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Results of the Complex Studies of Microstructural, Physical and Mechanical Properties of Engineering Materials Using Innovative Methods

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Abstract

The article is devoted to the pressing issues of a comprehensive study of the microstructure, physical and mechanical and tribological properties of a heterogeneous system in the surface layer. Study methodology mostly touches upon the processes in the liquid single-and two-phase medium with excitation of ultrasonic vibrations of high intensity and their impact on the study object. In light of the principles of the proposed methodology of micro-level analysis of the microstructure and physical and mechanical properties of construction materials it turns out to be possible to conduct a number of studies. Starting with the metallographic analysis and the study of the microstructure of the modified heterogeneous surface at the same time we can estimate their real relationship to the physical and mechanical properties of the monolayers of material zone under study. Sequential comprehensive analysis of the parameters under study brings out the influence of these factors on a number of important indicators such as erosive wear resistance, adhesive and cohesive robustness and load-bearing capacity of the modified material surface. Proposed research methods can reduce the amount of preparatory and experimental works, and as well significantly improve the reliability and quality of the data. Thus, experiments can be performed in various liquid mediums, simulating various conditions of lubrication and an impact of corrosive environments. In addition to the metallic materials analysis, the technique has found its application in dental practice – study of dental prostheses and restorations.

Keywords: surface layer, microanalysis, wear resistance, ultrasonic vibration, cavitation, micro-hardness, microsection.

INTRODUCTION

The surface layer of machine parts is one of the basic indicators of efficiency and reliability of the machines. Evaluation of the condition of the surface layer takes into account not only all kinds of irregularities, but also its basic physical and mechanical properties including microstructural, phasic, chemical composition and residual stresses, microstrain, microhardness etc. [1,2,3]. A set of parameters and techniques and a variety of study methodologies are used to evaluate the condition of the surface layer. In addition, a multipronged approach to ensuring the quality of the surface layer is provided for almost all the product life cycle stages (design, manufacture, inspection, testing, diagnostics, maintenance, repair and recovery). This situation has given rise to quite a new study of surface engineering. [4].

GENERAL METHODOLOGICAL REQUIREMENTS

In order to control the quality of the surface layer there is a wide variety of methods and means. However, most of them are passive, ascertaining separate indicators of physical and mechanical properties, such as contact rigidity, robustness, corrosion resistance, different kinds of wear resistance, etc. Its diversity and individual attention to estimating each method often leads to a significant spread of the same surfaces research result [4]. Evidentially, this suggests the need for a more unified multifactor testing methods of the workpiece surfaces which is one of the main research tasks discussed in this paper. Thereupon, it is offered the method of integrated micro-level analysis of physical and mechanical and tribological properties of the heterogeneous surface layer. This method is based on the processes occurring in the liquid medium with excitation of ultrasonic vibrations of high intensity. As an object of research it is offered the using of microsection. To accomplish the tasks there were developed and patented a number of ways of estimating the serviceability of the structural materials [5-8]. These include methods for estimating erosion resistance, water jet wear resistance, determining the erosion resistance of micro- and nano-objects, as well as the evaluation of microhardness indicator. According to the principle of influence on the object of research the ways are essentially the same, allowing to simulate the processes of erosive wear, abrasive wear, or some of them combined. Schematic diagram of the laboratory setup for the practical implementation of these methods is shown in general terms in Figure 1.

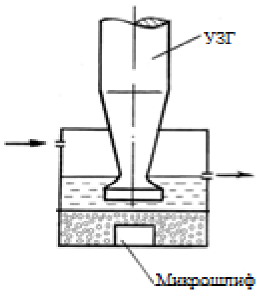

Figure 1: Principle diagram of the installation for the evaluation of hydroabrasive wear

It is known that during the excitation of ultrasonic waves in the fluid most of the processes are accompanied by the phenomena of cavitation and acoustic flows. Despite the lack of study of cavitation processes [9,10], the usage of the proposed methods allowed us to obtain a number of objective indicators which characterize the properties of robustness and tribological properties of the surface under study. This became possible due to the micro-level approach, using as an object of research a microsection, that was exposed to one or another type of surface modification. This technique is also applicable to the study of various coating properties, structural components and composite materials [11].

