Classification of Wear of Materials Under Conditions of High Pressures and Shock Loads

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ABSTRACT

This article analyzes the phenomena occurring in the zone of interaction of surfaces during high pressure and shock loads, as well as data on the wear of various materials in the tension shroud

Keywords: shock-abrasive, shock-waterjet, shock-fatigue, shock-thermal, abrasive, surface, surface, wear resistance, hardness, heat resistance, corrosion resistance.

With increased loads, and especially with its shock application, and damage to the friction surfaces will be determined not only by the type of material and its properties, but also by specific working conditions: heat stress, the level of dynamic effects, the aggressiveness of the medium, the presence of abrasive, etc. During impact contact of surfaces, the following types of wear are distinguished: shock-abrasive, shock-waterjet, shock-fatigue and shock-thermal.

The destruction of metal during impact-abrasive wear is carried out as a result of low-cycle fatigue of micro-volumes of metal due to cyclic application of load during elastic-plastic contact. Shock-abrasive wear is associated with the introduction of a solid particle into the metal. The criterion of wear resistance, as a rule, are the values of hardness. The higher the hardness, the higher the wear resistance.

In case of impact-waterjet wear, the collision of metal surfaces occurs in the presence of liquid and solid particles. In this case, wear occurs by direct introduction of particles associated with the impact and their relative displacement, which leads to micro-cutting.

Shock-fatigue wear occurs when surfaces repeatedly collide in the absence of abrasive particles. The mechanism of wear of this type is based on repeated deformation of the surface layer, leading to riveting, embrittlement and subsequent separation of particles. Wear resistance decreases significantly with increasing impact energy.

Shock-thermal wear occurs when surfaces collide, which, according to working conditions, experience significant volumetric heating. With this type of wear, the separation of particles occurs as a result of repeated plastic deformation or cutting of metal volumes during the introduction of solid particles.

The following requirements are imposed on materials that are stable when working under high pressures and shock loads:

a) increased hardness and at the same time a certain margin of plasticity;

b) increased heat resistance;

c) high corrosion resistance.

The wear resistance of materials operating under heavy loads, with their impact application, depends on many factors.

In case of impact-abrasive and impact, water-abrasive wear, the main criterion for the intensity of the know-how is hardness. M. Ts. Tenennaya evaluates the ability of abrasive particles to penetrate into the surface layer and destroy it when moving by the ratio of the values of the micro hardness of the tested material H and the abrasive on H_A:

$$K_T = \frac{H}{H_A}$$

At a critical value of the CT coefficient = 0.5�0.7, metal destruction is possible with a single exposure to an abrasive particle (micro-cutting); at CT >0.7, the wear process turns into a multi-peak (wear particles are separated as a result of repeated deformation of the metal) with a sharply decreasing wear intensity as the CT coefficient increases. With micro-cutting, the wear intensity is inversely proportional to the hardness, and with multi-cycle destruction, the dependence of the wear intensity on the hardness is not linear.

With the same hardness of steel, the wear intensity decreases as the content of residual austenite increases. Essentially, these are steels with metastable austenite. In the process of destruction of micro-volumes of metal, austenite is transformed into martensite; at the same time, a certain hardening of the surface layer is achieved, compressive internal stresses are created, fine carbides are isolated along the sliding planes.

During impact-abrasive wear, the linear relationship between wear resistance and hardness is maintained up to a certain value of the impact energy. With an increase in the impact energy, there is either an increase in the rate of wear intensity with an increase in hardness, or the hardness of a certain interval generally affects wear resistance. In case of impact-waterjet wear, depending on the impact energy, an increase in the carbon content and, accordingly, hardness has an ambiguous effect on the wear intensity.

In case of shock-fatigue wear, the choice of wear-resistant materials is determined not only based on hardness. The dynamic nature of the application of loads makes it impossible to use tool steels with high hardness. High hardness steels (HRC 60-63) have low ductility, including impact strength, and poorly redistribute stresses in areas of their concentrations. Therefore, the wear resistance associated with the accumulation of damage during cyclic loading will decrease in steels that do not have a certain margin of plasticity. In this regard, the work on the origin of the crack, and most importantly, the work spent on its development, in steels with high hardness, but a small margin of plasticity, is small.

For steels with a martensitic structure with a hardness above HRC 52-54, there is no direct relationship between hardness and strength. When overheating during quenching, despite the high hardness, the strength drops sharply (Fig. 1). During heat treatment, it is necessary to achieve a favorable combination of high hardness and strength and the necessary plasticity.

