COMPARATIVE STUDY OF THE EFFECT OF ANODIZING AND OF CLADDING FOLLOWED BY ANODIZING ON THE CYCLIC STRENGTH OF DI6T SHEET MATERIAL

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Aluminum alloy sheet materials are protected by cladding and subsequently anodizing them, while extrusions are protected by anodizing. The oxide film formed in the latter case effectively protects DI6T material against corrosion fatigue and also raises its fatigue strength in air [1]. Cladding, however, protects this material only very slightly against corrosion fatigue and reduces its fatigue resistance in air. Moreover, the cladding layer has been found to reduce considerably the beneficial effect of anodizing on the fatigue strength of DI6T material in air and in a corrosion medium [2].

The object of the present investigation was to determine the effectiveness of cladding sheet material and subsequently anodizing it as compared with anodizing alone under corrosion-fatigue conditions. Tests were carried out on DI6T and DI6AT materials (the latter being the clad sheet) rolled from the same alloy melt. Specimens [3] of the material with and without the clad layer were anodized in a sulfuric acid solution (1.84 g/cm$^3$) under the following conditions: 180 g/liter at 20°C and current density $i$ A/dm$^2$ for 35 min. The film was sealed in boiling tap water for 25 min. The best anodic films were obtained by using these conditions [4]. Fatigue tests were carried out on the specimens under conditions of pure symmetrical bending, using an MPI-4 machine with a frequency of stressing of 500 cycles/min. The basis of the tests was $5 \times 10^6$ cycles, and a 3% NaCl solution was used as the corrosion medium.

The endurance of anodized smooth specimens in air was higher than that of clad specimens and also of clad and anodized specimens; but it was lower than that of uncoated specimens (Fig. 1).* At stresses above 18 kg/mm$^2$ the endurance of anodized material was somewhat lower than that of uncoated material, as had already been observed in [4]. The corrosion-fatigue endurance of material investigated with all the coatings was higher than that of uncoated material.

The effect of cladding, of anodizing, and of the two processes together on the fatigue resistance of the material in air and in the corrosion medium was assessed by the respective coefficients

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\beta = \frac{\sigma_{-1}^{\text{coat}}}{\sigma_{-1}} \quad \text{and} \quad \beta_c = \frac{\sigma_{-1c}^{\text{coat}}}{\sigma_{-1c}},
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where $\sigma_{-1}^{\text{coat}}$ and $\sigma_{-1c}^{\text{coat}}$ are the fatigue limits of the coated material in air and in the corrosion medium, respectively, for a chosen endurance, and $\sigma_{-1}$ and $\sigma_{-1c}$ are the fatigue limits for uncoated material under the same test conditions.

It can be seen from Fig. 2a that anodizing raises the fatigue resistance of the material, whereas cladding and cladding followed by anodizing reduce it. The extent of the rise in strength of the material resulting from anodizing and also the extent of its reduction that results from cladding increase with rise in the endurance. At the chosen basis of the tests, anodizing raises the fatigue limit of the material by 19% ($\beta_{\text{an}} = 1.19$, curve 3), whereas cladding reduces it by 28% ($\beta_{\text{cl}} = 0.72$, curve 1). The extent of the fall in the nominal fatigue

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*The fatigue curves were constructed for a failure probability of 50% from the results of treating the data from tests on 7-10 specimens at each stress level.
Fig. 1. Fatigue curves for material without coating (1), with an anodic film (2), with a clad layer (3), and with a clad layer and anodic film (4) in air (a) and in a 3% NaCl solution (b).

Fig. 2. The coefficient $\beta_{cl}$ (1), $\beta_{cl\cdot an}$ (2), and $\beta_{an}$ (3) as functions of the endurance in air (a) and in the 3% NaCl solution (b).

All the coatings investigated raise the corrosion-fatigue resistance of the material (Fig. 2b). The extent of the rise in strength of the material increases with rise in the endurance; with anodizing it is 134% ($\beta_{an\cdot c} = 2.34$, curve 3), with cladding it is 42% ($\beta_{cl\cdot c} = 1.42$, curve 1), and with cladding followed by anodizing it is 110% ($\beta_{cl\cdot an\cdot c} = 2.1$, curve 2).

Compressive residual stresses were found to act in the anodic film. The effect of anodizing on the fatigue resistance of the alloy in air and in the corrosion medium is accounted for both by the presence of residual stresses in the film and its screening action and by the stress concentrations at the cracks formed in the film during cyclic stressing [4]. The smaller effectiveness of cladding followed by anodizing in comparison with anodizing alone is attributed to the fact that during cyclic stressing cracking occurs first in the clad layer (Fig. 3), and this gives rise to premature failure of the anodic film and the core of the specimen.

Under actual conditions the stressed members and the casing of an aircraft are in many cases joined by riveting. Consequently, in making an accurate assessment of the effectiveness of the coatings it is essential to know their influence on the endurance not only of smooth specimens, but also of specimens containing rivet holes. Tests were therefore made on specimens measuring $220 \times 20 \times 2\,\text{mm}^3$, which contained three holes 4 mm in diameter, situated 25 mm apart in the middle of the specimen and along its length. The holes were drilled after anodizing. As can be seen from Fig. 4, the fatigue resistance of the anodized material in air