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Development of a Building Block Approach For Crashworthiness Testing of Composites

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ABSTRACT

The CMH-17 Crashworthiness Working Group has initiated a building block exercise that began with coupon-level testing and is currently focusing on the crush testing and analysis of a C-shaped composite aircraft stanchion. The exercise will culminate with the numerical simulation and experimental crush test of a portion of a cargo floor support structure designed to be representative of that used in composite-intensive transport aircraft. Based on preliminary analyses, a 16-ply IM7/8552 carbon/epoxy "hard" laminate with 50% 0º, 25% ±45º, and 25% 90º plies was specified for the C-shaped stanchion. Dynamic flat-coupon crush testing was performed to select optimal laminate stacking sequences for energy absorption. Crush tests were performed using both an unsupported and pin-supported base to represent the flat and curved sections of the C-channel, respectively. Following crush testing of eight candidate "hard" laminates, two were selected for C-channel testing and analysis: $[90_2/0_2/\pm45/0_2]_S$ and $[90/+45/0_2/90/-45/0_2]_S$. Both of the selected "hard" laminates produced specific energy absorption (SEA) values greater than 50 kJ/kg using both the unsupported and pin-supported base conditions.

Using the selected laminates and ply layups from flat-coupon crush testing, follow-on dynamic crush testing was performed using C-channel shaped test specimens fabricated using the selected cross-sectional geometry. High-speed photography was used during impact testing to identify damage progressions and energy absorbing mechanisms associated with crushing. SEA values measured from the C-channel specimens were compared to predictions made using a volumetric rule of mixtures analysis based on unsupported and pin-supported flat-coupon crush test results. Additional sub element-level bearing crush testing was performed to investigate the crush behavior of bolted connections proposed for attaching the C-channel stanchion to the surrounding assembly. A single-shear dynamic bearing crush test, similar to ASTM D5379 Procedure C, was developed to provide laminate-level dynamic bearing response for representative joint and fastener configurations. Finally, methodologies were explored for generating a controlled compression failure followed by stable crush within the C-channel stanchion as part of the composite strut assembly. The use of laminate-level crush initiators, based on ply-drops within the laminate as well as geometric tapering of the C-channel cross section, were used to produce controlled compression failures below the failure load of the full-thickness C-channel cross section. Initial investigations focused on assessing the crush stability of ply drops within the laminate using the flat-coupon crush testing. Follow-on C-channel stanchion tests will be performed to demonstrate the ability to produce a controlled compression failure at a prescribed axial location near the bottom bolted section followed by stable crush behavior of the stanchion.