THE RESULTS OF THE EXPERIMENTAL RESEARCH

Evaluation of microsection surface condition exposed to hydroacoustic processing type in single-phase liquid medium [5] shows real differential relationship of the stability to the erosive (cavitation) wear of all modified and treated (reference) layers of the study sample under the same conditions of external influence. Obtained comparative data regarding the changes in roughness and surface relief allow to assess such important indicators as the cohesive strength of each monolayer, their adhesive bond, and as well as the load-bearing capacity. Also, the method allows to indirectly estimate the robustness of the various structural components, interphase boundaries, coatings, elements of the composition, etc., which cannot be evaluated using the conventional methods.

The method of hydroabrasive impact in the two-phase medium can further simulate abrasive wear processes [6] in case you add to the fluid an abrasive material of uniform particle size distribution. Once excited the ultrasonic waves in the medium, abrasive particles pass into the suspended state and oscillate between the surface of the ultrasonic transducer and the microsection surface under study. Dynamic effects of these particles simulate the abrasive tribological processes impinging uniformly on the surface under study. In the cavitational area of the ultrasonic vibration effect, simulation of the erosion-abrasive wear appears, and in the non cavitational field prevails abrasive wear.

Loose abrasive particles in suspension collide at high speed with a solid body surface and that's why significantly accelerate the deterioration process. At that, the particle size of the abrasive should be commensurate with the size of the structural components of the study object. During the combined effect of cavitation and hydroabrasive wear particle sizes then must be the same order of magnitude as the size of cavitation bubbles.

The processes of cavitation and mechanical erosion effects on the study object get even more active when the hydrostatic pressure in the process chamber gets higher. This is due to a large increase of the intensity of the shock waves from the collapse of cavitation bubbles [12], as well as an increase of their concentration because of the formation of additional gas microcavities due to the introduction of abrasive particles, which have a complex geometric shape, to the suspension.

Qualitative and quantitative assessment of the test items is similar to the method of erosive wear, i.e. by analyzing the profile of the sample surface using the recording of the profilograms.

The ultrasonic hydroabrasive treatment of the sample was carried out in a laboratory setting (Fig. 1) under an excess air pressure in the process chamber of 0.3 MPa. Aside from the distilled water an abrasive powder of homogeneous granulometric composition was placed in the chamber. There was used a microsection as a study sample with an additive powder PG-HN80SR2 cladded by the concentrated laser light source. Cladding was carried out on the laser processing station of continuous wave radiation with 800 W on proven technology.

Analysis of the obtained profilograms and the dependence of the microhardness in the heat affected zone (HAZ) shows an uprating in wear resistance of the cladded layer in relation to the original material.

The curve of the surface profile almost duplicates the curve of hardness distribution in the depth of the HAZ modified surface. This inference can also be confirmed in light of existing tribological test results conducted on the laboratory tribotechnical installations [11-18], which indicates the practical suitability of the proposed methodology of multimethod research and analysis of tribological and mechanical properties of modified surfaces. Using the same method of hydroacoustic oscillations impact when solid uniform spherical particles are inserted into the liquid it becomes possible to determine the indice of microhardness of separate monolayers, coatings, and structural components by analogy with a classical method of indentation with subsequent analysis plastic prints of practically any size, including nano-objects [7, 19-31].

CONCLUSION

In light of the principles of the proposed methodology of micro-level analysis of the microstructure and physical and mechanical properties of construction materials it turns out to be possible to conduct a number of studies. Starting with the metallographic analysis and the study of the microstructure of the modified heterogeneous surface at the same time we can estimate their real relationship to the physical and mechanical properties of the monolayers of material zone under study. Sequential comprehensive analysis of the parameters under study brings out the influence of these factors on a number of important indicators such as erosive wear resistance, adhesive and cohesive robustness and load-bearing capacity of the modified material surface. Proposed research methods can reduce the amount of preparatory and experimental works, and as well significantly improve the reliability and quality of the data. Thus, experiments can be performed in various liquid mediums, simulating various conditions of lubrication and an impact of corrosive environments. In addition to the metallic materials analysis, the technique has found its application in dental practice – study of dental prostheses and restorations.

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