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Effect of Rod Internal Pressure on Simulation of Halden Test IFA-650.9 with FE-based Fuel Analysis Code MERCURY

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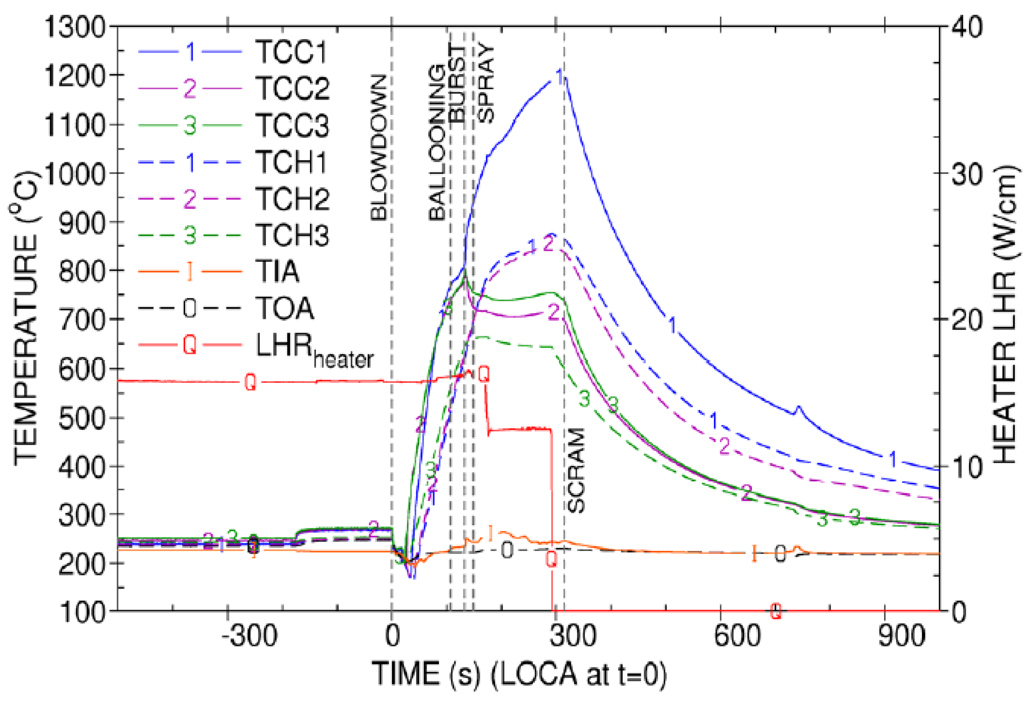
Introduction

- ❖ Analysis for the behavior of nuclear fuel in loss of coolant accidents in a nuclear reactor is being emphasized from the viewpoint of the characteristics of the nuclear fuel materials and the ability to maintain the coolable geometry.
- ❖ In particular, a nuclear fuel performance code based on the finite element method is being developed for the realistic nuclear fuel analysis. In KAERI, a multi-dimensional code development project for nuclear fuel analysis of accident conditions is being carried out, and a code named MERCURY is being developed.
- ❖ In this paper, the analysis results are presented in terms of the rod internal pressure of the MERCURY code for IFA-650.9, which is one of the IFA-650 series, which is the LOCA simulation test of the Halden Research Reactor for in-pile test data.

Halden Test IFA-650.9

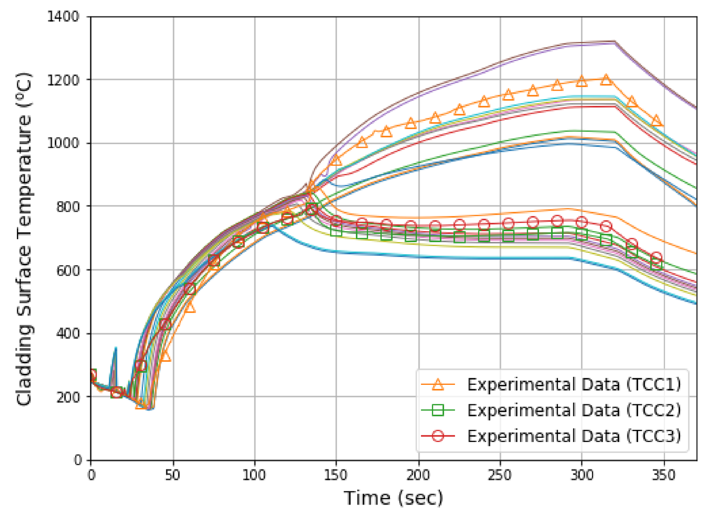
- In the Halden Research Reactor, the IFA-650 series to understand the behavior of nuclear fuel during LOCA was carried out as an OECD-NEA project.
- The IFA-650.9 test was carried out in April 2009 using a high burn-up PWR rod of 89.9 MWd/kgU from AREVA.
- The test was carried out using the low fission power to achieve the desired conditions for high temperature, ballooning, and oxidation.
- The results showed that the ballooning in the lower part of the rod occurred and was followed by a cladding burst and fuel relocation.



