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EFFECTS OF FATIGUE ON THE INTEGRITY OF A FRICTION STIR WELDED STRINGER-TO-SKIN LAP JOINT CONTAINING RESIDUAL STRESSES

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ABSTRACT

This research uses a non-destructive method of neutron diffraction to measure the tri-axial residual stresses in a friction stir welded aerospace fuselage component: a stringer-to-skin lap joint. Two different specimens were examined. Fatigue testing was performed on both specimens to determine their fatigue lives. Effects of the different components of residual stresses were examines and related to fatigue performance. A combination of fractography, hardness testing, and residual stress measurement was used to predict areas of high probability of structural failure in the friction stir welded lap joints.

Keywords: residual stress, fatigue life, friction stir welding, neutron diffraction, crack nucleation

INTRODUCTION

Damage tolerant design is used extensively in aircraft construction and is often mandatory for large civil aircrafts. Hence, the distribution of residual stress arising from the friction stir weld process and fatigue failure under aircraft service loading will be a major role in these damage tolerant design processes. The nature of the friction stir welding process introduced residual stresses in the lap joint after the weld has cooled. The present of residual stress affects the component's distortion behaviour as well as fatigue life. A post-welded process of hammer peened will be carried out to reduce the distortion and relive the residual stresses. A non-destructive method of neutron diffraction is used to measure the residual stresses in the lap joints before and after hammer peening. Fatigue testing will be performed on both specimens to determine effects of hammer peening on fatigue life of the FSW lap joint.

RESULTS AND CONCLUSIONS

The results from the fatigue testing of both the as-welded and hammer peened specimens are shown in Fig. 1. The two as-welded samples failed at approximately 100,000 cycles. After peening the surface of the weld, the samples failed at one order of magnitude greater than the as-welded specimen at 1,000,000 cycles.

This study demonstrates that there are significant residual stresses left in the lap joint after the weld has cooled. The highest tensile stresses are located in the transverse direction moving across the weld, 6 mm from the weld centerline. As-welded samples consistently failed in region of high tensile residual stress, low hardness value and areas of high welding defects.

Hammer peening the welded surface reduced the tensile residual stresses as well as increase the fatigue lives of these stringer-to-skin lap joints.

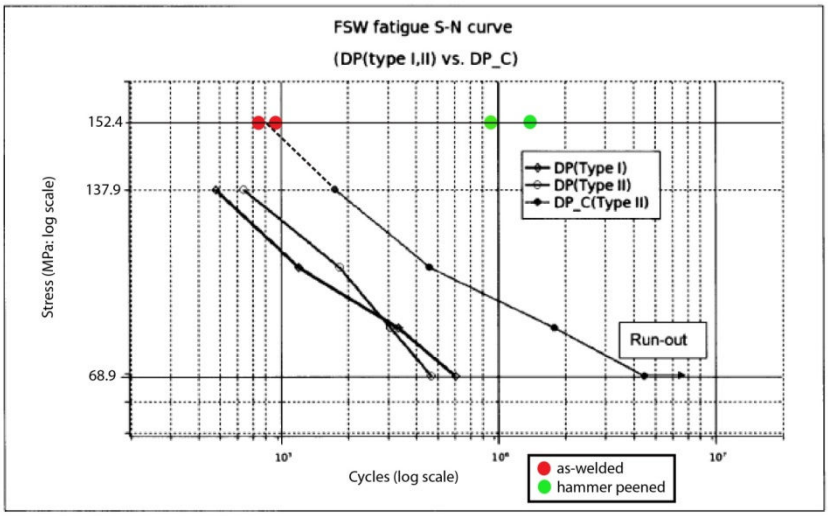

Fig. 1 - Cycles to failure of as-welded and hammer peened test specimens compared with previous fatigue testing of FSW lap joints

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REFERENCES

[1]-M. Skinner, Friction Stir Welding, 2004, <http://www.mts.com/en/TechnologyShowcase/FSW/index.asp>, (September 8, 2009).

[2]-T. Anderson, What is friction stir welding of aluminum?, 2009, <http://www.esabna.com/us/en/education/knowledge/qa/What-is-friction-stir-welding-of aluminum.cfm>, (September 10, 2009).

[3]-A. Merati, M. Gallant, L. Dubourg, and M. Jahazi, 2008, “Friction stir lap welding of AA 7075-T6 stringers on AA 2024-T3 skin”.

[4]-P.J. Withers, M. Turski, L. Edwards, 2008, “Recent advances in residual stress measurement”, International Journal of Pressure Vessels and Piping, Vol. 28, pp. 118-127.

[5]-S. Vaidyanathan, and I. Finnie, 1971, “Determination of residual stresses from stress intensity factor measurements”, Journal of Basic Engineering, Vol. 93, pp. 242-246.

[6]-M.B. Prime, 1998, “Measuring residual stress and the resulting stress intensity factor in compact tension specimens”, Fatigue Fracture Engineering Material Structure, Vol. 22, pp. 195-20.