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Abstract-2:

Demonstration of Hybrid Physics and Machine Learning enabled Composite Failure Analysis and Calibration Suite (CFACS) for Material Characterization

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Boeing and the University of Washington Boeing Advanced Research Center (UW – BARC) are engaged in a multi-year collaborative research project to develop a Hybrid Physics and Machine Learning Model for Material Characterization. This project has two key objectives. The first objective is to increase the fidelity of dynamic non-linear structural simulation models, by reducing uncertainties in material properties and by optimizing simulation parameters. The second objective is to explore what is the required amount of physical testing needed to characterize material properties. In this effort, an automated machine learning (probabilistic) material model and a software tool Composite Failure Analysis and Calibration Suite (CFACS) was developed. The current approach to characterizing new composite materials for design and simulation includes substantial coupon and component-level testing, and this level of effort has expanded significantly over time. Boeing has faced significant challenges in showing compliance with certification requirements for dynamic impact events, such as seat dynamics, bird/hail strike, engine fan blade out, thrown tire tread, and crashworthiness for smarter testing (certification by Analysis). The CFACS enables optimizing and validating material models used in dynamic simulations.

A hybrid physics and machine learning approach for material characterization has been developed, and the approach has been coded into a software tool called Composite Failure Analysis Calibration Suite (CFACS). A beta version of CFACS has been tested using coupon-level tests and simulations. The next step is to use CFACS with Boeing developmental programs that are planned or already in work. This will aid in evaluating the maturity level of CFACS, and also will provide direction on how to expand capabilities within CFACS.

The ML strategy selected for CFACS is to utilize a methodology based on the Gaussian Process Regression (GPR). GPR, which is a non-parametric approach, serves as an alternative method assessing highly nonlinear problems. GPR constitutes a primary computational engine for calibrating the matrix of material characterization parameters. The relevant parameters have been previously identified based on requirements for LS-DYNA MAT261, which was selected for initial evaluation. The most significant parameters are highlighted by the uncertainty quantification module of CFACS, built around the F-Test procedure. The values informed by this process are then utilized downstream in high-fidelity simulations. Numerical tests so far have indicated that CFACS is able to determine optimal material characteristics and to perform simulations with the desired level of accuracy, based on small sample sizes of physical test data.

This presentation will describe the structure of the CFACS tool and its key modules, including test anomalies detection, optimization using GPR, and uncertainty quantification capabilities. Options for expanding application of CFACS will also be presented. Although the CFACS is currently configured for use with composite materials, the framework supports all material characterizations, such as metallic, additive manufacturing, etc. The successful completion of this project will lead to more accurate material characterization with the right amount of testing, which is critical in building high fidelity structural simulation models for product qualification and certification.

CFACS Process outline: