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IMPROVING THE WEAR RESISTANCE OF THE SURFACES OF "SHAFT-SLIDING BEARING" INTERFACES OF PARTS OF SHIP TECHNICAL MEANS

Statement of the problem in general form and its connection with important scientific or practical problems.

Due to surface destruction during wear, it fails 60-80% of details of ship technical equipment (STE). Steel and cast irons continue to be the material of the most STE. Therefore, increasing the wear resistance of iron alloys, from which STE parts are made, is one of the most important and urgent tasks. The resistance of metallic materials to various types of wear is often determined to a greater extent not by the initial strength (hardness), but by the level of effective strength of the surface layer, which is achieved during frictional loading. In this regard, one can expect a significant increase in the most important physical and mechanical properties of steels and cast irons due to the formation of metastable structural states in them, capable of intense strain hardening as a result of phase and other structural transformations under the action of contact loading.

According to modern concepts, the most important physical and mechanical properties of metallic materials can be significantly improved by their conversion to the nanocrystalline state. Since nanocrystalline structures arise naturally during friction, one of the promising and relatively simple ways of surface nanostructuring of iron alloy products can be frictional treatment under sliding friction conditions, which exclude noticeable surface heating. Known methods of hardening machining of steel products (diamond smoothing, running-in, etc.) are usually used as a finishing operation after the standard heat treatment, including normalization or improvement. However, it is the deformation of tetragonal martensite that will maximize the positive effect of deformation dynamic aging processes to improve the physical and mechanical properties of steel surfaces.

It is customary to classify alloys with metastable structures as alloys with metastable austenite, which undergoes a deformation martensitic transformation under frictional action: chromium, nickel, vanadium and, as a rule, characterized by a low energy of stacking faults. At the same time, noticeably less attention was paid to the regularities of the influence

of carbon unalloyed retained austenite on the wear resistance of iron alloys.

The purpose of this study is:

to study structural mechanisms that provide a significant increase in the wear resistance of iron alloys by creating strengthening of metastable structures of various types (tetragonal martensite, retained austenite, nonequilibrium pearlite), as well as nanocrystalline friction structures.

Key words: ships' technical facilities, martensitic transformation, metastable structures, frictional action, resulting in "shaft-bearing kovzannya".

Presentation of the main investigation material

Under conditions of extremely intense deformation of the material of the STE parts in the frictional contact zone, not only in the residual austenite, but also in other phases, structural transformations develop, which have a strong effect on the effective strength of the surface and, accordingly, on the tribological properties of materials. As shown by D. Wilson, D. Kalish, M. Cohen, G.V. Kurdyumov and others, one of the most significant (in terms of the effect on the physical and mechanical properties of steels) structural transformations of α -martensite initiated by plastic deformation is the deformation dynamic aging or "deformation tempering" of martensite. It is of interest to study the features of the development of these processes in martensite during friction, including at negative temperatures - under conditions of reduced diffusion activity of carbon.

The most effective deformational dynamic aging under loading develops in untempered (tetragonal) martensite, which, due to its increased fragility, has not been widely used in technology for a long time. However, with the development of modern hardening technologies (laser, electron-beam, plasma, etc.), interest in the structure of tetragonal martensite has increased significantly, since when processing steel surfaces with concentrated energy flows, effective suppression of the processes of self-tempering of martensite is ensured, and subsequent tempering (mandatory in the case of bulk hardening) is often not carried out due to the preservation of the viscous core of the product. An increase in the wear resistance of alloys with a martensitic base due to the activation of the processes of deformational dynamic aging of α -martensite can also be achieved by optimizing the heat treatment and the chemical composition of iron alloys.

Until recently, it was accepted to consider pearlite as the most stable phase in comparison with other products transformations of supercooled austenite - martensitic and bainitic structures. However, it was found that thin-lamellar pearlite in high-carbon steels, obtained at temperatures near the lower boundary of pearlite decomposition (about 500 ° C), is a nonequilibrium structure, the increased strength properties of which are eliminated even with short-term heating, at which no visible changes in the pearlite structure are observed. In this regard, it is of interest to study the behavior of this non-equilibrium thin-lamellar pearlite in comparison with the structures of coarse-lamellar pearlite, upper bainite, and low-temperature pearlite, which can arise in high-carbon steels in the temperature range between upper and lower bainite transformations, for various types of wear.

