Final work : Impact Damage Modelling on Composite Structures

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Faculté : Faculté des Sciences appliquées
Diplôme : Master en ingénieur civil en aérospatiale, à finalité spécialisée en "turbomachinery aeromechanics (THRUST)"
Année académique : 2022-2023
URI/URL : http://hdl.handle.net/2268.2/18327

Université de Liège - Faculté des Sciences Appliquées

Impact Damage Modelling on Composite Structures

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Academic year 2022–2023

Summary

The advanced properties of carbon fiber reinforced composite materials, such as their low strength and stiffness-weight ratios, make them a very attractive alternative for aerospace applications, particularly for fan-blade design. However, their integration is truncated due to its susceptibility to impact phenomena, and the lack of reliable numerical models that capable to predict their damage response. Aircraft components, particularly fan blades, are known to experience harmful foreign impact events e.g. tool-drop, ice ingestion, bird strike, etc. The aim of this project is to provide the necessary theoretical background on the failure mechanisms experienced by a composite during an impact, and to build Foreign Object Impact (FOI) model on a rectangular composite plate for the cases of low and high velocity. The focus of the high velocity model is to validate the ballistic response of a composite rectangular plate by means of experimental and numerical results found in the literature [1, 4], and to analyze the main sources of damage present and the influence of relevant physical properties i.e. thickness, stackup sequence, etc. On the other hand, the low velocity model is focused in delamination modelling. Two different sub-models are developed in this case: (1) ”Elastic Model”, in which only interlaminar damage between the plies is modelled and, (2) ”Failure Model”, where both intra and interlaminar failure are considered. The final goal is to provide an organized numerical methodology to model an impact on a composite structure and to analyze the effect of the projectile velocity on the damage mechanism developed by the composite target.

Keywords: Foreign Object Damage (FOD), Intralaminar failure, Interlaminar failure or Delamination, Tiebreak contact, Residual velocity

