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Simulating the Impact Response of Three Full-Scale Crash Tests of Cessna 172 Aircraft

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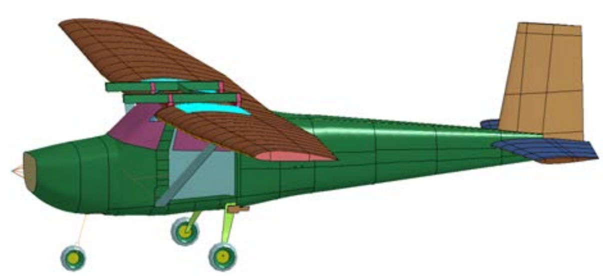
Abstract
During the summer of 2015, a series of three full-scale crash tests were performed at the Landing and Impact Research (LandIR) Facility located at NASA Langley Research Center of Cessna 172 (C-172) aircraft [1-2]. The first test (Test 1) represented a flare-to-stall emergency or hard landing onto a rigid surface. The second test (Test 2) represented a controlled-flight-into-terrain (CFIT) with a nose down pitch attitude on the aircraft, which impacted onto soft soil. The third test (Test 3) also represented a CFIT with a nose up pitch attitude of the aircraft, which resulted in a tail strike condition. Test 3 was also conducted onto soft soil. These crash tests were performed for the purpose of evaluating the performance of Emergency Locator Transmitters (ELTs) and to generate impact test data for model calibration. Finite element models were generated and impact analyses were conducted to simulate the three impact conditions using the commercial, explicit nonlinear transient dynamic code, LS-DYNA [3, 4]. The focus of this presentation is to summarize test-analysis results for the three full-scale crash tests.

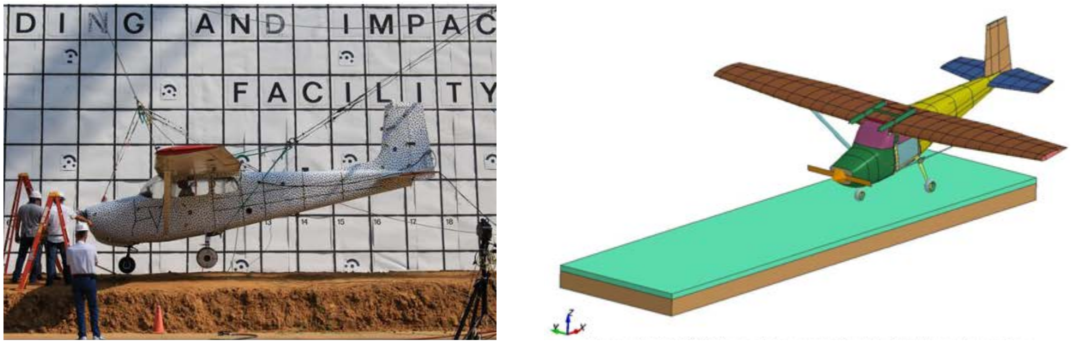
Pre-test photographs of the test articles and finite element models are shown in Figure 1-3, for Test 1, Test 2, and Test 3, respectively. Measured impact conditions for Test 1 were 722.4-in/s forward velocity and 276-in/s vertical velocity with a 1.5° pitch (nose up) attitude. These conditions represent a survivable hard landing. The impact surface was concrete. During the test, the nose gear tire impacted the concrete, followed closely by impact of the main gear tires. The main landing gear spread outward, as the nose gear stroked vertically. The only fuselage contact with the impact surface was a slight impact of the rearmost portion of the lower tail. Thus, capturing the behavior of the nose and main landing gear was essential to accurately predict the response, as documented in Reference 5.

(a) Test 1 C-172 aircraft.



(b) LS-DYNA model.

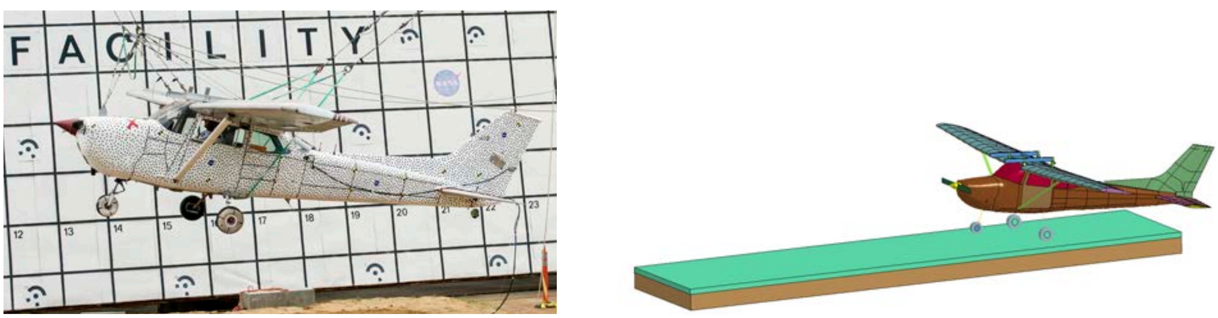
Figure 1. Photograph of Test 1 aircraft and finite element model.



(a) Test 2 aircraft. (b) LS-DYNA model.

Figure 2. Photograph of Test 2 aircraft and finite element model.

Measured conditions for Test 2 were 823.2-in/s forward velocity, 344.4-in/s vertical velocity, 16.1-deg/s pitch angular velocity with a pitch attitude of 12.2° (nose down). The total weight of the aircraft was approximately 2,114-lb. The left side of the aircraft was painted white, with 1-in.-diameter black dots added to provide a speckle pattern for the purpose of collecting three-dimensional photogrammetry data during the test. Sixty-four channels of data were collected at 10,000 samples per second using the onboard Data Acquisition System (DAS). A 2-ft. high soil bed was spread above the concrete surface. The soil was a sand/clay mixture that was wetted one hour before the test. As in many high-wing crash tests into soft soil, the airplane flipped over and landed upside down at the end of the impact event. Also, the tail of the fuselage buckled early in the crash. Buckling initiated at the bulkhead behind the cabin, and by 0.240 seconds the buckle was fully formed. The challenge for this simulation was to accurately simulate the interaction between the landing gear and the soil and the aircraft and the soil, which was represented as a layered hard-to-soft soil configuration [6].



(a) Test 3 aircraft during pre-lift. (b) LS-DYNA model.

Figure 3. Photograph of Test 3 aircraft and finite element model.

Measured impact conditions for Test 3 were 682.8-in/s forward velocity, 283.2-in/s vertical velocity, 13.1-deg/s pitch angular velocity with an 8° pitch (nose-up) attitude at impact. Due to the slight amount of roll and yaw, the airplane left main gear impacted the soil first. As the tire and the gear deformed, the tail contacted the soil surface shortly after impact. Next, the nose gear and the nose cone of the airplane contacted the surface. As with Test 2, after the nose gear penetrated into the soil surface, the airplane started to exhibit a rotation around the nose. The rotation of the aircraft continued after impact and eventually the aircraft rotated approximately 180° and ended upside down. During the impact, the tail section of the aircraft separated almost completely from the cabin section. As with Test 2, the challenge for the impact simulation was to predict aircraft interaction with the soil and tail separation. The final presentation will summarize test-analysis results for each of the three impact simulations.

References

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