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Abrasive Blasting of the Teeth of Linter Saws with the Aim of their Activation

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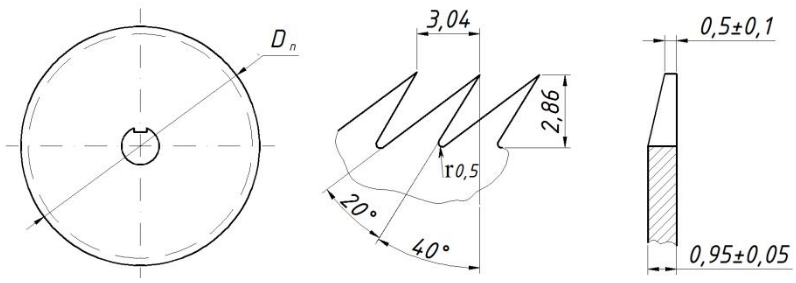
ABSTRACT: The article presents materials on the effective use of abrasive blasting of the side surfaces of the teeth of saw blades in order to activate them during lintering. The scraping action and cutting of short fibers from seeds is enhanced by micro roughnesses of the formed micro profile after impact interaction of an abrasive particle with a metal surface. Using atomic force microscopy, we obtained the height and step parameters of the roughness of the machined tooth surface, which are compared with the transverse dimensions of the cotton fibers, and thus a model for the intensification of the lintering process is proposed.

KEYWORDS . Lint, lintering, saw blade, abrasive blasting, abrasive particle, microprofile, microscopy, roughness height, cotton fiber, seed quality.

I.INTRODUCTION

After the ginning operation, the cotton seeds still have a fibrous cover consisting of comparatively short fibers, the amount of which depends on the selection and industrial varieties of raw cotton. So, for medium-fiber varieties, the amount of fibrous material is 11-16% of the seed weight and for fine-fiber material 3-5% [1]. The fibrous material remaining on the cotton seeds consists of fibers from 1-1.5 mm long to 25-26 mm long. At the same time, fibers with a length of 6 mm or more are referred to the lint. The total mass of lint, expressed as a percentage of the initial weight of the seeds, is determined as the total or total pubescence of the seeds. The cotton lint is a valuable raw material for a number of industries (textile, chemical) and is characterized by parameters such as length, grade, type, moisture and weediness. The lint variety is determined by the maturity of the fibers and does not depend on the methods of processing raw cotton and lintering of seeds. The type of lint is determined by the staple length, initial pubescence of the seeds, the amount of removal for one lintering and its multiplicity. The moisture content of the lint depends on the moisture content of the seeds, and the weediness depends not only on the weediness and humidity of the original seeds, but also on the condition of the working organs, the equipment and the availability of a lint and seed cleaner in the raw cotton process.During lintering, the saw teeth (Fig.1) cut into the formed and rotating seed roller. Further contact interaction consists in the separation and scraping from the cotton seeds of the fiber remaining after ginning. Considering the importance of lint as a raw material, the issue of intensification of the lintering process seems urgent, while maintaining quality indicators of the lint is the most important task in the modern ginning industry. It should be noted that enhanced seed cleaning is carried out by the work of scraping the lint with the top of the tooth and the performance of lintering was previously associated only with the geometric parameters of the teeth of the saw blade (Fig.1, a). The lintering process as a whole depends on the degree of capture of the lint and the possibility of its transportation, determined by the front face of the saw tooth. The shape of the cutting part of the saw tooth affects not only the intensity of scraping, but, therefore, the performance of the linter, but also the quality indicators of the lint and seeds.



a) б)

Fig. 1. A liner saw with a diameter of D_n (a) and a tooth profile with dimensions of geometric parameters (b)

