EFFECT OF ELECTROLYTIC HYDROGENATION ON THE PROCESS OF CUTTING OF CARBON STEELS

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We study the effects of preliminary electrolytic hydrogenation of 20 and U8 carbon steels and a cutting tool on some parameters of the process of orthogonal cutting. The power consumption observed in the process of cutting of 20 and U8 steels (the force $P_t$) decreases in the presence of hydrogen. This effect is maximum if we hydrogenate the blanks. Hydrogen also decreases the bulk characteristics of the process of deformation of steel (surface roughness $R_a$ and chip shrinkage $k$) and localizes the cutting zone. Its influence on the strain hardening of materials in the cutting zone is ambiguous. Thus, for 20 steel, cold-hardening is intensified but, for U8 steel, becomes weaker. We analyze the regularities of the behavior of these parameters from the viewpoint of the influence of hydrogen on the deformation and fracture processes in steels.

Introduction

The machinability of metals is determined by the processes running in the cutting zone and affecting the physicomechanical properties of the metal and the material of a cutting tool. The cutting zone is characterized by high mechanical stresses, intense deformations, and thermo- and exoemission of electrons from the juvenile surfaces of a metal [1-4]. All these factors promote the oxidation of surfaces and enhance their roughness, which, in turn, results in a considerable increase in the friction coefficient and in the deterioration of the parameters of cutting. To increase the efficiency of cutting, it is customary to use cutting liquids. Especially high technological parameters can be attained by introducing high-molecular compounds (polymers) into cutting liquids [3-5]. It was established that specific conditions in the cutting zone are sufficient for the realization of chain depolymerization of the components of cutting liquids resulting in the formation of a pyropolymer in the form of active carbon and hydrogen [3, 4]. It is customary to believe that the positive influence of polymers on the process of cutting is predominantly a result of the sorption of hydrogen by the metal. In this case, hydrogen intensely affects the deformational and strength parameters of most structural metals and alloys [6-10]. Dissolved hydrogen weakens Fe-Fe bonds, thus increasing the parameter of the crystal lattice [8] and facilitating the processes of splitting of metallic bonds [11] and formation of covalent bonds in local volumes [12]. As a result, depending on the testing conditions and structural state, these phenomena either result in the plasticization of steel (hydrogen promotes the formation of dislocations, favors cross slip [9], and decreases the lower and upper yield limits [7]) or in its embrittlement (hydrogen intensifies the process of strain hardening [6] and increases the ultimate strength and yield limit [8]).

Since the destruction of polymers and, hence, the formation of atomic hydrogen run especially intensely on the juvenile surfaces of the metal, one must bear in mind the fact that atomic hydrogen also moves into the fracture zone due to the transport by dislocations (in the absence of surface barrier films) [10]. Moreover, the positive influence of hydrogen is explained by the fact that it, as a reducing agent, weakens the interaction between air oxygen and the tool in the cutting zone, thus decreasing its wear. Therefore, the enhancement of the efficiency of cutting liquids caused by the introduction of polymer components is explained by the ability of the latter to produce hydrogen. However, there are also some other procedures for introducing hydrogen into the cutting zone. Thus, the removal of the metal in the process of abrasive machining with a corundum wheel in water can be intensified by cathodic polarization [3].

In the present work, we study the influence of preliminary electrolytic hydrogenation of the machined material and the cutting tool on the parameters of cutting of steels.

Experimental Procedure

For certain methodological reasons [1], we applied low-speed orthogonal planing. For this purpose, we constructed an experimental installation on the basis of a UDM-5 tensile-testing machine. A holder with cutting tool equipped with a dynamometer was mounted on a movable crossbar. In the upper part of the columns, we fastened a vise with mandrel for a machined blank. The tangential component of the cutting force was recorded with an 8ANCh electronic amplifier and a KSP4 potentiometer.

We used plates 30×20×4.8 mm in size made of 20 steel (σ0.2 = 250 MPa, σu = 420 MPa) and U8 steel (σ0.2 = 440 MPa, σu = 750 MPa) in the as-received state. Tetrahedral plates 17×17×10 mm in size made of R6M5 high-speed steel served as cutting tools. They were quenched from 1200–1230°C with subsequent triple tempering for 1 h at a temperature of 560°C up to a hardness of 62–65 HRC (their structure can be described as tempered martensite). The tolerance for the sharpening of the working angles was kept within the limits ±30' and the surface roughnessRa was as high as 0.2–0.3 μm.

The material and cutting plates were hydrogenated in a 10% H2SO4 solution under currents with densities i = 2, 4, 6, and 8 A/dm2 for 30 or 90 min at a temperature of 22°C. Then the leading edge of the cutting plates was grind on a diamond wheel for 1 min to attain the radius of curvature of 0.001–0.002 mm. We used the following velocities, width, and depth of cutting: v = 0.002, 0.01, and 0.05 rev/sec, b = 4.8 mm and a = 0.1 mm, respectively.

The degree of cold-hardening of chips was evaluated by the formula

\[ N = \frac{H^1_{\mu}}{H^0_{\mu}} \]