Since products with the structure of thin-lamellar pearlite can be heated during various technological operations (welding and tempering of rails, hot-dip galvanizing or brass-plating of wire, annealing to improve machinability, etc.) and during operation (frictional heating of the surfaces of ropes, railway rails and wheels; heating of casting crane ropes with heat from a molten bath, etc.), it is practically important to study changes in wear resistance, strength and plastic characteristics of pearlitic steels during high-temperature heating.

The tribological properties of metallic materials largely depend on the structural state formed on their contact surface in the process of friction. Intense plastic deformation, localized near the friction surface, frictional heating, and the effect of the environment cause the formation in the frictional metal contact zone of a whole "hierarchy" of specific structures that are highly heterogeneous in depth of the active layer.

The use of various alloy compositions, carburizing modes, laser (CO₂ gas and solid-state YAG lasers), electron beam and volume quenching, cold treatment and tempering made it possible to reveal the effect of carbon concentration in martensite on wear resistance (up to 1.35 %), retained austenite, alloying with substitutional elements (up to 4%), excess cementite, graphite inclusions, grain size, degree of coagulation and volume fraction of tempering carbides.

The resistance of carbon martensite to abrasive wear when tested against corundum (under microcutting conditions) increases linearly as the carbon concentration in it increases to 0.9% (hardened steel U10) (Fig. 1). When tested on a softer abrasive - flint, the transition to high-carbon martensite is accompanied by a sharp increase in wear resistance due to a

change in the main wear mechanism - from microcutting to plastic displacement (scratching). With the implementation of the plastic displacement mechanism, an increase in the carbon content in the α -phase by more than 1% leads to a decrease in wear resistance (Fig. 2, ϵ -flint, curve 2) due to the embrittlement of the martensitic structure.

