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Technological Features Hardening Of The Case Of The Roller Track Of The Transport Machine By Ball Knurling Tool And Cartooning With Microballs

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Abstract
The influence of the hardening method of processing by surface plastic deformation with a ball knurling tool for the integrated provision of the quality indicators of the surface layer of the part of the roller track holder (ORD) of transporting machines and the complex hardening with steel balls and cartooning with glass balls that improve the operational characteristics of the surface layer and resistance to abrasive wear and the formation of surface corrosion ORD layer of transporting machines operating in an active environment, made of alloyed steel 20KhGSA and its substitute 30KhGSA. Workpieces belong to grade steels and alloys. Various parts of machines operating with alternating loads at temperatures up to 2000C are made from it. Observed by the operated OSD to the application of a treatment method that protected from external impact loads.

The purpose of this work was to evaluate the effectiveness of hardening the ORD transporting machines made of alloyed grade steel grade 20KhGSA with glass beads, and to develop a technology for complex hardening of the ORD with thin edges. To achieve this goal, the tasks of hardening the surface layer of the OSS with steel and glass balls in the optimal mode, assessing the quality parameters of the surface layer and testing them for fatigue and corrosion resistance were solved.

The technology of hardening the surface layer of the ORD of transporting machines was carried out on a lathe in the established mode of processing PPD.

Thus, caricaturing with glass beads with small efforts of the surface of the part, after rolling with ball deforming tools, ensures the formation of favorable characteristics of the surface layer and without the formation of overhardening, successfully destroys the microdefects of the surface layer formed at the previous stages of the technological pass, and is also accompanied by a noticeable increase in the endurance limit and dominated by the fact of finishing by manual polishing.

Key words: Clips of the roller track of transporting machines; rolling with steel balls; caricature with glass balls.

Introduction

Forged and forged blanks made of 20KhGSA alloy steel (substitutes for 20KhGSA) are graded steels and alloys. They are standardized by GOST 1133-71 and GOST 4543-71. Foreign analogues of the 20HGSA steel grade are 20ChGSA (Bulgaria) and 20HGSA (Poland). In mechanical engineering, they are used to make lead screws, axles, shafts, worms and other parts that operate under wear conditions and under alternating loads in an active medium at temperatures up to 2000C.

In recent years, the increased interest of companies in operating roller tracks in active conditions that cause adhesive and corrosive wear has shifted to the development and application of more efficient methods of processing the hardening of parts with balls, followed by caricaturing the surface of the roller track cage (ORD) of transporting machines with glass balls, mainly due to with large material losses due to early decommissioning of the pressure vessel due to damage to the casing surface under the influence of adhesion and corrosion.

An analysis of representative parts shows that the number of RDWs prematurely removed from service due to damage to the RDW surface layer due to adhesive and corrosive wear, including alternating loads, is up to 40% of the total number of prematurely removed ones [1, 2].

Typical operational damages of OSA are nicks, scuffs, fittings and corrosion formation on the working surface of the clip. A common design feature of the ORD profile parts is their thin-walledness: the ratio of the maximum thickness of the profile Cmax to the chord Vpr for the section at the root of the clip profile ($C_{max\ отн.}$ = $C_{max}/B_{пр.}$ = 0,06…0,1 [2].

One of the effective ways to reduce wear - and corrosion resistance of the ORD is associated with improving the roughness and microhardness of the working surface of the cage - increasing the radius of curvature of the convex part formed by rolling with steel balls. Studies have shown that the maximum decrease in the endurance limit is observed when the value of the damage depth approaches the value of the bulge radius, i.e. at a depth of 0.5 mm, the step of the convexity must be at least 1 mm. This requirement is successfully met by rolling on steel balls followed by caricaturing with glass balls (the diameter of the ball is taken as intended, 4,6,8,10 and no more).

Experimental-analytical methods for solving this problem in this case are very time-consuming and ineffective.

To increase the bearing capacity of the ORD, finishing and strengthening methods are widely used in the industry, which make it possible to form a favorable combination of the characteristics of the surface layer, such as;

- roughness parameters;
- surface hardening (microhardness);
- residual stresses under the surface layer;
- textures.

The role of the surface layer for the profile part of the ORD in the formation of the bearing capacity is great, since the thickness of this layer is commensurate with the thickness of the ORD cross section, especially when the depth of the imprint of the rolled steel ball is known. The optimal depth of the plastically deformed layer is about 0.15 Nd, where Nd is the thickness of the part [2].

