EFFECT OF LOADING FREQUENCY ON THE FATIGUE STRENGTH OF AN ALUMINUM ALLOY V95 SUBJECTED TO THE PHYSICO-CHEMICAL ACTION OF THE WORKING MEDIUM

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Most modern structures are subjected to the simultaneous action of various working media and complex alternating service loads in a wide frequency range. The effect of loading frequency on the fatigue strength of metals operating under these conditions was studied by many workers [1-4]. It was established in some of these investigations that the corrosion-fatigue strength of smooth specimens increases with increasing stress cycle frequency within quite a wide frequency range: 1500-10 000 cpm [1]; 6-1450 cpm [3]; 60-1410 cpm [4].

This article describes the results of an experimental study of the effect of loading frequency (200 and 6000 cpm) on the fatigue and corrosion-fatigue strength of smooth and V-notched specimens of an aluminum alloy V95 possessing the following mechanical properties: UTS = 58 kg/mm²; YP = 45 kg/mm²; elongation = 9.5%. Fatigue test pieces were prepared from rod stock of a single melt, in accordance with GOST 2860-45. The notches (three on each specimen) were cut with a forming tool; the notch depth was 0.75 mm, the included angle α = 60°, and the notch root radius R = 0.24 mm. The fatigue tests were carried out in rotating bending on type MUI-6000 machine; tests at the low stress cycle frequency were carried out on modified machines of the same type. Owing to a wide scatter of fatigue test results on aluminum alloys, 7-10 specimens were tested at each stress in the high-stress range, and 10-17 specimens at low stresses at which some of the specimens remained unbroken. The results were processed by the statistical methods of [5, 6]. The fatigue curves reproduced in this article were plotted for a probability of fracture P = 50%, which ensures the best reproducibility of replicate test results.

As shown in Fig. 1a (curves 1 and 2), increasing the loading frequency from 200 to 6000 cpm produces an increase in corrosion-fatigue strength of smooth specimens. This effect is evidently attributable to a reduction in the cyclic plastic strain, in the degree of electrochemical heterogeneity under these conditions [4], and in the time during which specimens tested at high loading frequencies are acted upon by the corrosive medium. The corrosion-fatigue strength of notched specimens remains practically the same at the loading frequencies studied (see Fig. 1a, curves 5 and 6).

Previous investigations [2] of the corrosion-fatigue strength of identical specimens tested at 5000 and 10 000 cpm also produced no evidence of the results being affected by the loading frequency. It may therefore be concluded that the corrosion-fatigue strength of alloy V95 specimens with sharp notches is not affected by variation in loading frequency in the range 200-10 000 cpm.

If one compares the corrosion-fatigue curves obtained for notched specimens at 200 and 6000 cpm with the corresponding curves for smooth specimens, it may be postulated that the absence of a frequency effect in the former case is associated with the presence of notches whose effectiveness as stress raisers depends on the time the specimen remains in the corrosive medium. This is indicated by the fact that curves 1, 5 and 2, 6 in Fig. 1 converge as τ increases. Curves 2 and 6 intersect at N = 10⁷ cycles which corresponds to τ = 880 hr; this means that at a low loading frequency the
corrosion-fatigue strength of smooth and notched specimens becomes the same. This effect is not observed at the high loading frequency although there is a clear tendency for the curves to converge; in this case, however, \( N = 10^7 \) cycles is equivalent to \( \tau = 28 \) hr. The difference between curves 1, 5 and 2, 6 is evidently associated with the difference in the time during which the notch (i.e., the stress raiser) is acted upon by the corrosive medium. At a low loading frequency, the effectiveness of stress raisers is considerably lower than at high frequencies because of the longer action of the corrosive medium. Other investigations \([7, 8]\) produced similar results.

To explain the fact that loading frequency has no effect on the corrosion-fatigue strength of notched specimens, it is necessary to compare curves 1, 5 with curves 2, 6 (Fig. 1), which were obtained under identical test conditions. The relative positions of curves 5 and 6 should evidently be similar to those of curves 1 and 2, i.e., the corrosion-fatigue strength of notched specimens fatigued at a low frequency should be lower than at a higher frequency. The effectiveness of the action of stress raisers is many times lower at low loading frequencies, however; as a result, no reduction in the corrosion-fatigue strength of notched specimens tested at these frequencies takes place.

Thus, the absence of any effect of loading frequency on the corrosion-fatigue strength of notched specimens may be attributed to a more substantial reduction in the effectiveness of stress raisers at low frequencies due to the longer action of the corrosive medium on the stress raisers at the same stress levels.

On the other hand, the fatigue strength of notched specimens does depend on the loading frequency, the magnitude of this effect depending on the number of cycles to fracture (Fig. 1a, curves 3 and 4). For instance, the corrosion-fatigue limit at \( N = 4 \times 10^4 \) cycles is increased by 15% when the loading frequency is increased from 200 to 6000 cpm; at \( N = 10^4 \) cycles it is slightly (by 5%) reduced. It is known that the effect of loading frequency is associated mainly with the influence of the strain rate on the resistance of metals to plastic deformation \([9, 10]\). Increasing the loading frequency produces an increase in the strain rate and, as a result, leads to a reduction of the probability of recovery and to an increase in the resistance to plastic deformation, i.e., intensifies the strain-hardening effect. This is the most likely cause of the increase in fatigue strength produced by increasing the loading frequency in the high stress range. On the other hand, the reduction in the fatigue strength of notched specimens in the low stress range (below 10 kg/mm\(^2\)) is due, as was shown in \([2]\), to a reduction in the effectiveness of the stress-raising action of the notches under the influence of the corrosive action of air, whose relative humidity in our tests (lasting 140-880 hr) was comparatively high (80-85%). Since the critical humidity of air for aluminum alloys does not exceed 70-75%, it becomes obvious that the corrosive action of the atmosphere had manifested itself in our tests and affected the loading frequency effect.

The effect of loading frequency in fatigue tests is usually measured in terms of the ratio of endurances at respective frequencies. In the present investigation, we used the coefficients

\[ K = \frac{N_f}{N_h} \quad \text{and} \quad C = \frac{\tau_f}{\tau_h}, \]

where the stress \( \sigma \) is expressed in kg/mm\(^2\) and the endurance \( N \) in cycles.