On the thermo-mechanical modeling of crack propagation and healing in a brittle solid

Lucas Salmon*[1,2], Stéphane Lejeunes*[3], Mihail Gărăjeu[2], Socie Adrien[1], Victor Blanc[1], and Thomas Helfer[1]

[1]CEA – Centre de recherche du Commissariat à l'Energie Atomique - CEA Cadarache (Saint Paul-lez-Durance, France) – France

[2]Laboratoire de Mécanique et d'Acoustique [Marseille] – Aix Marseille Univ, CNRS, Centrale Marseille, LMA, Marseille, France – France

[3]Laboratoire de Mécanique et d'Acoustique [Marseille] (LMA) – Aix Marseille Université, Ecole Centrale de Marseille, Centre National de la Recherche Scientifique, Aix Marseille Université : UMR7031, Ecole Centrale de Marseille : UMR7031, Centre National de la Recherche Scientifique : UMR7031 – 4 impasse Nikola TeslaCS 4000613453 Marseille Cedex 13, France

Abstract

In this communication we consider the case of a brittle, isotropic elastic solid exhibiting cracking and healing mechanisms when subjected to cyclic thermo-mechanical loadings. More precisely, we focus on the case of oxyde fuel materials for which the mechanical state impacts core reactivity. The healing process is related to a welding phenomenon of primary cracks that occurs under specific irradiation conditons and can be considered on the macroscopic scale as a chemo-physical process driven by the thermodynamic state. We developed a local model within the framework of the cohesive zone approach (CZM). This model incorporates the damage and healing mechanisms with the help of two scalar internal variables that are coupled and allow the cracks to propagate and heal. The healing variable can be viewed as a healing reserve and thus naturally incorporates a limited number of cracking/healing cycles. We show that the model is thermodynamically consistent and permits to account for the reciprocal impact of the cracks upon the heat diffusion. The CZM is implemented into a finite-element code and we insert cohesive elements between the edges or surfaces of each volumic element of the structure. We discuss the comparison with a phase-field approach towards crack propagation, in particular for the calibration of CZM material parameters. We consider a few numerical examples to illustrate the interest of such an approach, while showing the limitations and drawbacks inherent in this type of modeling. As a perspective we will depict an investigation of introducing a healing phenomena into a non local damage model.

*Speaker