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Hardening of a Surface of Teeths of the Drive of Spherical Mills to Methods Superficial and Plastic Deformation (Technique and Experiment)

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Abstract: In article on the basis of the analysis of dynamic methods of finishing - strengthening processing of surfaces plastic deformation suggested a technique of hardening of a surface of cogwheels of the drive of spherical mills. Experimental works on superficial and plastic deformation of a surface of a shaft from steel of 35L are performed. Researches were carried out on the lathe with various modes of processing speed of rotation of preparation, effort of pressure of an roller and feed speed. During experimental works, parameters of surface hardness and roughness were registered. Surface hardness was measured up to the depth of 2 mm. On the basis of the experimental data, graphs with the above mentioned parameters are represented.

Key words: Hardening · Surface - plastic deformation · Finishing-strengthening processing · Cogwheel · Tension · Roller · Roughness · Hardness

INTRODUCTION

To increase service life of the drive of a spherical mill, it is necessary to considerably increase the hardness of a surface of teeths of the driving and conducted gear wheel mounted on the frame (cowling) of a drum of a spherical mill. One of perspective ways of hardening is the surface - plastic deformation (SPD).

In recent years, in metal-working technology, dynamic methods of finishing-strengthening processing of the surface-plastic deformation (SPD) among which the important place is taken by finishing-strengthening processing of details by a multicontact vibropercussion instrument were widely adopted [1].

Distinguish the static, shock, vibration and ultrasonic surface - plastic deformation (SPD). Rollers, balls, fraction, etc. are used as working items. SPD can be carried out by several methods of processing (combined SPD) or it is consecutive also several methods (combined SPD) [2].

Processing of machine parts by surface -plastic deformation is one of the simplest and effective methods of hardening. Surface-plastic deformation increases the fatigue strength, contact endurance and wear resistance of details and, thereby, increases durability of machines and equipment. As a result of surface-plastic deformation the microstructure and physic-mechanical properties of the top layer of metal change: its hardness and strength increase, there is favorable squeezing residual tension. The roughness of a surface becomes lower.

The most effective is a local hardening of SPD of areas of stress concentrators which is much more productive and cheaper than universal.

For increase durability of an open gearing on wear, as well as the contact durability of teeths, it is necessary to increase the hardness of their working surfaces. On the other hand, increase of hardness of working surfaces of teeths reduces speed of their burn-in and leads to long work at significant unevenness of load distribution on the length of contact lines that reduces the fatigue strength of teeths. Nevertheless, world leaders on production of drum mills equip its with the open tooth gearings having hardness of working surfaces of gear teeths according *to* $HB1=550\text{-}600$, $HB2 = 230 - 305$ that considerably exceeds a similar indicator for the mills made in Russia and in Ukraine, where $HB1=260\text{-}300$, $HB2=180\text{-}200$. Thus, to create a competitive drum mills and ensuring their reliable operation it is necessary to find reserves for reducion of bending stresses in the dangerous section of tooth of open transfer [3].

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For experimental studies, standard methods of planning and processing of experimental data and also statistics theories were used [4-8].

The analysis of methods of hardening of a surface of teeths is carried out by the various methods of SPD with the purpose of selection of the technologies of hardening of a tooth gearing of the drive of a spherical mill, the most effective blasting processing method was taken for the basis allowing to increase surface hardness for 30 - 40%, this will have a positive impact on increase of operation resource of the gear drive. As a modeling method of processing was adopted surface-hardening deformation by a ball (roller) at which cold hardening forms on a detail surface and the residual stresses develop in it and the depth of the strengthened layer is identical to shot peening.

Number of experiments were made to determine the main parameters of a roughness of Rz from effort P appendics of the calibrating-rolling tool (a roller or a ball) to the blank executed in the form of steel shaft 35L, parameters of hardness of HB surface of a blank from S supply at various P efforts and promptness *п* during running-in by a ball, parameters of hardness of HB surface of a blank from promptness *п*, parameters of change of HB hardness by depth of the strengthened layer.

The detail (Figure 1) made from steel 35L, is clamped in the three-jaw chuck with drawing in from the center of poppethead then is exposed to rotation using roller with ball (Figure 2, a) and roller (Figure 2, b) tips, processing of detail steps is made at various modes (effort on an roller P, H, rotation speed *п*, rpm, S supply, mpr).