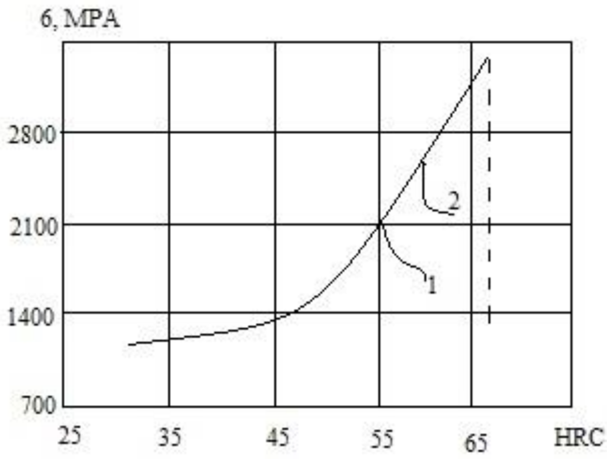

Fig. 1. Tensile strength of tool steels depending on hardness.

The tensile strength is determined (for HRC up to 52-53) and bending strength (HRC > 54-55). Dashed lines indicate the dependencies obtained as a result of overheating during quenching: 1 – steel with 0.5% C; 1.5% Sg and 2.5% W; 2 – steel with 1.2% C; 1.7% W; 0.7% Sg and 1% Si; 3 – high-speed steel of type P6M5

The decrease in hardness from HRC 68 to HRC 55 does not change the plasticity indicators much. A significant increase in these indicators occurs when the hardness of HRC decreases to 45-48 due to the coagulation of carbides. Plasticity increases to a greater extent in steels containing fewer carbides with a greater ability to coagulate (carbides M3C, M23C6), and to a lesser extent for more alloyed steels with carbides of the M6C type.

The following ranges of hardness values are recommended for steels of various purposes: high (St. HRC 59-66) for metal-cutting tools and cold forming dies (hardness close to the average limit is set for finishing cutting tools and for dies for pressing and drawing); moderate (HRC 42-50) for hot deformation stamps, primarily for creating high resistance to thermal fatigue, cold deformation stamps (landing, etc.) working under shock loads, some woodworking and plumbing tools. The wear resistance of steels decreases as the tempering temperature increases. The rate of wear resistance reduction is the same for steels, although the overall level of wear is significantly lower for U8 steel.

Destruction under conditions of shock-fatigue wear manifests itself most fully during the operation of the die tool during cold deformation of the metal. The wear of alloy and carbon steels at the same hardness is different. Alloy steels are more wear-resistant than carbon steels. So, steel U12 has 2-3,2 times less wear resistance than steel X12M. Complex carbides in alloy steel have a positive effect on wear resistance at low impact energy (5 J/cm2). With an increase in the impact energy up to 14 J/cm2, the carbide phase accelerates wear. It is a kind of stress concentrator and contributes to the coloring of individual micro-volumes.

For die steels, the carbon content is limited to 0.3-0.5%. The less carbon, the higher the content of alloying elements is allowed.

In case of shock-thermal wear, the reliability of tools is determined primarily by the resistance to thermal fatigue. This characteristic is determined by heat resistance – the ability of alloys to maintain the structure and properties necessary for the passage of the working process (cutting, deformation, etc.) when the working part is heated during operation. The heat resistance of carbide-hardened steels is most associated with the properties of a solid solution. The higher the phase transformation temperature, the greater the heat resistance of the steel.

In steels with intermetallic hardening, heat resistance is determined by the released particles of the hardening phases, which can effectively delay the overall softening of the steel due to the large dispersion, differences in the type of crystal lattices and high resistance to coagulation during heating.

Thermal fatigue resistance is also characterized by heat resistance – the resistance of steel to the formation of surface cracks during repeated heating and cooling. This is especially important for stamped steels – heat-resistant and semi-heat-resistant. The heat resistance is affected by the structural state and the reserve of plasticity, sensitivity to oxidation, etc.

With the hardness of steel in the finished stamp HRC 45-50, the structure is troostite. Weak areas in such steels are individual inclusions of ferrite and carbides. With a ferrite content of more than 10-15%, the resistance to heat resistance decreases very significantly. Carbides or intermetallides greatly reduce the heat resistance at a content of more than 5-8% and with their uneven distribution.

For the main group of die steels, the higher the ductility (viscosity), the higher the heat resistance. For steels used in molds and for liquid stamping, the influence of plasticity on the heat resistance affects to a lesser extent. The occurrence of cracks is a consequence of the active action of liquid metals (P.A. Rebinder effect), corrosion and erosion.

For the manufacture of parts operating under conditions of impact-abrasive wear, high–manganese steels are widely used - in particular, austenitic steel grade 11G13 (1-1.3% Si 11-14% Mp, up to 0.3% Si, no more than 0.03% P and 0.03% S). In the cast state, its structure is an austenitic matrix and carbides. To increase its strength and plasticity, it is tempered in water from a temperature of 1100-1150 ° C (this achieves the dissolution of carbides and obtaining a more homogeneous austenite). The steel heat-treated in this way, as a result of deformation and impact during operation, is riveted and acquires high wear resistance. Links of tracks (tracks) of tractors and other tracked vehicles, balls of crushing mills, cheeks of stone crushers and other products working with shock-abrasive wear are made of 110G13 steel.

High-cobalt (20-30% Co) hard alloys of type B and CS have high wear resistance at high pressures and shock loads.

They are used to equip drilling tools and die tools working under significant shock loads.

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