Assessment of Emerging Metallic Structures Technology through Test and Analysis of Fuselage Structure

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During the past decade, the aerospace industry has made significant advances in the development of emerging metallic structures technologies (EMST) aimed at being competitive with composite materials in performance while reducing manufacturing cost. The aluminum industry in particular has invested heavily in the development of new alloys and product forms, improved structural concepts, and more efficient production and fabrication processes.

The introduction of a new material or structural concept in the aerospace industry can be quite challenging. A significant amount of test data at the coupon, substructure, and structural level is needed to fully vet and properly assess a new technology and to understand potential certification and continued airworthiness issues. Large-scale testing provides data that captures more of the effects of the manufacturing and assembly process and provides a pathway to an increased technology readiness level. In recognizing these challenges, the FAA, Arconic, and Embraer have collaborated in an effort to evaluate several EMST through full-scale testing and analysis. The goal is to demonstrate the potential for fuselage concepts using EMST to improve durability and damage tolerance compared with the current baseline aluminum fuselage. Several EMST are being considered including single piece frames, friction stir welded longitudinal skin joints, new metallic alloys (aluminum and aluminum-lithium), bonded stringers, and hybrid construction. Altogether, seven panels with various EMST are planned to be tested using the FAA's Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) fixture that is designed for structural testing of fuselage panels and is capable of simulating aircraft service load conditions through synchronous application of mechanical and environmental loading conditions as indicated in Figure 1.

A phased approach is being undertaken to study three damage scenarios; 1) a two-bay skin crack, along the hoop direction, with central stringer severed; 2) a mill-line crack parallel to stringer, located near the edge of the milled section of the bay, and; 3) a two-bay skin crack, along the axial direction, with the central frame severed. For each damage scenario, strain surveys will first be conducted and compared to finite element prediction to verify proper load and panel alignment. The panels will then be subjected to fatigue crack growth testing using an equivalent constant amplitude load sequence, determined through coupon level tests that represent the complex load history of a fuselage panel located on the crown of the aircraft, forward of the wing. The final stage of testing will be a residual strength test to limit load conditions. Data from this program will be used to demonstrate the improvement in damage tolerance and the structural safety potential of the EMST and to assess the relevance of existing regulations

Recent efforts have focused on testing the first baseline panel consisting of 2524-T3 skin and conventional 7000-series aluminum substructure assembled through riveting. Initial results of testing the baseline panel are highlighted in Figure 2. In summary, a two-bay circumferential skin crack having a length of 33-mm was inserted with the central stringer severed. The panel was then fatigue tested under simulated flight load conditions for 33,600 cycles, during which the skin crack extended across two stringer bays to a final length of approximately 287-mm. Afterwards, a residual strength test was conducted during which the panel was subjected to a 2.5G axial load. Limited stable tearing extension was observed from each crack tip. During all phases of testing, crack growth was monitored and recorded using high magnification cameras, strain gages, a structural health monitoring system, and digital image correlation system. In general, slow and stable crack growth was observed during fatigue. The crack surface morphology had distinct transition points, where on the left side, the surfaces changed from V (valley) to S (slant) fracture and on the right side transitioned from a +45° to - 45° slant. Preliminary results indicate that crack growth rates changed at these transition points similar to that observed in coupon tests conducted on M(t) specimens.

Results from the baseline panel test will be compared with advanced panels containing varying EMST to assess the damage tolerance performance. Preparation and testing of the second panel in this program is underway, consisting of all aluminum-lithium construction including 2060-T8E30 skin, 2055-T84 extruded stringers, and 2099-T83 integral frames assembled through riveting. This paper/presentation will provide the ICAF community an overview and update of this multi-year collaborative program including test and analysis results of the first two panels and plans for future work.

