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*INFLUENCE OF ELECTRIC POTENTIAL ON ALUMINUM FRACTURE SURFACE FORMED UNDER THE CREEP TESTS**

ABSTRACT. Fracture surface analysis has been performed after creep of aluminum with 1 V, 5 V electric potential and without it. Scanning electron microscopy method was used for this investigation. In the research a negative effect of the electric potential on creep performance resulting in a creep rate increase and material durability reduction has been discovered. It has been found out that application of electric potential to the surface of the samples of pure aluminum under creep test leads to quantitative changes of the parameters the fracture structure is characterized by. It is demonstrated that application of electric potential up to 5 V is accompanied by pits of fracture of wide range of sizes and consequently by fracture viscosity reduction upon creep testing, as well as test time reduction. All this can cause premature failure of the item in service when electric potential is applied.

KEY WORDS. Creep, electric potential, fracture surface, fracture pits.

The metal parts made of aluminum alloys for heat and power elements, chemical, and other equipment being in operation under static mechanical loads, eventually plastically deform. One of the major problems in modern physics of strength and plasticity is the development of such materials, the mechanical properties of which would provide the greatest durability of the product at the maximum continuous operation [1].

Earlier studies performed on the aluminum creep and stress relaxation under the electric potential as high as 1 V proved, that it is possible to influence these processes, change their speed and durability of the material [2, 3]. Thus, the application of the potential as high as 1 V to aluminum is capable to increase the creep rate by almost twofold compared with the creep without applying the potential [3, 4]. The works [4, 5] have shown that the application of the potential as high as 1 V affects the evolution (the rate of accumulation and annihilation, the mechanisms of nucleation and restructuring scheme) of the defective volume substructure and the nearsurface pure aluminum layer under creep by contrast to the non-impact potential creep.

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Fault detection and analysis of the fracture surface under the aluminum creep of low temperature applying the potentials 1 V and 5 V is the aim of the present work.

The test material of the study is technical-grade aluminum of A85 grade. Before creep tests, the flat samples with dimensions 170 x 5 x 1.8 mm^3 obtained after rolling were subjected to recrystallization annealing at $T = 773\ K$, $t = 2h$. Some samples were deformed during creep under normal conditions (without electrical stimulation); another part was subjected to the electric potential of 1 V and 5 V. The temperature during the tests was controlled and was 300 K.

Throughout the creep, test an electrical potential was applied to the samples by means of a stabilized power supply. To exclude the electric current flow through the sample during the test, the samples were electrically insulated from the elements of the test rig.

Experiments were carried out on the test rig equipped with a software module, which allowed to fix the extension in time of the test samples at a constant load (60 mPa), a detailed description of which is given in [6]. Investigation of the fracture surface was carried by applying scanning electron microscopy methods with the use of FE-SEM Hitachi S 4-800 instrument in the laboratory of microstructural analysis of the Institute of Advanced Materials of Tsinghua University (Shenzhen).

As in [3, 4] during the experiments, it is determined the effect of accelerating creep by applying the electric potential to the samples. Figure 1 shows a typical experimental curve of aluminum creep with the application of 1 V potential. The average creep speed in the samples deformed without electrical stimulation was 0.03 1/h. With potential application the average speed increased: at 1 V the speed was 0.19 1/h , at 5 V—0.06 1/h. The greatest potential effect was indicated at 1 V.

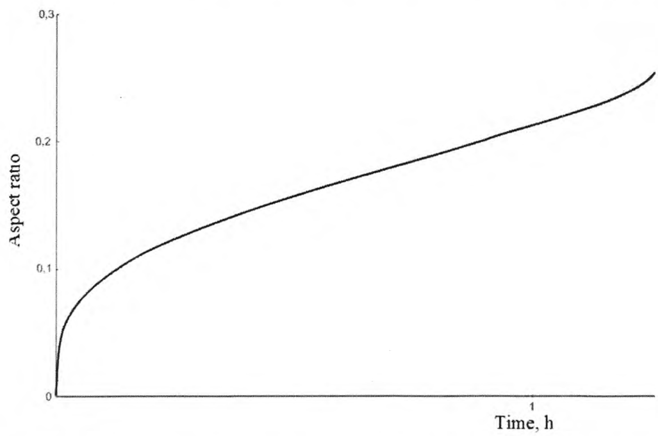

Fig. 1. Experimental curve of aluminum creep (without potential influence)

To identify the influence of the electrical potential effect on the fracture behavior, it was carried out the quantitative analysis of the diameters of fracture pits according to 5 fracture patterns for each condition of the material, i.e. without electrical stimulation and with the application of potentials.

Typical images of the fracture surface are shown in Figs. 2 and 3. Generally, the fracture surface of smooth cylindrical samples consists of a fiber area, a radial area, and a shear area [7]. In this case, the fracture surface of the flat sample comprises a fiber area and a shear area. The fiber area is located in the center of the fracture and it is characterized by a large number of fracture pits. There is a great number of slip bands near the fracture surface. The side surface microfractions are not detected.

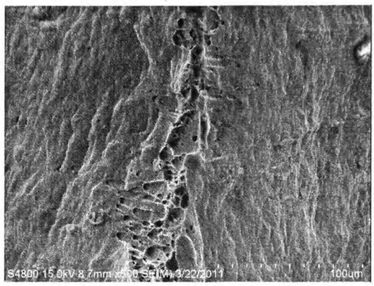

Fig. 2. Aluminum fracture surface; the creep without applying a potential

In the samples, those were destroyed in the creep process, applying the potential, shear pits and shear fracture pits mainly formed (Fig. 3), extended in the same direction (in the direction of the shear).

