PhD proposal

Damage tolerance and impact behavior of thermoplastic composite materials for high temperature aeronautic applications: numerical modeling and experimental study

For aerospace applications, low velocity impact (characteristic of a tool falling during a maintenance phase for example) is one of the most critical stresses for laminated composites, as it generally induces delamination (ply delamination) which affects their residual strength. In previous work [1-4], low velocity impact tests were performed using a Charpy pendulum impact tester (Figure 1). The specimens used for these tests were 100*150mm2 plates impacted by a hammer equipped with a hemispherical indenter. The impact pendulum was equipped with an in-situ heating module via a heating resistor to apply a homogeneous temperature in the composite specimen prior to the impact test. In this study, the materials tested were PEEK thermoplastic matrix composites reinforced with carbon fiber/glass fabrics (material used for structural parts of the A350 engine mast). The understanding of the behaviour under impact requires the study of the damage tolerance of these materials, with the quantification of the characteristic quantities of the rupture at different temperatures such as the translaminar [5-7] and interlaminar toughness, which are input data of a numerical model allowing simulating the rupture behaviour of laminated composites with thermoplastic matrix.

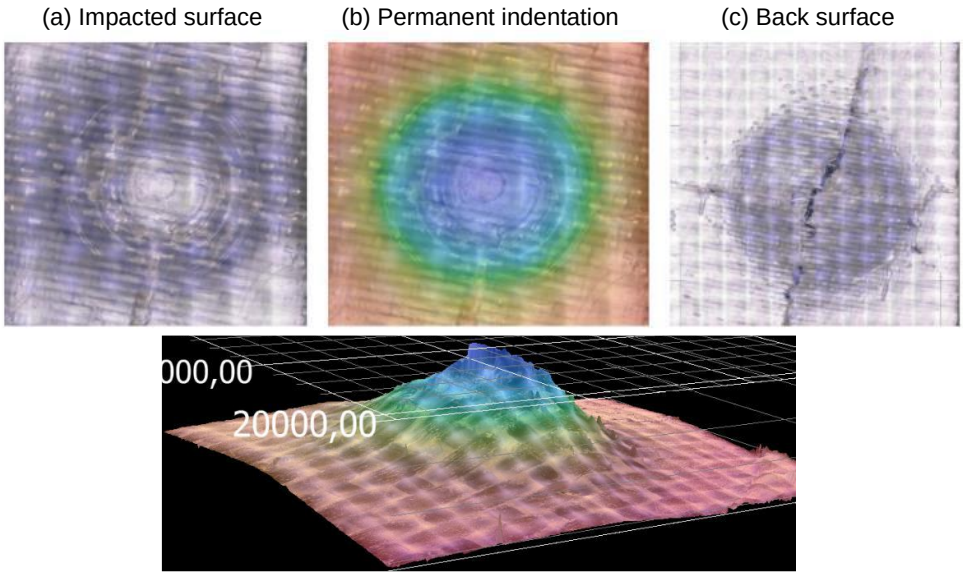

Fig. 1 – Impact test on hybrid thermoplastic composites: observations by means of a 3D optical microscope of impacted (a) and back surfaces (c) - permanent indentation (b)

The main objective of this thesis is thus to study the influence of temperature on the damage tolerance and impact behaviour of aeronautical composite materials intended for high-temperature applications (150°C). Impact damage results in a permanent indentation that alters the mechanical properties of the material. Previous work has highlighted the role played by temperature on the viscoplasticity of the PEEK polymer matrix on the damage mechanisms and the toughness of the material. By exploiting a numerical model developed in the Abaqus Finite Elements code in the framework of Pujols Gonzalez thesis [7], it is possible to predict the initiation and propagation of damage within the different plies of the laminate (Figure 2). This is achieved by considering the local (visco)plastic behaviour of the matrix, whose contribution to the damage mechanisms depends significantly on temperature.