Measurement of surface hardness were registered on the TK-2M model device, roughness measurement – on the profilograph P-154 (Figure 3).

The purpose of the research is to establish the characteristics of the surface layer, i.e. hardness from regime parameters (P, S, n).

The Technique of Work Consists in the Following:

- To install blank in the machine centers, a lathe tool – in a tool-holder of a support.
- For experiments, Turn five areas (steps) of the blank with one installation of cutting modes.
- To measure diameters of all five sites using a caliper.
- To measure the average arithmetic profile hardness deviation (on HB) on all pierced areas before run- in.
- To measure the average arithmetic profile roughness deviation (on R_z) on all pierced areas before run- in.
- To fix the blank in the machine centers and roller install in in a tool-holder (Figure 4).

Fig. 1: Cylindrical sample in the form of a shaft

a) The ball b) The roller

Fig. 2: Roller

Fig. 3: Devices for hardness and roughness measurement

Fig. 4: Scheme of roller work

- To install run-in modes for each site separately.
- To install run-in effort of for the first corbel. For that, to bring roller to a contact with a ball surface of the first corbel and to make supply on 0,05 mm with rotation of the load screw. To run-in a corbel for one trip. To repeat mentioned techniques for remaining areas, consistently changing support of S run-in, keeping effort P and promptness п without changes.

Table 1: The summary table of experimental data after ball run-in

No.experiment	Diameter of a shaft before run-in, mm	Shaft HB before run-in	Rz before run-in	*S*, mpr	*n*, rpm	*P*, kg	Diameter of a shaft after run-in, mm	Shaft HB after run-in	Rz after run-in
1	36,69	153	20	0,05	224	20	36,49	184	7,5
2	36,69	153	20	0,06	224	20	36,51	184	7,5
3	36,69	153	20	0,075	224	20	36,49	184	7,5
4	36,69	153	20	0,09	224	20	36,51	184	7,5
5	36,69	153	20	0,1	224	20	36,49	184	7,5

Table 2: The summary table of experimental data after ball run-in

HB after run-in and removal of 0,1 mm	*HB* after run-in and removal of 0,3 mm	*HB* after run-in and removal of 0,8 mm	Removed a layer of metal, mm	*HB* after run-in and removal of metal	Removed a layer of metal, mm	*HB* after run-in and removal of metal
177	176	172	1,4	169	1,6	158
177	176	172	1,2	169	1,8	158
177	176	172	1,0	169	2,0	158
177	176	172	0,8	169	-	-
177	176	172	0,6	170	-	-

Table 3: The summary table of experimental data after ball run-in

No. experiment	*S*, mpr	*n*, rpm	Diameter of a shaft before second run-in, mm	Shaft HB before second run-in	*S*, mpr	*n*, rpm	*P*, kg	Diameter of a shaft after second run-in, mm	Shaft HB after second run-in	R_z, after second run-in
1	0,05	900	31,0	153	0,5	630	40	31,0	160	4,5
2	0,05	900	31,0	153	0,4	450	40	31,0	160	4,5
3	0,05	900	31,0	153	0,3	315	40	31,0	160	4,5
4	0,05	900	31,0	153	0,2	224	40	31,0	160	4,5
5	0,05	900	31,0	153	0,1	160	40	31,0	167	4,5

Table 4: The summary table of experimental data after roller run-in

No. experiment	Diameter of a shaft before run-in, mm	Shaft HB before run-in	*S*, mpr	*n,* rpm	*P*, kg	Diameter of a shaft after run-in, mm	Shaft HB after run-in	Rz after run-in
1	30,5	153	0,1	630	40	30,5	160	5,0
2	30,4	153	0,1	450	40	30,3	158	5,0
3	30,3	153	0,1	315	40	30,3	157	5,0
4	30,0	153	0,1	224	40	30,0	157	5,0
5	30,3	153	0,1	160	40	30,3	157	5,0