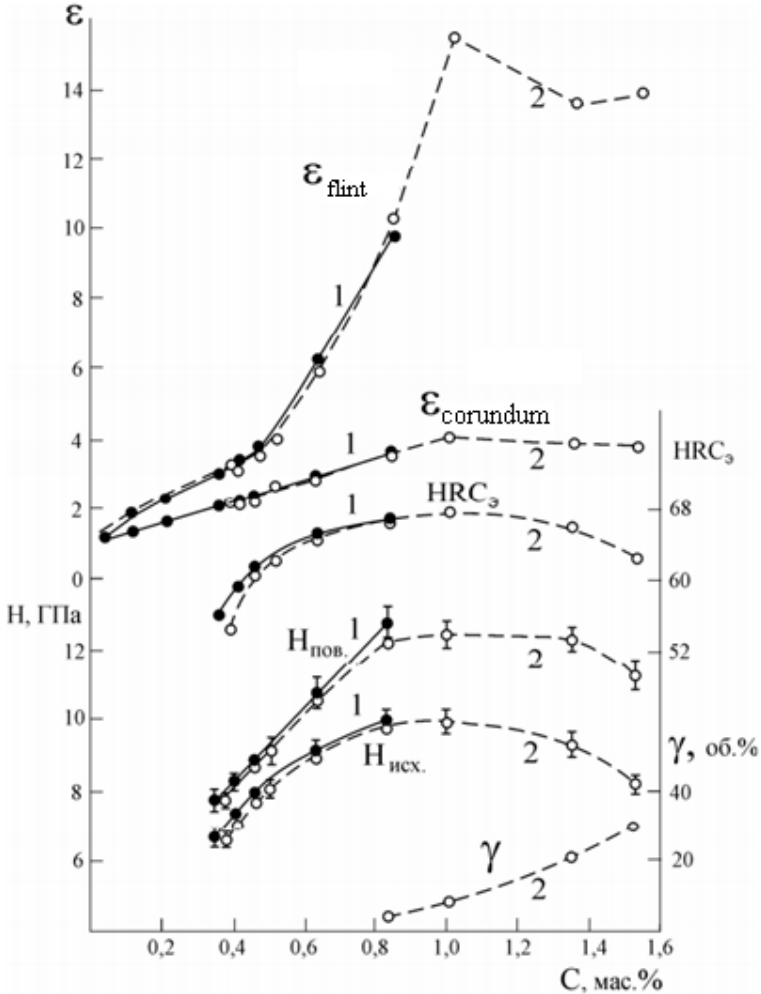


Fig. 1. Influence of carbon content on abrasive wear resistance ϵ , hardness HRC_e, microhardness (initial H_{исх} and on the surface of abrasive wear H_{пов}) and the content of retained austenite γ in the structure of carbon steels

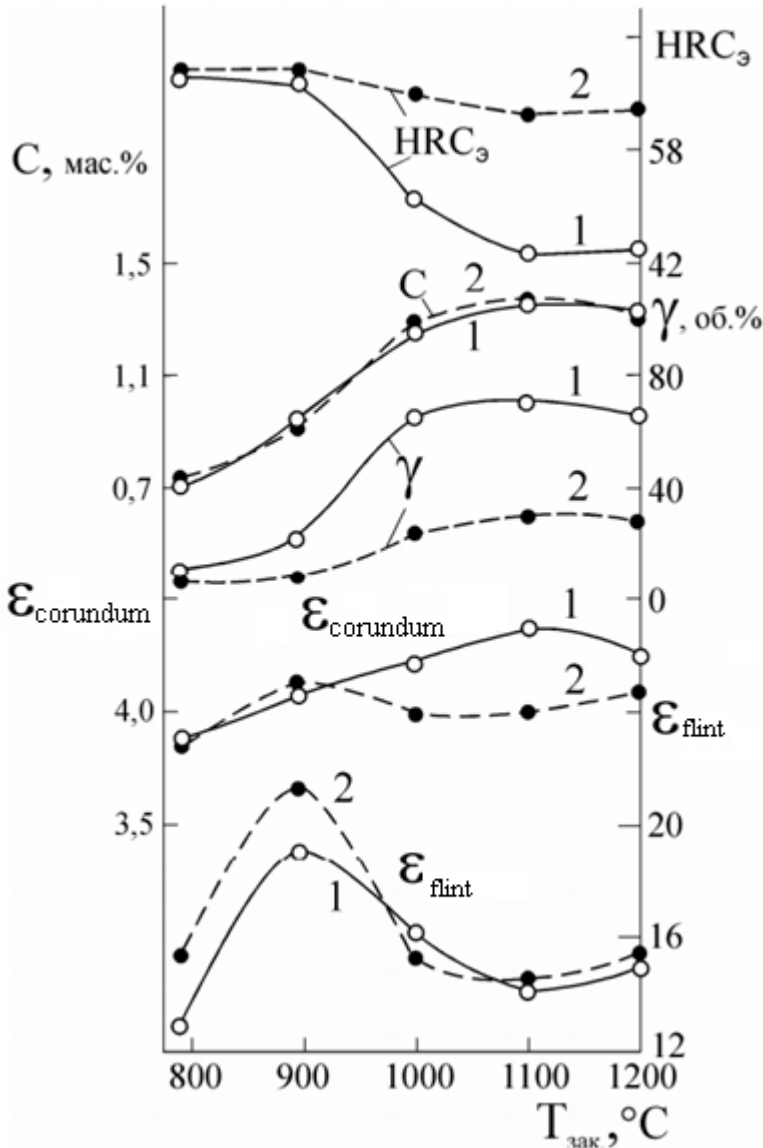


Fig. 2. Influence of hardening temperature on hardness HRCe, carbon concentration in martensite C, retained austenite content γ in the structure and abrasive wear resistance ϵ of U15 steel: 1 - hardening; 2 - hardening, cool.-196 °C
 1 - laser hardening; 2 - volumetric quenching, cool. -196 °C (for steels with 0.83-1.53% C)

