

Strain-Rate Dependant Damage Material Model for Layered Fabric Composites with Delamination Prediction for Impact Simulations

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The high specific stiffness and strength, the ease of shaping as well as the great impact performance of layered fabric reinforced polymers encourage their diffusion in the automotive industry. In order to increase the predictability of explicit finite element analysis (FEA) a material model intended for impact simulations has been developed.

The material model combines the intralaminar behaviour and the effect of delamination without using computationally expensive methods, such as the use of cohesive elements. This allows the use of one element across the thickness of the laminate and an interaction between intra- and interlaminar damage.

The intralaminar behaviour model is based on the explicit formulation of the matrix damage model developed by the ONERA. Coupling with a Maxwell-Wiechert model, the viscoelasticity is included without losing the direct explicit formulation. The numerical instabilities, due to the strain-softening from the fibre failure, are managed by the smeared-crack approach depending on the element size. Additionally, the intralaminar model is formulated under a total Lagrangian scheme in order to maintain consistency for finite strain by tracking the material direction and by ensuring objectivity.

Thanks to the membrane deformation provided by a Reissner-Mindlin shell formulation and the stacking sequence, the material model is able to compute the through-thickness strains. Based on a higher-order zigzag displacement theory with interfacial imperfections, the strains are established by using an internal loop, which ensures the internal energy equilibrium between both plate theories. The stress at Gauss points are then computed by using the intralaminar model.

This work provides a way to precisely predict the damage and the behaviour of composite plates under impact loading.