THE EFFECT OF CORROSION DAMAGE AND AGGRESSIVE MEDIA ON THE ENDURANCE OF ALUMINUM SHEET

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The article describes the results of an investigation of the endurance and corrosion-fatigue strength of grade-D16AT aluminum-clad duralumin with crater-like corrosion pits. It was established that the fatigue resistance of duralumin decreases with increasing depth and surface area of corrosion-induced defects of this kind.

In aircraft servicing and overhaul there are often occasions when it is necessary to estimate the condition of various parts and structures damaged by corrosion. In many cases, the corrosion damage is so severe that the need for replacing a given component becomes obvious even after visual examination. Sometimes, however, the issue is not so clear cut, and the load-carrying capacity of structural elements partially damaged by corrosion can be estimated only on the basis of experimental data on the effect of corrosion damage on the static and fatigue strength of materials in question. Some pertinent data can be found in [1, 2], where the effect of crater-like pits (simulating localized corrosion damage) on the UTS and elongation of grade-DIT duralumin is discussed. Some information on the effect of relatively small and shallow surface defects (scratches, file marks, cuts, etc.) on the fatigue strength of steel is given in [3-5].

The aim of this investigation was to study the dependence of fatigue and corrosion-fatigue strength of grade-D16 duralumin on the geometry of localized corrosion damage.

The fatigue and corrosion-fatigue tests were carried out on flat specimens (Fig. 1) with a 15 mm-wide gauge portion. The specimens were made from 2 mm-thick grade-D16AT aluminum-clad duralumin (4.2% Cu; 1.6% Mg; 0.5% Mn; 0.3% Fe; 0.2% Si; $\sigma_B = 45.7$ kg/mm$^2$; $\sigma_T = 36$ kg/mm$^2$; $\delta = 16.6$%). To imitate localized corrosion damage, crater-like pits were produced with the aid of hydrochloric acid [1, 2] on the surface of the specimen gauge portion. To increase the probability of fracture, three such craters were made on each specimen (Fig. 1). Specimens with craters of different depth (including through holes) and diameter were tested; the crater diameter and depth were measured with the aid of a microscope and a special depth-measuring instrument [6].

The specimens were tested in pure bending at 500 cpm and at a stress of $\sigma = \pm 11.5$ kg/mm$^2$, which approaches the conditional fatigue limit ($\sigma_{-1} = 10$ kg/mm$^2$) of this material corresponding to $N = 10^7$ cycles. The tests were carried out in air and in a 3% NaCl solution (supplied to the specimen by a drip-feeding method).

The effect of crater-like corrosion pits and corrosive medium on the fatigue properties of the specimens tested was expressed in terms of a coefficient $\gamma$ which is the ratio of values $N$ (the number of cycles to fracture) recorded under various test conditions. The effect of craters on the endurance of specimens fatigued in air and in NaCl is characterized by the coefficients

$$\gamma_{cr} = \frac{N_{cr}}{N} \quad \gamma_{cr} = \frac{N_{cr}^C}{N_C},$$

where $N$ and $N_C$ denote the endurance of smooth specimens tested in air and in the corrosive medium at a given stress level, while $N_{cr}$ and $N_{cr}^C$ are endurances of specimens with craters tested under the same conditions.

These coefficients show how the endurance of specimens tested in air and in NaCl is affected by the introduction of corrosion pits (craters).

The effect of the corrosive medium on the endurance of specimens with craters is characterized by the coefficient $\gamma_C^{cr} = N_{cr}/N_{cr}$. The combined influence of craters and NaCl is characterized by coefficient $\gamma_{cr} = N_{cr}/N$.

The results of fatigue and corrosion-fatigue tests are reproduced in Fig. 2. It will be seen that endurance of duralumin depends on the depth and diameter of the corrosion craters: it decreases as these parameters increase. The reduction in endurance both in air (Fig. 2a) and in NaCl solution (Fig. 2b) is specially marked for the crater depth corresponding to 25-30\% of the material thickness. Further increase in the depth of corrosion damage produces a relatively smaller reduction in the endurance. Thus, introducing craters 2 mm in diameter and 0.5 mm deep (which correspond to 25\% of the material thickness) reduced the endurance of specimens tested in air by 46\% ($\gamma_{cr} = 0.54$, Fig. 3a), the corresponding reduction for specimens tested in 3\% NaCl solution being 48\% ($\gamma_{cr} = 0.52$, Fig. 3b). Increasing the crater depth to 2 mm (so that through holes were obtained) produced an additional reduction in the endurance of only 22\% in air ($\gamma_{cr} = 0.32$) and 23\% in NaCl solution ($\gamma_{cr} = 0.29$).

The endurance of duralumin is most markedly affected by the combined influence of corrosion craters and corrosive medium, the effect of which is characterized by coefficient $\gamma_{cr}$. The effects of these two factors are not additive, however. Thus, while the endurance of specimens without craters under the influence of NaCl solution was reduced by 50\% ($\gamma_C = 0.5$)* and the reduction produced by craters 2 mm in diameter and 0.5 mm deep was 46\% ($\gamma_{cr} = 0.54$), their combined influence produced a reduction of 75\% ($\gamma_{cr}^{cr} = 0.25$, Fig. 3).

Figure 4 shows how the coefficients $\gamma$ are affected by the diameter of the craters of different depths. These data make it possible to determine the admissible size of localized corrosion damage, i.e., the dimensions of pits which have no effect on the endurance of aluminum-clad duralumin. Experiment shows that when the depth of corrosion craters does not exceed 0.1 mm (i.e., when the damage is confined to the cladding material), the fatigue fracture does not as a rule take place through a crater. Only when the duralumin core is damaged to a certain depth does the fatigue crack run through a crater†, this being markedly

* $\gamma_C = N_{cr}/N$ is the coefficient characterizing the effect of the corrosive medium on the endurance of smooth specimens.

† The fracture in these cases took place through any one of the three craters, at random.