Relevant Figures

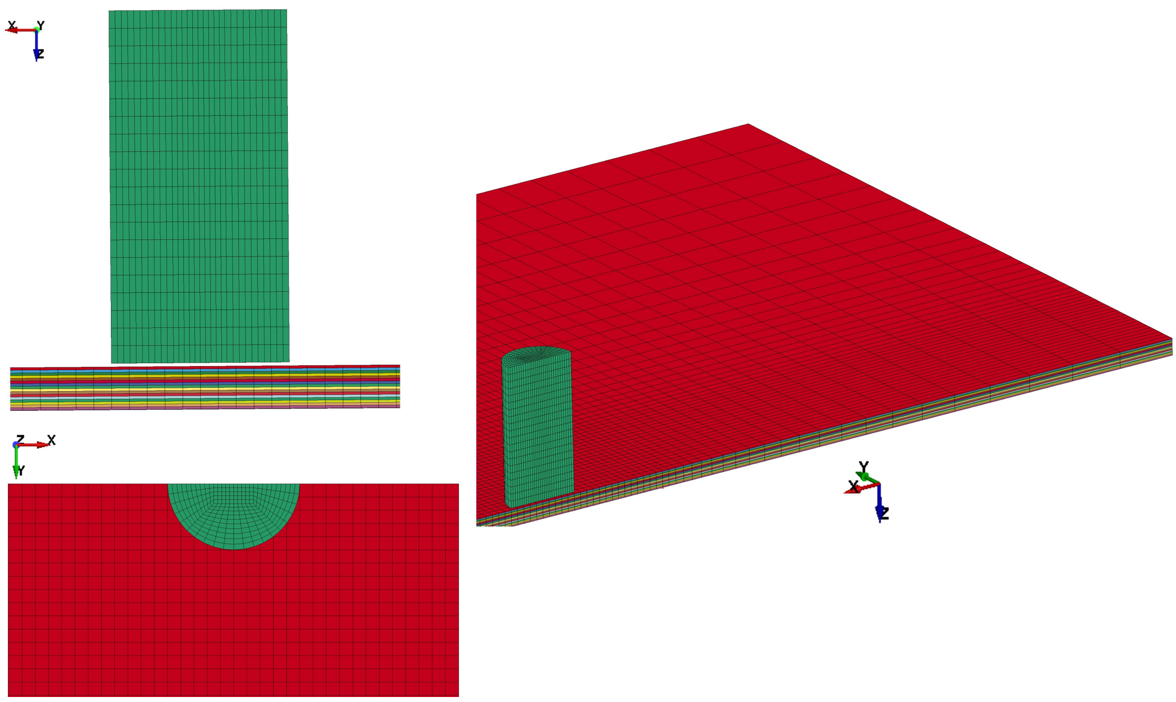

Figure 2: High Velocity Ballistic Impact on a Composite Plate Aerospace Working Group Model [1]. Frontal (top left), top (bottom left) and isometric (top right) views of the model in LS Dyna interface.

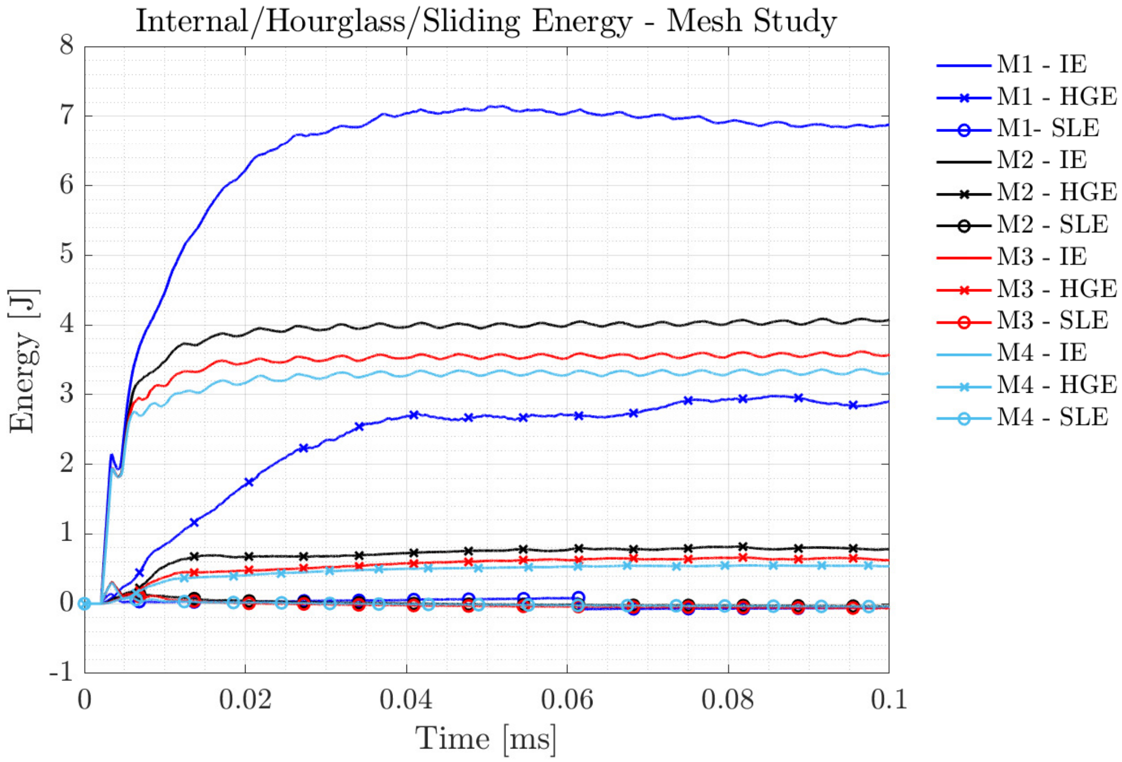

Figure 3: Internal, Hourglass and Sliding Contact energy evolution during High Velocity Impact, for different impact area mesh densities: M1=1.3x1.3x0.2mm, M2=0.6x0.6x0.2 mm, M3=0.3x0.3x0.2 mm and M4=0.15x0.15x0.15 mm.