Widely used in mechanical engineering for the manufacture of parts with the best quality indicators is processing methods

surface plastic deformation (SPD), which is a set of processes that, as a rule, make it possible to reduce the surface roughness of a part, create a surface layer with favorable (compressive) residual stresses, obtain a more uniform structure in it, create the necessary surface relief, and reduce the effect on the fatigue resistance of concentrators stresses, etc., which contributes to an increase in the fatigue resistance of the material of the part [4].

Studies of alloyed alloys have shown that standard smooth samples have $\sigma_{-1} \approx 0,5\ \sigma_в$, a, and for the ORD σ_{-1} = $0,25\sigma_в$.

In the presence of special hardening treatments, including PPD, it is possible to increase σ_{-1} before $0,4\ \sigma_в$ [2].

To neutralize technological microdefects in mass production, at the final operations in the manufacture of transport machines, rolling hardening with steel balls is used, followed by caricaturing with glass balls.

Finishing such as rolling hardening allows you to fully achieve high endurance parameters. When the number of passes is limited (no more than 3), overhardening is not formed on the surfaces, since the processing process occurs smoothly without impact and due to the rounding of two rotating bodies (ball and part). To create a mirror surface and shine, after rolling, the surface is caricatured with glass beads. This eliminates the lack of applications of manual polishing. Manual polishing of the surface significantly increases the laboriousness of the manufacture of the OSD, leads to the redistribution of residual stresses and the creation of transverse scratches at the edges - technological stress concentrators. This ultimately leads to a sharp decrease in the effectiveness of hardening by the SPD method with caricature with glass beads of the ORD.

It is not possible to achieve a significant increase in the endurance limit in ORD transporting machines, cuts, due to the use of intensive methods of surface hardening, and in some cases, with an edge thickness of 0.6 ... 1.3 mm, there is a decrease in fatigue resistance due to damage to the edges due to through work hardening, which contributes to a decrease in the plastic properties of the material [2]. On the sample, the wall thickness is 3 mm; in order to avoid such shortcomings, it is possible to use glass beads with a minimum deforming force as reinforcing bodies.

One of the progressive technologies for increasing the bearing capacity of parts operating under alternating loads is complex hardening with balls. There is information in the literature about the use of the technology of complex (combined) hardening with balls for the formation of favorable characteristics of the surface layer of parts from various materials [5, 6, 7]. Despite this, the significant factors hindering the introduction of this method of hardening into the production of parts for heavy-duty transport machines operating in an open active environment are the inconsistency of the available information and the lack of research on the effect of plastic deformation of a thin surface layer during PPD on its ability to resist fatigue and corrosion failure.

The purpose of this work was to evaluate the effectiveness of hardening of the ORD transporting machines made of alloyed grade steel grade 20KhGSA and its substitute 30KhGSA with glass microballs, and to develop a technology for the complex hardening of ORD with thin edges. To achieve this goal, the tasks of hardening the surface layer of the OSS with steel and glass balls in the optimal mode, assessing the quality parameters of the surface layer and testing them for fatigue and corrosion resistance were solved.

Experimental technique

As an object of research, we used serially manufactured ORD of transporting machines used in an open condition. Serial HRDs were processed with a bladed tool. After treatment with the latter, the roughness of the surface layer of the ORD was Rz = 0.16 μm. ORD are made of deformable alloyed grade steel 20KhGSA. This steel belongs to the group of single-phase (α) pearlite class alloys.

The chemical composition of alloyed grade steel grade 20KhGSA (Auremo) is shown in Fig. 1 [10], in Table 1.

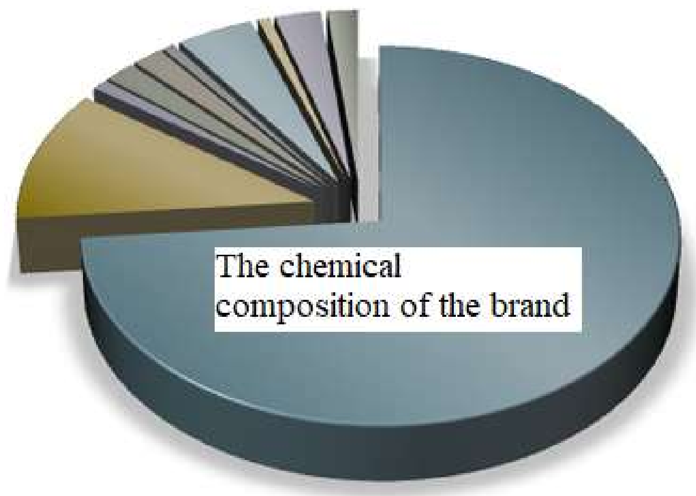


Fig.1. Chemical composition of alloyed grade steel grade 20KhGSA

Mass fraction of chemical elements of grade steel (data in%)

