DISCUSSION ON THE PROBLEM OF CHEMICOTHERMAL TREATMENT OF GEARS

The Editorial Board has decided to issue in a brief form the materials of the papers of V. B. Nosov, V. I. Pustovalov, and S. A. Yurasov "On the problem of the expediency of a section on 'Surface Engineering'" devoted to critical analysis of the article of V. M. Zinchenko "Surface engineering: a way to provide maximum properties in articles" (Metalloved. Term. Obrab. Met., No. 7, 1999) and the answers of V. M. Zinchenko to the critical comments. An analysis of these materials has shown that the authors, who represent two leading Russian enterprises producing automobiles (the ZIL and NIITavtoprom Companies, respectively), have essentially similar opinions on the role of chemical composition and structure in the service properties of gears, but their understanding of the problem of maximum service properties of the parts differs in principle. The fact that today both approaches give acceptable results seems to be connected with the difference in the requirements on the set of mechanical and operational properties of the parts. In the case where the problem requires realization of the ultimate possibilities of materials in a specific structure, only one point of view should be chosen. The Editorial Board hopes that the discussion in our journal will help in making the appropriate choice.

ON THE PROBLEM OF THE EXPEDIENCY OF A SECTION ON 'SURFACE ENGINEERING'[1]

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Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 2, pp. 34 – 35, February, 2001.

In the opinion of V. M. Zinchenko, the essence of structure "design" for providing ultimate properties consists of the obligatory determination of the coefficients $K_1 = H_{ts} h_{ns}$ and $K_2 = H_c h_{ns}$, where H_{ts} is the microhardness of the core and h_{ns} is the thickness of the near-surface zone (up to 250 μm). These parameters are considered the most important in the evaluation of the endurance of carburized and nitrocarburized automobile gears and shafts. The coefficient K_1 determines the contact strength, and K_2 determines the cyclic and static strengths. The microhardness is evaluated in a single place, i.e., the middle of the tooth space. It is universally known that the mechanical properties are determined by the phase composition and the microstructure. It is senseless to determine only the microhardness of the near-surface layer. For example, one and the same value of the microhardness can be obtained in a structure with 10% troostite and in a steel bearing no troostite which contains 50% retained austenite. In these cases, the endurance parameters are quite different.

Unfortunately, the relation between the coefficients K_1, K_2 and the "design of the phase composition" is not shown by the author. There is no indication at what distance from the surface the values of H_{ts} and H_c should be measured and what should be taken for the boundary of h_{ns}. It is not clear why the values of H_{ts} and h_{ns} measured in the tooth space should determine the contact strength, which is characterized by the mechanical properties of the volumes of the metal in the zone of the pitch circle. The cooling rates in quenching of these zones differ severalfold and, consequently, the hardenability of the near-surface zones differs. Moreover, the fracture behavior differs too, i.e., pitting occurs in the zone of the pitch circle and a fatigue crack develops at the root of a tooth. The maximum Hertz tangential stresses act at a distance of 0.4 – 0.5 mm from the surface, and the role of the near-surface zone is less important than the effective thickness of the layer.

The absence of structural treatment of the coefficient K_1 naturally gives rise to questions that should be exhaustively answered by the author. First, what is implied by the near-surface layer? If the author understands it as a defective layer that consists of oxides on the surface, a cementite film[2] 1 – 2 μm thick, and troostite formed in quenching due to the chromium and manganese depletion of the solid solution as a

[1] Abridged; the standpoint of the authors on the expediency of a section devoted to surface engineering can be found in Metalloved. Term. Obrab. Met., No. 12 (2000).

[2] The "film" is understood as a layer of chemical compounds (cementite) on the surface. (*Ed. note*).

result of internal oxidation, then H_{ts} decreases to 500 H when the latter grows. Both factors (especially the value of H_{ts} measured at a distance of at most 50 μm from the surface) markedly shorten the life of the part (the cyclic and static strengths).

The maximum endurance is attained at $h_{ns} = 0$, i.e., in the absence of defective zone, which does not agree with the analytical expression for K_2 and the dependence of the mechanical properties presented by the author, in accordance with which the latter generally increase with the growth in h_{ns}.

The growth of the defective zone of the nitrocarburized layer, the defects in which are connected with the formation of a CrCN compound at nitrogen concentrations in the layer sufficient for the occurrence of a reaction that yields chromium carbonitride (as a rule, at least 0.15% N), depends on the nitrogen distribution in the layer due to saturation and its maximum value on the surface. The thickness of the defective layer also depends on the cooling intensity in quenching, the geometry (size) of the part, and the chemical composition of the steel, i.e., on the hardenability of the saturated layer.

The "ultimate" properties are attained if the layer is fully hardened for a structure of martensite and austenite, which eliminates the presence of a cementite film on the surface. In this case, the saturation of the steel with nitrogen and carbon and the quenching of the part should guarantee the requisite thickness of the effective zone the structure of which eliminates the presence of troostite. The size of the austenite grains should correspond to No. 10 (GOST 5639–82). In addition, the steel should necessarily have a maximum purity with respect to nonmetallic inclusions, and the degree of microsegregation (striation) should be reduced to a minimum.

As for the thickness of the core and the permissible range of its determination, the limiting permissible values are determined by two criteria, namely, quenching for either a structure of 100% martensite or a structure of "semimartensite" (50% martensite and 50% troostite). The choice of the criterion depends on the level of the load.

In order to provide the requisite criteria, we should possess new quenching equipment that would allow us to control the cooling rates within a wide range and eliminate the possibility of formation of troostite zones in the layer as well as control the possibility of the appearance of a semimartensite structure in the core or the requisite distribution of the hardness over the cross section of the part.

The method for calculating the hardenability recently developed by the authors can be a basis for designing new structures of quenching devices.

Moreover, control of the cooling rates in quenching of parts of a specific type from heats with the same composition is more efficient economically than other means (higher degrees of alloying with chemical elements that compensate for the chromium and manganese depletion of the solid solution, removal of the mentioned defects by mechanical methods, use of high-temperature vacuum carburizing, etc.).

Unfortunately, the problem of hardenability, especially the methods for its calculation, is not given due attention in domestic practice, in contrast to foreign experience, though the hardenability makes it possible to relate the structure and the mechanical properties of steels of specified chemical compositions with the parameters of their heat and chemicothermal treatment. This can be associated with the absence of data on hardenability and methods for calculating its parameters for specific parts.