Under conditions of sliding friction, an increase in the carbon concentration of more than 0.8% can also cause a decrease in the resistance of hardened steels to the polydeformational wear mechanism (an increase in weight loss) due to an increase in the brittleness of the surface layer, which is especially manifested during tests in an oxidizing air environment (Fig. 3). The embrittling effect of frictional oxidation leads to a decrease in the resistance to fatigue wear of the surface of high-carbon steels in comparison with friction in a non-oxidizing nitrogen atmosphere, while the wear rate of less strong steel 35 during the transition from an oxidizing to a non-oxidizing test environment increases sharply, since the resulting under frictional loading in air, oxides interfere with the adhesive interaction of contacting metal surfaces (see Fig. 3). A decrease in the test temperature in nitrogen from room temperature to -196°C causes accelerated wear of hardened high-carbon steels, initiated by their low-temperature embrittlement (see Fig. 3).

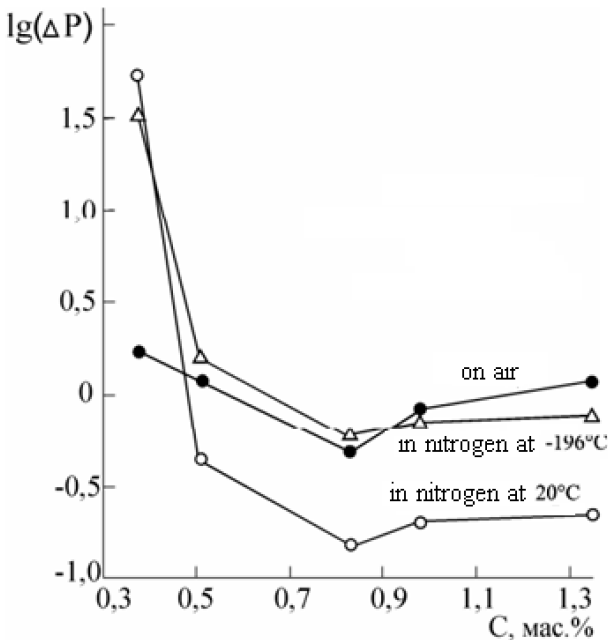


Fig. 3. Influence of carbon content in carbon steels on weight loss of specimens under frictional loading with an indenter made of VK8 alloy: volume quenching, cool. -196°C (for steels with 0.83-1.53% C)

The absence of a proportional relationship between the initial hardness and the abrasive wear resistance of martensite is due to an increase in its ability to work hardening with an increase in the carbon content of more than 0.5% (see Fig. 1) due to the activation of deformation dynamic aging processes in high-carbon martensite during wear. These processes are characterized by the formation of segregations from carbon atoms on dislocations arising from friction. These segregations are formed due to the high energy of interaction between dislocations and carbon atoms located in octahedral interstices of the crystal lattice of α -martensite.

Strong pinning of numerous dislocations by impurity atmospheres causes intense strain hardening of high-carbon martensite during friction and the corresponding growth its resistance to various types of wear. Optimal alloying with carbon (more than 0.5%) and substitution elements makes it possible to enhance the positive effect of deformational dynamic aging on the wear resistance of martensitic alloys. In particular, vanadium (1.2% V), which increases the ability of martensite to harden during wear, provides a significant (up to 70%) increase in the abrasive wear resistance of high-carbon martensite, laser and bulk quenching.

Conclusions

1. The wear resistance of carbon alloys with a martensitic structure can be significantly increased due to the activation of dynamic deformation aging processes in tetragonal α -martensite, which under conditions of frictional action proceed intensively even at low (down to -196°C) temperatures, providing an increase in strain hardening of the friction surface. This activation is achieved by carrying out thermal treatments, ensuring the preservation of the highest possible carbon concentration in the crystal lattice of martensite, as well as alloying the alloys with an increased (more than 0.6%) amount of carbon and substitutional elements that enhance the interaction of dislocations with impurity atoms in the α -phase.

2. A sharp decrease in the abrasive wear resistance of carbon, low-alloy, and cemented iron alloys during low-temperature tempering can be effectively slowed down by the formation of metastable residual austenite in the structures of laser and bulk quenching, which, due to the transformation under the action of friction into high-strength nanocrystalline martensite, is not inferior to the non-tempered martensite in cooling wear resistance.

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