NTech Lehrstuhl für Nukleartechnik
HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF
itu Institute for Transuranium Elements
e·on
TUM

Improvement and Validation of a Computer Model for the Thermo-mechanical Fuel Rod Behaviour during Reactivity Transients in Nuclear Reactors

► Introduction

Over the last few decades the discharge burn-up of nuclear fuels has been increased in order to achieve a more efficient fuel consumption. After an extended irradiation time in a reactor, the nuclear fuel develops a so-called high burn-up structure (HBS). The HBS can have an important potential effect on the fuel behaviour during design basis accidents (DBA) like reactivity initiated accidents (RIA). Fuel cladding failure as seen in the RIA test VA-1 (Fig. 1) must be avoided.

Fig. 1: Post-test appearence of rodlet VA-1, OECD (2010)

To investigate further the behaviour of high burn-up fuel under RIA conditions, new experiments will be carried out in the ongoing CABRI Water Loop Project of OECD/NEA.

► Main Objectives

- Implementation of new models for the simulation of reactivity initiated accidents (RIA) by the fuel performance code TRANSURANUS (related to high burn-up) [1,2]
- Validation calculations with TRANSURANUS for reactivity initiated accidents (related to high burn-up) [3]
- Development of a multi-physics coupling between the reactor dynamics code DYN3D and TRANSURANUS for full core analysis [4]

► TRANSURANUS R&D activities for RIA

In the frame of the OECD RIA Fuel Codes Benchmark data from several RIA experiments [3] were provided, calculated with TRANSURANUS and compared to other fuel performance codes world-wide. The pulse width of a RIA

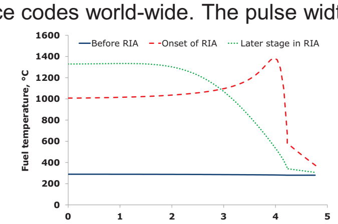

Fig. 2: Radial temperature distribution in fuel and cladding during RIA

transient is typically a few tens of ms. Thence kinetic effects play an important role. For example, the radial temperature distribution peaked in the periphery of the pellet under RIA (Fig. 2) is caused by kinetic effects as well as high burn-up. On the basis of the benchmark, TRANSURANUS models were improved for the Xe depletion in HBS [1] and were newly developed for the burst release from HBS [2].

► New Code System DYN3D-TRANSURANUS

Most of the reactor dynamics codes, thermal hydraulics system codes and sub-channel thermal hydraulics codes include a simplified fuel behaviour model. Due to the coupling approach to TRANSURANUS, DYN3D can take into account the fuel behaviour in greater detail for the whole core, at reasonable computational costs.

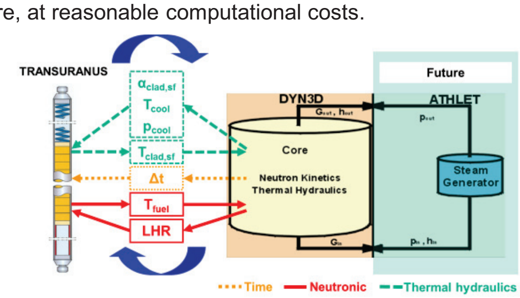

Fig. 3: Data transfer between DYN3D and TRANSURANUS

The necessity of this coupling approach for a reliable safety analysis is addressed in ref. [4]. The importance for a more detailed fuel rod description can be seen by the wide spread of fuel centerline temperatures as shown in Fig. 4 in case of RIA.

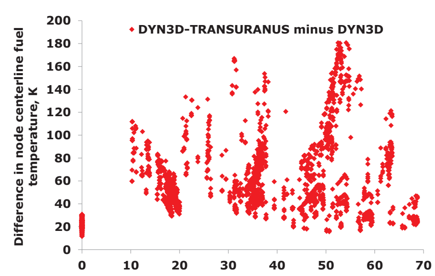

Fig. 4: Nodewise maximum differences in centerline fuel temperature

In the frame of this project, a general TRANSURANUS coupling interface was also developed that can be used for other TRANSURANUS couplings [4].

References to Selected Publications

[1] Holt, L. et al., Sensitivity Study on Xe depletion in the high burn-up structure of UO_2, Journal of Nuclear Materials (accepted for publication).
[2] Holt, L. et al., Journal of Nuclear Engineering and Design (under preparation).
[3] RIA Fuel Codes Benchmark, OECD/NEA, Paris, France, 2013 (including TRANSURANUS calculations performed by Holt, L.).
[4] Holt, L. et al., Development of a General Coupling Interface for the Fuel Performance Code TRANSURANUS - Tested with the Reactor Dynamics Code DYN3D, Annals of Nuclear Energy, Special Volume on LWR Multi-Physics (abstract accepted, under preparation).

Acknowledgements

The project is funded by E.ON Kernkraft GmbH within the knowledge preservation program in the German nuclear safety research.

For further questions, please contact

l.holt@hzdr.de (PhD-student); u.rohde@hzdr.de; Marcus.Seidl@eon.com; Arndt.Schubert@ec.europa.eu; Paul.Van-Uffelen@ec.europa.eu

Issue Date

February, 2014