THE INFLUENCE OF IMPULSE HARDENING ON THE WEAR RESISTANCE OF SCH21-40 GRAY IRON IN AN OIL-ABRASIVE MEDIUM

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One of the most promising methods of surface hardening of machine parts is impulse treatments, including mechanical-ultrasonic, friction hardening, electrohydroimpulse, and others. The influence of these treatments on the wear resistance of rubbing pairs, especially in an oil-abrasive medium, has been insufficiently studied. The purpose of this work is an investigation of the influence of impulse hardening of SCH21-40 iron on its wear resistance.

Rings with a diameter of 40 mm and a width of 10 mm were hardened and inserts with a contact area of 2.0 cm² were ground with a synthetic corundum wheel. The wear-resistance tests (iron on iron) were made on MI-1M wear-test machines with a rate of sliding of 0.9 m/sec and specific loads from 0.75 to 6.0 MPa in an oil-abrasive medium (I-30A oil + 0.1% abrasive with a particle size up to 20 µm) using the method of [1, 2]. The friction-hardening treatment [3] was done on a lathe with a disk of hardened and low-temperature-tempered 40Kh steel with a diameter of 190 mm and a working portion width of 14 mm. The treatment conditions were circumferential speed of the disk and the part, respectively, 65 m/sec and 0.05 m/sec, longitudinal feed 2.27 mm/rev, and transverse feed (depth of the cut) 0.2 mm. The treatment was done in a single pass with an abundant supply of I-30A mineral oil to the contact zone.

Mechanical-ultrasonic treatment [3] was done with the use of a UZG-10-22 generator. The ultrasonic oscillations were delivered to the zone of contact by a PMS-15A-18 magnetostrictor with acoustic feedback and equipped with a tip of 40Kh steel in the form of a conical rod, the lower portion with a radius of curvature of 5 mm of which was reinforced with a bar of T30K4 hard alloy. The treatment conditions were circumferential speed of the part 0.42 m/sec, longitudinal feed 0.07 mm/rev, force for clamping the tool to the treated part 200 N, one pass, and without cooling.

Electrohydroimpulse treatment [4] was done in a production tank filled with distilled water. The negative electrode was the samples being hardened. The positive electrode was located perpendicular to the samples at a distance of 15 mm from the surface being hardened. Such an interelectrode spacing provided the greatest area of treatment and satisfactory quality. The treatment conditions were operating voltage 30 kV and capacitance of the condenser battery 12 µF.

For comparison other treatments were used; high-frequency induction hardening, roller burnishing, and high-frequency induction hardening with subsequent friction hardening. The high-frequency induction hardening was done on a type LZ-208 unit with water cooling. The depth of hardening was 3-4 mm and the hardness
Rockwell C 40-45. Roller burnishing (roller diameter 40 mm, radius of the profile 5 mm) was done on a three-roller attachment with a load on the roller of 200 N, a circumferential speed of the samples of 0.17 m/sec, and a feed of 0.097 mm/rev. The surface roughness did not exceed \( R_d = 0.52 \mu m \).

The tests showed that in roller burnishing the microhardness of the surface layers increased to 4.0 GPa at a depth of not more than 80 \( \mu m \), while phase transformations in the iron were absent. The impulse treatments create a specific structural and stressed condition and the metal acquires valuable physicomechanical properties. The thickness of the structure formed (Fig. 1) after mechanical-ultrasonic treatment was 35-40 \( \mu m \), after friction hardening 50-80 \( \mu m \), and after electrohydroimpulse treatment 80-100 \( \mu m \) (the thickness of the hardened layer obtained by mechanical-ultrasonic and electrohydroimpulse treatments was determined after grinding of irregularities and spatters). The microhardness of these layers after mechanical-ultrasonic and electrohydroimpulse treatments was 6.8-7.2 GPa and after friction hardening 6.5-6.8 GPa with 1.9-2.2 GPa for the original structure. It should be noted that the least roughness of the hardened surface is found after friction hardening (\( R_d = 0.48-0.56 \mu m \), class 8). After grinding with a synthetic corundum wheel it was higher (\( R_d = 0.72-0.79 \mu m \)). Since after mechanical-ultrasonic treatment the surface becomes flaky with irregularities of 0.1-0.15 mm and after electrohydroimpulse treatment it has spatters to 0.4 mm, before wear resistance testing all of the samples were ground, removing a layer up to 0.4 mm thick. A characteristic feature of the white layers created by the investigated methods is the fact that the residual austenite content in them increased. For example, the quantity of \( \gamma \)-Fe after friction hardening is 30-32\%, and with distance from the surface it steadily decreases. The dislocation density in the white layer increased to \( 2.9 \times 10^{11} \) cm\(^{-2} \). In a good-quality white layer there are always residual compressive stresses, which in the case of iron are as high as 580 MPa.

Since gray iron contains an increased quantity of carbon (in our case 3.56\%) and manganese (0.95\%), its microthermal emf has a negative value of 13-14 \( \mu V/\degree C \). The microthermal emf of the white layer is shifted in an even more negative direction and is 16.5-17 \( \mu V/\degree C \), which may be explained by refinement of the structure, the formation of finely dispersed austenite, and a change in chemical composition of the metal.

The presence on the surface of the iron samples of a continuous white layer increases their wear resistance in oil-abrasive wear. For example, in friction with a specific load of 4.5 MPa the wear of samples with a white layer obtained by friction hardening decreased by 3.5 times, with that created by mechanical-ultrasonic treatment by 3.0 times, and with that occurring as a result of electrohydroimpulse treatment by 2.8 times in comparison with the wear of samples without the white layer (Fig. 2). It is characteristic that the wear of the ground inserts of the same iron decreases by almost as many times as that of the rings operating in the pair. An interesting picture is observed in the wear of rings after mechanical-ultrasonic treatment with a discontinuous white layer. Wear both of the rings and of the inserts decreased by 10-20\% in contrast to that of the unhardened. This may be explained by the fact that abrasive entering into irregularities is not carried away but is pressed into the basic structure of the metal between portions of the white layer and operates as emery.

High-frequency induction hardening and roller burnishing also provide some increase in wear resistance in the oil-abrasive medium but significantly less than a white layer. For example, after high-frequency induction hardening the wear resistance of the rings increased by 1.4 times and after roller burnishing by 1.2 times, while that of the inserts increased by 1.5 and 1.4 times, respectively (Fig. 2). The greatest increase in wear resistance was found after combined treatment (high-frequency induction hardening and then friction hardening). The wear both of the hardened rings and of the ground inserts operating in the pair decreased by