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In [2,3], an increase in lintering productivity was achieved by activating the working edges of the teeth of the saws by changing the parameters of the edges of the teeth by grinding the side surfaces with the exit of the grinding wheel to the front face. Thus, an additional two-sided grinding of the tooth flanks is carried out, and the resulting macro-irregularities of 0.043 mm on the teeth from the side of the punch exit (they are absent in standard saws) contribute to an increase in the scraping ability of the teeth. An increase in the scraping effect of the teeth of the linter saws can also be achieved by straightening the transverse edge at the top of the tooth and thereby creating an additional cutting blade by treating notched and ground saws around the periphery. The increase in productivity by 13 and 10% was achieved due to double-sided grinding, and additional processing of the saw periphery after double-sided grinding increases the productivity of lintering by 17 and 18%, respectively, during the first and second lintering.The intensification of the lintering process is also possible by setting the teeth (flexible in dies) according to the following scheme [2]: two teeth were bent to one side relative to the saw blade, three teeth were left in the initial position, the next two teeth were bent to the other side, etc. This arrangement of the teeth relative to each other leads to the fact that the two lateral working edges are in different planes and therefore contribute to an increase in their activity when interacting with cotton seeds.As noted by the author [4], not participating in the process of scraping the lint of the side surfaces of the saw teeth 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 linter's throughput for seeds. The use of the abrasive grinding operation, as is known [5], leads to a deterioration in the quality of the machined surface of parts, since harmful tensile residual stresses form in the surface layer under the influence of a powerful thermal factor, burns and embrittlement appear, as well as the development of a network of microcracks. The operation of grinding the lateral surface of the teeth is also undesirable for the reason that a certain allowance is removed, which reduces the thickness of the active part of the saw tooth. As a result of this, the stiffness of the teeth and their resistance to destruction due to the reduction of the wear volume of the metal is reduced. Therefore, the use of abrasive grinding for chamfering on the teeth of gin and linter saws should be carried out with abundant supply of coolant - cutting fluid or burrs on the teeth should be eliminated (reduced) after they are cut by mechanical methods of surface plastic deformation, for example, micro-ball processing shot blasting hardening of machine parts [6]. A common operation for deburring gin saws is their processing in a sand bath as part of a saw cylinder [7].Thus, it becomes obvious that by creating an adjustable microprofile on the tooth flanks by mechanical action without the powerful heat factor that occurs during abrasive grinding, lintering can be significantly intensified and the durability of saw blades can be simultaneously increased due to the effect of strain hardening of the tooth surface layer.In order to increase the efficiency of the lintering process due to the activation of the teeth of the saw blades and increase the scraping ability of their side surfaces, in this work, the mechanical processing of the teeth by a directed flow of abrasive particles under air pressure is proposed. As abrasive particles (Fig.2), black silicon carbide (BC) has been used, which has high cutting properties and is usually used for the manufacture of grinding wheels capable of cutting machined surfaces with the formation of micro-chips. In contrast to traditional grinding with bonded abrasive, abrasive blasting refers to grinding with free abrasive [8] and metal surfaces are processed with a high degree of discreteness for a very short time (duration of impact). The main methods of grinding with a free abrasive are inkjet (Fig.3), ultrasonic and lapping. In this case, the jet method is implemented in air or liquid medium.

Fig. 2. Abrasive particles (grinding) black silicon carbide (BC)

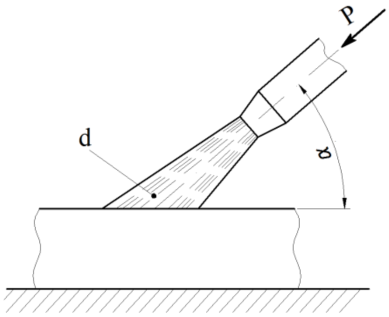

Fig. 3. The scheme of the jet (air, liquid) method of processing (grinding) with a free abrasive

Abrasive particles (Table 1), in particular, black silicon carbide, having high mechanical properties [9], with dynamic contact with the treated surface, leave risks on it, grooves with an influx at the periphery as a result of the micro-cutting process. The BC particle, having many cutting wedges with different geometries, under the influence of

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the pressure of the air stream performs micro-cutting with the formation of surface roughness on the workpiece.Abrasive blasting of metal surfaces is characterized by the following parameters: angle of attack α, particle size d and its physical and mechanical properties, compressed air pressure p. The teeth processing of saw blades for linter was carried out in a special abrasive blasting chamber (Fig.4), installed on the site of LLC GAUCH (NPO Technolog) and having the following technical characteristics:
1) dimensions of the working area , mm - 1070 ˣ 1350 ˣ 1100;2) working pressure, MPa - 0.2...0.4;3) consumption of compressed air, m^3/min-0.6...1.5;4) hopper volume for abrasive, l–50;5) the method of transporting the abrasive to the nozzle is ejector;6) productivity, m^2/hour - 1...3.

