NASA TECH BRIEF
Langley Research Center

Strain Gage Attachment By Spot Welding Reduces the Fatigue Strength of Ti-6A1-4V, Rene 41, and Inconel X

Some existing resistance strain gages and other types under development are attached by spot welding. An experimental investigation was conducted to evaluate the effect of spot welding, as used for instrumentation attachment, on the fatigue behavior of Ti-6Al-4V, Rene 41, and Inconel X.

For the titanium-alloy specimens, a commercially available weldable resistance strain gage with a metal back was used. The resistance element for the gage was embedded in compacted magnesium oxide powder and insulated from a small metal tube that was attached to the gage backing. The metal backs were made from three alloys: a titanium alloy, a gold alloy, and a stainless steel alloy. For the superalloys, weldable strain gages were simulated by metal foils spot welded to the specimen. The foil alloy was the same as the specimen alloy in both cases.

Fatigue tests were conducted with constant-amplitude axial stresses in the ratio of minimum stress to maximum stress of 0.05 ($R = 0.05$). Specimens with and without strain gages were tested at room temperature 21°C (70°F), and superalloy specimens with and without simulated strain gages were tested at room temperature and at 815°C (1500°F).

Ti-6Al-4V tests: At 10^7 cycles, the fatigue strength of Ti-6Al-4V specimens with weldable gages was less than one-eighth of that for plain specimens. This effect is much greater than would be expected from stress concentrations resulting from typical structural fabrication. Thus, especially for titanium-alloy structures, the detrimental effect of spot welding should be carefully considered when the use of weldable strain gages is contemplated.

Rene 41 tests: At 10^7 cycles, specimens with simulated weldable gages tested at the two temperatures had the same fatigue strength. For stresses higher than the fatigue strength, the tests at elevated temperature resulted in much shorter fatigue lives than the tests at room temperature. At both temperatures, the fatigue strengths at 10^7 cycles for specimens with simulated weldable gages were about two-thirds of the value for plain specimens. This result is nearer to that expected from stress concentrations in fabricated structures in contrast to the large difference observed for the titanium alloy.

Inconel X tests: The room-temperature fatigue strength, at 10^7 cycles, of Inconel X specimens with simulated weldable gages was about two-thirds that of the plain specimens. However, at 815°C the fatigue strengths of the Inconel X specimens with and without the simulated gages were the same and somewhat lower than the room-temperature strengths. These effects are of about the same magnitude as usually expected from fabrication effects in structures.

As an aid to understanding the effects of spot welding, a failed specimen of each material was examined metallographically. The examination showed that the effect of spot welding was restricted to very small regions in all three alloys. Spot welding produced nuggets 0.25 mm (0.01 inch) in diameter in the superalloys. Distinct nuggets were not formed in the titanium-alloy specimens, but spot welding produced microstructural changes within a heat-affected zone about 0.51 mm (0.02 inch) in diameter.

(continued overleaf)

Note:

Requests for further information may be directed to:

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No patent action is contemplated by NASA.

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