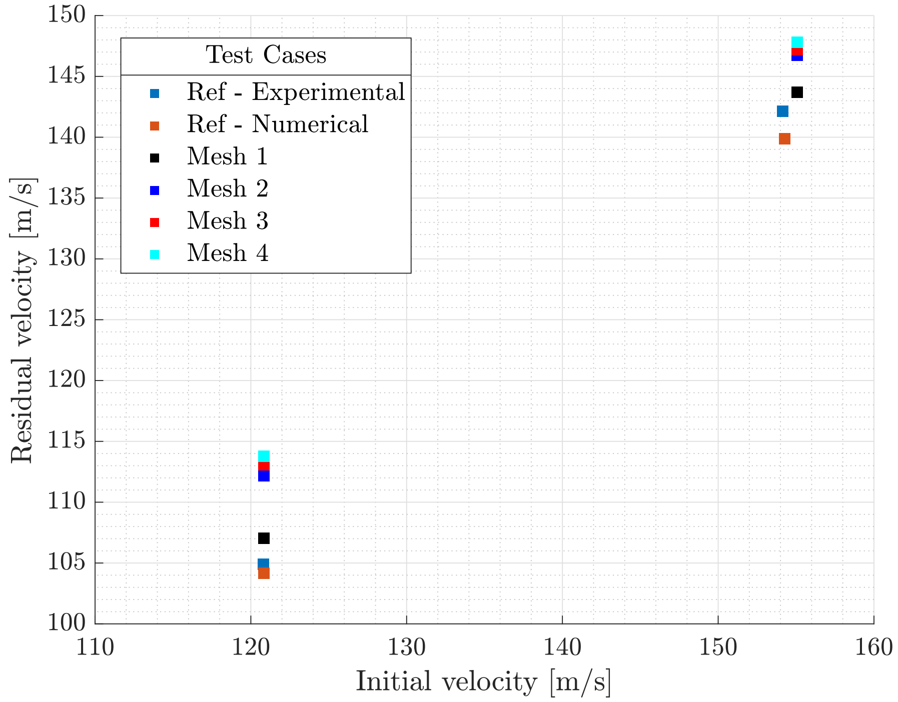

Figure 4: Projectile residual velocity after High Velocity Impact for different mesh densities: M1=1.3x1.3x0.2mm, M2=0.6x0.6x0.2 mm, M3=0.3x0.3x0.2 mm and M4=0.15x0.15x0.15 mm. Validation with experimental and numerical results from the reference ballistic test case [4].