- To run-in with the ball all five areas with various S supply speed.
- To measure diameters of corbels, HB hardness and Rz roughness of its surface on all areas, to register results in Table 1.
- To remove 0,1 mm of a metal layer from blank, to measure HB hardness, to repeat measurements of hardness when remove 0,3 mm, 0,8 mm, 1,2 mm, 1,6 mm, 1,8 mm, 2,0 mm, 2,2 mm of the metal layer.
- With supply of *S = 0,05 mpr* and promptness n=900 rpm to treat the blank for further experiments. To measure the diameters, hardness of HB surface.
- To make the run-in with the ball with various S supply speed, promptness п and keeping effort P.
- To measure diameter of a shaft, HB hardness, Rz roughness.
- All received results after running-in with ball, to register in Tables 1, 2 and 3.
- For experiments, To turn the blank with the calibrating-rolling tool with roller tip.
- To measure shaft diameter and hardness of HB surface.
- To run-in with roller with fixed S supply and P effort, but with various promptness *n,* Figure 5.
- To measure shaft diameter, HB hardness, Rz roughness.
- All received results after running-in with a roller, to register in Table 4.

In the result of experiment, there were formulated following graphs: Rz = f (P); HB = f (S); HB = f (n); HB = f (h); = f (T).

Fig. 5: Scheme of work of a roller

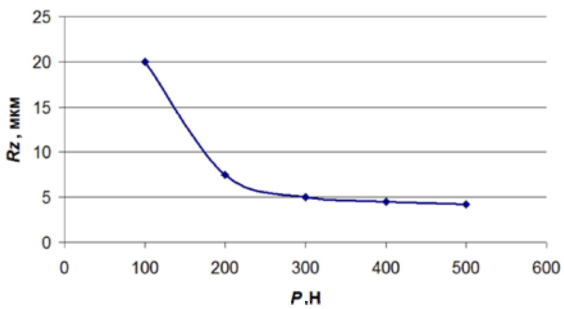

Fig. 6: Schedule of dependence of Rz roughness of blank surface from P effort pressing of the tool

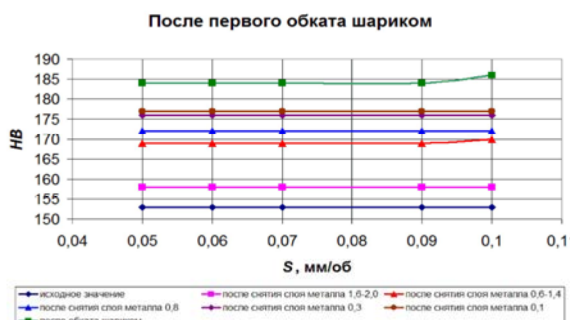

Fig. 7: Schedule of dependence of HB hardness of blank surface from S supply at P effort =200H, n=224 rpm at ball run-in

In Figure 6 there was presented the schedule of dependence of Rz roughness of blank surface from P effort pressing of the tool that shows that with increase of radial effort of roller, the Rz roughness of blank surface decreases.

In Figure 7 there was presented the schedule of dependence of blank surface HB hardness from S supply at P effort = 200H, n = 224 rpm at ball run-in on which

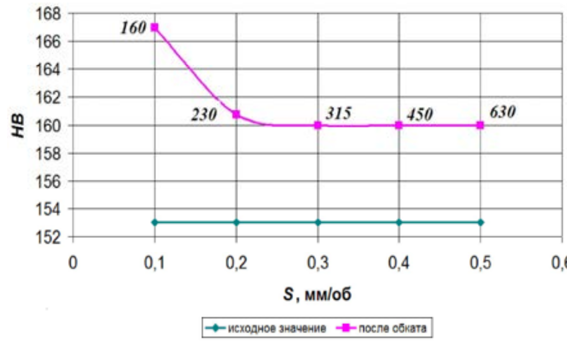

Fig. 8: Schedule of dependence of blank surface hardness from supply at P effort =400H tool, n=160-630 rpm at ball run-in

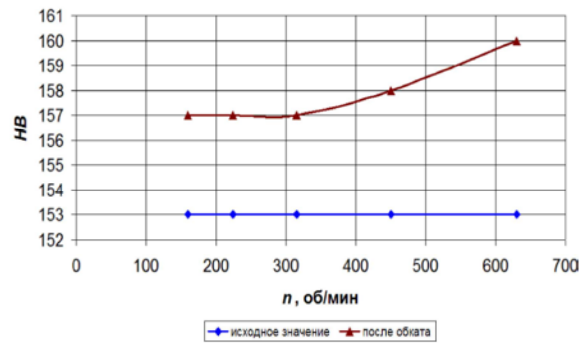

Fig. 9: Schedule of dependence of HB hardness of blank surface from promptness n at effort by the tool P=400H, S=0,1 mpr at roller run-in

