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Promoting Contact Strength of Steel by Rolling

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Abstract—The article deals with findings of experimental research on the running-in process of steel pieces with rollers that harden the contact strength. The hardening effectiveness of steel pieces physically simulates the bearing strain process, the physical and mechanical properties of the surface layer and its microstructure, and the diffusion of chemical elements by surface deformation using the chemical microanalyzer. The method and technology of running-in steel pieces of complex profile with the wedge roller and the device for the process implementation are developed. The findings are demonstrated for the adaptation of novel technology to production.

Keywords: surface plastic deformation, contact strength, rolling, wedge roller

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INTRODUCTION

During operation in steel pieces of machinery, equipment and design elements, the fracture begins mostly by the surface wear, fatigue, contact interaction, etc. Therefore, in many cases, the reliability and durability depend on the quality, strength, and stress-strain state of the surface metal. The contact stresses and deformation are the main factors that govern the pattern and wear rate of machinery. The easiest and most available, and often the most feasible, hardening method is the surface cold plastic deformation. The surface hardening of the layer of responsible metallic pieces is achieved by the surface plastic deformation when rolling or die stamping. To improve the marketable look and wear resistance of the surface layer are achieved by pure surface plastic deformation and work hardening to relieve fatigue. The effective industrial application of the surface plastic deformation was enabled by B.M. Braslavsii [1], I.V. Kudryavtev [2], D.D. Papshev [3], L. M. Shkolnik [4], and others who scientifically established this processing method. By managing the surface-layer properties during rolling running-in, it is possible to achieve the needed contact strength and the durability of steel pieces can be achieved.

METHODS AND RESULTS

To study the bearing strain contact of steel pieces, a standard wear MI appatus and a vertical lathe were used. The cylindrical roller-specimen contacts the conical roller-standard with an angle at the top $\alpha = 4$ (Fig. 1). The angle was selected taking into account the possible scewing of real machinery pieces in operation. In the process of tests, the edge crumpling, which forms a flat face on the cylindrical surface of the roller specimen during testing was used. It has a width that is inversely proportional to the wear resistance to crumpling. It was measured with an MPB-2 counting microscope with an accuracy of 0.05 mm without removing the specimen from the machine after it stops. The reference conical rollers were made from KhVG steel with hardness *HRC* 58–62.

The needed angle $\alpha/2 = 2$ was achieved by polishing of a series of specimens at a single adjustment of the polishing lathe. The roller specimens were made from 20, 25L, 35L, 40, and 34Kh1M steels.

The specimens were run-in with a single roller turning lathe (the roller diameter equals 60 mm) that

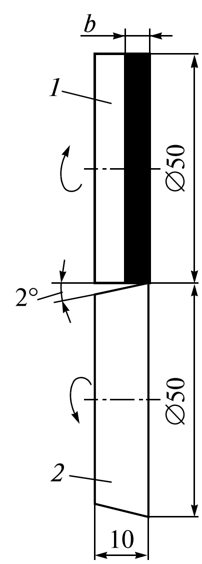

Fig. 1. Scheme for testing wear specimens.

has a spring appliance at a speed of 12 m/min per pass. the running-in conditions of rollers were selected according to the method described in [5].

Before testing, a metallographic study of the specimens was performed to determine the microstructure. The structure of steels 20, 25L and 40 is perlite on the ferrite base. The running-in makes the grains elongated (rippling). The surface clearly shows the plastic deformation traces. The structure of 34Kh1M steel contains sorbite and austenite debris of the second stage without any plastic deformation traces, which is explained by the insignificant promotion of the hardness of specimens during hardening.

The hardness of specimens was measured by the Vickers method with a KhPO-250 instrument under a load of 0.10 kN (*HV*10) at the end faces after fine finishing. The relative gain of the surface hardness and the depth of plastic deformation propagation is presented below. The calculated depth of plastic deformation propagation was determined with by the following formula by S.G. Kheifets [6]:

$$t = \sqrt{\frac{P}{2\sigma_y}}, \quad (1)$$

where P is the running-in force, kN, and σ_y is the steel yield limit, kN/mm^2.

The actual depth was rated by the start of *HV*10 changes in the specimen cross section.

Steel grade	20	25L	25L	35L	35L	40	40	34Kh1M
Running-in force, kN	12.00	12.00	1.20	10.00	1.80	8.00	0.50	12.00
Surface hardness *HV* 10, MPa :								
original	158	151	151	188	188	200	200	366
after rollling running-in	235	266	198	272	232	253	236	405
Relative hardness augmentation, %	48	76	31	45	22	27	18	11
Plastic deformation propagation depth, mm:								
estimated	4.4	4.47	1.41	3.9	1.64	3.27	0.82	2.32
actual	5.0	6.0	1.76	4.4	2.3	4.0	0.9	3.0

The highest relative gain hardness is observed among steels with ferrite–perlite structures. The tests were conducted during frictional rolling with a driving reference roller. The rotation speed of the specimen roller was 31.4 m/min (200 cycles per minute), the force on the specimen was 1.00 kN, and the lubrication was with the motor oil. The criterion for estimating the contact strength of the specimen on the crumpling edge was the number of test cycles when the width of the contact belt reaches a set value. This criterion characterizes the tendency to harden.

In our case, the tests completed when the width belt reached 5.5 mm at a minimum of three measured points. The findings during the tests of the specimens run-in under different conditions and the number of cycles N are shown in Fig. 2. The specimens run-in under pure conditions (curves *3*, *5,* and *7*) show an insignificant contact strength gain in crumpling versus non run-in conditions. It is explained by a small hardness gain of the specimens and the insufficient depth of plastic-deformation propagation. The run-in of specimens under hardening condictions have shown a considerably higher durability during crumpling versus the non run-in ones. There is an apprant relation between the hardening effectiveness of the specimens as they become harder when run-in. Thus, the specimens made from 25L steel (Fig. 2b) with the maximum hardness gain had become four time more durabile, the specimens made from 40 steel (Fig. 2d) with the lowest hardness became harder by only 1.9 times.

A particularly high effect of the hardening rolling is observed among the cast 25L and 35L steels and low carbon steel 20. It is due to the strength gain and the hardness due to the predominating ferrite in their structure. Among the cast steels, this effect augments due to the softening of cast pores and cavities. The insignificant hardening effect of 34Kh1M steel (Fig. 2e) can be explained by the high orignal hardness (*HB* 329) and a fine grain sorbite structure, a low tendency to work hardening. This structure was obtained as a result of steel heat treatment.

When testing the specimens for the wear mechanism, the rotaing surfaces come into contact, while in most cases, the inner edge of the bushing crumples due to the skewing of harder shafts. The tests for rolling hardened bush specimens from 25L and 34Kh1M steels were conducted with the vertical lathe under conditions close to the operating conditions of shafts and bodies.

Information about the relative gain in surface hardness after rolling and the depth of the propagation of plastic deformation is presented below:

Steel grade	25L	34 KhN1M
Hardness, *HV* 10, MPa:		
Original	148	207
After running-in	215	248
Relative hardness augmentation, %	45	19
Plastic deformation propagation depth, mm:		
Estimated	12.7	6.7
Actual	13.5	7.0