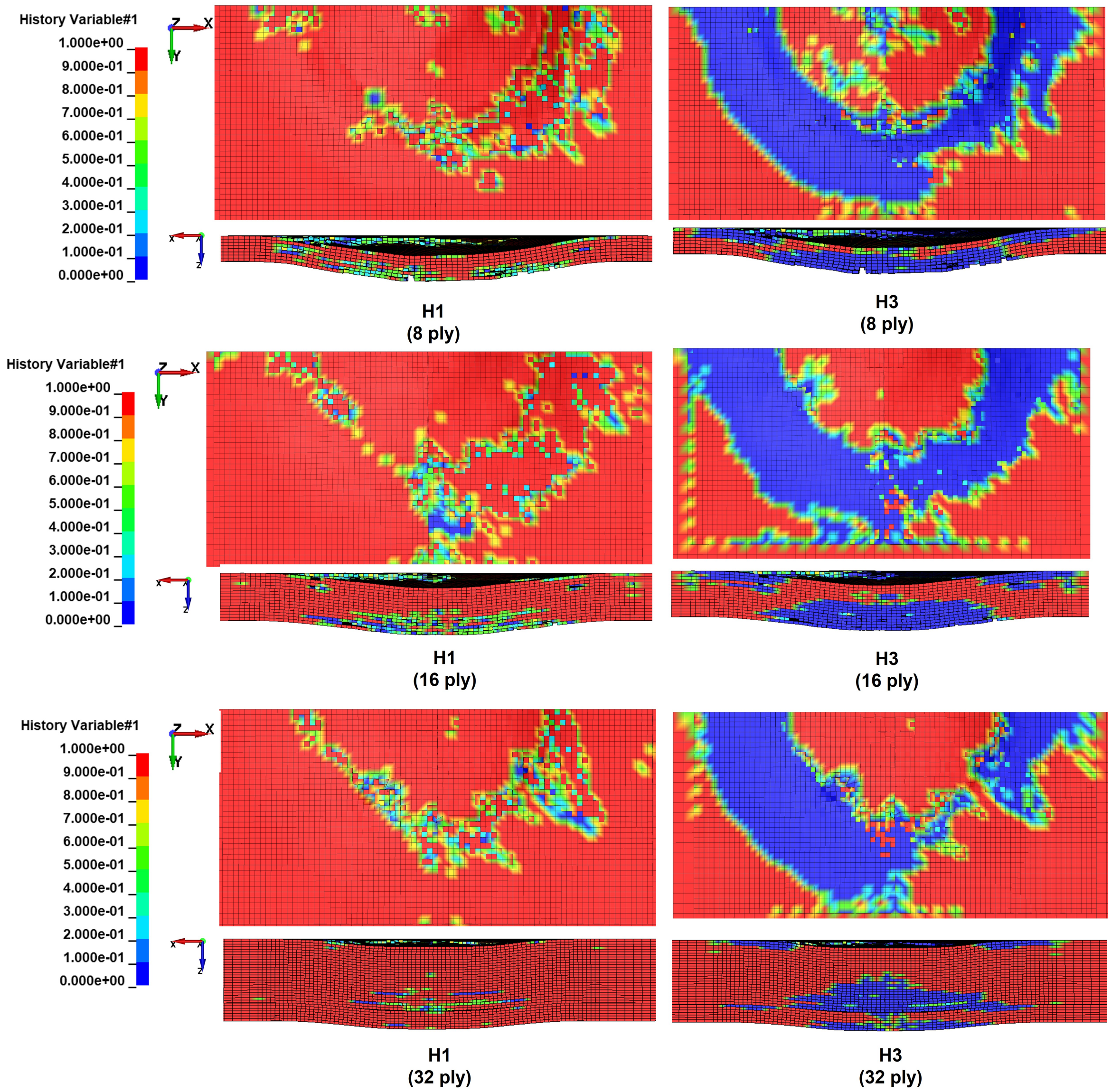

Figure 5: History variables ($t = 7.5E - 3$ms) of the fibre (H1, left) and the matrix (H3, right) tensile cracking modes for different plate thickness: 8-ply (top), 16-ply (middle) and 32-ply (bottom). For all history variable plots, the top (upper) and frontal (lower) views are presented.

