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TOUTATIS: Pellet-Cladding Interaction (PCI) modelling with the Cast3M finite element code

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ABSTRACT

TOUTATIS [1, 2, 3] is a thermomechanical simulation tool based on the structural finite element computation code Cast3M [4] developed at CEA Saclay. It is an advanced research tool simulating local behaviour of a fuel rod segment, and is devoted to the comprehension of experimental power ramps [5], taking into account geometrical and materials non-linearities. TOUTATIS has been developed in order to model locally and accurately three-dimensional effects induced by PCI on thermomechanical behaviour.

The numerical scheme takes into account thermal and mechanical coupling induced by heat exchange evolution in pellet-cladding gap. Furthermore, it allows computation of severe thermal transients.

As for the mechanical behaviour of both cladding and fuel, up-to-date behaviour laws are used. Elastic and inelastic strains accumulated in cladding are computed simultaneously at every time step with the help of CEA's MISTRAL modulus [6]. The UO2 model [7] devoted to fuel behaviour has been developed in the Lab. It is based upon the coupling of Ottosen's micro-cracking model, which represents brittle fuel behaviour in tensile area, and of Gatt-Monerie viscoplastic fuel model [8] which represents ductile fuel behaviour at high temperature. We show that experimental and simulated cracking pattern after irradiation are alike.

Moreover, the Coulomb friction model at pellet cladding interface was implemented in TOUTATIS [2, 3]. Associated with the initial pellet cracking and the delayed micro-cracking which appears during the irradiation, it shows stress and inelastic strain concentration at inter-pellet level in front of fuel radial cracks. This result is consistent with experimental observation of a PCI/SCC (stress corrosion cracking) cladding failure initiating in this area during power transients [5].

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