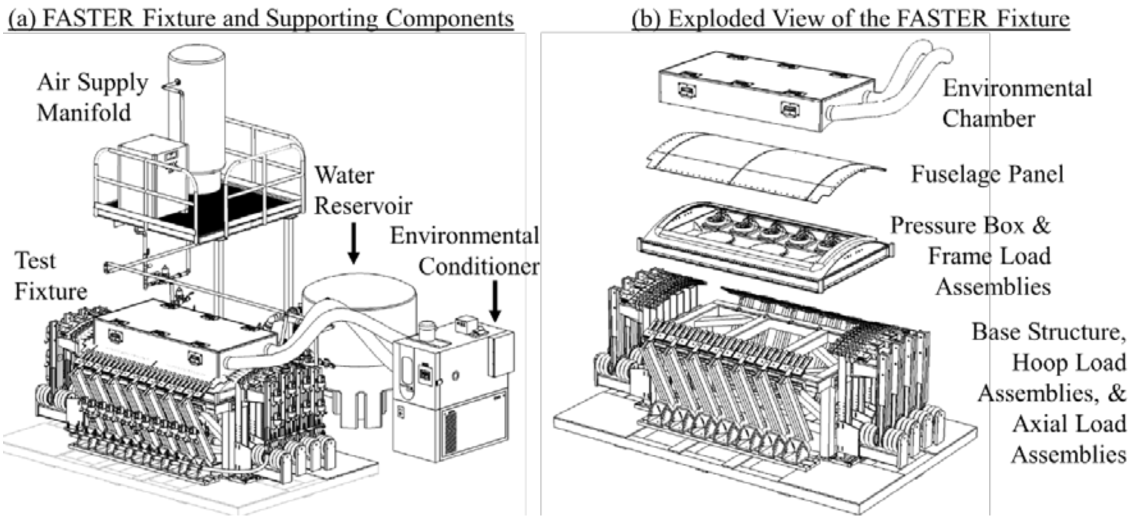

Figure 1. Full-Scale Aircraft Structural Test Evaluation & Research (FASTER) fixture

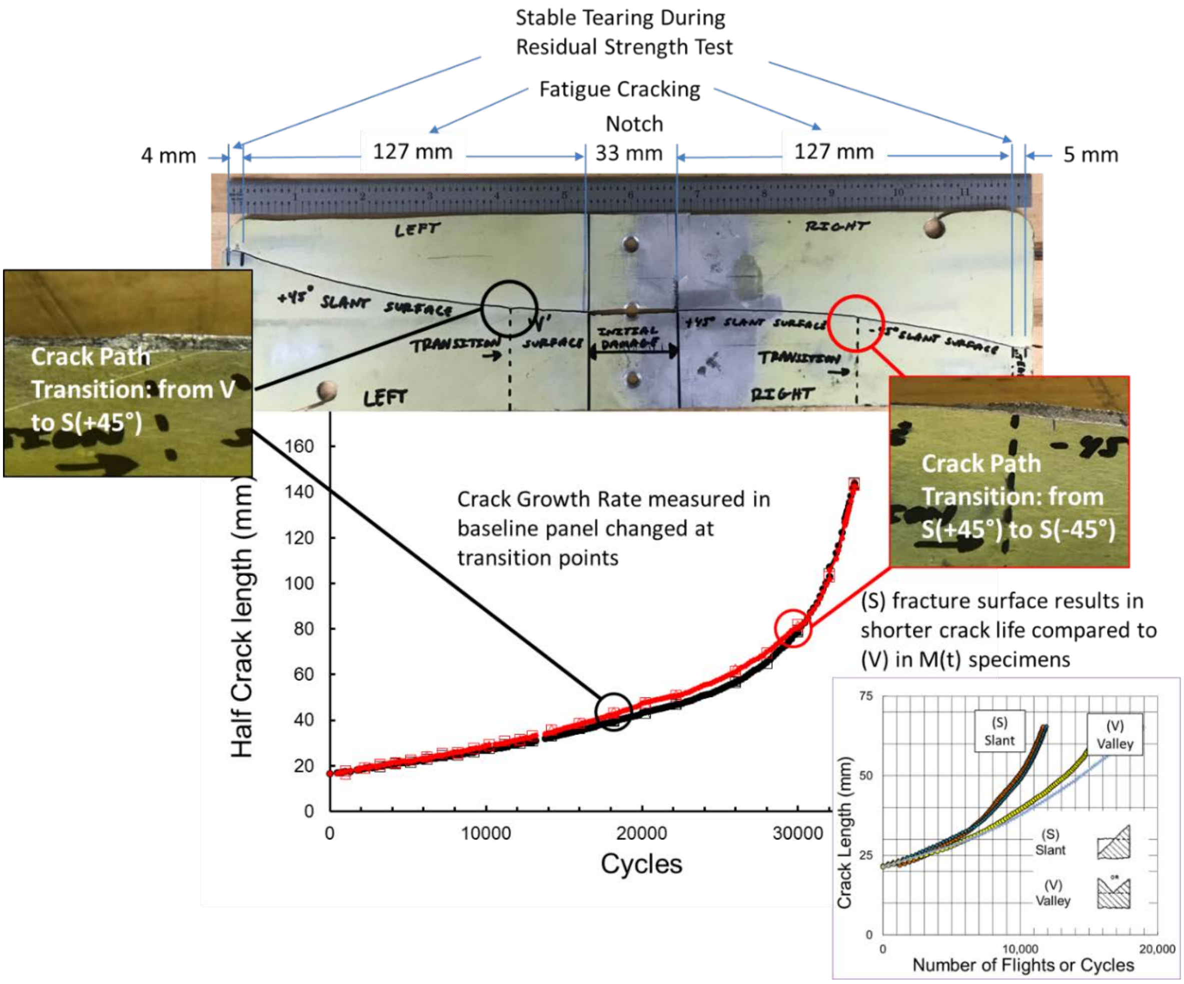

Figure 2: Phase 1 test results of baseline panel showing crack surface morphology and effect on fatigue crack growth.