Table 1

Grade steel	Si	Mn	Cu	Ni	S	P	C	Cr
			до					
20 KhGSA	0,9-1,2	0,8-1,1	0,3	0,3	0,025	0,025	0,17-0,23	0,8-1,1

In the engineering industry, blanks come in the form of forgings and forgings. Long products, including shaped form: ГОСТ 4543-71, ГОСТ 2590-71, ГОСТ 2591-71, ГОСТ 2879-69, ГОСТ 10702-78. Of these, forged and forged blanks are standardized according to ГОСТ1133-71, ГОСТ4543-71. All standards belong to the Russian Federation.

The chemical composition, mechanical, technological and physical properties, machinability, temperature of critical points, and other information of alloyed grade steel grade 20KhGSA (Auremo) were given in tables 1,2,3,4,5.

Machine parts operating under wear and alternating loads, operating at temperatures up to 2000C, are made from 20KhGSA grade steel or 30KhGSA substitute,

The mechanical properties of grade steel grade 20KhGSA (Auremo) are listed in Table 2.

Table 2

Grade steel 20HGSA	Section, (mm)	Physical and mechanical properties of grade steel 20KhGSA				
		$\sigma_{0,2}$, (MPa)	σ_B, (MPa)	δ_5, (%)	ψ, (%)	KCU (kJ/m2)
State	15	640	780	12	45	69
Terma - treatment	Hardening 880^0C, oil. Vacation 500^0C, water or oil					

The mechanical properties of grade steel grade 20KhGSA (Auremo), depending on the tempering temperature, are listed in table 3.

Table 3

Grade steel 20HGSA	Section, mm (Samples)	Physical and mechanical properties of grade steel 20KhGSA				
		σ_B, (MPa)	δ_5, (%)	ψ, (%)	KCU (kJ/m2)	HB
State supplies	200	1520	9	49	59	420
	300	1470	9	52	59	400
	400	1340	8	50	49	360
	500	1080	10	50	78	325
	600	880	17	52	98	255
Terma - treatment	Hardening 900^0C, exposure after tempering 30 min, cooling in air					

Technological properties of graded steel grade 20KhGSA (Auremo).
Flexibility to plastic deformation: - inclined.
The temperature during processing by surface plastic deformation is 400 - 460, not more.
Weldability:
without restrictions RDS, KTS, ArDS, ADS submerged and gas-shielded, EShS - subsequent heat treatment is required.
Machinability:
with HB = 140 – 207, $K_{U\ \text{ТВ.СПЛ}}$ = 0,7 и $K_{U\ \text{б.СТ}}$ = 0,7

Propensity to release ability, prone.

Flock - a defect in the form of a rupture of the casting body under the influence of hydrogen dissolved in steel and internal stresses, passing completely or partially through the volumes of primary austenite grains.

Floken sensitivity, not sensitive. The temperature of the critical points of grade steel 20KhGSA (see table 4).

Table 4

Critical point	Ac_1	Ac_3	Ar_1
Temperature	755	840	690

The physical properties in relation to the density of grade steel 20KhGSA were given in Fig.5. in table

Table 5

Temperature tests, ^{0}C	20	100	200	300	400	500	600	700	800
Density	7760	7725	7700	7660	7640	7600	7570	-	-

A characteristic feature of the ORD transporting machines is the presence of a thin wall. Rounding radii at the edges of the cage R_1 and R_2 along the length vary from 0.008 to 0.120 and from 0.128 to 0.1 mm, respectively, the maximum thickness C_{max} – from 0.35 to 1.05 mm, respectively. At a distance of 1 mm from the edge to the other, the thickness of the clip C1 and C2 is in the range of 0.095 ... 0.02 and 0.077 ... 0.02 mm, respectively.

Hardening with steel balls of the ShKh15 brand with a diameter of 10 mm installed in a ball with a holding cap included in the details of a ball deforming tool, fixed in a tool holder of a lathe, the work was performed in optimal modes:

speed of rotation of the ORD n = 400 - 600 rpm;

longitudinal feed rate S_0 = 0.017 mm/rev;

efforts of the deformable force P = 800 N;

hardening time was determined by the formula $T_0 = L \cdot i / n_0 \cdot S_0$ min.,

where: n_0 – spindle speed with workpiece; S_0 – longitudinal feed speed; L – reinforcement length, 62 mm; *i* – number of passes per time (1, 2, 3).

Caricaturing with glass beads with a diameter of 4, 6, 8 and 10 mm, processing modes except for caricature force, $P_ш$ =10 H, as well as the previous paragraph, we carried out on a lathe the installations of the ORD in a collet chuck through an inner hole with a diameter of ø 62 mm, an outer diameter of ø 65 mm.

The surface roughness was measured using a Perthometr M3 electronic petrograph. The microhardness of the surface of the HRD processed by various methods was determined on samples cut from the 2X edges and the middle part of the HRD. Microhardness measurements were made on a PMT-3 device (Shora) with a load of 1N on the diamond pyramid. The value of microhardness was determined as the average value for ten indentations of the correct form.

The degree of hardening was calculated by the formula:

$$H = \frac{H_\mu^n - H_\mu^c}{H_\mu^c} \cdot 100\%$$

where:

H_μ^n – microhardness of the surface of the test sample, MPa;

H_μ^c – microhardness of the standard sample, MPa.

The surface layer during the processing of SPD parts is formed as a result of complex interrelated phenomena occurring in the deformation zone and adjacent zones: multiple elastic and plastic deformations, changes in the strength and plastic properties of the deformed metal, friction and thermal processes, changes in the macro- and microstructure, microgeometry of the surface itself and etc.

The study of residual stresses on the deformed layer of the ORD was carried out by a mechanical method developed by Acad. N.N. Davidenkov using the formulas from [9] for plotting.

To carry out X-ray diffraction studies, samples (standard) 20 mm long and 9 mm wide were cut out from the XRD. The samples had the following markings (see Table 4): H - sample at one edge of the ORD; C - the middle of the ORD; B - the other end. The survey was carried out in monochromatic radiation on a DRON-1 diffractometer with computer registration and data processing. Scanning was carried out with a step of 0.01 degrees. The width of the slots limiting the X-ray beam was 2 mm, and the height of the irradiated area was 12 mm. The degree of texture was evaluated using the parameter $k = I_{103} / I_{110}$, which is the ratio of the intensities of the diffraction line 103 (in the numerator) to the intensity of the line 110 (in the denominator). As an additional parameter, we considered $\varepsilon = I_{004} / I_{110}$, for which the numerator is the intensity of the 004 line, as fourth-order reflections from the (0001) planes, and the denominator is the intensity of the 110 line. The level of microstresses in the samples was estimated from the 213 α-phase line. At which it takes the form of a pearlite structure.

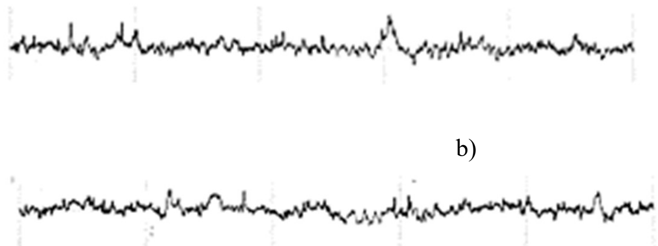
Steels with a perlite structure showed that they are well subjected to plastic deformation and cartooning with glass beads.

Fatigue tests were performed by the standard method on the basis of 100 million cycles by dynamic excitation of oscillations in them along the first bending form on an electrodynamic vibration stand VEDS-200. The HPS was tested in the resonant mode until a macrocrack 1–3 mm long appeared, which corresponded to a 2–3% drop in the frequency of natural vibrations.

