INVESTIGATION OF THE OPERATION OF GALVANIC CELLS FORMED AS A RESULT OF STRESS GRADIENTS DURING CORROSION FATIGUE OF AN ALUMINUM ALLOY

A. V. Karlashov and A. P. Batov


This article describes the results of an experimental study of galvanic cells formed by specimen surface regions in different stress states during corrosion fatigue of a grade D16 aluminum alloy.

Separate surface regions of metals subjected to corrosion fatigue are, for numerous reasons, acted on by stresses of different magnitude.

As previously shown [1], alternating stresses shift the electrode potential of aluminum alloys toward the more negative values.

The higher the applied stress level, the lower the electrode potential of the alloy. It may be postulated on this basis that a difference in stresses acting on two adjacent surface regions leads to the formation of a galvanic cell, the regions of higher and lower stress acting, respectively, as anodes and cathodes. It has been established [2], that the reduction in the fatigue strength of steel under the influence of corrosive media is directly associated with the magnitude of currents generated by cells of this kind. Studies of the operation of such cells formed on the surface of aluminum alloys are therefore of considerable importance as a means of elucidating the mechanism of corrosion-fatigue failure of these alloys.

This investigation was concerned with an aluminum alloy D16 (4% Cu; 1.29% Mg; 0.76% Mn; 0.19% Si; UTS (σ₀) = 55 kg/mm²; proportionality limit σ₀ = 43.5 kg/mm²; δ = 13%) solution-treated and age-hardened at room temperature. The tests were carried out on notched and unnotched specimens made from rod of a single melt in accordance with GOST 2860-46. The notch was in the form of a V-shape circular groove 0.75 mm deep with an opening angle of 60° and notch root radius of 0.24 mm.

The specimen surface was painted with an acid-resistant varnish (undercoat VL-02 and lacquer KhSL) leaving exposed only a circular band in the center of the gage portion (a band 10 mm wide in the case of smooth specimens and the surface of the groove in the case of notched specimens). The exposed surface areas of two identical specimens were cleaned with a fine emery paper, degreased in benzene, acetone, and ethyl alcohol, after which they were placed in a desiccator for 24 hr.

To measure currents generated by galvanic cells formed as a result of stress gradients, we constructed an apparatus (Fig. 1) consisting of two MUI-6000 machines with a common drive, two communicating chambers for the corrosive medium, and an automatic recording N378-2 microampere-millivoltmeter. The specimens were connected to the electric circuit with the aid of current collectors in the form of brass rods with flexible copper strips. The two MUI-6000 machines were electrically insulated from each other.
Fig. 2. Time dependence of the current between two smooth specimens of a D16 alloy in a 3% NaCl solution at the following cyclic stress gradients (kg/mm²): 1) 20; 2) 15; 3) 10.

Fig. 3. Time dependence of the current between two notched specimens of a D16 alloy tested in a 3% NaCl solution at the following stress gradients (kg/mm²): 1) 12; 2) 10; 3) 8.

Each test was started by measuring the current generated between two unloaded specimen rotating at the same speed.*

Then, one of the specimens was loaded and fatigued to fracture. Thus, one specimen was subjected to the influence of alternating stresses and a corrosive medium, the other being exposed only to the action of the corrosive medium. The testing equipment ensured pure rotating bending and a symmetric stress cycle. The stress reversal frequency was 3000 cpm, a 3% NaCl solution was used as the corrosive medium. The results of measurements of currents generated between stressed and unstressed specimens are reproduced in Figs. 2–4. Tests at each stress level were repeated 3–5 times. Each curve in the figures relates to one pair of specimens.

Data in Fig. 2 show that an electric current is generated as soon as a cyclic stress is applied to one of the specimens. The magnitude of this current in the initial test stages is small (1–3 µA) and remains constant for a certain time which increases with decreasing stress. As the number of stress cycles (time) increases, the current also increases at a rate and to a level which increases with increasing stress. It is significant that from the moment of loading to fracture the stressed specimen is the anode of the galvanic cell studied.

The character of the variation in current generated by cells consisting of notched specimens is slightly different (Fig. 3). After reaching a certain level the magnitude of the current remains practically constant for a relatively long time. Increasing the stress gradient also leads to an increase in the current generated by cells of this kind.

* A device relieving the specimens from the weight of headstocks is not shown in Fig. 1.