Constitutive Shell Model Calibration for Low-Velocity Impact on Basalt Fibre Reinforced Composites
Felipe Vannucchi de Camargo1, Ana Pavlovic1, Cristiano Fraggassa2, Raffaele Ponzini2
1Department of Industrial Engineering, Alma Mater Studiorum Università di Bologna, Viale del Risorgimento 2, 40136 Bologna, Italy
2CINECA, Super Computing Applications and Innovation Department - SCAI, Milan Operational Site, Via Raffaello Sanzio 4, 20090 Segrate, Milan, Italy

SCOPE

Acknowledging composite plastics as the most adequate materials for structural applications where light-weight components are required and encouraging the usage of natural reinforcements for more sustainable designs, the present study aims at calibrating a numerical model of a basalt fibre/vinyl ester laminate to allow a more practical assessment of the low velocity impact behaviour of such material than through extensive experimental tests. In this work, the composite was considered for application on the monocoque chassis of a solar powered electric vehicle, being an essential step to evaluate the possibility of using basalt in its structure. However, the simulation guidelines described can be considered in any case involving low energy impact for the material considered.

MATERIALS AND METHODS

Reproducing the experimental low-velocity impact test performed according to ASTM D71361, the specimen of dimensions 150x100x4 mm impacted on a drop-weight tower by a hemispherical-tip steel impacter was drawn and meshed in Ansys Workbench and then exported to LS DYNA for material properties set up. All the computations were performed on the CINECA HPC facility “Galileo”, a Linux Infiniband Cluster computing system (CentOS 7.0 OS) made of 516 nodes, each one equipped with two 8-cores (16 cores/node, 8256 cores in total) Intel Haswell with a clock frequency of 2.40 GHz per node and a RAM of 128 GB/node. Thanks to the parallel computing resources using 16 cores, the average run time usage was less than 30 minutes on a mesh of 218,897 elements, although the scalability of the LS DYNA was previously analyzed and tuned to get the best computational performances and time saving on up to 128 cores.

Basalt plies modeled with MAT_54 adopting the Chang Chang2 failure criterion where the elements fail by fiber or matrix tensile or compressive modes.

Rigid MAT_20 hemispherical tip indenter represented with density correspondent to the testing machine weight of 1.25 kg.

Mesh refinement on the impact region to assure stable interbody contact and fracture formation.

Ply representation with 4 shell element layers with 2 integration points each.

RESULTS

Calibration of constitutive and degradation parameters: constitution of a basalt/vinyl ester numerical model applicable to general low energy impact conditions, with a correlation coefficient to experiments of 97.6%.

Delamination: modeled with the interply contact definition AUTOMATIC_ONE_WAY_SURFACE_TO_SURFACE_TIEBREAK providing resistance inputs to delamination by tension (NFLS = 60 MPa) and shear (SFLS = 35 MPa)

Calibration of failure parameters especially for basalt:

\[
\begin{align*}
\sigma_{cr} &= \frac{G_{12}}{3} \sigma_{cr} - \alpha \sigma_{cr}^2 \\
\sigma_{cr} &= \frac{2}{3} \sigma_{cr} \left( 1 + \frac{\beta}{\sigma_{cr}} \right) - 1 \\
\sigma_{cr} &= \frac{2}{3} \sigma_{cr}^2 + \beta \sigma_{cr}^2 - 1 \\
\{X, Y, X', Y', YC\} &= \{X, Y, X', Y', YC\} \times \text{SOFT} \\
\{X, Y, X', Y', YC\} &= \{X, Y, X', Y', YC\} \times \text{FIBRT} \\
\{X, Y, X', Y', YC\} &= \{X, Y, X', Y', YC\} \times \text{YFCAC} \\
\end{align*}
\]

Delaminated areas: defined by the superposition of neighbour layers and identification of common stress zones with superior magnitude to NFLS (60 MPa) on tensile stress in the through-the-thickness z direction and SFLS (35 MPa) on shear stress in the in-plane xy direction.

CONCLUSIONS

The adjustment of unmeasurable explicit parameters has shown to be of utmost importance not only to build a numerical model of a basalt composite subjected to impact, but also to understand in a quantifiable way the influence of each failure mechanism described by the Chang Chang constitutive material model (the influence of shear and the degradation of the material near the indentation zone being key factors). Therefore, a precise virtual representation of the damage caused by low-energy shocks on basalt/vinyl ester composites was successfully attained, providing both an accurate stress-strain response and a visual depiction of the failed regions consistent with experimental tests.

REFERENCES


International CAE Conference – 8th - 9th October 2018 - Vicenza, Italy