Fig. 4. Abrasive blasting chamber with ejector method of transporting the abrasive to the nozzle

The abrasive blast chamber has a multifunctional purpose, as it can be used in various industries for a number of preparatory and auxiliary technological operations: cleaning; removal of rust, sand and scale; defective layer removal; matting; hardening; deburring; polishing; obtaining the necessary roughness, as well as for preparing surfaces before applying an anti-corrosion coating. Among the above features of abrasive blasting for the teeth of a saw blade of a linter, especially important and necessary are, firstly, the creation of the necessary roughness on the lateral surface of the teeth in order to activate them to intensify the lintering process and, secondly, the use of the effect of strain hardening of the surface layer of teeth for increase resistance to abrasive wear.At the first stage of experimental research, it was important to prove the fundamental possibility of using abrasive blasting of teeth of saw blades for linter. For this, it is necessary to study the quantitative and qualitative side of the formed microprofiles of surfaces as a result of shock contact interaction of an abrasive particle with a metal surface, which takes place under conditions of elastic and plastic deformation with the metal being displaced as an influx, as well as a subsequent cut (scratching) of the processed material within the depth of penetration of the abrasive particles.Preliminary tests were carried out on the above installation under the following conditions and processing conditions: air pressure p=0.2...0.4 MPa; angle of attack $\alpha=15^0...45^0$; the abrasive particle is black silicon carbide (BC) with a granularity of 40. The material of the saw blades is U8G carbon tool steel (tensile strength σ_b=1150 N/mm^2; elongation δ=6%; hardness HRA 67-70).The values of the angle of attack α of the abrasive particles are taken from the consideration that, in general, the grinding process has much in common with the wear process during friction. Therefore, the results of experimental studies [10] are quite acceptable, showing that the wear of ductile materials (carbon steels) varies significantly depending on the angle of direction of flow of abrasive particles to the surface (angle of attack) - increases with increasing angle α from 10^0 to 40^0-50^0 and further decreases at $\alpha>60^0$.Structural studies were carried out on samples cut from a saw blade and subjected to abrasive blasting using atomic force microscopy (Agilent 5500 scanning probe microscope). We used silicon contilevers with a hardness of 9.5 N/m^2 and a frequency of 145 kHz.The maximum scanning area: along the x and y axes is 5 ˣ 5 μm^2, along the z axis - 1 μm. Some results of structural studies of the tooth flank after abrasive blasting are presented in Fig.5. In contrast to the classical method for assessing the roughness of a treated surface [11] using the measurement data on a profilometer - profilograph, when three altitude (R_{max}, R_z, R_a, μm), two step (S, S_m, μm) are determined in accordance with GOST (State All-Union Standard) 2789-73 and one structural (η,%) parameters, in this study, a local scan of the tooth flanks was performed, similar to worn metal sections under abrasive wear as a result of scratching of solid particles with subsequent slices and the formation of micro-chips.

