



CECAM Bulletin C05-05

"Full-Scale Damage Tolerance of Sandwich Structures"

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Sandwich constructions are widely used in airframe structural applications due to the distinct advantages they offer over other metallic and/or monolithic composite structural configurations in terms of stiffness, stability, specific strength, corrosion resistance, ease of manufacture and repair, and above all the weight savings. However, the sandwich structures are very susceptible to localized transverse loads, due to their inherent construction. These loads are transient in nature and could be inflicted on the airframe structure during various stages of the aircraft's life. The response of sandwich structures to the transient loads, the resulting damage states, their detectability and the effects of the damage states on the residual properties have been widely investigated using experimental and analytical methods. However, most damage resistance and tolerance investigations have been limited to laboratory coupons and the studies on full-scale airframe components are rare. In this report, a brief summary of the lessons learned from the coupon level testing of sandwich panels is presented, on which damage resistance and tolerance investigations of full-scale components are proposed.

The damage resistance and tolerance characteristics of flat sandwich panels with thin facesheets were observed to be highly dependent on the impactor size (DOT/FAA/AR-00/44). The blunt impactors (3" diameter, hemispherical) produced large damage areas, which were subsurface in nature with predominantly core crushing damage with almost negligible residual indentation, while the sharper impactors (1" diameter) produced smaller damage areas accompanied by skin fractures and considerable residual indentation depths, as illustrated in figure (1a). The residual properties of the impact damaged sandwich panels were studied using in-plane compression tests. The damage states due to blunt (3") impactors promoted a stability-induced failure; with the core crush region and slight indentation constituting a geometric imperfection. The damage states due to 1" impactor, produced stress concentration induced compression failures of the skins. The residual strengths associated with stability-induced failures were consistently lower than that of compression failures (figure 1b). The use of these studies in damage tolerance design processes requires additional knowledge of the effects of scaling, combined loading, presence of substructures, stress raisers (cut outs) etc.

Figure (1): (a) Combinations of Planar Damage Area and Maximum residential indentation depth for different sandwich configurations impacted with 1" and 3" diameter impactors (b) Residual strength vs. planar damage area for panels impacted with 1" and 3" diameter impactors.

The primary objective of this program is to extend the previous work and conduct a series of full-scale tests on curved panels at the FAA's test facility in Atlantic City, NJ. The activities outlined in this proposal describe a joint effort between WSU/NIAR, Adam Aircraft Industries and the FAA Technical Center to conduct these full-scale tests.

A composite sandwich test article was designed to study the damage tolerance characteristics under combined longitudinal, hoop and pressurization loading in the Full-scale Aircraft Structural Test and Evaluation (FASTER) Facility at the FAA William J. Hughes Technical Center in Atlantic City, N.J. Unlike aluminum test articles, the composite test article is desired to be representative of a monocoque fuselage, i.e., without any frames or stringers. The objective of the test is to simulate the strain fields that exists under the combined longitudinal and pressurization loading in a portion of the fuselage structure. The test article was designed in such a way that the strain fields are close to that of the actual fuselage structure, over a large portion of the test article. The test article had to be suitably reinforced around the periphery for external/reactive load introduction to eliminate undesirable failures near the edges. The edge stiffening resulting from reinforcements along the edges must not however alter the strain distributions in the test section away from the edges. The following constraints and features were imposed on the design of the sandwich test article.

1. The test article should have an internal radius of 74"
2. The circumferential length must not exceed 77" and the longitudinal length must not exceed 125". These lengths are inclusive of the edge reinforcements for load introduction.
3. Due to the absence of frames, alternative method of reacting unbalanced radial loads must be identified and appropriate modifications/additions to the FASTER fixture must be made.
4. Design appropriate attachment members to connect the test article to the fixture, which was originally designed for semi-monocoque metallic test articles.

Figure (2): Scope of the current investigation

(a) Full-scale articles manufactured and delivered to the FAA technical center FASTER facility for full-scale testing. These coupons will be fabricated by Adam Aircraft of Englewood, CO.

(b) Coupon tests to represent the material configurations selected for the production of the full-scale articles.

(c) Perform full-scale tests on a number of panel configurations at the FAA FASTER facility. Panels including ones with 10" diameter hole in the facesheet on the convex side of the panel and, 10" long longitudinal and circumferential notches will be tested, The damage tolerance of sandwich panels under different combinations of longitudinal and pressurization loading will be investigated. Displacement and strain fields around the holes/notches will be mapped using a digital image correlation technique.

References:

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