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Nano- and Micromechanical Parameters of AISI 316L Steel

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Abstract—The nano- and micro-indentation mechanical parameters of the AISI 316L stainless steel, such as nanohardness (H_{NI}), microhardness (H_{MI}), the Young modulus (E), the indices of plasticity (H/E) and resistance (H^3/E^2), and relaxation parameters h_s, h_{res}, $h_{e\text{-}p}$ and their dependences on the value of P load applied to an indenter were studied. Hardness is shown to be slightly decreased in the microindentation interval (P = 100–500 mN) with an increase in the load, whereas it grows substantially with P decrease in the region of nanoindentation (P < 100 mN) to exhibit the Indentation Size Effect. The major peculiarities of the deformation process were established resulting from the study of the indenter penetration character. The presence of various mechanisms of the plastic deformation is supported during the indentation of AISI 316L steel (intragranular, intergranular, and rotational), and a physical interpretation of the observed patterns is offered. The results obtained are of great importance for practice, since the compound AISI 316L belongs to medical steels being used as implants in stomatology, bone impregnation, and biotechnology.

Keywords: AISI 316L steel, nano- and microindentation, hardness, Young's modulus, plasticity and resistance indices, relaxation parameters, plastic deformation mechanisms

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INTRODUCTION

One major problem in material sciences is the study of mechanical properties and estimation of their connection with a crystalline structure. The mechanical properties characterize the ability of the material to resist deformation and destruction [1–5]. Mechanical properties, such as elasticity, hardness, plasticity, viscosity, fatigue resistance, and sliding motion resistance, in most cases serve as the basis for the selection of the material meant for practical application [6–10]. Knowledge of the mechanical properties is essential both for the constructors and technologists. For metals, such as materials for construction, these features are primary [11–13].

The change in mechanical properties of a material can be greatly affected by the value of the applied load. In particular, the dependence of microhardness on the load magnitude has been the focus of research for a long time, particularly starting with discrepancy detection between the values of macrohardness and microhardness (later, nanohardness as well) for one and the same material, which were measured in similar conditions [1, 6, 7, 14]. For instance, on metals and ionic and covalent crystals, the "hardness-load" curves show, as a rule, two different stages of deformation, where an increase in the value of the applied load causes a decrease in microhardness [14–16]. Multicomponent semiconductors of ceramic and glass are more complicated [17–19]. For iron alloys, it was revealed that the dependence of hardness on the load, which is determined using the Vickers quasi-static method $H_v = f(P)$, is nonmonotonic when the load value changes in the range of P = 200–3000 mN. With a further increase in the load, hardness is decreased [20]. However, the general laws of this effect on metals were not completely established. The latter is mainly due to a fairly large number of factors (such as the chemical composition, the type of the crystalline structure, the method of deformation, the value of the applied load, the rate and temperature of the load being applied, etc.), which introduce an independent or joint contribution to the finite value of microhardness.

Taking into account all the aforementioned, this work is devoted to studying the effect of P load value, which is applied to an indenter, on the change of the mechanical properties of the AISI 316L samples, which are exposed to the action of the concentrated