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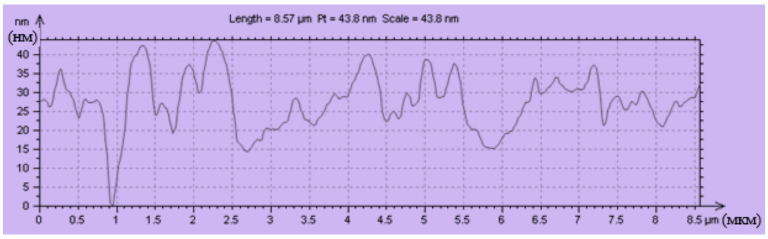
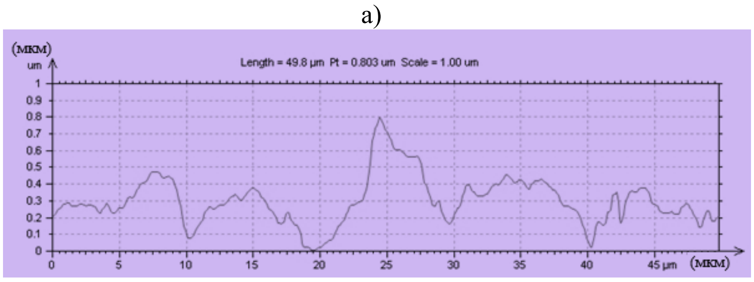
Table 1
Basic physical and mechanical properties of some abrasive materials

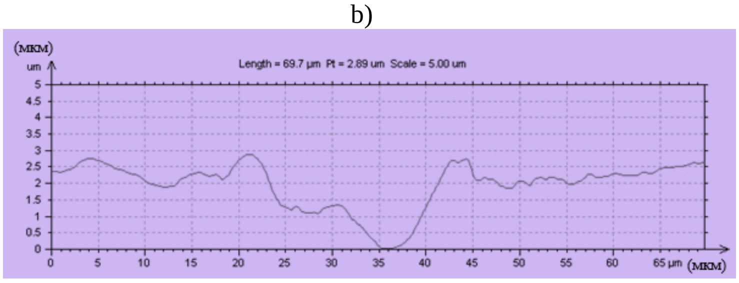
Abrasive material	Origin	Micro hardness kgf / mm^2	Density, g / sm^3	Abrasive ability of grain № 16 on glass	Bulk density g / sm^3 зерна № 16	Bulk density g / sm^3 зерна № 40	Heat sustainability, °C
Boron carbide	Synthetic	4000—4500	2,5 ±0,02	0,500	1,04 ±0,05		700—800
Silicon carbide: green		3300—3600	3,20 ±0,05	0,450	4,48 ±0,05	1.48 ±0,05	1300—1400
the black		3300—3600	3,20 ±0,05	0.400	1,48 ±0,05	1,48 ±0.05	1300—1400
Electrocorundum: normal		1900—2000	3,90 ±0,05	0.145	1,76 ±0,05	1,87 ±0,05	1700—1800
white		2000—2100	3,95 ±0,05	0,155	1,73 ±0,05	1,83 ±0,05	1700—1800
Corundum	Natural	1900—2200	4,00 ±0,10	0,135	1,75 ±0,05	1,82 ±0,05	1700— 1800



a)



b)



c)

Fig. 5. Scanned microprofile of the side surface of the teeth of the saw blade:
a) without processing; b) after abrasive blasting (p=3 atm., α=15^0); v) after abrasive blasting (p=3 atm., α=45^0)

The aim of the study was to determine the maximum roughness height R_{max} (μm) and an approximate estimate of the distance S between the peak values of the roughness height. By comparing the values of these parameters with the estimated diameter d_p of the cotton fiber [12], we can formulate a technological condition under which an additional

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cut of short fibers from seeds will occur due to the participation in the lintering process of the formed irregularities during abrasive blasting, i.e. activation of the tooth flanks:

$$S \geq n \cdot d_p, \qquad (1)$$

where n=1,2,3,... is the number of fibers located within the S step of the irregularities.To compare the micro profile data in Fig.5, it is necessary to determine the calculated diameter of cotton fibers having a linear density of T=0.13-0.22 tex (mg/m), according to the formula [11]:

$$d_p = 0{,}0357\sqrt{\frac{T}{\delta}}, мм \qquad (2)$$

where δ is the average density of elementary cotton fiber equal to 0.9-1.3 mg/mm^3.

