INTERNAL FRICTION MEASUREMENTS OF THE EFFECTS OF THE ELECTROCHEMICAL-ABRASIVE TREATMENT OF TITANIUM ALLOY

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The influence of electrochemical grinding on the properties of WT3-1 titanium alloy is studied by the method of mechanical spectroscopy. On the basis of the experimental investigation of internal friction (with and without taking into account the amplitudes), it is shown that the formation of hydride phases is accompanied by the appearance of dislocations with complicated structure and the formation of stresses.

Electrochemical grinding used to machine the parts of complex shape consists of the anodic and abrasive treatment of the metal surface. The role of anodic polarization is to oxidize and dissolve the excess material, whereas grinding mechanically activates the surface and improves its quality. Very complicated processes run inside the crevice (30–50 μm) between the machined part and the tool. Thus, parallel with the anodic dissolution and evacuation of gases, we detected the ingress of hydrogen into the ground material [1]. Since hydrogen affects the mechanical properties of the metal, hydrogen charging may be used for the intensification of electrochemical grinding. In the present work, the effect of cathodic polarization and grinding on the elastic and inelastic properties of commercial titanium alloy is studied by the method of internal friction.

Experimental Procedure

Preparation of Specimens

Specimens (32.2 × 5.2 × 1.0 mm) were cut out from the WT3-1 commercial-grade titanium alloy containing 6 wt.% Al, 2 wt.% Cr, and 2 wt.% Mo. The structure of the material was formed by the α- and β-phases with a mean grain size of 100 μm.

Two types of surface treatment—mechanical and electrochemical—were applied. For the electrochemical treatment, the specimens were mounted in special clamps and immersed into an electrolyte (10 wt.% NaCl and 2 wt.% Na₂SO₄ in water; pH = 5.7) containing electrocorund abrasive particles (55–75 μm in size). The abrasive particles guaranteed the existence of a certain space between the tool and the machined part. The machined part was polarized cathodically and pressed with a force \( F \) of 5 N to the tool, which was polarized anodically as shown in Fig. 1. Voltages of \(-5\) and \(-10\) V were applied between the part and the tool. Mechanical polishing was carried out by using the same scheme without polarization with a diamond abrasive disc under a pressure force \( F \) of 20 N for a tool speed \( V = 20 \text{ m/sec} \). Both types of treatment were performed for 10 min.

After each treatment, the specimens were cooled to 200°K and then tested for internal friction.

Measurements of Internal Friction

Internal friction and resonance frequency were measured by using a computerized automatic relaxator of acoustic frequencies [2]. The specimen was mounted as a beam between two electrodes. A sinusoidal voltage was applied to excite bending oscillations at the resonance frequency in the specimen. The amplitude-independent measurements were carried out at a strain amplitude of \( 1 \cdot 10^{-4} \) in the process of heating from 200 to 480°K (at a heat-
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The rate of 1.5 K/min) and then in the process of cooling. The procedure was repeated twice. The amplitude-dependent measurements (within the strain-amplitude range from 2 · 10^{-5} to 1 · 10^{-3}) were performed at 475 K after the first and second heating of the specimen.

Fig. 1. Schematic diagram of the cathodic polarization of materials: (1) specimen (cathode), (2) metal disk (rotating anode), (3) electrolyte, (4) injector, (5) abrasive particles.

Hydrogen Absorption

The amount of absorbed hydrogen was measured by the vacuum extraction of hydrogen at 775 K from specimens both polarized cathodically as described above and polished without polarization.

Results

The amount of hydrogen absorbed by the studied specimens subjected to different types of treatment and extracted in the process of vacuum heating is shown in Table 1. It is seen that mechanically polished specimens absorbed some amount of hydrogen. Lower levels of hydrogen absorption under a voltage of -10 V than under a voltage of -5 V can be explained by an increase in the pH value of a solution as a result of the intense evacuation of hydrogen in the former case [1].

The values of the resonance frequency at a temperature of 350 K at which relaxation processes do not run in the studied materials are shown in Table 1. It is easy to see that the cathodically polarized specimens exhibited higher resonance frequencies than the mechanically polished specimens and the higher the concentration of hydrogen, the lower the resonance frequencies. These data reveal the effect of hydrogen on the elastic moduli of the treated material.

For the cathodically polarized material (Fig. 2), the behavior of $Q^{-1}$ as a function of temperature is quite complicated. Within the studied temperature range, one can distinguish two peaks, namely, a broad and complex peak $P_1$ at about 280 K and a narrow peak $P_2$ at about 415 K. The peaks $P_1$ and $P_2$ are observed in the course of both heating and cooling of the specimens. The spectra of internal friction of mechanically treated specimens also exhibited the peaks $P_1$ and $P_2$ (Fig. 3). The temperature and height of the peaks $P_1$ and $P_2$ appearing in the internal-friction measurements for specimens subjected to different types of treatment are summarized in Table 1.

The quite sharp $\lambda$-shaped peak $P_2$ was observed in all cases. It was accompanied by bands or peaks in the temperature dependence of the frequency (the upper parts of Figs. 2 and 3). This peak is also characterized by the pronounced hysteresis: the temperature of the peak was by 38 K higher in the process of heating than in the process of cooling (Table 1). The maximum height of the peak $P_2$ was observed in the second heating run (Table 1).