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Benchmark of COSMOS Code for PRIMO MOX Fuel

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1. Introduction

To harness MOX fuel in LWRs, KAERI has developed a MOX fuel-related technology: a nuclear physics code, a fuel performance code, and fabrication. The MOX fuel technology was validated by a successful in-pile test in the Halden reactor [1].

The OECD/NEA Nuclear Science Committee has recognized the utilization of MOX fuel (in particular, mixed with weapon-grad plutonium) in the commercial PWR as a priority. In this regard, the Committee has established an Expert Group that deals with the status and trends of reactor physics, nuclear fuel performance, and fuel cycle issues related to the disposition of weapons-grade plutonium such as MOX fuel. A part of these activities includes benchmark studies of MOX fuel behaviour by using PRIMO – a ramping test of MOX fuel after base irradiation [2,3] .

This paper describes the review of the released testing program. In addition, the fuel performance code, COSMOS, analyzed the measured fission gas release and the prediction was compared with the measured value.

2. PRIMO Program

One MOX fuel rod (Fig. 1) in-pile tested in the frame work of the PRIMO was adopted for benchmarking [2,3].

The PRIMO programme was an investigation on MOX fuel to demonstrate MOX fuel's comparability in PWRs during steady and ramp irradiation test.

The fuel rod was manufactured at BN using the MIMAS (Micronized Master Blend) process. The use of the Master blend leads to some Pu-rich particles in MOX fuels, which can locally reach the content of ~30% PuO_2 of the primary blend.

The MOX fuel rod was base irradiated in the BR3 reactor up to the peak pellet burnup of 38 MWd/kgHM.

After base irradiation, the fuel rod was submitted to a power excursion in the OSIRIS reactor. The fuel rod was preconditioned at a peak LHGR of 189 W/cm for 27 hours. The subsequent power excursion reached a terminal power of 395 W/cm during 20 hours with a ramping rate of 77 W/cm-min.

Non-destructive examinations were performed on the base irradiation MOX fuel. The destructive examinations were performed after a ramp test, which revealed a fission gas release of 11.24% with an Xe-to-Kr ratio of 15.4.

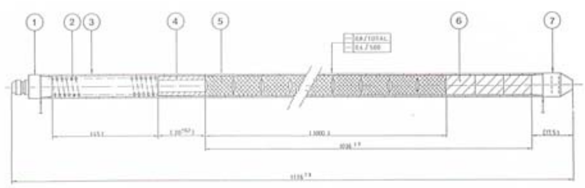

Fig. 1. Schematics of the MOX fuel from the PRIMO programme: (1) upper-end plug (2) Hold down spring (3) cladding tube (4) spacer tube (5) MOX fuel pellet (6) UO_2 blanket pellet (7) lower end plug.

3. Comparison between Measured and Calculated FGR

Considering the features of the MOX fuel of inhomogeneous Pu-rich agglomerates, a fuel performance code, COSMOS, has been developed for the analysis of both MOX and UO_2 fuel during steady-state and transient operating conditions [1]. The COSMOS code has already been verified with the MOX database as well as many other databases for the high burnup UO_2 fuels.

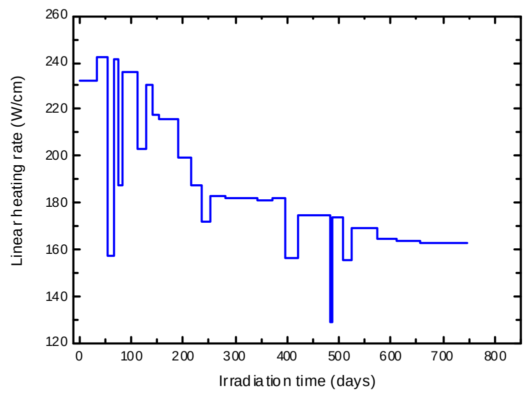

Fig. 2. Linear heating rate during base irradiation.

