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Behavior of the grade 5 titanium alloy in different structural states in conditions of high-speed erosion

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Abstract

Behavior of a Grade 5 titanium alloy after high pressure torsion (HPT) and equal channel angular pressing (ECAP) under conditions of high-speed erosion was studied. Samples of the alloy in the ultrafine-grained state after the HPT and ECAP treatment were tested in an abrasive flow with various velocities using a technique similar to those presented in article Petrov et al. (2017). Two abrasive powders were used: with 109 and 230 μm average particle size. The tests were carried out at room temperature. Fracture surface parameters were studied for all tested specimens and fracture type (ratio of viscous and brittle fracture) was evaluated in each case. Additionally, surface roughness mass loss dependencies on particle flow velocity was investigated for both HPT and ECAP samples.

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Keywords: Grade 5 titanium, HPT, ECAP, high-speed erosion

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1. Introduction

The reliability and efficiency of modern equipment operating under aggressive erosion conditions depend on the quality of the surface of metals and alloys. In recent years, an improvement in the mechanical properties of these materials has more often been achieved by means of the formation of an ultrafine-grained structure. In particular, some parts of jet engines, nuclear reactors, steam turbines, and boilers have usually been subjected to intense erosive action. The surface damage of materials occurs due to the flow of solid, liquid, or gaseous particles or as a result of electrical discharges. Impacts caused by the flow of finest particles lead to the damage of the surface layer of the metal. In this paper, we compare the results of investigations on the high-speed erosion of the Grade 5 titanium alloy in a different structural state after high pressure torsion (HPT) and the equal channel angular pressing (ECAP) Valiev and Langdon (2006).

2. Materials and experimental technique

Grade 5 Ti alloy (or Ti-6Al-4V) samples after high pressure torsion (HPT) procedure and equal channel angular pressing (ECAP) were examined. The Grade 5 Ti alloy has the following composition: has the following composition: Ti – 89.%, Al – 6%, V – 4%, Fe – 0.25, O – 0.2%. This alloy is widely used in many applications including manufacturing of medical implants and production of parts for gas turbine engines.

The HPT procedure had the following parameters: imposed compressive pressure – 6 GPa, 10 revolutions of anvils with 0.2 revolution/minute rotation speed, room temperature. ECAP procedure included 4 passes of samples through the press at room temperature. In order to perform a solid particle erosion test, one should either fix the tested object in a two-phase air flow (accelerated air or another gas with mixed in abrasive particles) Goodwin et al. (1969), Kamkar et al. (2013), (2015) or move the object through the abrasive medium Tilly and Sage (1970).

In this study the abrasive powder was accelerated by an air flow in a small-scale wind tunnel. Figure 1 schematically shows the experimental setup. The velocity of the air flow is controlled by pressure in the system. Relation between air pressure and flow velocity is known due to calibration procedures. A special feeder device is used to mix abrasive particles into the air flow providing possibility to control concentration of the abrasive particles. The experiment duration is set with a remotely controlled sample inlet system. Thus, all basic parameters of the erosion experiment were controlled and therefore various conditions were obtained. All the tests were performed at room temperature and the impingement angle was equal to 90 degrees.

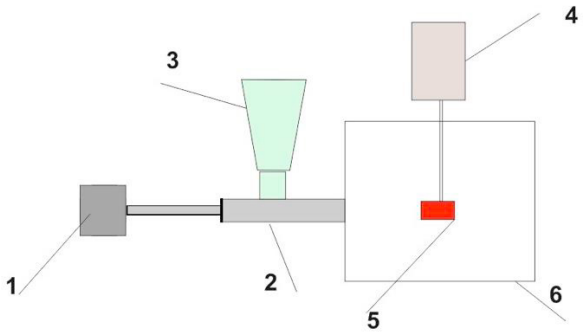

Fig. 1. Scheme of the experimental setup: 1 – compressor room, 2 – airflow acceleration pipe, 3 – solid particles feeder device, 4 – sample inlet device, 5 – holder with a mounted sample, 6 – working chamber

Corundum was used as an abrasive material. Two abrasive powders (with 109 and 230 μ m average particle size) were used for the experiment. In order to test both HPT and ECAP samples in equal conditions, a special sample