surface hardness is shown with reference value HB=153. Surface hardness is HB = 184, i.e. the increase was on 31 units. 0,1 mm was removed from blank surface, HB hardness - = 177, at removal 0,3 mm of metal layer – HB hardness = 176, at removal 0,8 mm of metal layer - HB hardness = 172, at removal of 0,6 - 1,4 mm of metal layer, hardness - HB = 169 - 170, at removal of 1,6 - 2,0 mm of metal layer - HB hardness = 158.

In Figure 8 there was presented the schedule of dependence of HB hardness of blank surface from S supply at P effort by the tool = 400H, n = 160-630 rpm at ball run-in. On graphics it is shown that at constant P effort and various promptness n, the HB hardness of blank surface increases.

In Figure 9 there was presented the schedule of dependence of HB hardness of blank surface from promptness n at P effort by the tool = 400H, S = 0,1 mpr at a roller run-in. Before experiment there was measured the hardness of a surface HB = 153, after roller run-in at constant values of P and S, but at various values n, change of hardness of blank surface to HB = 160 is noticeable.

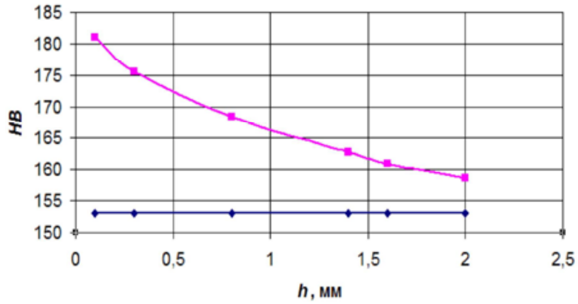

Fig. 10: Schedule of dependence of change of HB hardness of blank along the depth Δ

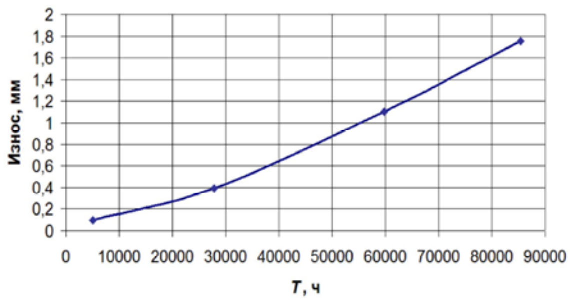

Fig. 11: Schedule of dependence of wear value of a spherical mill cogwheel from T operation time

In Figure 10 there was presented the schedule of change of HB hardness of blank along the depth Δ (a reference value of HB = 153). Regression equation: y=5.1*x2- 23*x+190.

In Figure 11 there was presented the schedule of service life of a cogwheel of a spherical drum mill it shows that the more the term of operation of a cogwheel of a spherical drum mill, the more its wear.

Summary: Increase the hardness of a teeth gearings surface of spherical mills drive on HB = 31 units increases the hardness of teeth surface to 22% of the initial. Àccording to experimental data of spherical mills operation in production, drive service life can be increased by 30-40%. Analyzing the results of experimental research, the following conclusions can be drawn:

- With increasing pressure of roller with a ball tip within P=200-400H, the Rz roughness of a surface decreases to 5 microns;
- With set modes of run-in with ball tool, the depth of the hardened layer was 2 mm and the hardness of the surface layer *HB* = 184 units at *P* = 200H, *HB* = 167 units at *P* = 400H.
- At roller run-in – HB = 160 units;
- Service life of gears with wear limit 2 mm makes– 150.000 hours and with using recommended technology of a teeth gearing burn-in, blasting processing and using of Lubricating coolant for hardening of the friction surface and decrease the friction coefficient, service life of gearing can increase twice.

CONCLUSIONS

The technique of experiments by determination of surface hardness was worked out, all results were registered in tables according to which respective schedules of dependencies were drawn up.

Increase the hardness of a teeth gearings surface of spherical mills drive on HB = 31 units increases the hardness of teeth surface to 22% of the initial. Àccording to experimental data of spherical mills operation in production, drive service life can be increased by 30-40% and on assumption of realization of invention with using blasting process increases in to times.

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