Results and discussion

The magnitude of the roughness and the nature of the microrelief are one of the main characteristics of the surface layer, which have a significant impact on the level of technological stress concentration on the surface of the OSD (at the edges and in the middle). Separate risks, especially transverse scratches on the surface of the blades, may be the site of the initiation of fatigue cracks. The profilograms and surface roughness parameters, taken on an electronic digital device model ROTE 1001, are shown in fig. 2 and in Table 6 showed that the lowest numerical value of the roughness in terms of the Ra parameter was obtained on the surface of the ORD treatment and after cartooning with glass beads.

a)



x 1000 times.

b)

x 1000 times.

Fig.2. Profilograms of the surface layer of the roller track cage according to the processing sequence:
a) – roughness after rolling with ball deforming tools;
b) – roughness after cartooning with glass beads.

Roughness parameters of the surface layer of the ORD.

Table 6

Method processing	Initial (after cutting)	rolling (with steel balls)	Caricaturing (with glass beads)
Ra, мкм	0,33	0, 22	0,23

The Ra value decreased from 0.33 to 0.23 µm. The deterioration of the Ra value during caricature by 0.01 µm compared to knurling is that caricature does not leave deep scratches, and the surface gloss is reached to a glossy level. The type of relief takes on a form that has not yet been described.

Studies of microhardness have shown that after rolling, the microhardness is on average 4790 MPa, and after hardening with glass beads in the process of cartooning with 10N loads, the microhardness of the surface layer is 5320 MPa; the degree of hardening reaches 11.11%. It is characteristic that the microhardness changes insignificantly along the length of the surface of the ORD, within the limits of dispersion. It should be noted that compressive stresses reduce the level of alternating tensile stresses and also inhibit the process of fatigue crack initiation at the blade edges in the presence of operational damage. To assess the effect of hardening treatment on the stress state of the RDW, studies were carried out on the magnitude and nature of the distribution of residual stresses after each of the treatment methods (Fig. 5). Analysis of the results shows that after cartooning on a lathe after rolling, without changing, the mounting base, with glass beads, the level of compressive stresses increases on the surface from 378 MPa to 430 MPa, and the depth from 25 to 35 microns. A more intense force impact during combined processing leads to a significant increase in the depth from 25 to 55 µm, and a high level of residual compressive stresses remains at a depth of up to 20 µm, which should have a significant effect on increasing the fatigue resistance of the hauling machines.

A comparative study of the structural characteristics of the surface layers of the ORD made of 20KhGSA steel after rolling and subsequent cartooning of the outer surface with glass beads was carried out. The width of the processed surface layer was 62 mm, which was easily assessed visually, since after beading this surface stands out with an intense silvery color compared to the part of the surface after blade processing. The data obtained are shown in Table 7. The analysis of the obtained data (Fig. 2-4) allows us to note a significant change in the texture in the samples along the length of the surface of the XRD both after rolling and subsequent processing (characterization) with glass beads.

The number of grains with a basic orientation and a pyramidal texture component close to it increases. In the first extreme part of the ORD after rolling, k was 4.3 compared to the sample cut from the ORD, for which k plus caricature is 3.1. Similarly, the parameter ε increased from 0.6 to 1.9.

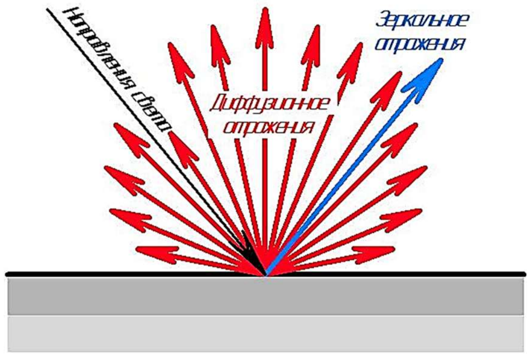


Fig.3. Gloss (gloss) - an optical characteristic of a surface property

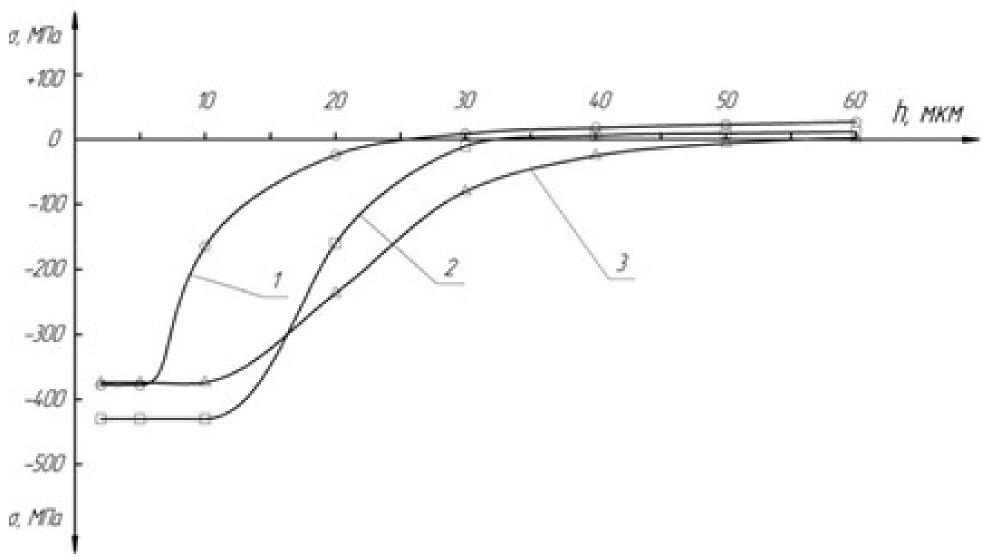


Fig. 4. Distribution of residual stresses after:

1 - rolling with steel balls, d = 10 mm;

2 - rolling with steel balls, d = 10 mm + cartooning with glass balls, d = 4 mm; 3 - rolling with steel balls, d = 12 mm + cartooning with glass balls, d = 6 mm.

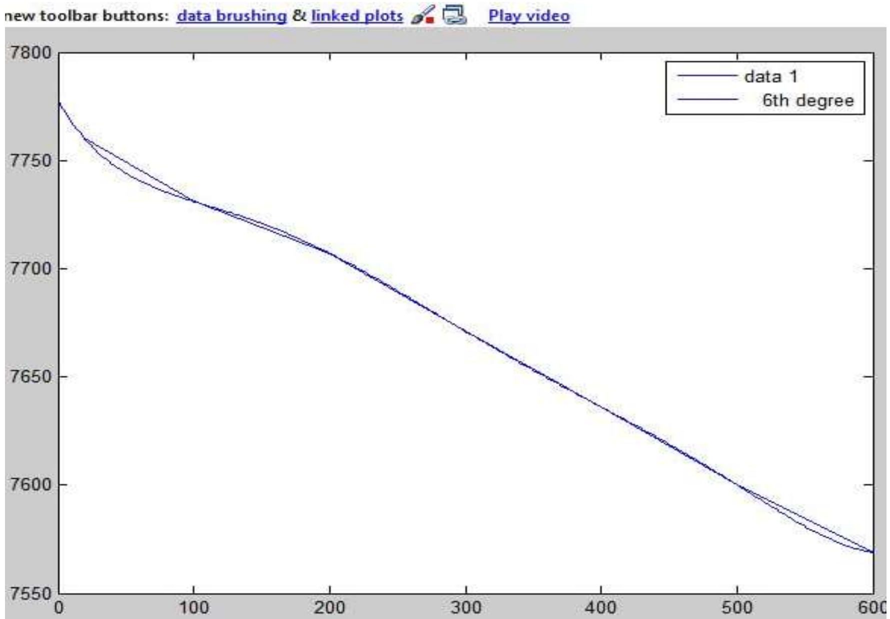


Fig. 5. Physical properties of grade steel 20KhGSA

$Y = 1{,}2\, e^{-0{,}13} \cdot X^6 - 2{,}3\, e^{-0{,}10} \cdot X^5 + 1{,}7 e^{-0{,}07} \cdot X^4 -$

- $6\, e^{+1{,}1} \cdot X + 7{,}8 e^{+0{,}03}$ - obtained using the MATLAB program allows you to specify changes in the density of the material with increasing temperature, see table 5.

Table 7 - Parameters k = I_{103} / I_{110} и ε= I_{004} /I_{110}, characterizing the texture-formation and line width103 (in degrees) after various types of treatments.

