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Support Tube Manufacturing Trials, Simulation, and Validation for the CMS Inner Tracker Phase II Upgrade

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Purdue's Composites Manufacturing and Simulation Center is responsible for manufacturing the inner tracker support tube (ITST) for the CMS high luminosity upgrade. Predicting the mechanical performance of the manufactured tube is necessary to ensure the success of the structure and guide preemptive redesigns. As preliminary validations of the modeling and simulation methods, scaled down ITST sections of 100mm length have been manufactured and subjected to a compression-like loading scenario. Matching Finite Element Models (FEMs) are validated against the experimental test data, specifically comparing the load-displacement curves, effective tube stiffness and eventual failure point. Two cases are used to validate the data; (I) a simple tube with 6 plies thickness (1.5mm) and no track support, (II) a complete model with 12 plies thickness (3mm) and the track support with a foam core.
FE simulations are dependent upon proper mesh quality, physical phenomena, and material inputs, so simplified mode I interlaminar fracture models were created and compared for solid and shell elements to determine the appropriate finite element mesh dimensions and confirm the crack propagation behavior in the FEM. Shell elements were found to be significantly more efficient and provided adequate representation of delamination failure behavior. Experimental material tests, performed to the ASTM standards, provide inputs for tensile, flexural and shear properties.

The multiaxial loading FEM iterations were then performed to capture the phenomena observed during experimental deformation and failure at the joint and surrounding regions of the two-piece tube. Two specific behaviors critical to accurate simulation of this structure are: adhesive delamination of the bonded joint in a peeling type failure mode, and delamination in the composite structure surrounding the joint. The influence of these behaviors is isolated and presented using cohesive modeling in consecutive FEMs. All final models have close agreement to experimentally determined behavior. These sub-component simulation and validation results provide confidence that similar FEMs of the full ITST assembly and loads can be used to minimize mass and maximize structural performance.

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