EFFECT OF LOADING FREQUENCY ON THE ENDURANCE OF DURALUMIN
IN AIR AND IN CORROSIVE MEDIA

V. P. Tokarev


The effect of loading frequency (6000 and 200 cpm) on the endurance of D16T duralumin in air and in water was studied. It was established that the "frequency effect" depends on the working medium.

According to Ratner [1], the influence of loading frequency on the corrosion-fatigue strength of metals is associated mainly with its effect on the time of exposure of the metal to the action of a corrosive medium. It is therefore to be expected that the "frequency effects" in the case of metals fatigued in air and in corrosive media will be different.

The aim of this investigation was to estimate the effect of loading frequency on the endurance of D16T duralumin (σb = 53 kg/mm²; proportionality limit = 48 kg/mm²; δ = 12%) in air and in a corrosive medium. The fatigue tests were carried out on unnotched and notched specimens (GOST [Soviet standard] 2860-45) at loading frequencies of 200 and 6000 cpm. The tests were carried out on modified MUI-6000 machines. The notch was a V-shaped circular groove 0.75 mm deep with an occluded angle of 60° and a notch-root radius of 0.24 mm. Specimens for tests in air had three notches each; specimens for tests in the corrosive medium had only one notch.

A jet of the corrosive medium (water) was played on the specimen which ensured that its gauge portion was continually wetted.

A statistical approach was used in the investigation: 6-9 specimens were tested at each stress level. This made it possible to perform linear regression analysis of the results obtained and to estimate the probability of fracture.

The fatigue curves reproduced in Figs. 1 and 2 correspond to a probability of fracture P = 50%. This probability was chosen because relative values, especially coefficients measuring the "frequency effect", are most likely to be reproducible in replicate studies.

It will be seen that change in the loading frequency from 6000 to 200 cpm produces a change in the endurance of duralumin both in air and in water (Figs. 1 and 2). The magnitude of this change and sometimes its sign depend on the applied stress level. Thus, curves 1 and 2 in Fig. 1 show that the most marked reduction in the endurance of duralumin in air due to decreased loading frequency is observed at high stress levels: a 45% reduction in the case of unnotched specimens fatigued at σ0 = 25 kg/mm², and a 50% reduction in the case of notched specimens tested at σ0 = 15 kg/mm². Decrease in the stress level (from 25 to 15 kg/mm² for unnotched specimens and from 15 to 9.5 kg/mm² for notched specimens) leads to a gradual decrease in the magnitude of the "frequency effect." Further reduction in the stress level (below 9.5 kg/mm²) leads to a change in the sign of the "frequency effect." According to current theories [2, 3], decrease in the loading frequency (which produces a reduction in the strain rate) increases the possibility of recovery and

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**Fig. 1.** Fatigue curves of D16T duralumin tested at 200 cpm (broken lines) and 6000 cpm (continuous lines): 1) unnotched specimens; 2) notched specimens. Number of unbroken specimens: I) 7; II) 7; III) 10; IV) 5; V) 2.

**Fig. 2.** Corrosion-fatigue curves of duralumin tested at 200 cpm (broken lines) and 6000 cpm (continuous lines): 1) unnotched specimens; 2) notched specimens. Number of unbroken specimens: I, II, III, IV) 8; V) 10.
Fig. 3. Stress dependence of the "frequency effect" in air (curves 1 and 2) and in water (curves 3 and 4): 1, 3) unnotched specimens; 2, 4) notched specimens.

Fig. 4. Stress dependence of $\gamma_c$ at loading frequencies of 1) 200 and 2) 6000 cpm.

reduces the resistance of metals to plastic deformation, i.e., increases the extent of fatigue-induced weakening of the material. This evidently explains the reduction in the fatigue strength in air.

On the other hand, the fact that the fatigue strength of notched specimens tested at stresses lower than 9.5 kg/mm$^2$ is increased by reducing the loading frequency from 6000 to 200 cpm can be explained only by a reduction in the effectiveness of stress raisers [notches] due to atmospheric corrosion, which takes place as a result of high humidity of the laboratory atmosphere (exceeding by 10-15% the critical humidity for aluminum alloys) and by increased test duration (150-800 hrs).

The influence of atmospheric corrosion on the effectiveness of stress raisers at low loading frequencies during long-time (200-800 hrs) fatigue tests was experimentally verified on V95 alloy [4]. Reduction in the loading frequency leads to a decrease in the corrosion-fatigue strength at all stress levels studied; the magnitude of this reduction increases with decreasing stress level. Thus, the character of the stress dependence of the "frequency effect" in air and in corrosive media is different.

A quantitative measure of the "frequency effect" is given by coefficient $K = N_{200}/N_{600}$ where $N$ denotes the endurance (cycles to fracture) at loading frequencies indicated by indices. The stress dependence of $K$ of various specimens is shown in Fig. 3.

Comparison of curves 1 and 3 with 2 and 4 in Fig. 3 shows a substantial difference in the extent of the influence of the loading frequency on the fatigue strength of duralumin in air and in water. Thus, in the case of smooth specimens (curves 1, 3) fatigued at stresses higher than 21 kg/mm$^2$ the effect of the loading frequency on the endurance of D16T alloy in air is larger than that in water (for instance, at $\sigma = 25$ kg/mm$^2$ the reduction in the endurance of specimens tested in air and in water is 46 and 10%, respectively); at stresses lower than 21 kg/mm$^2$ the situation is reversed: at $\sigma = 15$ kg/mm$^2$ the endurance of specimens tested in water is reduced by 60%, while the endurance of specimens tested in air remains the same.

These differences are attributable to the fact that the endurance of duralumin fatigued in corrosive media at various loading frequencies is determined not so much by the strain rate as by the degree of influence of the corrosive medium. This degree of influence depends both on the time of exposure to the corrosive medium and on the strain rate, and it is measured by coefficient $\chi = N_c/N_a$, where $N_c$ and $N_a$ denote endurance in the corrosive medium and in air, respectively.

Data in Fig. 4 show that at stresses higher than 21 kg/mm$^2$ the effect of the corrosive medium at the high loading frequency is more pronounced than at the lower loading frequency and that the reverse applies at stresses lower than 21 kg/mm$^2$. The stronger influence of the corrosive medium at low loading frequencies is associated with a longer time of exposure of specimens to the action of the medium.

In the case of notched specimens the effect of the loading frequency also depends on the working medium (Fig. 3, curves 2 and 4). The resulting difference in the endurance is small at stresses of 13-15 kg/mm$^2$, but increases at stresses below 13 kg/mm$^2$; at stresses lower than 9.5 kg/mm$^2$ the "frequency effect" in the case of notched specimens changes its sign; i.e., reduction in the loading frequency increases the endurance of these specimens in air and substantially decreases their endurance in water. Thus, reduction in the loading frequency at a stress of 8 kg/mm$^2$ produced a 60% increase in the endurance in air and a 50% reduction in the endurance of specimens tested in water.