Development of a Modern Aerospace Strategy to Evaluate the Crashworthiness of the Transport Aircraft Fuselage

By

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ABSTRACT

A 30-ft/s vertical drop test of a fuselage section of a Boeing 737 aircraft was conducted in October of 1999 at the FAA William J. Hughes Technical Center in Atlantic City, NJ. This test was performed to evaluate the structural integrity of a comfortable auxiliary fuel tank mounted beneath the floor and to determine its effect on the impact response of the airframe structure. The objective of the test was to determine the interaction between a typical transport aircraft fuselage, particularly its floor structure, and a comfortable auxiliary fuel tank under severe, but survivable, impact conditions. The fuel tank used in this test is representative of tanks being installed in narrow-body transport aircrafts. The 10-foot airframe section from a Boeing 737-200 aircraft was dropped from a height of 14 feet, generating a vertical impact velocity of 30 ft/sec. The airframe test section weight of 8780 pounds simulated the load density at the maximum takeoff weight condition. The weight included cabin seats, dummy occupants, and simulated fuel in the 500-gallon fuel tank.

Structural response data were obtained during the impact from instrumentation installed on the fuselage structure, floor structure, and the fuel tank. The fuselage test section sustained severe damage after the test. Portions of the cabin floor were damaged due to the impact with the auxiliary fuel tank located in the cargo compartment. Portions of the fuselage bottom were crushed by approximately 2 feet. The bottom of the fuel tank was punctured in numerous locations causing fuel to leak out. The strength and rigidity of the fuel tank limited the inherent ability of the fuselage structure to absorb energy crushing during the impact. The test data were used to compare with a finite element simulation of the fuselage structure and to gain a better understanding of the impact physics through analytical /experimental correlation. To perform this simulation, a full scale 3-dimensipnal finite element model of the fuselage section was developed using the explicit, Nonlinear 3-D Finite Element code, LS-DYNA. The emphasis of the simulation was to determine the structural deformation and floor-level acceleration responses obtained from the drop test of the B737 fuselage section with the auxiliary fuel tank. In the later research program, a 1/20th scale model of a fuselage was built and instrumented and drop tested at the National Institute for Aviation Research (NIAR). The Nonlinear LSDYNA 3-D was used to model the experimental 1/20th scaled model. The results of simulations validated the experimental data within only 8.9%anomalies.

Furthermore, the scaled modeling effects continued with modeling the 1/5th, 1/10th, 1/15th , and a full-scale with FEM computer models. The results are confirmed with that of the experimental scaled drop test model. The focus of the second part of this thesis was to evaluate the scaling concept and possible incorporation into the crashworthiness evaluation of fuselage as a possible future crashworthy evaluation tool.

The impact design requirement for the 1/20th scale model fuselage section is to achieve and maintain 500-g floor-level acceleration for a 30 ft/s vertical impact onto a rigid surface. This impact requirement corresponds to 25-g floor-level acceleration for a geometrically and constitutively similar full-scale fuselage section. Sub floor concepts was then evaluated by conducting dynamic tests and by performing finite element analyses using the LS-DYNA and confirmed with analytical calculations. Finally, an assessment of model accuracy is provided with suggestions for improvements to achieve a better correlation results. These tests are to determine the fuselage crashworthiness level and safe limit loads prescribed by FAA, and to consider the satisfy design goals for improved crashworthiness. Analytical codes have the potential to greatly speed up the crashworthy design process, to help certify seas and aircraft to dynamic crash loads, to predict fuselage and occupant response to impact with the probability of injury, and to evaluate numerous crash scenarios not economically feasible with full-scale crash testing. To build confidence in the application of these finite element codes to aircraft structures, it is important to demonstrate their computational capabilities through analytical/experimental validation.

A through investigation was made on the existence of scaling effects and to demonstrate the application of scale model technology in the development of a new feasible methodology to evaluate the crashworthiness of the transport aircraft fuselage. This innovating and cost effective crash test concept has a great potential to plays a major role in a cost-saving methodology to evaluate the aircraft fuselage structures crashworthiness. The 1/20th scaled model was built , tested and simulated with LS_DYNA Fem package and results were validated and confirmed with experimental drop test.