Given the above data, the calculated fiber diameter was d_p=11.3...17.7 microns. As follows from the structural analysis of the scanned microprofile (Fig.5, a) for the unprocessed tooth flanks, all peak values of the roughness height do not exceed the value R_{max}=0.045 μm, the roughness step along the vertices is within S=0.5...2.0 μm. The interaction of the tooth with fibrous fibers does not allow to intensify the lintering process, since the transverse fiber size is incompatible with steps S (the condition is not fulfilled (1)). From the scanned profile of the lateral surface of the teeth of the liner saws after abrasive blasting (p=3 atm, α=15^0), shown in Fig.5, b, the height of the irregularities increases significantly compared to the untreated surface and is 0.803 μm. At the same time, the step of irregularities along the vertices also significantly increases, reaching S=7.5...14.0 μm. The lateral surface of the teeth with such parameters is more favorable for fiber entrapment in the troughs of irregularities, jamming or trapping by microprotrusions of the surface, which ultimately contribute to the strengthening of the lintering process.With an increase in the angle of attack α of abrasive particles (α=15^0, p=3 atm) due to an increase in the depth of the elastic-plastic penetration of abrasives, the height of the bumps should also increase. This is evidenced by the structural analysis of the scanned microprofile in Fig.5, v. Thus, the maximum roughness height in this scan section is R_{max}=2.89 μm, and its average value is in the range of 1.5-2.0 μm, which is approximately several times higher than the height of the roughness obtained at α=15^0 (Fig.5, b) As follows from fig.5c, the average step S of the irregularities increases to a value of 28 μm, i.e. in such a space between the irregularities at least two fibers can be located, and the irregularities in this case play the role of fixing elements for their reliable retention during lintering. Thus, a favorable microprofile of the tooth surface, formed as a result of abrasive blasting, is the main activation of the teeth of the linter saws.The abrasive blasting of the teeth of the saw blades for the linter creates good prerequisites for enhancing the exciting ability of the fibers with the formed irregularities and their subsequent cutting. This is proved by the photo in Fig.6, which shows the fixation and concentration of fibers on the teeth of the linter saws after local and single grinding with a mass of cotton seeds.

a) b)

Fig.6. The exciting ability of the teeth of the saw blade: untreated (a) and treated with a stream of abrasive (b)

On the untreated teeth (Fig.6, a), the fibers, as expected, are concentrated mainly on the top of the tooth. On the teeth after abrasive blasting (Fig.6, b), a large number of fibers are fixed on the side surfaces, which clearly confirms the fact that these surfaces are activated by the formed irregularities of the tooth microprofile. Table 2 shows the results of comparative laboratory studies of cotton seeds after lintering with factory saws and saw blades, the teeth of which were subjected to abrasive blasting. The quality control of seeds was carried out in accordance with the requirements of the O'z Dst (Uzbekistan State Standard) 596-2014 standard in the Quality Seeds laboratory of Gulistan extract oil JSC.

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Table 2
The results of comparative laboratory studies of seed quality

№ I.O.	Name of indicators of seeds	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.	Pubescence, %	5,5	6,8

For the lintering process, the same modes were created for machines that meet the rules of technical operation. An analysis of the average values of the quality of seeds and lint showed significant advantages of linter saws with pre-treated teeth with a stream of abrasive particles, contributing to their activation due to the formed micro-irregularities. The height of the irregularities, several times greater than the transverse size of the fiber, creates favorable conditions for the capture of fibers and cut with the relative movement of the teeth of the saw in the seed shaft. The mechanical damage to the seeds is 0.9%, which is 25% less compared to littering with factory saws. The pubescence of seeds is 5.5%, which is 19% less than that when sawing without abrasive blasting.Thus, on the basis of the studies it is necessary to draw the following conclusions:

1. For the first time, the effectiveness has been proved and the rationale for abrasive blasting of the lateral surfaces of the teeth of saw blades in order to intensify the lintering process has been completed.
2. The possibility of atomic force microscopy for scanning and quantifying the micro profile of the treated metal surface, both the roughness height and the step of their location, is shown.
3. A mechanism for intensifying the lintering process due to the additional work of scraping with the increasing effect of trapping by the formed irregularities of the treated tooth surface is proposed.
4. Experimental studies of the lintering process and laboratory tests to determine the quality of seeds and lint fully confirmed the high efficiency of abrasive blasting of the teeth of saw blades for linter

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