Table 7

Treatment	Rolling with steel balls			Caricature with glass beads		
Marking, plot sample clippings	*k*	*ε*	b, degr	*k*	*ε*	b, degr
Extreme part	4,3	2,9	0,99	3,6	1,9	3,087
middle part	4,2	2,88	1,66	3,4	1,83 00,037	2, 99
Other extreme part	4,1	2,87	1,53	3,5	1,78	3,01

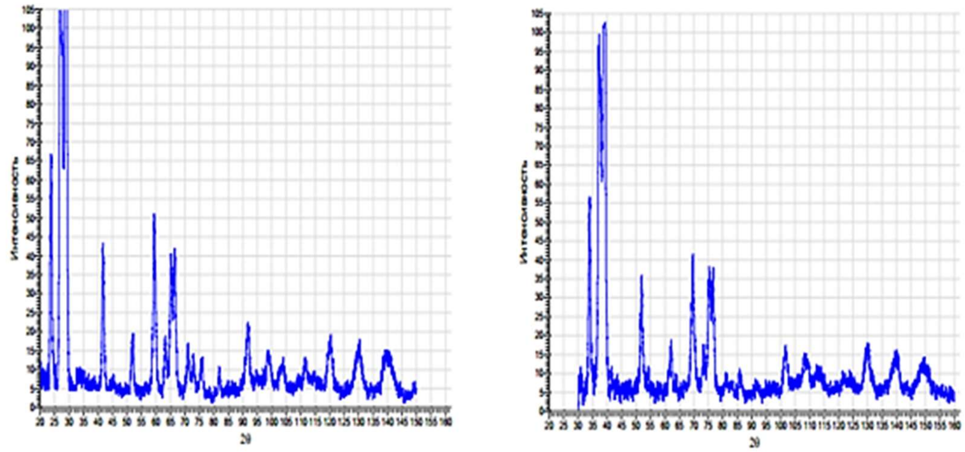


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Fig.6. Diffraction patterns taken from the first edge of the sample surface (H), after rolling (A) and rolling + cartooning with glass beads (B)

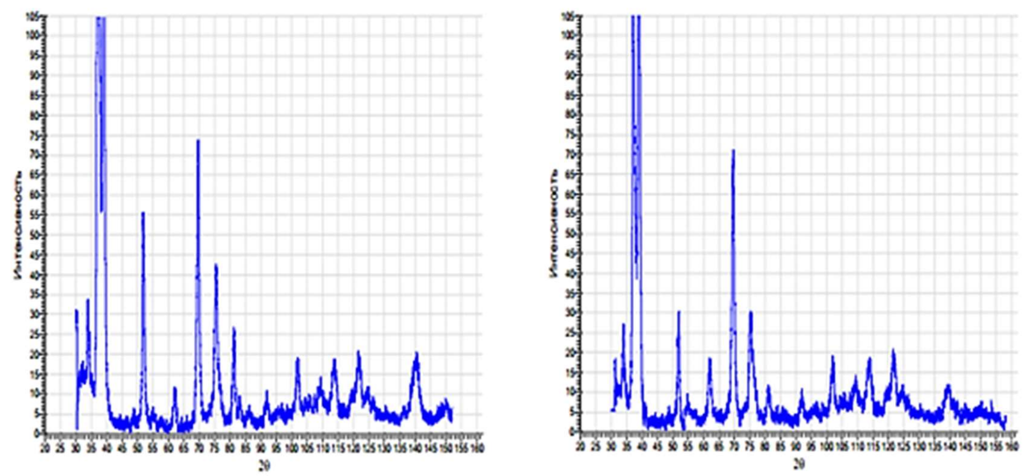

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Fig.7. Aperture taken from the middle of the surface of the ORD (sample C), after rolling (A) and rolling + cartooning with glass beads (B)

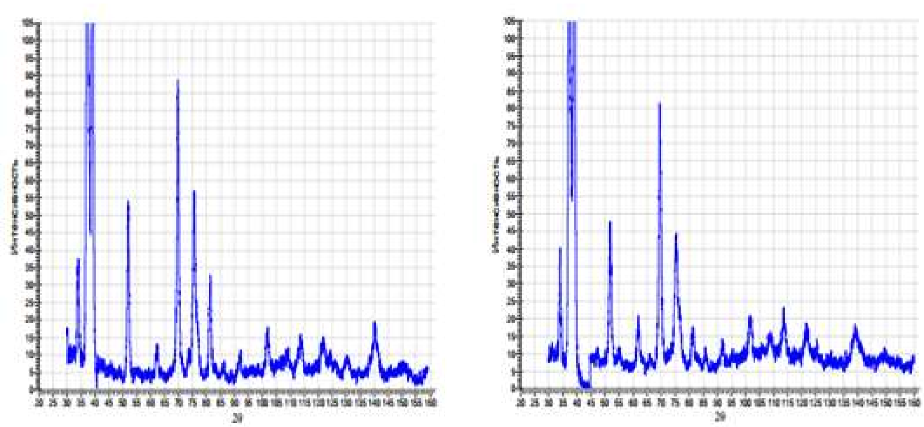

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Fig.8. Diaphragm taken from the other edge of the surface of the ORD (sample C), after rolling (A) and rolling + cartooning with glass beads (B)