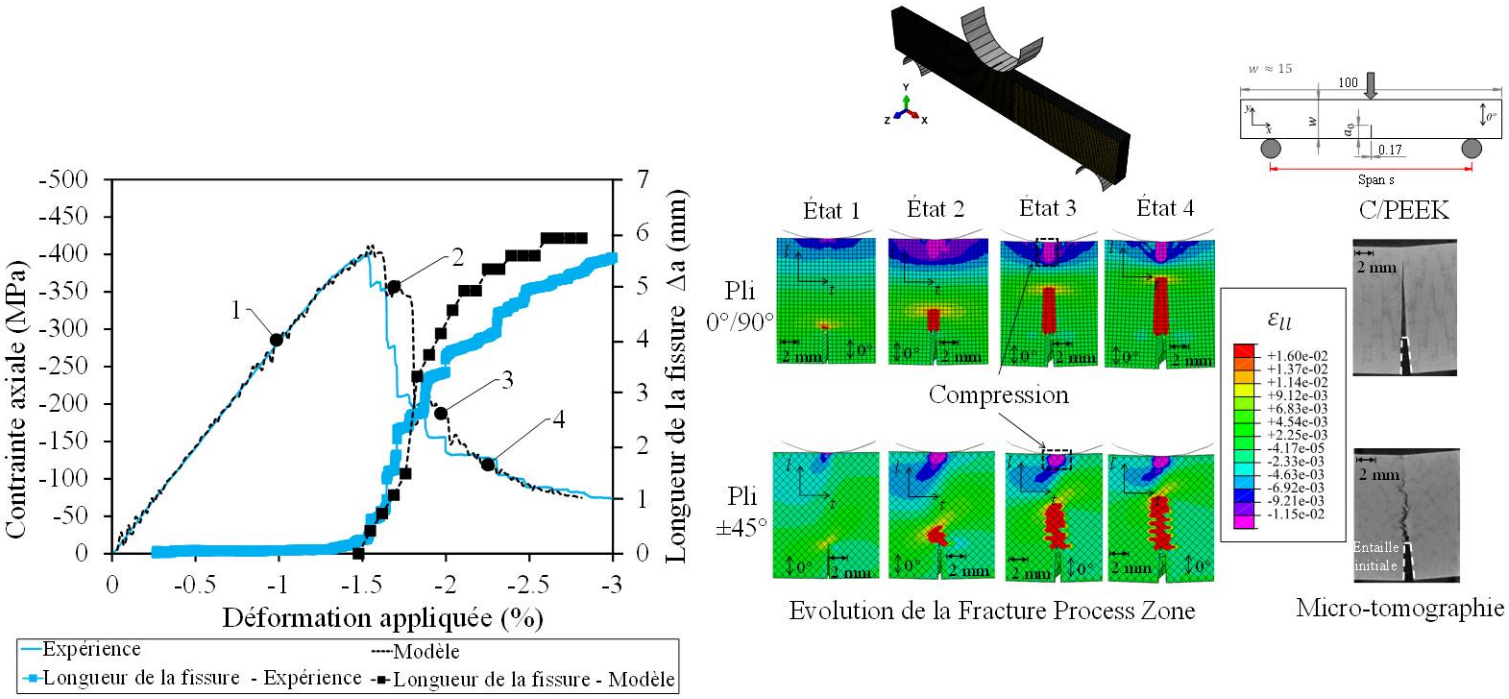

Fig. 2 – Single-edge-notched 3 points bending tests: modelling vs experiment

To achieve this goal, we will proceed in different stages:

- Study the influence of temperature on damage tolerance and impact behaviour,
- Analyse fracture behaviour by optical microscopy to measure permanent indentation induced by impact at high temperature,
- Carry out a post-impact compression test campaign to characterize the damage tolerance of thermoplastic composites,
- Develop the numerical model by implementing a viscoplastic behaviour law in Abaqus,
- Simulate the fracture behaviour of laminated composites for different loading conditions (tensile hole, notched bending tests, impact).