It is discovered that the diameters of the fracture pits range from 0.5 to 19.5 μm.

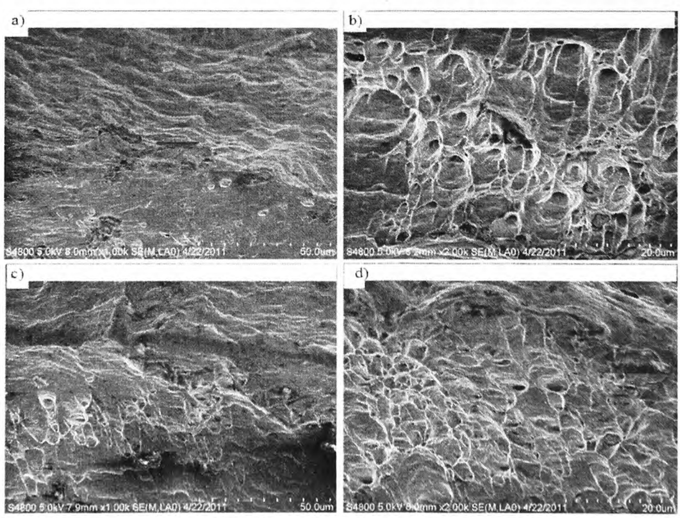

Fig. 3. Aluminum fracture surface formed under the creep, applying 1 V potential (a, b) and 5 V potential (c, d)

The quantitative analysis of the fracture surface determined that the diameters of fracture pits range from 0.5 to 19.5 μm. The average diameter of the pits in the samples destroyed without applying a potential (Fig. 4a) is 4.76 μm. The average diameter of the pits in the samples destroyed with the application of potentials 1 V and 5 V, make 2.09 μm and 2.12 μm respectively (Figs. 4b, c). Thus, the electric potential reduces the diameter of the pits in 2.2 times.

The shape and depth of the pits (micropores) can be linked (assuming one test material and identical loading scheme) with fracture toughness. Deep conical pits are often observed at fracture of very ductile materials [7]. It is believed [8] that the increase in fracture toughness is accompanied by an increase in the depth of pits on the fracture surfaces. Assuming that the depth of the shear fracture pits is proportional to their size, it can be concluded that the application of a potential contributes some reduction in fracture toughness of pure aluminum under creep conditions.

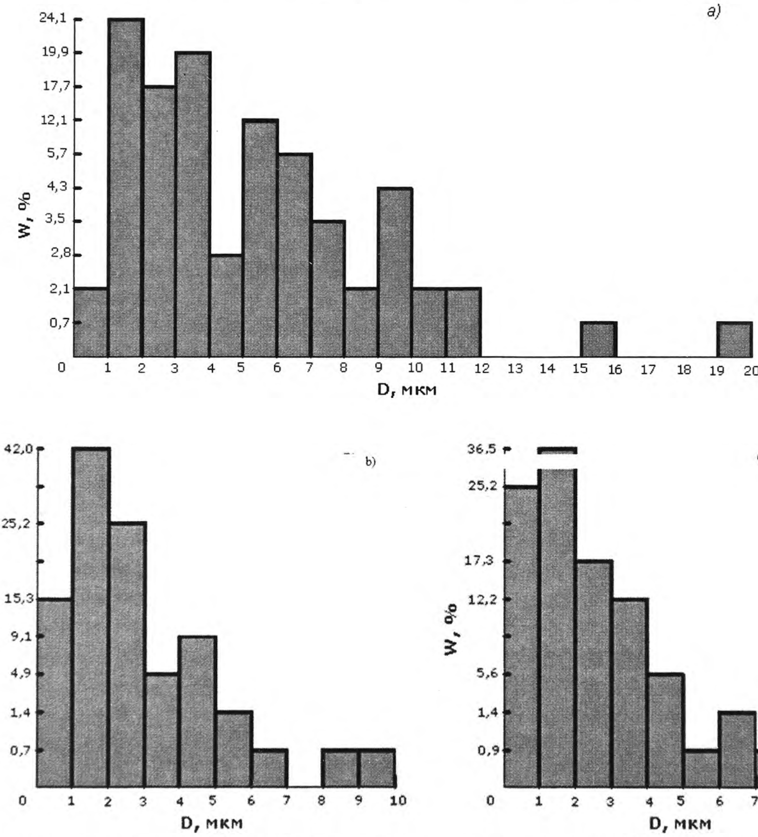

Fig. 4. The distribution of the diameters of shear fracture pits according to the size: without applying a potential (a); applying 1 V potential (b) and 5 V potential (c)

Since the rise of the number of nucleation sites reduces the size of the pits, we can conclude that the application of electric potential increases nucleation sites of shear fracture pits and leads to the reduction of fracture toughness.

The analysis of the fracture surface revealed that the application of an electric potential to the surface of pure aluminum subjected to creep test results in the change of the quantitative parameters which characterize the fracture. It has been indicated that the application of electrical potentials as high as 5 V is accompanied by the formation of a wide range of shear pits sizes and, respectively, by the decrease in fracture toughness under the creep tests, and by the decrease in test duration. All of this may lead to premature failure of the goods subjected to an electrical potential.

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