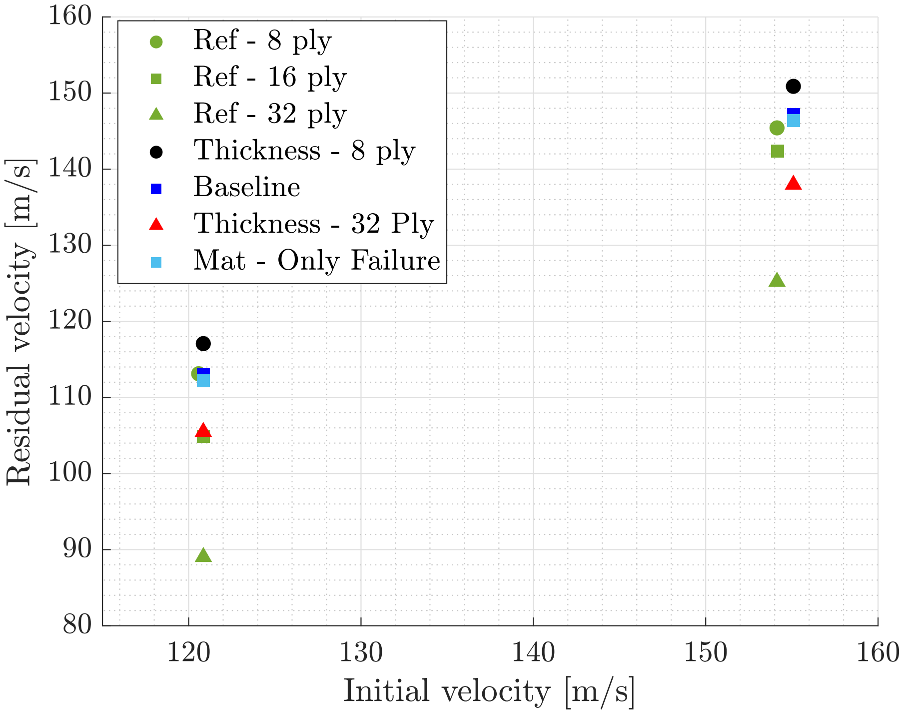

Figure 6: Projectile residual velocity after High Velocity Impact for the different cases of the Physical Parametrical Study: 16-ply plate with material formulation with erosion strain parameters (Baseline), 16-ply plate without erosion strain parameters (Mat- Only Failure), 8-ply plate (Thickness - 8 ply) and 32-ply plate (Thickness - 32 ply).

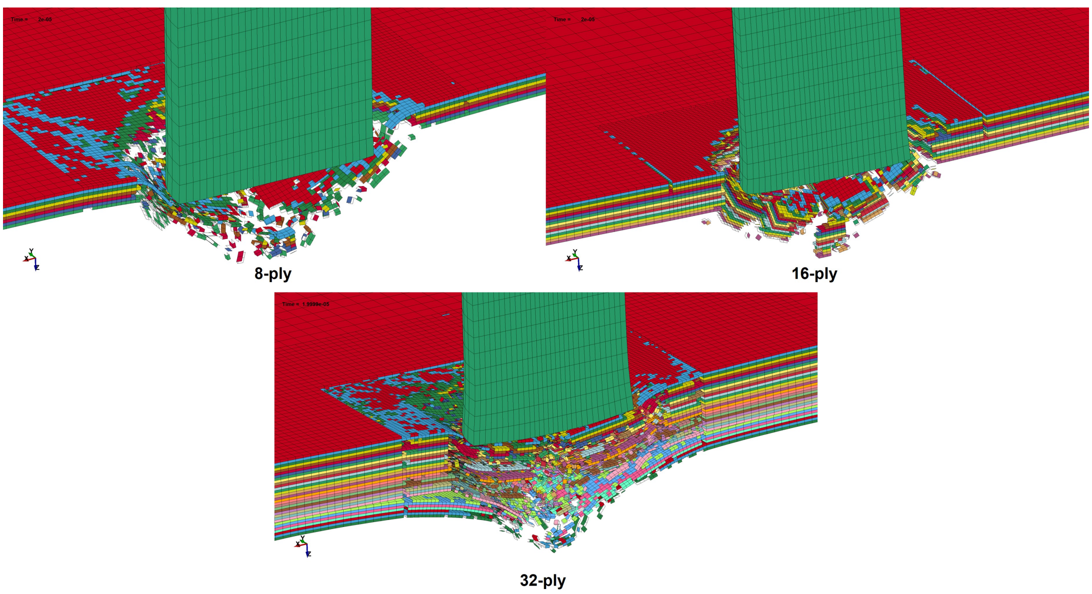

Figure 7: High Velocity Impact in a 8 (top, left), 16 (top, right) and 32-ply (bottom, middle) composite plates at a $t = 2e - 2$ ms.

