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WEAR OF 16MnCrS5 STEEL SURFACE LAYERS IN THE PULSING CONTACT LOADS

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Approaches to actualizing the use of modern alloy steels that are in demand in the Eurasian technological space are proposed. According to the criterion of resistance to contact fatigue, quantitative indicators of wear of the surface-hardened layers of steel 16MnCrS5 were revealed. With the contact stress amplitude up to 950 MPa, the composite material of carbonized and nitrocemented layers is characterized by a period of high resistance with minimal manifestations of structural hardening by the mechanism of softening of the material. The obtained composite material with carbonized and nitrocemented layers is characterized by a period of high resistance up to 15 000 cycles.

Keywords: 16MnCrS5, wear, layers on surface, pulsing contact loads, thermal treatment

INTRODUCTION

Cyclic contact loads acting on the working surfaces of machine parts and mechanisms are the reason for the loss of their operability [1-3]. Among the possible ways to increase the contact endurance of such parts, much attention is paid to strengthening technologies, creating the necessary structure of the surface layer. One of the known methods that can form a hardened layer of high hardness and considerable depth, which leads to increased durability under the action of contact cyclic loads, is carburizing [4-5]. Simultaneous saturation of steel surfaces with carbon and nitrogen is called nitrocarburizing. This method also effectively affects the wear resistance of the machined parts [6-7]. It is also known that the use of surface plastic deformation creates a gradient hardened layer with residual compression stresses and increased hardness [8-9].

With such processing, there is no sharp transition from the hardened material to the base, which eliminates its peeling. At the same time, the change nature in the metal properties of the transition region between the hardened layer and the base is of great importance. Static-pulse treatment affects the surface with a deformation wave, which makes it possible to change the resulting structure of the hardened layer and its properties within a wide range at a depth exceeding the carburizing depth [10-11]. It is possible to technologically create a heterogeneously hardened surface, the efficiency of which will be quite high when working parts under contact fatigue loads. The use of combined hardening technologies, for example, changing the crystal structure of the surface by preliminary plastic deformation, has a beneficial effect on subsequent carburizing. Therefore, a promising technology for creating a working surface layer with the possibility of regulating its properties over a wider range will be the combined hardening of static-pulse treatment or surface plastic deformation with carburizing or nitrocarburizing.

Based on the preferences of OJSC "Belorussian Steel Works – management company of "Belorussian Metallurgical Company" holding", aimed at increasing the steel output in demand in the European Union, 16MnCrS5 alloy has particular interest. Its appearance on the domestic market is positioned as a competitive replacement for other cemented steels used for loaded machine parts operating under conditions of pulsating contact loads affecting their surface layer. Based on this, the influence of thermochemical treatment modes on the operational characteristics of this alloy, as well as the structure evolution during contact wear is interested to engineering and technical workers of mechanical engineering and other related enterprises.

The paper investigates the effect of pulsating contact stresses on the wear-fatigue characteristics of 16MnCrS5 steel subjected to various types of thermochemical treatment. Special attention is paid to the study of the ultimate bearing capacity of a composite material, including a hardened layer and a sublayer (core), under the action of very high contact stresses for this alloy.

MATERIALS AND METHODS

Experimental assessment of contact wear was carried out on an original installation for testing materials for contact fatigue and wear. Detailed description of the installation is given in work [12].

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Hardening of the surface layer of steels was carried out by carburizing and nitrocarburizing. To compare the hardening effectiveness, thermochemical treatment was carried out according to two technological modes: in the first case, carburizing at temperatures of 920 °C was carried out for 8 and 12 hours, in the second case, high-temperature nitrocarburizing in urea modified charcoal was carried out for 6 and 8 hours at temperatures of 850 °C. The final operations included quenching at a temperature of 860 °C and tempering at a temperature of 200 °C.

RESULTS AND DISCUSSION

The choice of two types of diffusion saturation that are sufficiently close in chemistry is associated with the possibility of using high-temperature nitrocarburizing, which is available for implementation at almost any mechanical engineering enterprise, carried out in a simple reagent - charcoal modified with urea. The peculiarities of using this treatment dictate to strictly limit the duration of the saturation stage due to the possible appearance of the so-called “dark zone”, which degrades the characteristics of the hardened layer. According to some data, it appears due to an increased nitrogen content and leads to the formation of layers of increased brittleness containing decay products of martensite. When carbonizing steel alloyed with Cr, Mn, Ti, V, with simultaneous implantation of nitrogen to concentrations of 0,15 % and higher, carbonitrides are formed. Their localization along the grain boundaries stimulates a decrease in the decomposition temperatures of austenite, reducing its stability.

As a result, at the end of the thermochemical treatment, the grain boundary sections of the crystal blocks of the hardened layer acquire the structure of bainite, or even troostite, which negatively affects the contact fatigue characteristics of the composite material. Based on the indicated danger, it is important to control the nitrogen and carbon potential when trying to create sufficiently developed hardened layers, which requires the use of expensive thermal equipment, usually using vacuum technologies. In our case, the hardening concept is based on numerous results of researchers reflecting the high saturation efficiency of both elements achieved in the presence and during fairly short periods of saturation. The noted approach is successfully implemented by scientific schools of the Russian Federation and is relevant and cost-effective for conditions of single and small-scale production.

The thickness of the layers synthesized on experimental samples using nitrocarburizing was about 0,5 – 0,6 mm, with 1,0 – 1,2 mm after carburization (Figure 1).

The hardness distribution in both cases does not differ in the presence of a plateau of equal hardness in the hardened layer. The structural features of the transeutectoid site are expressed only on cemented layers. Its thickness does not exceed 0,2 – 0,3 mm, providing a good technological layer for the use of grinding in the final processing of carburized parts. This concept is also acceptable when using nitrocarburized parts, but with a reduction in the allowance for finishing up to 0,1 mm.