A possible explanation for the observed variable parameters *k* and *ε* occur in the structure during the formation of the profile and and the shape of the ORD. The upper part of the ORD was subjected to more deformation, therefore, an increase in the dislocation of grains oriented by the (0001) and pyramidal (3110) basal planes is observed compared to sample H at the ORD root, for which k = 3.6 and ε = 1.9. The same state of change in the parameters k and ε does not change after processing with balls. The decrease in the absolute values of the parameters k and ε is apparently related to the scale factor, since the steel balls were rolled directly into edges about 3.0 mm wide. It should be noted that there is a minimal difference in the nature of the change in the parameters k and ε, i.e. convergence of their values along the length of the ORD (parameter k increased from 4.3 to 3.6, and ε - from 2.9 to 3.3). When cartooning with glass beads, additional deformation occurs with the involvement of grains oriented by 2011 prismatic planes on the subsurface layer. .

The data for determining the width of the diffraction line (213) are also given in the table. After processing with balls, the line width increases for all three samples cut from different parts of the ORD. The latter indicates significant changes in the structure of the surface layer, when the number of defects increases during deformation, the dislocation structure becomes more complex and, as a result, the level of microstresses increases. In the upper part of the blade, their value is somewhat less, which is also confirmed by the previously obtained values of macrostresses measured by the mechanical method, when a decrease in the level of compressive stresses was observed with a decrease in the thickness of the sample. It is known that the expansion of a plastically deformed surface layer with a small specific volume is prevented by an elastically deformed core. If the sample thickness decreased, then the resulting level of compressive stresses decreased. Apparently, a similar picture was observed in our case.

To assess the effectiveness of the hardening treatment, fatigue tests were carried out according to the standard (Nb = 100 million cycles) of serial ORD, at the finish cartoonized with glass beads and processed by the complex method: rolling (T_0 min) + cartooning with glass beads.

It has been established that hardening of the surface layer by caricaturing with glass beads leads to an improvement in the endurance limit by up to 30%, and by rolling + caricaturing with glass beads by up to 35% by other methods, for example, final honing or vibration polishing, which ultimately contributes to an increase in the bearing capacity of the ORD of transporting machines.

Table 8 - Results of tests for fatigue of the OSA after cartooning with glass beads.

Table 8

ORD code	Test stress, MPa	Number of cycles, mln.	Note
O 11	480	100	F.e.
O 10	500	100	F.e.
O 7	520	100	F.e.
O 1	550	100	F.e.
O 12	600	100	F.e.
O 14	620	58	Res. by input cr. L=22mm
O 24	600	100	F.e.
O 25	620	40,5	Res. by input cr. L=22mm

Table 9 - Results of tests for fatigue of the OSA after rolling + cartooning with glass beads

Table 9

ORD code	Test stress, MPa	Number of cycles, mln.	Note
O 111	520	100	F.e.
O 110	550	100	F.e.
O 77	600	100	F.e.
O 11	650	27,4	Res. by input cr. L=31mm
O 120	620	100	F.e.

O 140	630	100	F.e.
O 204	630	55,6	Res. by input cr. L=22mm
O 205	620	100	F.e.

Conclusion:

1. Thus, caricaturing with glass beads is not a big effort, P_{III} =10H surface layer, after rolling with ball deforming tools, it ensures the formation of favorable characteristics of the surface layer and without the formation of overhardening, successfully detects microdefects of the surface layer formed at the previous stages of the technological pass, and is also accompanied by a noticeable increase in the endurance limit and does not require subsequent fine-tuning by manual polishing.

2. The developed technology for the complex hardening of the surface layer of the ultrasonic-separation machine for transporting machines, including sequential processing with steel and glass balls, is an effective finishing operation that allows you to provide a given service life of the ultrasonic-separation machine and increase the load-bearing capacity, such as endurance parameters and resistance to abrasive and corrosion damage.

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