To analyze the MOX fuel behaviour by the COSMOS code, a power history (Fig. 2) during base irradiation was simulated first to obtain the incipient conditions of the ramping test. The power history was combined with the axial power peaking defined on twelve axial zones.

The ramping test was simulated by the power history shown in Fig. 3 with the axial power peaking (Fig. 4). The cosine-shaped power peaking was intentionally divided into 12 axial zones, and the averaged power peaking was adopted for determination of power level in each segmented zone.

The other input parameters were prepared with the assumption that the tested MOX fuel behaviours are similar to the attrition-milled MOX fuel[1]. Based on the assumption, the thermal conductivity was obtained from the model developed by KAERI [1]. The fuel geometrical changes were assumed:

- A maximum densification of 1%
- A swelling rate of 0.85% per 10MWd/kgHM

The gas puncturing data performed after power ramping was compared with the COSMOS prediction.

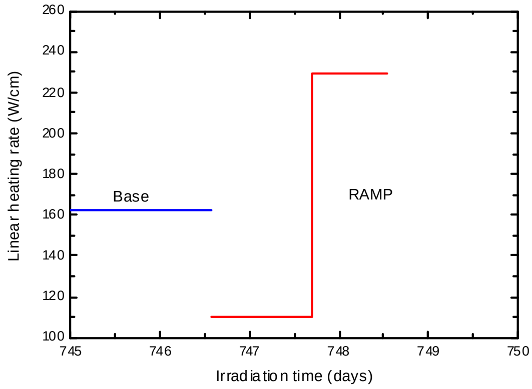

Fig. 3. Linear heating rate of the power ramp.

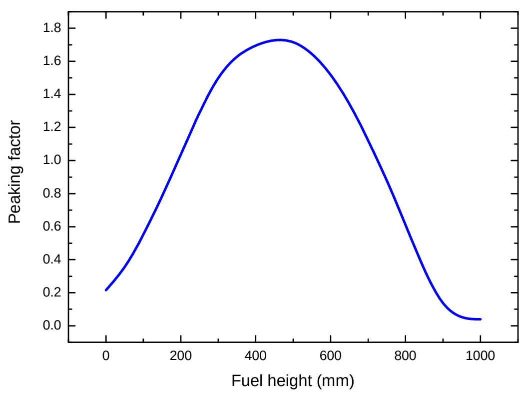

Fig. 4. Peaking factor in the OSIRIS ramp

The COSMOS code analyzed the fission gas release with two options [4]: (1) activating the option for the burst release through microcracks occurring during the rapid power transient, and (2) not activating the burst release option.

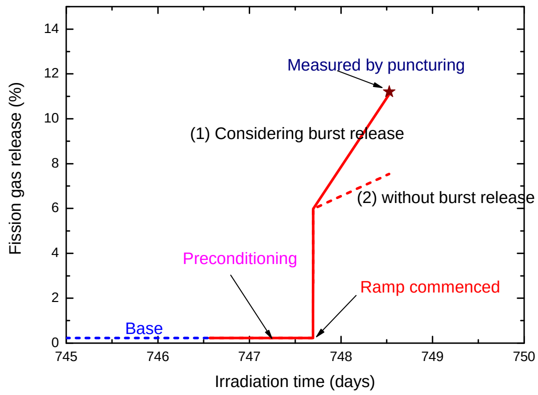

Fig. 5. Comparison between measured and calculated FGR at EOL.

Fig. 5 shows both calculation results. The measured fission gas release is also displayed in the figure. It can be seen that the fission gas release , while considering the burst fission gas release through microcracks, agrees well with the measured value. The comparison confirms the assumption that the entire fission gas inventory at the grain boundaries is released instantaneously during the rapid power ramping.

4. Conclusions

The OECD NEA performed a benchmark program by using one MOX fuel in the framework of the PRIMO programme. The fuel performance code, COSMOS, joined the benchmark. The prediction by the COSMOS code was compared with the fission gas release measured by gas-puncturing after a power excursion. The comparison revealed a very good agreement by considering the burst fission gas release through microcracks.

Acknowledgements

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