

# Numerical Modelling of Impact Damage in Composite Structures

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## 1 Introduction

Use of composite materials in wind turbine structures becomes increasingly favorable due to their preferable mechanical features such as high inplane strength and stiffness-to-weight ratios. The low strength of composite laminates in through-the-thickness direction, however, has remained a problematic issue. The fact that turbine blade structures are uncontrollably subjected to out-of-plane impact loading such as hail and bird strike during operation [1] or as impact of mating parts during offshore blade installation [2] unveils this weakness in combination of three major forms of failure mechanisms: matrix cracking, delamination and fiber rupture. The variety and complexity of failure mechanisms necessitate comprehending the impact damage formation sequence. In early experimental studies, damage process is reported such that matrix cracks are formed as initial failure mode and followed by delamination and fiber breakage, respectively.

For proper use of multidirectional composite laminates in design of aerospace and wind turbine structures, recent studies attempted accurate numerical simulations of impact induced failure mechanisms. Development of virtual experimental setups by means of simulations based on numerical methods received a particular attention with the intention of reducing the number of tests.

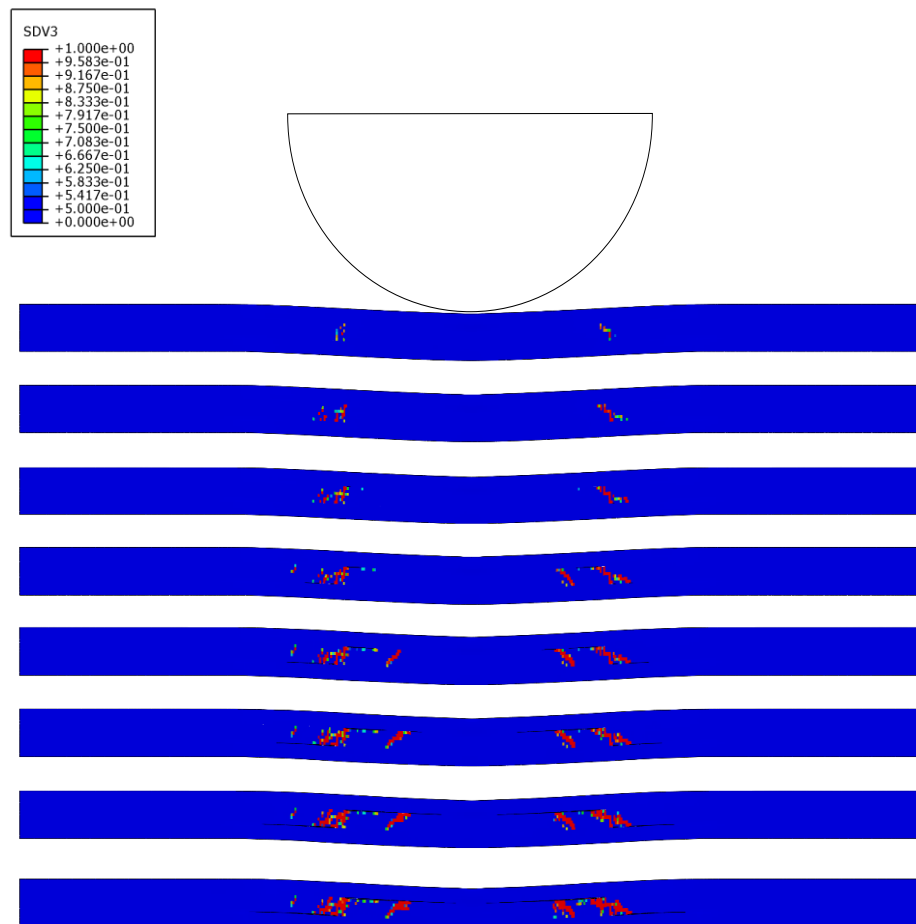
In this study, low-velocity impact (LVI) damage process of composites is investigated on cross-ply beam and plate laminates made of glass/epoxy unidirectional layers. The objective is making a correlation between failure mechanisms elucidated via 2D line impact on beam laminates and complex damage progression scheme in 3D impact of plates. Additionally, generation of accurate numerical simulation is useful for decreasing number of tests required in design.

## 2 Method

Numerical simulations based on finite element method are conducted in ABAQUS/Explicit. 3D model representing LVI experiments is generated. Impactor is modeled as a rigid body. 3D solid elements are used in modeling of composite laminates. Matrix and fiber damage mechanisms are simulated by implementation of continuum damage mechanics based composite damage model via a user-written VUMAT subroutine. Cohesive interfaces are modeled by insertion of cohesive elements between clustered plies. Bilinear traction separation law is introduced to cohesive elements for simulation of delamination damage.

### 3 Results

The results seen in Figure 1 show that the damage starts with a shear crack along the 90 ° layers clustered in the middle of the laminate and the damage formation sequence is in good agreement with the experimental results presented in the relevant literature. In addition, the effect of the third dimension on the damage scheme occurring in the linear impact event is clearly demonstrated.



**Figure 1** Damage formation sequence in the  $[0_5/90_3]_s$  carbon/epoxy beam. (Interframe time is 1  $\mu$ s, SDV3 is the damage variable for tensile matrix mode).

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### Bibliography

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