The main quality characteristics of loaded mobile joints are their reliability and longevity, which are largely determined by the operational properties of construction materials that depend on the characteristics of mechanical properties (hardness, wear resistance, fatigue strength). The surface layer is the object, starting from which, the destruction of the part starts. Therefore, the technical solution of the problem of increasing the reliability and longevity of articles is associated with the production provision of the quality of their surface layer, in which the main deformational and physicochemical processes are implemented with their contact interaction.

Existing traditional technologies of fabrication and strengthening the surface layers of highly loaded details made of heat-resistant steels, including important details of turbine construction and engines, cylinder sleeves for internal combustion engines, gear wheels, and various details of complex configuration, need improvement. An improvement in the quality of parts can be achieved due to the development of new technologies of thermal and chemical-thermal treatment. They are based on the activation of diffusion saturation, ensuring the bulk and finely dispersed surface state of construction materials, which is achieved by the methods of preliminary intense force and the thermal effect and subsequent chemical-thermal treatment.

This study is aimed at the provision of requirements for increased hardness, wear resistance, and contact endurance limits for steels VKS-7 and VKS-10 found experimentally in various test conditions are presented. Characteristics of mechanical properties of heat-resistant steels are improved by the use of the new complex technology of thermal and chemical-thermal treatment based on the formation of a finely dispersed structure during hot deformation and activation of diffusion saturation during ion-plasma nitriding.

MATERIALS UNDER STUDY AND TREATMENT

Tested samples were made of steels VKS-7 (#16Kh2N3MFBAYu-Sh# according to TU (Technical Specifications) 14-1-4483-88) and VKS-10 (#13Kh3N3M2VFB-Sh# according to TU 14-1-4999-91).

The samples of steels, prepared for ion-plasma nitriding, were subjected to preliminary thermal treatment, which consisted in normalization and high tempering according to the regime: normalization at 950°C and high tempering at 640—670°C; the treatment time was 6 h. To form the finely dispersed state of the surface layer, the samples made of steels VKS-7 and VKS-10 were subjected to preliminary intense plastic deformation (IPD)—compression at 700°C and a degree of deformation of 80% in conditions of multiaxial deformation. After compression in the axial direction, the billet was subjected to short-term heating and then pulling in the transverse direction. In this case, the direction of the axis of the applied deforming force and, correspondingly, deformation changed, which ensured the formation of a uniform finely dispersed structure [1, 2]. The ion-plasma nitriding was performed using an experimental installation in a nitrogen—hydrogen gas mixture with the composition 95% N₂ + 5% H₂ at 500°C for 20 h.
TEST PROCEDURES

Evaluation of Microhardness

The microhardness distribution over the thickness of the treated layer was evaluated on a transverse slice formed on the samples cut using a Duscotom-6 lathe with cooling in water. The samples pressed into a special resin were ground and polished using a Tegramin-25 automated installation. The slices were etched in a 5% nitric acid–alcohol solution. Microhardness was evaluated using a Durascan-70 microhardness tester at a load of 100 g.

Tests for Wear Resistance

These tests were performed according to two schemes. (i) The first scheme was implemented using an eight-position stand with a bidirectional motion of conjugated samples having plane friction surfaces. Nitrided sample 1 under study with a smaller friction surface is immobile, and the load is applied to it. Steel 20 in the state after cementation and quenching to hardness 59–60 HRC was used as a counter sample (sample 2 with a larger friction surface). It moves bidirectionally relative to an immobile sample with an average sliding velocity of 0.19 m/s. The run of a mobile sample \( h = 0.04 \) m. The lubricating material was a Litol-24 plastic lubricant (TU 0254-116-04001396-05) used for lubricating all types of rolling and slider bearings, gear hinges, and industrial mechanisms and electrical machines. The wear of the strengthened layer was determined on a stand for 15 h at \( p = 10 \) MPa \( (N = 705.6 \) N). The magnitude of the linear wear and wearing intensity according to GOST (State Standard) 27674-88 was evaluated by the weight loss of the samples of five similar friction pairs.

(ii) The second scheme was implemented on a SMTs-2 stand in slippage rolling conditions, which are characteristic of the operation of gears. Two rolls participate in the test: roll 1 made of tested steel and conjugated roll 2 made of steel #18KhGT# (60 HRC). Wear-in was performed under dropped lubrication with I-20A industrial oil (GOST 20799-88) with a rate of 30 drops/min in conditions of stepped increase of the load each 10 min of operation. Loading steps during wear-in are 200, 300, 400, and 500 N to complete conformity of the friction surfaces. The wear of the strengthened layer was determined after the operation on a stand for 1 h at \( N = 500 \) N \( (p = 348 \) MPa) and \( V = 0.96 \) m/s, slippage 4.8% in I-20A oil. After finishing the tests, the weight loss was determined, and the wear intensity according to GOST 27674-88 was determined by the calculation from the weight loss.

Tests for Contact Fatigue

These tests were performed using a Sh-17 two-position stand, which simulates rolling with sliding: a test sample with diameter \( d = 30.2 \) mm is compressed from two sides in the radial direction by push counterbodies with diameter \( D = 121 \) mm. The test sample is rotated using a multiplying gear; counterbodies are rotated using reducing gears, which connect the shafts of the sample and the counterbody. The summary rolling velocity is 25.47 m/s; the sliding velocity on a lagging sample surface is 0.75 m/s (the specific sliding on this surface is 6.1%). Loading of experimental samples was performed using compression springs. Oil I-20A was used as a lubricant.

RESULTS OF TESTS AND DISCUSSION

Figure 1 shows the microhardness distribution curves over the thickness of the nitrided layer. It is seen that the thickness of the diffusion layer is 0.3–0.5 mm and depends weakly on nitriding conditions. However, nitriding conditions substantially affect the attained microhardness level in the layers immediately adjoining the surface. For example, the maximal hardness after the conventional gas nitriding for VKS-7 steel reaches 820 HV, and after the ion-plasma nitriding with the preliminary deformation and heat treatment it is 950 HV, while the hardness for VKS-10 steel reaches 1050 HV. Thus, heat-resistant steels under study correspond to requirements of an increased hardness of the surface layer after the complex treat-