This PhD proposal is part of a collaborative work, started 10 years ago (for your guidance, you may consider the references), between two Joint Research Units of CNRS (National Center for Scientific Research): The Institute Clément Ader (ICA - UMR 5312) and the Group of Materials Physics (GPM - UMR 6634).

The ICA is a joint mechanics laboratory (https://institut-clement-ader.org/) between INSA Toulouse, IMT Mines d'Albi, INSA Toulouse, Toulouse III University, ISAE-SUPAERO and the CNRS.

The GPM is a research laboratory (http://gpm.univ-rouen.fr/en) belonging to the University of Rouen Normandie, the INSA Rouen Normandie (https://www.insa-rouen.fr/en), member institutions of the ComUE Normandie Université and the CNRS (UMR 6634). The laboratory is specialized in scientific instrumentation and the study of matter at the finest scales in order to explain its physical properties and to link subnano-micro-macro-structure scales. The laboratory is structured in 5 departments: Materials-Aging-Mechanics, Scientific Instrumentation, Nanosciences, Disordered Systems-Polymers and Nano-Health-Physics. It gathers 160 staff including 60 Lecturer-Researchers, 30 ITAs and 70 PhD/Postdocs/Interns.

The recruited PhD student will be primarily attached to the Science and Mechanics of Materials department within the ERMECA team (Research Team in Mechanics of Materials - 5 teachers and researchers, 3 Post-Doctoral students and 7 PhD students) at INSA Rouen - GPM. This team is interested in the characterization of the thermo-mechanical behaviors of materials at different scales by implementing a multi-physical approach, allowing in particular to study the relations

between processes-microstructure and properties. Occasionally, she(he) will conduct tests or tomographic scans at ICA in Toulouse.

The applicant should hold a master's degree in materials mechanics, or an engineering degree with an equivalent profile, and should have a strong taste for experimental science and finite element numerical modelling.

PhD supervisors:

Benoit Vieille – Professor at GPM – INSA Rouen Normandie
benoit.vieille@insa-rouen.fr
Christophe Bouvet – Professor at Sup'aero – Institut Clément Ader
christophe.bouvet@isae-supaero.fr

References

[1]DUBARY N., TACONET G., BOUVET C., VIEILLE B. **(2017)**
Influence of temperature on the impact behavior and damage tolerance of woven-ply thermoplastic laminates for aeronautical applications. Composite Structures, 168, pp. 663–674.
[2]VIEILLE. B., CASADO V.M., BOUVET C. **(2014)**
Influence of matrix toughness and ductility on the compression-after-impact behavior of woven-ply thermoplastic- and thermosetting- composites: a comparative study. Composites Structures, 110, pp. 207-218.
[3]VIEILLE. B., CASADO V.M., BOUVET C. **(2013)**
About the impact behavior of woven-ply carbon fiber reinforced thermoplastic-and thermosetting-based composites: a comparative study. Composites Structures, 101, pp. 9-21.
[4]VIEILLE B., PUJOLS-GONZALEZ J.-D., BOUVET C., BRETEAU T., GAUTRELET C. **(2020)**
Influence of impact velocity on impact behaviour of hybrid woven-fibers reinforced PEEK thermoplastic laminates. Composites Part C, 2: 100029.
[5]VIEILLE B., PUJOLS GONZALEZ J-D, BOUVET C. (**2019**)
Prediction of the ultimate strength of quasi-isotropic TP-based laminates structures from tensile and compressive fracture toughness at high temperature. Composites Part B, 164, pp. 437-446.
[6]VIEILLE B., PUJOLS GONZALEZ J-D, BOUVET C. **(2019)**
Fracture mechanics of hybrid composites with ductile matrix and brittle fibers: Influence of temperature and constraint effect. Journal of Composite Materials, 53(10), pp. 1361-1376.
[7]PUJOLS-GONZALEZ J.-D. **(2020)**
Etude de la rupture translaminaire à haute température dans les stratifiés thermoplastiques à plis tissés pour des applications aéronautiques: caractérisation expérimentale et simulation numérique. PhD thesis of INSA Rouen Normandie, December 2020.