Cladding and heater power in IFA-650.9 test.
[Halden Report HWR-917, 2009]

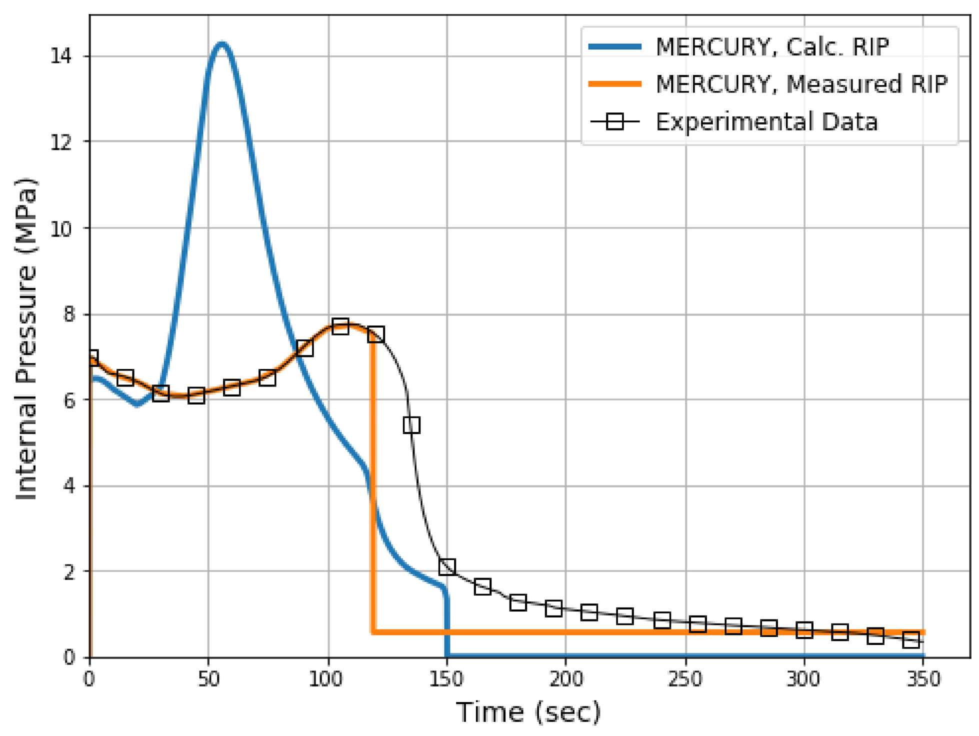
Thermal-Hydraulic B.C. from SOCRAT Aanlysis

- In the IAEA-CRP FUMAC, the well-turned thermal-hydraulic boundary conditions were suggested through the SOCRAT code as contribution of Russia.
- Since the MERCURY code does not analyze the coolant outside the fuel rod, it is reasonable to bring and use the appropriate boundary conditions to evaluate the characteristics of MERCURY code.

