Feeding the Digital Twin – Using Ultrasonic Waveforms for Part Specific Features for Finite Element Analysis of Composite Components

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**Abstract**

The use of carbon fiber reinforced materials has become mainstream in the aerospace, automotive, and sporting industries due to their versatility, performance, and high strength to weight ratio. Parts are often designed under a defect-free assumption, and then a factor of safety approach is imposed to allow for unknown manufacturing variabilities. The present work presents a new approach where internal features, often termed defects, are captured using non-destructive techniques and then incorporated into the finite element simulation allowing for inspection informed digital twin modeling. The talk highlights some of the current work by the research team at Baylor University for a variety of common manufacturing induced defects that can be quantified using non-destructive testing. The talk then transitions to a deep dive into a fastener application to show the broader approach of inspection inspired modeling. This work presents a novel method to nondestructively characterize the damage induced by drilling within a laminated composite, and incorporates the characterized damage zone into the finite element model domain to estimate the as manufactured part performance. The inspection is performed using high-frequency ultrasound to create a three-dimensional image of the delamination zone, and results are compared to those from micro-X-ray computed tomography and are in excellent agreement. The characterized three-dimensional damage zone is then incorporated into a finite element model domain, and using a novel cohesive zone damage progression model, simulations of the damage profile under tensile testing is captured. The finite element results for the strain field are then compared to physical test results of the strain field during loading from digital image correlation (DIC). The novelty of the presented method is the combination of physical testing, non-destructive testing for the geometric extraction, to structural predictions using the inspection data directly thus closing the loop of the true digital twin.