6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 – 15 June 2018, Glasgow, UK

Multi-physics modelling of the pellet cladding gap closure phenomenon for the GERMINAL SFR fuel performance code

M. Temmar[1], B. Michel[1], I. Ramiere[1], N. Favrie[2]

[1] CEA Cadarache, DEN, DEC, F-13108 Saint-Paul-lez-Durance, France E-mail: mourad.temmar@cea.fr, bruno.michel@cea.fr, isabelle.ramière@cea.fr
[2] IUSTI university of Aix-Marseille E-mail: nicolas.favrie@univ-amu.fr

Key Words: *Multiphysics modelling, Mechanics, porosity migration, Code coupling, Fuel pin behaviour under irradiation*

Sodium nuclear Fast Reactor fuel pins are made of UPuO2 pellets inserted in a steel alloy cladding tube. Fuel pin behaviour under irradiation is simulated with the GERMINAL fuel performance code developed in the PLEIADES software environment. In the GERMINAL code, the fuel pin is described as a stack of slices, each of them being modelled by a 1D axisymmetric representation. Regarding the thermal behaviour, the pellet-cladding gap behaviour has a strong impact on the fuel maximal temperature and hence has to be precisely modelled. The pellet radial displacement, needed to compute the gap size, is assessed through an empirical formulation in the GERMINAL code. Based on experimental observation, this displacement seems to be related to the formation of a hole in the centre of the pellet under a high thermal radial gradient leading to the porosity migration phenomenon [1] and associated fuel restructuration. The aim of this work is to improve the pellet-cladding gap closure model through a physical formulation of the coupling between the mechanical behaviour and the fuel high temperature restructuration.
A preliminary work based on a 3D fuel pin slice representation has confirmed that the mass transfer, induced by the porosity migration, can explain the motion of fuel pellet fragment. Based on the mechanism tested in this 3D model a fully coupled formulation between the central-hole mass transfer and the pellet fragments radial relocation has been proposed to improve the current GERMINAL relocation model. The coupling consists in introducing the volume expansion induced by the mass transfer in the relocation model as an inelastic strain in the nonlinear mechanical behavior. The mass transfer is derived from the porosity diffusion model and the associated volume expansion is calculated thanks to a creep compressible formulation [2], where the local volume variation depends on the porosity fraction in fuel pellet. The porosity diffusion model has also been improved to take into account the contribution of free volumes coming from cracks, which arise in the ceramic pellet at the beginning of irradiation. In this first approach we assumed that free volumes induced by cracks and fabrication porosity moves according the same mechanism. So they are both used to initialize the porosity transfer model. Simulation results of this coupling formulation will be presented for several fuel pins and compared with experimental results.

REFERENCES

[1] Ronchi, C., and C. Sari. *Properties of Lenticular Pores in UO2, (U, Pu) O2 and PuO2,* Journal of Nuclear Materials 50, no. 1, February 1974, Pages 91–97.

[2] Y.Monerie and J.M. Gatt, *Overall viscoplastic behavior of non-irradiated porous nuclear ceramics,* Mechanics of Materials, Volume 38, Issue 7, July 2006, Pages 608-619.