edges of the punch and the matrix, inaccuracy of their installation, wear of the cutting edges contribute to the formation of burrs on the front and rear surfaces of the saw tooth. According to [9], on the front surface of a saw tooth the size of burrs is 20...580 µm with an average value of 240...250 µm; on the back surface – 20...220 µm with an average value of 80...90 µm. If the size of the burrs is more than half the fineness of the cotton fiber and during the ginning process it comes into contact with the working surface of the saw tooth, then the fiber, having caught on these burrs, will receive mechanical damage in the form of a cut and the length of the fiber can be significantly reduced. Given this circumstance, burrs should be removed by grinding.

The most common and accessible method of grinding gin and linter saws after cutting teeth in cotton mills is grinding saws in a sand bath - a mechanical process of finishing operation with free abrasive material (river siliceous sand with a fraction size of 630...2500 microns). Grinding of teeth using quartz sand should be carried out within 30 minutes, with the first 15 minutes (the saw cylinder should rotate in one direction) of the working movement, and the next 15 minutes - in the opposite direction [2]. Having high productivity, low cost, and simple equipment designs, this method currently does not meet the increasing requirements for the quality of saws. Despite the effectiveness of a number of finishing operations based on electrochemical, galvanic, mechanical, ultrasonic, vibration and other processes, due to the complexity of practical implementation in cotton factories, they have not found application.

High quality indicators of processed products during ginning and linting are primarily ensured by the geometric parameters of the teeth and the condition of their working surfaces. The geometric characteristics of the processed surface include roughness, waviness and the direction of processing irregularities [10].

Abrasive blasting of metal surfaces of parts, in accordance with the classification of mechanical processing methods, refers to grinding with free abrasive, the totality of which is directed onto the surface being processed at a certain angle α (angle of attack) and under pressure p of compressed air or in the composition of an anti-corrosion liquid (water abrasive blasting).

Abrasive blasting of working surfaces of parts includes a number of processes of contact interaction of an abrasive with a metal surface: impact and penetration of an abrasive particle to a certain depth, microcutting (scratching) and, as a consequence, the formation of an irregular microprofile. These processes are based on plastic deformation of the contact microvolume of the metal, where the stress intensity exceeds the yield strength of the material being processed. Therefore, based on the physical essence of the process of plastic deformation of metals and noting the peculiarities of its occurrence in a particular processing method, it is possible to effectively solve a number of technological problems.

Thus, in accordance with the classification of schemes for interaction of fiber with metal surface irregularities (Table 1), we have a case where $S/d<1$ and activation of the side surfaces of the teeth is impossible.

The main result of abrasive blasting of linter saw teeth is the formation of a microprofile with a significant unevenness pitch ($S>20$ μm), several times greater than the corresponding pitch of unprocessed teeth and comparable to the diameter of cotton fibers (at $d = 20$ μm).

In accordance with the classification of fiber interaction patterns (Table 1), the profile of saw teeth after abrasive blasting is characterized by the ratio $S/d>1$ with a roughness height of $Rz=2\text{-}10$ μm and $S=12\text{-}20$ μm. The favorable profile of the tooth surface in the process of abrasive blasting is ensured by the high cutting abilities of the abrasive - black silicon carbide, which has a cutting and hardening effect when impacted in the air mixture on the surface being treated.

Taking into account the mechanics of the contact interaction of an abrasive particle with the surface being treated, it can be quite reasonably noted that with an increase in the size of abrasive particles, the height of the resulting unevenness will also increase. If the height of the irregularities is in the range $Rz=10 – 80$ μm (Table 1), then this creates the condition for placing cotton fibers in several rows in height, i.e. a condition will arise for additional intensification of the linting process.

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Experimental studies of the microprofile of the side surfaces of linting saw teeth after abrasive blasting showed that the formed surface contains the potential for intensifying the linting process. Let us create a technological condition for activating the side surfaces of the teeth, under which additional cutting of short fibers from seeds will occur due to the participation in the process of linting of formed irregularities during abrasive blasting. The determining role in the activation of the side surfaces of the teeth belongs to the average pitch of irregularities:

$S \geq nd_p$, μm (2)

where n=1,2,3,… is the number of fibers falling into the space between adjacent peak values of surface roughness; dp – estimated diameter of cotton fiber, mm.

The estimated diameter of cotton fibers having a linear density T=0.13...0.22 tex (mg/m) can be determined by the formula [14]:

$d_p = 0.0357\sqrt{T/\delta}$, mm (3)

where δ is the average density of elemental cotton fiber, equal to 0.9 – 1.3 mg/mm3.

Depending on the ratio of linear density T and density δ of cotton fiber for the given ranges of their values, the calculated fiber diameter is in the range of 11.3...17.7 microns. If we compare the values of the average pitch along the tops of the irregularities and the diameter of the fiber, we can note that at least two fibers are placed in the space between the irregularities. Getting into the space between the irregularities and being held in it due to the irregularities during the continuous rotational movement of the saw blade, there is a high probability of cutting the fibers. The following fibers of cotton seeds fall into the freed space and the cutting process is repeated.

Abrasive blasting of the teeth of linter saw blades creates good preconditions for enhancing the gripping ability of fibers by formed irregularities and their subsequent cutting. Proof of this is the photo in Fig. 2, which shows the fixation and concentration of fibers on the teeth of linter saws after local and single lapping with a mass of cotton seeds

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a)

b)

Rice. 2. Gripping ability of saw blade teeth: untreated (a) and treated with an abrasive flow (b)

On untreated teeth (Fig. 2a), the fibers, as expected, are concentrated mainly at the tip of the tooth. On the teeth after abrasive blasting (Fig. 2, b), a large number of fibers are fixed on the side surfaces, which convincingly confirms the fact that these surfaces are activated by irregularities in the microprofile of the teeth.

The results of comparative experimental studies [15] of the linting process with saw blades with machined and unprocessed teeth are presented in Table. 2.

Table.2

Results of comparative laboratory studies of seed quality

№ п.п.	Name of seed indicators	Research data	
		experimental saws	factory saws
1.	Mechanical damage,%	0,9	1,2

2.	Clogging, %	0,2	0,2
3.	Humidity, %	7,8	7,8
4.	Hairiness, %	5,5	6,8

In Fig. For comparison, Fig. 3 shows seeds after linting on machines running simultaneously after 24 hours of operation.

a) b)

Rice. 3. Visual assessment of comparative experimental studies of the linting process:

a – linting with factory saw blades;

b – linting with saw blades after abrasive blasting of teeth

Visual assessment indicates a noticeable advantage of the linting process using saw blades with abrasive blasting of the teeth.

Thus, convincing evidence has been obtained of the high efficiency of using abrasive blasting on the side surfaces of the teeth of saw blades for linters, which is expressed in the creation of a favorable surface microprofile that promotes their activation and intensification of the linting process.

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