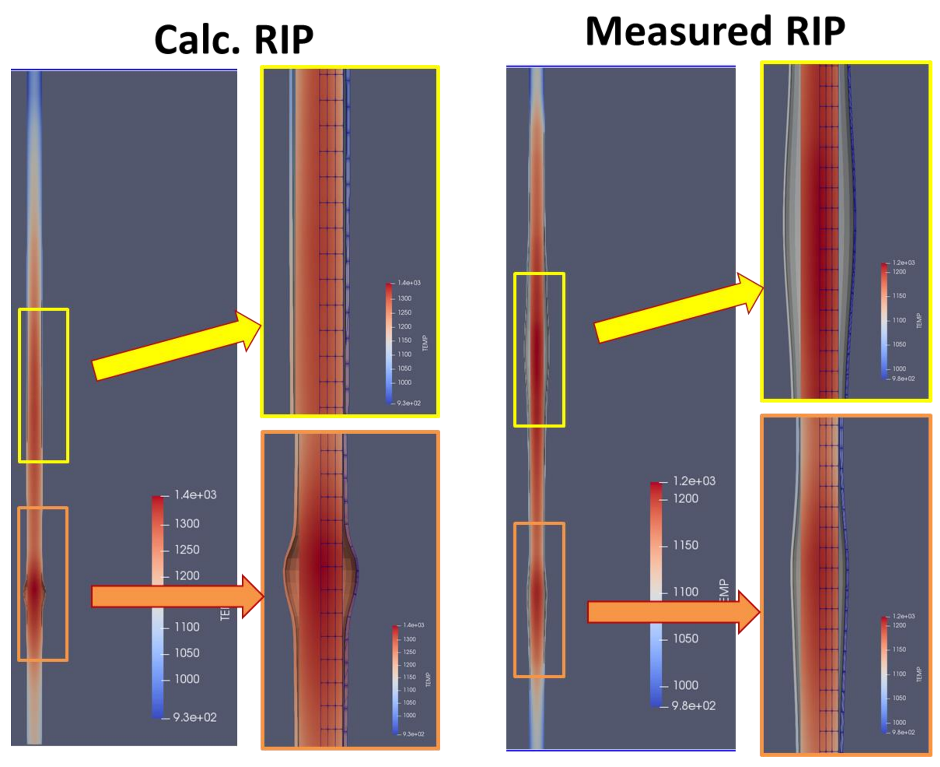


Rod Internal Pressure and Ballooning

- The geometry is composed of 2126 nodes and 576 elements for two volumes of the fuel pellet and cladding.
- In the analysis model, the axial length of the fuel is 480 mm, and the outer diameter and thickness of the cladding are 10.75 mm and 0.725 mm respectively. Displacement in the axial direction was fixed as a boundary condition.
- The comparison of the results of the case where the internal pressure was calculated using the default option of the MERCURY code, which is to add 5 K to the cladding surface temperature and the case where the measured internal pressure was applied as the fixed condition.
- When the default option is used, the free volume temperature is applied too high, and the internal pressure is predicted to be significantly higher than the pressure measured in the experiment.



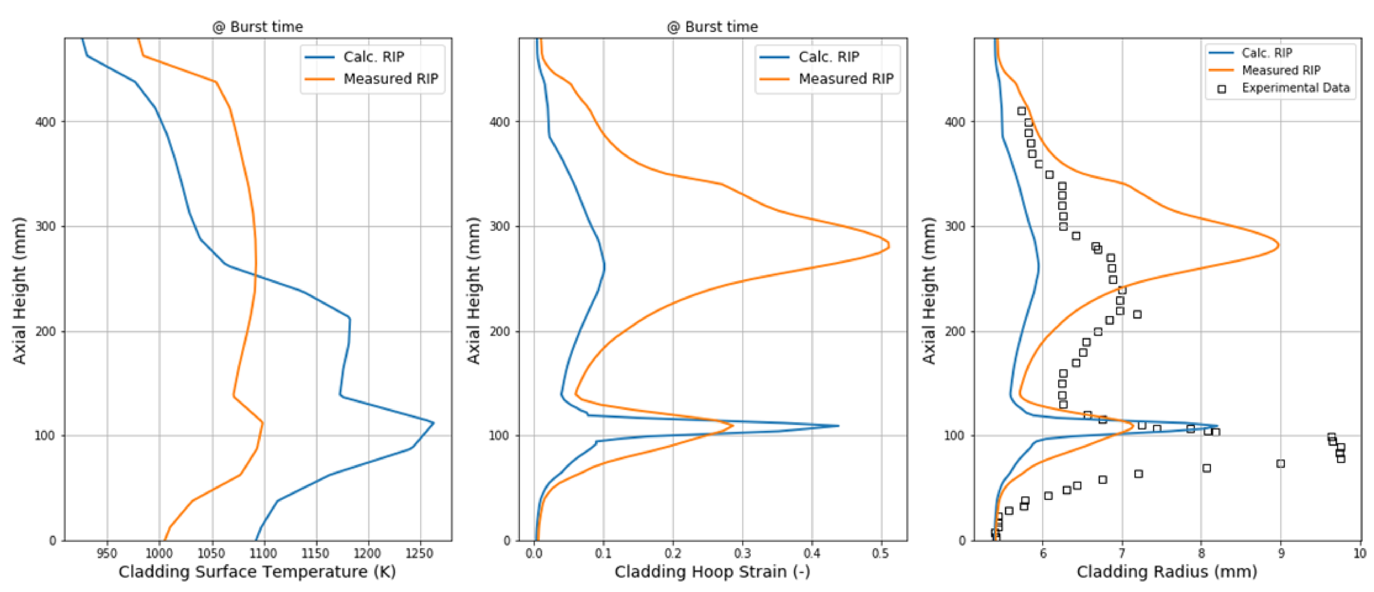
The rod internal pressure calculated using default option of MERCURY and experimental measured data.



Fuel temperature and deformation shape at the time of cladding rupture.

Rupture

- When the default option was used, high temperature was concentrated in the lower part and large deformation occurred concentrated in the lower part, whereas when the internal pressure was fixed as the experimental value, two high temperature regions appeared, which resulted in two deformation peaks.
- Since the creep model for the large deformation is a function of temperature, the two ballooned regions occur in cladding. The rupture time of experiment exists between both calculation cases. The deformation shape at the rupture is similar to calculated RIP case due to the similar rupture time compared to measurement.



Conclusions

- ✓ The analysis of LOCA simulation test, IFA-650.9 was performed using the accident condition nuclear fuel analysis code, MERCURY.
- ✓ In the analysis of IFA-650.9, the evaluation of the fuel rod internal pressure has a great influence on the cladding deformation.
- ✓ As an important factor in predicting the internal pressure of fuel rods, an appropriate assumption about the gas temperature is required.
- ✓ In Mercury, an option to apply the temperature of the free volume as a function of time by a user input has been added, and the results of the temperature effect through this will be summarized and presented later.

Acknowledgement

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