Ph.D. Seminar

Low Velocity Impact Study on Basalt Fiber Reinforced Uni-Directional and Plain Woven Composites: Mechanical Characterization and Numerical Modeling

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Abstract

Composites are made up of two or more constituent materials in order to utilize the advantages of both the constituents to provide excellent properties like high specific stiffness, high specific strength, good corrosion and fatigue resistance etc. However, their sensitivity to impact damage arising due to tool drops, hail stones, bird strike etc. poses serious threats as the damage is tough to detect from visual inspection. Besides impact use of less environmental friendly fibers and matrix materials are also a cause of concern in use of composites. Basalt, a mineral fiber obtained from rocks requires less chemicals during processing compared to glass and carbon, but its composites are less explored in their mechanical performance and low velocity impact (LVI) behavior. The present thesis emphasizes on developing constitutive models for Uni-Directional (UD) and Plain Woven (PW) lamina and their mechanical characterization for providing inputs to the proposed models to simulate numerically the response under LVI cross-ply and PW laminates.

Tensile and compressive tests were conducted on UD and PW laminates to evaluate the moduli and strengths of lamina in longitudinal and transverse directions. Intralaminar fracture toughness in tension and compression were obtained using Compact Tension (CT) and Compact Compression (CC) tests. The interlaminar fracture toughness energies were determined in Mode-I and Mode-II testing configuration using double cantilever (DCB) and end-notch flexural (ENF) tests to model the delamination between plies. Shear tests were performed to measure the modulus, shear strength and the non-linear behavior arising from both damage and plasticity. Cyclic off-axis

tests were performed and using effective stress concept damage was decoupled from the plasticity in the non-linear stress strain curves under off-axis loadings to obtain the parameter of general quadratic yield function. Continuum Damage Mechanics (CDM) based elasto-plastic constitutive laws were developed for both UD and PW lamina using a three-dimensional plastic potential function. The elastic stiffness in different directions was degraded once damage initiation criteria were satisfied. In UD lamina model damage was assumed in principal material directions and damage variable in shear was a function of the damage variables in these directions. In PW lamina variables independent shear damage variables and damage laws were used. Exponential damage evolution laws used material softening parameter 'm' for a particular mesh size was determined for principal directions in tension and compression its value was related to the experimentally obtained intralaminar fracture toughness. Delamination between plies was modeled using surface based cohesive zone modeling (CZM) for predicting delamination damage between plies. Experimentally determined interlaminar fracture energies were used in CZM. These constitutive models for UD and PW materials were implemented in a user subroutine, VUMAT for ABAQUS/Explicit and used to predict the force-time, displacement response of laminates of these materials under LVI.

LVI experiments at different impactor velocities were also performed on cross-ply and PW laminates using drop weight impact tester. The force-time and displacement response from the simulations matched with those obtained from experiments. The extent of damage from simulations also matched well with damage measured using ultrasonic C scan. The constitutive models for UD and PW lamina were thus validated.