IRRADIATION OF LWR MATERIALS IN BR2

Background

The behaviour of construction materials of Light Water Reactors (LWR's) under irradiation, in particular the pressure vessel steel and internal core components is a constant concern to nuclear power plant (NPP) operators and to scientists. A better understanding of material degradation is essential and experimental proof of material properties is needed to identify when the replacement of specific components is required or if extended life service is aimed at. The CALLISTO facility, operating at Pressurised Water Reactor (PWR) conditions, allows performing in-pile testing of structural materials from reactor pressure vessel and internal core components under representative conditions of temperature, pressure and water chemistry.

Objectives

Using the dedicated experimental devices installed in the BR2 reactor, we perform irradiation of LWR material under conditions representative to their in-service environment to build up the data base needed to improve and/or to validate material degradation models and to get information on the behaviour on existing power plants materials after accelerated irradiation.

Principal results

1. The LEMONIZ programme

Specimens extracted from the stainless steel cladding of the pressure vessel of the LEMONIZ power plant (Spain) have been irradiated in the In-Pile Section nr 2 (IPS 2) of CALLISTO during cycle 01/2005. The material involved in this experiment is a stainless steel weld deposit. A macrograph of the cladding is shown in next picture. Three zones can be identified: from bottom to top: base material, first layer (~ 4.5mm), second layer (~4.5mm). We have extracted tensile specimens in the L & T orientation and compact tensile specimens in the LT & LS orientation from both top layers.

Macrograph of the cladding. From bottom to top three zones can be identified: base material, first layer and second layer. Total cladding thickness is about 9 mm.

2. The CUPRIVA programme

Unexpected behaviour of metal welds from the Garoña nuclear power plant (Spain) has been observed. Weld material should be evaluated at higher neutron doses in order to further study the irradiation effect. Higher doses can be achieved in Garoña from other surveillance capsules or through irradiation in a material test reactor. In this frame, the Garoña nuclear power plant has selected BR2 to evaluate the weld behaviour under higher neutron doses. The irradiation at 295°C took place in reactor cycle 04/2005. Post Irradiation Examinations (PIE) of the specimens have been done in the LHMA at SCK•CEN

3. The FRISCO programme

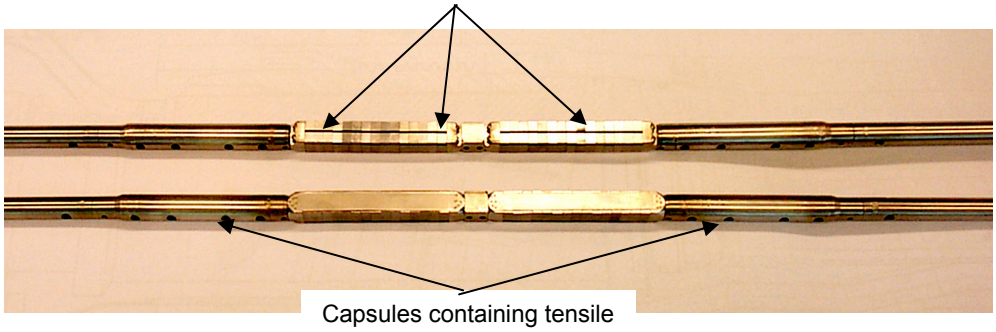
The Heavy-Section Steel Irradiation (HSSI) Program, funded by the U.S. Nuclear Regulatory Commission (USNRC) at Oak Ridge National Laboratory (ORNL), has proposed to collaborate with SCK•CEN on a project to investigate the effects of relatively high fast neutron flux on reactor pressure vessel steels and on fusion materials.

The irradiation programme called FRISCO (Fusion and Reactor material Irradiation SCK•CEN – ORNL) consists of 2 separate experiments: characterization of fusion materials and characterization of reactor pressure vessel (RPV) steels.

Specimens from the FRISCO-R experiment are made of different RPV steels; most of them have been irradiated in IPS 3 of CALLISTO during 2 cycles, starting from cycle 04/2005. They were assembled to form 5 needles and have been loaded in the positions A, B, D, E & I of the CALLISTO basket, which was rotated by 180° between the 2 cycles. For the higher flux irradiation of the Palisades weld material (US power plant), a similar set of specimens were inserted for one cycle (cycle 03/2005) in IPS-2, such that the fast neutron flux (E > 1 MeV) was about 1×10^{14} n/(cm^2.s), resulting in a fluence of about 1.7×10^{20} n/cm^2, a value about

the same as another Palisades weld currently located in an unopened surveillance capsule in the Palisades reactor storage pool.

Assembly of C(T) – specimens



Sections of FRISCO needles: Assembly of Tensile specimens (loaded in a tube) and Compact Tensile specimens C(T)

4. The PERFECT programme

The PERFECT experiment aims to test 3 dedicated materials in the framework of the study of the Stack Fault Energy (SFE) i.e. to make a link between the physical properties of a material (hardening, micro-structure …) and its behaviour under irradiation. It is made of 36 tensile specimens, 18 Positron Annihilation Spectroscopy (PAS) specimens and 60 Transmission Electron Microscopy (TEM) specimens.

5. The MIRE-Cr programme

The MIRE-Cr irradiation campaign is the experimental part of the scientific program *"Modelisation of irradiation effects, modelling oriented experiments on pure Fe-Cr-C alloys"*. The experiment consists of a total of five irradiation cycles that started in the 5th BR2 cycle of 2004.

The objective is to provide the necessary experimental support for the validation and further development of the existing computational models for material irradiation damage effects. These experiments can even offer a good reference point to study the effect of additional elements, such as W, V, and Ta, on the defect accumulation behaviour.

We loaded 777 mini specimens from six different materials in the CALLISTO loop; the samples were encapsulated to prohibit reaction with the coolant and to control the temperature by making good use of gamma heating and thermal barriers.

Future work

- Extension of the MIRE-Cr programme to test specimens made of very special Fe-Cr alloys (single crystals oriented in specific directions).
- Negotiations to prepare the further materials irradiation programmes managed by the Institute for Materials Research (IMR) at the Tohoku University are about to be completed successfully.
- Collaboration with the Heavy-Section Steel Irradiation (HSSI) Program, funded by the USNRCat ORNL will continue.

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Main reference

R.W.Bosch, M. Wéber, M. Vankeerberghen, *"In-pile electrochemical measurements on AISI 304 and AISI 306 under PWR conditions: the first results"*, EUROCORR 2005 - The European Corrosion Congress, Lisbon, 4 – 8 September 2005