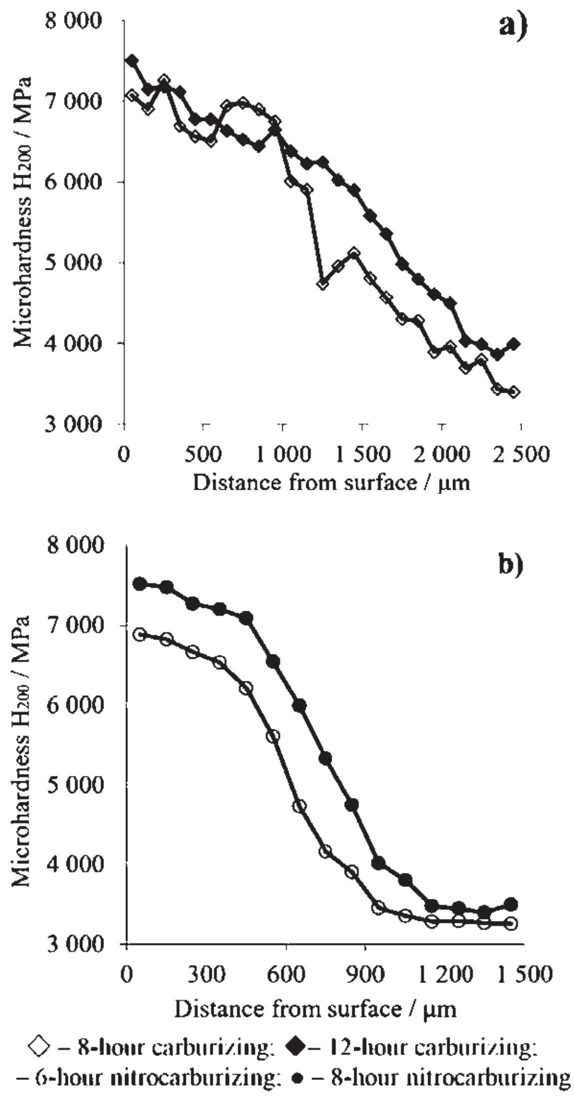

Figure 1 Microhardness distribution of carburized (a) and nitrocarburized (b) layers of 16CrMnS5 steel

Contact wear tests at the first stage were carried out at the pulsating contact stress of 950 MPa. Such high stresses are characteristic of heavily loaded transmission elements of modern mechanisms in various kinds of machines. The peculiarity of testing flat samples is characterized by more stringent loading conditions, in which the reaction of the material to external influences is not realized in the direction of the side surfaces. In this case, it can be concluded about a purposeful tightening of the test conditions with the transfer of experimental samples to a state of flat stress. This allows to consider the obtained research results as a quantitative parameter of resistance to contact wear with a guaranteed margin of safety when considering real machine parts in which volumetric loading of the composite material of the surface layer gives an advantage in durability due to the implementation of a comprehensive (three-dimensional) stress state.

As can be seen in Figure 2, the tests of all samples were characterized by the manifestation of three stages of contact wear. At the first stage, the durability of the composite material of the hardened layers was distinguished by a high index of the preservation of the geometric shape of the contact strip. This result in quantitative terms provides a recommendation on the reliability of the tested alloy with hardened surfaces during 15 000 loading cycles. Further tests showed that on all samples, due to the evolution of the structure by the riveting mechanism, characteristic changes in the shape of the structural components – carbides, carbonitrides and grains of the metal matrix took place.

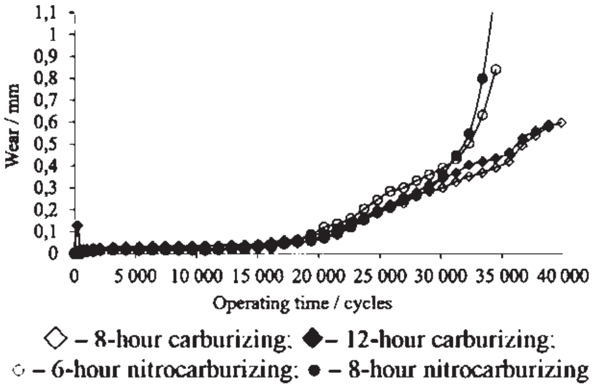

Figure 2 Wear curves of 16CrMnS5 steel samples after loading with a contact pulsating stress of 950 MPa

The processes of moderate intensity of the riveting ended after 30 000 loading cycles in the layers formed by nitrocarburizing. And the carburized layers did not change their behavior during the testing process until half of their effective depth was worn out. Tests at increased contact stress amplitude of 1 085 MPa significantly reduced the period of precision resistance of all batches of samples to 7 000 – 8 000 cycles.

CONCLUSIONS

In this paper the effect of pulsating contact stresses on the wear-fatigue characteristics of 16MnCrS5 steel subjected to various types of thermochemical treatment was investigated. The obtained results made it possible to identify a quantitative index of precision resistance for hardened layers of 16MnCrS5 steel. When the amplitude of the contact stress is up to 950 MPa, the composite material of carbonized and nitrocarbonized layers for different durations is characterized by a period of high resistance with minimal manifestations of structural hardening by the material softening mechanism. The guaranteed period of precision durability is at least 15 000 cycles. An increase in the amplitude of the pulsating contact stress leads to a reduction in the material wear-fatigue life. Also it was revealed that increasing of carburizing or nitrocarburizing duration time leads to reduction in the wear level after 30 000 cycles.

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Note: Translated by D. Rahimbekova, Temirtau, Kazakhstan