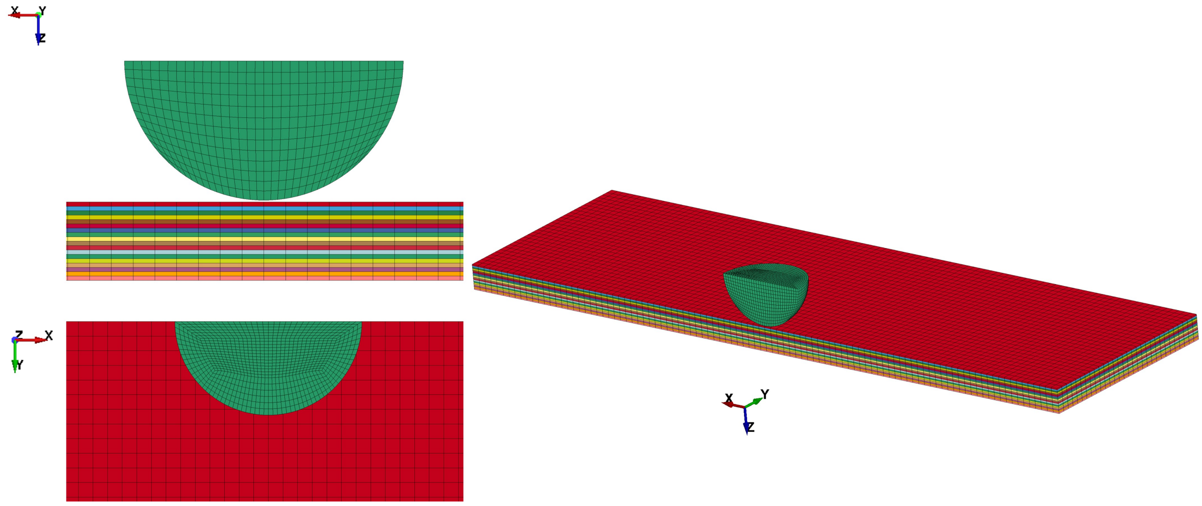

Figure 8: Low Velocity Impact on a Composite Plate model [3, 2]. Frontal (top, left), top (bottom, left) and isometric (right) views of the model.

