STRAIN RATE DEPENDENT CONSTITUTIVE MODEL FOR TEXTILE COMPOSITES SUBJECTED TO IMPACT

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ABSTRACT
Composite structures used in aerospace applications are frequently subjected to impact loads during in-service conditions [1]. In order to reduce the extension of delamination in aeronautical components, textile composites are progressively replacing the traditional unidirectional laminates, however, the lack of constitutive models able to account for their complex failure mechanisms and the interaction among them increases the cost of integrating these materials in aeronautical components.

The aim of this work was to develop a mesoscale constitutive model able to predict the damage evolution of textile composites subjected to impact loads at low and high energy levels, with emphasis on the strain rate dependency. The constitutive model was formulated at lamina level in which the finite element size implemented was at least ten times bigger than the representative volume element. To obtain a good prediction of the damage evolution, a continuum damage mechanics approach was used to account separately for the response of the warp and weft yarns. Failure modes included yarn tensile failure by fibre breakage, yarn compressive failure by fiber kinking, and transverse failure of the yarns, under tension or compression, accounting for matrix cracking and fibre debonding. Evolution of damage was implemented by a phenomenological softening function controlled by the fracture toughness of the material at each particular direction and the element size. Strain rate dependency was implemented in the ply properties [2] together with a damping algorithm for stability purposes.

Validation of the constitutive model was carried out for a quasi-isotropic 8 harness satin S2 glass woven laminate subjected to low and high velocity impact, covering a wide range of impact events. Low velocity impact was carried out by drop weight test [3] in square plates of 145 x 145 mm^2 with a free surface of 127 x 127 mm^2 and a hemispherical tup of Ø12.7mm. High velocity impact was accomplished by means of ballistic tests [4]. Square plates of 100 x 100 mm^2 were impacted with spherical steel projectiles of Ø5.5 mm at velocities ranging from 300 m/s to 700 m/s. A set of finite element models was generated to replicate the experiments in Abaqus/Explicit. The constitutive model described before was implemented as a user subroutine to account for the lamina response. Interply delamination was controlled by cohesive elements included in the interface between layers.

Good correlation was obtained in terms of mechanical response and delamination for both, low and high velocity impacts. Impact performance of the laminate was highly dependent on the ply strength and had a very strong influence on the prediction of the force-displacement curves of drop weight test and ballistic limit velocity for impact test. Furthermore, strain rate dependency was a critical parameter to obtain a correct prediction of the ballistic limit of the material and lower sensitivity was found for drop weight test, due to the lower deformation rate. Delamination patterns were correctly predicted as well. In the particular case of drop weight test, delamination was located under the tup and coupled with matrix cracking decreasing the extension of damage along the plate. In ballistic tests, the delamination propagated over a wider area 5 times larger than the projectile diameter and the model was capable of predicting the delamination extension and the crack path through plies with

different orientation leading to a characteristic delamination pattern. The constitutive model helped to understand the role played by the different failure mechanisms during impact and was sensitive enough to predict a different performance when impacting at different energy regimes.

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