Mechanical behavior of oxide/oxide ceramic matrix composite bolted joints

M. Broutelle [1, 2], F. Lachaud [2], A. Daidié [2], L. Barrière [1], C. Dupleix-Couderc[1], F. Bouillon[3]

1 : IRT Saint-Exupéry
118 route de Narbonne – CS44248, 31432 Toulouse Cedex 4, France
e-mail : marion.broutelle@irt-saintexupery.com, ludovic.barriere@irt-saintexupery.com, chloe.dupleix-couderc@irt-saintexupery

2 : Institut Clément Ader
UMR CNRS 5312, Université Fédérale Toulouse Midi-Pyrénées
3 rue Caroline Aigle 31400 Toulouse Cedex 4, France
e-mail : frederic.lachaud@isae.fr, alain.daidie@insa-toulouse.fr

3 : SAFRAN Ceramics
Rue de Touban, Les Cinq Chemins, 33185 Le Haillan, France
e-mail : florent.bouillon@safrangroup.com

In order to fulfill the current economic and environmental requirements, the use of new materials in the aeronautical structures is necessary. Thanks to their thermo-mechanical properties, ceramic matrix composites are considered to be introduced in hot sections on aircraft engines. At intermediate temperatures (750 °C), oxide/oxide CMC are particularly interesting compared to the carbide based CMC. They do not suffer from oxidation issue, and their fabric is less expansive and faster [1]. In this context, IRT Saint-Exupery and Institute Clement Ader in collaboration with SAFRAN Ceramics have started a research project to study bolted junction between oxide/oxide CMC plates. The aim of this work is to characterize and to model the damage development in junctions undergoing a bearing load.

The studied material consists in a highly porous alumina matrix reinforced with alumina fibers. The use of a weak matrix allows crack deflection at the fiber/matrix interface, improving the CMC damage tolerance [2-3].

An experimental campaign on bearing specimens was conducted to define the damage chronology. The damage observed experimentally are similar to those usually seen in organic matrix composites: fiber buckling, matrix breakage, ply delamination and shear bands (Fig. 1) [4-5].

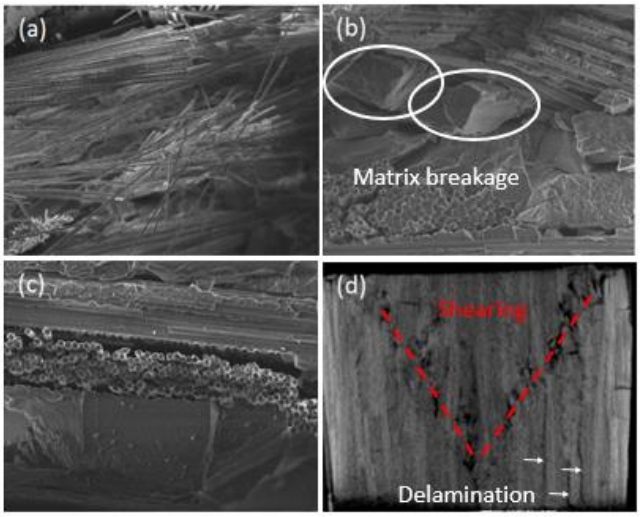

Fig. 1 : Bearing damage: (a) fiber buckling, (b) matrix breakage, (c) ply delamination, (d) shear bands

Numerical simulations have been run to model the damage. Constitutive laws describe damage evolution at the ply level by degrading the composite elastic properties. These laws are based on

damage functions which are coupled to define damage variables. The simulation results show a good correlation between the experimental and the numerical study [6].

This work will be pursued with a study on the influence of several parameters such as the specimen geometry, the stacking sequence, the applied torque and the fit between the drilling and the bolt. An optimal design will be obtained through an experimental design and studied with and experimental campaign and the associated modelling (Fig. 2).

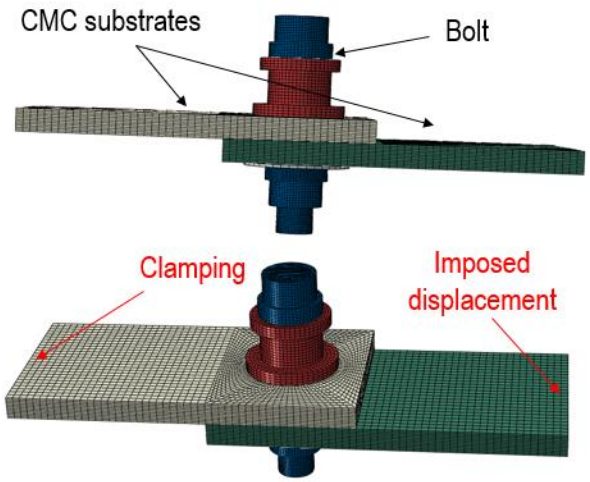

Fig. 2 : Model of the CMC bolted junction

Acknowledgements
The authors would like to thanks SAFRAN Ceramics for their scientific contributions to the subject.

References

[1] C. BEN RAMDANE, « Etude et modélisation du comportement mécanique de CMC oxyde/oxyde». *Thèse de l'Université de Bordeaux*, 2014.
[2] KA. KELLER, G. JEFFERSON, RJ. KERANS « Oxide-oxide composites ». *Handbook of Ceramic Composite*, pp. 377-421, 2005.
[3] FW. ZOK, CG. LEVI, « Mechanical properties of porous-matrix ceramic composites ». *Advanced Engineering Materials*, Vol. 3, pp. 15-23, 2001.
[4] W. XIAO, T. ISHIKAWA, « Bearing strength and failure behavior of bolted composite joints (Part I: experimental investigation) ». *Composites Science and Technology*, Vol. 65, pp. 1022-1031, 2005.
[5] PP. CAMANHO, S. BOWRON, FL. MATTHEWS « Failure mechanisms in bolted CFRP». *Journal of reinforced plastics and composites*, Vol. 17, pp. 205-233, 1998.
[6] M. BROUTELLE, F. LACHAUD, C. DUPLEIX-COUDERC, A. DAIDIE « Comportement en matage de composites à matrice céramique oxyde/oxyde », *JNC20, 2017*.