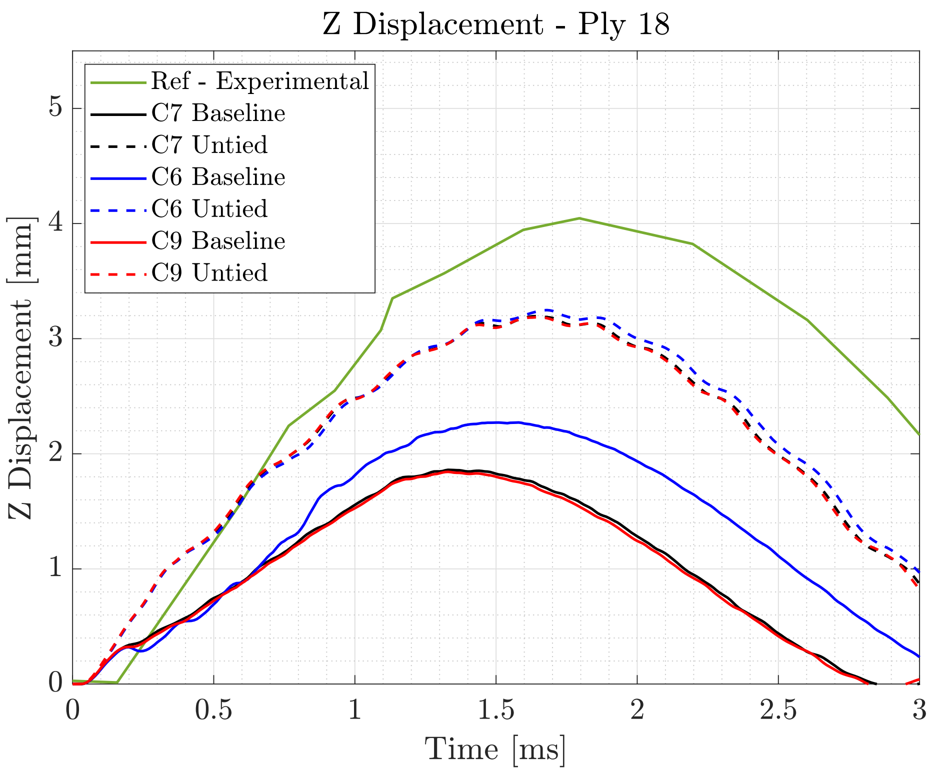

Figure 9: Displacement in the Z-axis of the bottom ply (Ply 18) during the Low Velocity Impact. Results from the "Elastic Model" for different contact algorithms: Baseline (all the plies interact with tiebreak contact), Untied (only plies with different fibre orientations interact with tiebreak contacts), C7 (Tiebreak contact with no damage law, OPTION=7), C6 (Tiebreak contact with linear damage law, OPTION=6) and C9 (Tiebreak contact with bilinear traction separation law with mixed loading capability, OPTION=9).

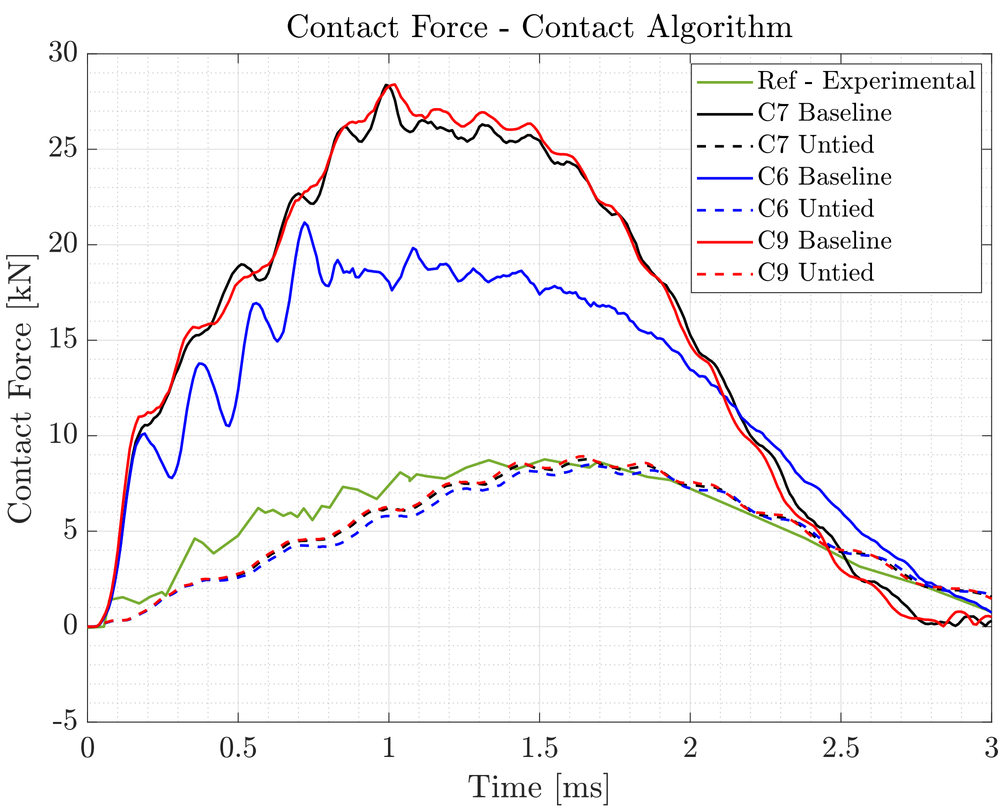

Figure 10: Normal contact force average of all contact interfaces at each time step for different contact algorithms: Baseline (all the plies interact with tiebreak contact), Untied (only plies with different fibre orientations interact with tiebreak contacts), C7 (Tiebreak contact with no damage law, OPTION=7), C6 (Tiebreak contact with linear damage law, OPTION=6) and C9 (Tiebreak contact with bilinear traction separation law with mixed loading capability, OPTION=9).

