THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING
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Final Report

A STUDY OF HIGH-SPEED MILLING

Part III. Stress Corrosion Cracking

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ABSTRACT

The consistent absence of corrosion cracking in pre-strained specimens of heat-treated B-120 titanium, over a range of temperatures that normally results in cracking of spot-welded specimens in a corrosive environment, suggests that corrosion cracking does not result in this case from prior plastic deformation alone. The known conditions present in the welded specimen that are absent in the pre-strained specimen are (1) residual stresses, and (2) plastic deformation at elevated temperatures. Studies are described that should aid in discriminating between these two factors and thus improve understanding of this particular example of stress corrosion cracking.

I. RESULTS OF TESTS

The current study has been directed toward defining the conditions under which stress corrosion cracking will and will not occur in titanium alloys, B-120 in particular, of specimen size 0.025 in x 1 in. x 4 in. An initial hypothesis was that prestrain alone, in the presence of a chlorine-base liquid, followed by heating to 600-800°F, might produce cracking. Test were carried out, as reported in detail in the monthly progress reports, in which the B-120 was exposed to a wide range of plastic strains, through lateral compression, both before and after immersion in a corrosive liquid. At the outset carbon tetrachloride was used, but later it was learned that Houghton Cut-Max 568, a machining fluid, was very effective in causing cracking in B-120 spot welds. Therefore, HCM 568 was used in all subsequent tests. In no case of prestrained B-120 titanium, held at temperatures from 70-800°F for periods of 1 to 6 hours, was visible cracking produced. Since some association between prestrain and pitting was observed, however, it may be possible that pitting occurred preferentially at the root of prior cracks that had been slightly prestrained.

A series of tests was conducted with notched specimens, prestrained in bending. In several instances, short cracks at the roots of the notches were produced by the bending prestrain alone, but in no case did cracking occur during heating.

From these limited tests, it is concluded that prestrain alone is not sufficient to cause cracking during heating in the presence of HCM 568.

II. EFFECT OF RESIDUAL STRESSES

A simple test may be devised to determine the influence of residual stresses on stress corrosion cracking. Using the same specimen size, 0.025 in. x 1 in. x 4 in., a jig could be devised to hold the specimen in bending during heating. Tests on prestrained and non-prestrained specimens might show the difference between these two parameters. Although the stress field would not be "residual" in the sense that there are no external loads, the behavior of the stressed material should be similar to the behavior of material subjected to residual stress fields.

current theories of stress corrosion cracking provide for progressive intergranular cracking of a brittle type, in the presence of stress, as a result of reduced surface energy in the presence of the corrosive environment. In order to compare the fracture of the B-120 alloy with theory, it would be desirable to establish the nature of cracking. This could be accomplished through metallographic examination of fractures of spot-welded specimens.

III. EFFECT OF ELEVATED TEMPERATURE PRESTRAIN

While it is not believed that the prestrain that occurs during the high-temperature portion of spot-welding is a primary contributor to cracking, it may play a part of sufficient importance to warrant attention. In other materials, notably steels, deformation at moderately elevated temperatures (500-600°F) is now known to cause a remarkable reduction in ductility at room temperature. If such an effect exists for B-120 titanium, then cracking in the presence of a corrosive environment would be made even more likely.

To test this hypothesis, carefully controlled prestraining would have to be performed on a number of specimens at temperatures from 70°F to as high as possible. Each of these could then be subjected to a standard brittleness test (a simple bend test, for instance, in which the deflection at fracture is a measure of ductility) to detect the extent of embrittlement resulting from deformation over a range of temperatures. The already low ductility of the heat-treated B-120 alloy at room temperature severely limits the amount of prestrain in this range. The ductility under elevated temperature environments is not known for this alloy, but it is certainly higher.

IV. OBJECTIVE OF THIS STUDY

Even without the study of the effect of elevated temperature prestrain, if the tests on artificially stressed specimens at elevated temperatures produce stress corrosion cracking, it should be relatively easy to devise a reproducible test to measure the sensitivity of B-120 alloy (or other alloys, almost certainly) to a particular corrosive environment. From the application of this test to cutting fluids that are found to have otherwise desirable properties, it should be possible to select the most promising fluid—if any one of the fluids is clearly more promising than the others.