Description of thermal shocks using micromorphic damage gradient models

Pedro Nava Soto*†[1,2], Olivier Jamond[3], Olivier Fandeur[3], David Siedel[2], Thomas Helfer[1], and Jacques Besson[2]

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

[2]Centre des matériaux – MINES ParisTech, PSL Research University, MAT-Centre des Matériaux CNRS UMR 7633, BP 87, 91003, Evry, France – France

[3]CEA- Saclay – CEA Saclay, 91191 Gif-sur-Yvette Cedex, France – France

Abstract

A nuclear fuel rod in Pressurized Water Reactors (PWR) is a stack of cylindrical pellets enclosed in a metallic cladding. The fuel material is made of uranium dioxide, a brittle ceramic. During the reactor start-up, a complex network of crakcs develops in the fuel material. This crack network has important consequences on the overall thermomechanical evolution of the fuel rod during normal and off-normal operating conditions.

This contribution describe some micromorphic damage gradient models and their applications to describe the crack network generated by thermal shocks.

The micromorphic framework has several key advantages:

• Micromorphic behaviours are grounded on the rigorous thermodynamic bases of standard generalized materials allowing to express the evolution of the structure as a minimization principle.

• The irreversibility constraint is treated exactly at integration points.

• Micromorphic behaviours are versatile allowing to describe complex coupled behaviours. They are also able to approximate classical phase-field models (AT1 and AT2).

• Their numerical implementation is straightforward and efficient.

This contribution illustrates those advantages on several examples of thermal shocks from the litterature using the newly developed HPC solver Manta, developed by the French Alternative Energies and Atomic Energy Commission (CEA).

Micromorphic behaviours is then applied to the simulation of the crack network in the fuel pellet during the reactor start-up.

*Speaker

†Corresponding author: Pedro.NAVASOTO@cea.fr