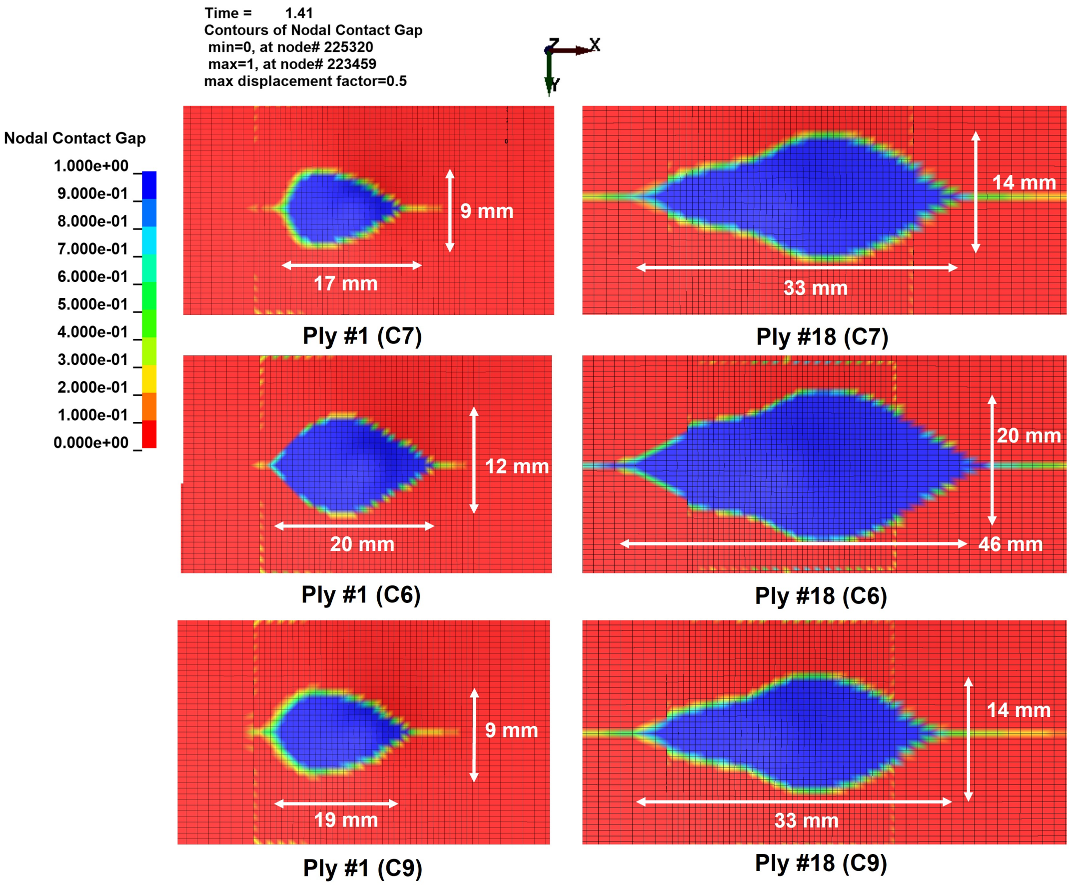

Figure 11: Top view of delaminated area in impacted surface (ply 1) and non-impacted surface (ply 18) for different tiebreak contact options: C7 (Tiebreak contact with no damage law, OPTION=7), C6 (Tiebreak contact with linear damage law, OPTION=6) and C9 (Tiebreak contact with bilinear traction separation law with mixed loading capability, OPTION=9).

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