PhD Position – October 2018

Creep behavior of pre-oxidized zirconium based cladding alloys under LOCA thermal-mechanical conditions

The context of the thesis is a postulated Loss of Coolant Accident (LOCA) induced by loss of tightness of the primary loop of a Pressurized Water Reactor (PWR).

More specifically, the study will address the thermal-mechanical behavior of the zirconium alloys containing the fuel pellets. During a LOCA, there is an increase in cladding temperature (>800°C) and also of the hoop stress applied to the cladding resulting from both: gas pressure increase within the rod and primary loop pressure decrease. This loading induces cladding ballooning limiting the core coolability. The normal operating conditions result in cladding oxidation and hydriding also influencing the cladding ballooning.

To address this topic, creep tests simulating LOCA conditions (temperature ranging between 750 and 850°C, and internal pressure between 20 and 100 bars) were tested by Damien Campello in a previous thesis in the same laboratory defended in 2016. The highly instrumented test rig provided a huge amount of data during each test including Digital Image Correlation (DIC) and Near Infrared thermography (NIRT) measurements. The test analysis required finite element computations using the ABAQUS software.

The creep behavior of as-received and pre-hydrided samples was determined. A few tests were also performed to check any possible influence of a pre-oxide scale on the obtained creep law. As illustrated in figure 1, there are some stress conditions inducing a strong reduction of creep rate.

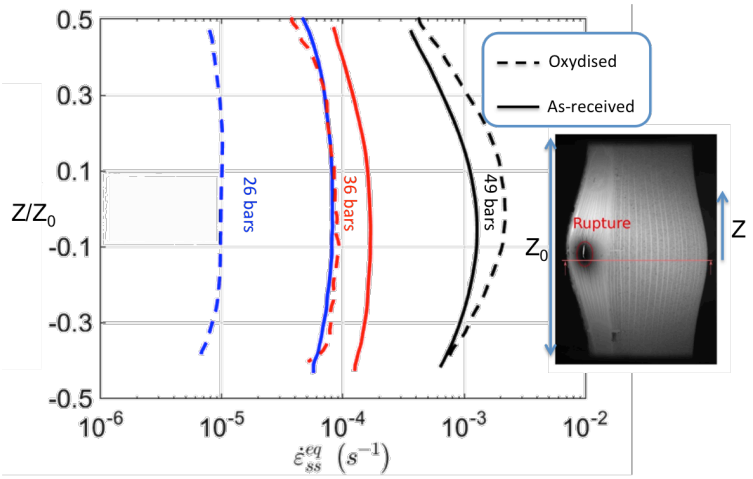

Fig. 1. Zircaloy-4 creep rate of as fabricated and pre-oxidized samples

The pre-oxidized zirconium alloy cannot be considered as homogeneous but rather as having mechanical properties affected by oxygen diffusion and hydrogen motion within the sample during the test, but also oxide scale damage. To characterize and model this coupled and complex phenomenon two possible ways are envisioned. The simplest approach consists in chaining the various physical phenomena and a more complex but powerful approach consists in modeling the coupled physics relying on phase field modeling.

Supervisors :

IRSN :	J. Desquines	T. Taurines
LaMCoS :	M-C. Baietto	N. Tardif
GeM :	M. Coret	J. Rethore