Fatigue Fracture and Micro-structure Analysis of Friction-Stir-Welded (FSW) Butt Joints of Al-Li aerospace alloys

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ABSTRACT
The aluminum-lithium (Al-Li) alloy 2195 which has a significantly higher strength and stiffness than the conventional 2219 alloy can make significant contributions in weight reduction and performance enhancement in next generation launch vehicles. Highly critical applications like cryogenic tanks require defect free welds. Friction stir welding (FSW) is the most popular method for joining aluminum alloys because it can produce welds with less distortion, more reproducible properties than can be obtained by fusion welding. Friction-Stir-Welding (FSW) is a solid-state joining process and is used for applications where the original metal characteristics must remain unchanged as far as possible [1]. Welding, which is in solid state, is achieved by plastic flow of frictionally heated material. The hot metal is constrained by the colder surrounding material and between the tool shoulder and the backing plate forcing it to flow around the rotating probe forming a joint. Extensive research has been accomplished on developing the friction stir welding process for the aluminum alloys used in aerospace applications. However, the fatigue crack propagation behavior of the friction stir welded Al-2195 alloy has not been reported in the open literature. The future launch vehicles which will have to be reusable mandates the material to have good fatigue properties, which prompts an investigation into the fatigue behavior of the friction stir welded Al-2195 alloy. The friction stir welded butt joints of Al-2195 alloy are subjected to fatigue loading under ambient and humid environments. The joints are fatigue tested with corrosion preventive compound (CPC) and under variable amplitude conditions. After performing fatigue testing the samples are cut from the near-failure surfaces of different mode areas and are examined using the scanning electron microscope (SEM). The initial notch was made in the weld nugget region, it has been observed that the fatigue crack proceeds gradually with the crack-closure phenomenon predominating the failure mechanism under variable amplitude conditions, the crack morphology follows the tortuous nature of crack propagation in the parent material, also crack morphology depends on oxide defects and the grain structure in the nugget region. The notion that crack growth is a mutual competition between intrinsic micro-structural damage mechanisms and extrinsic crack-tip shielding mechanisms provides a useful framework to compare fatigue mechanisms of ductile and brittle materials [2]. Further the loading sequence of overloads is changed and the change in fatigue failure mechanism is observed. The specimen where the material bonding is discontinuous, the propagation of the crack proceeds.
through the weakest region in the weld through sudden changes in angle and direction. The use of CPC has a beneficial effect on the fatigue life. Further numerical analysis of the fatigue fracture using finite element methods is proposed to compare and validate the test results.

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References: