FURTHER CHARACTERIZATION OF IRRADIATED STEELS BY INDENTATION AT HIGH TEMPERATURE

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The characterization of the mechanical properties of irradiated reduced-activation ferritic-martensitic (RAFM) steels is currently demanded with a view to further development and validation of structural materials for fusion applications. Such post-irradiation experiments (PIE) are limited in space, highly expensive if considering the costs of irradiation volume, and require adapted mechanical testing tools. The instrumented indentation technique, making use of a data post-analysis program based on neural networks [1], was selected according to its ability to examine tensile properties by multistage indents on miniaturized irradiated samples. This method could be used up to now for room temperature material's characterization with an adapted commercial indentation device situated in a hot cell of the Karlsruhe Fusion Materials Laboratory (FML). Considering the demands in characterization of irradiated steels at high temperature and in post-irradiation annealing experiments, an instrumented indentation facility for testing up to 650 °C has been developed at the KIT. This instrument will enable experimental investigations on both RAFM and oxide dispersion strengthened RAFM (ODS) steels up to their operating temperature limit in fusion reactors.

The mechanical behavior of Eurofer97 and F82H-mod specimens previously neutron-irradiated in the High Flux Reactor at Petten (HFR) up to a dose of 15 dpa at 250 °C to 450 °C was initially investigated at room temperature [2]. The significant irradiation-induced hardening effect present at 15 dpa in the range of 250-350 °C could be observed in Vickers hardness and in the calculated material's strength parameters. Moreover, recovery of the irradiation damage could be identified from post-irradiation annealing treatments of Eurofer97 at 500 °C and 550 °C. The effects of the reaction kinetics on hardness and strength changes could also be detected for different durations of thermal treatment. The recovery of DBTT observed from Charpy impact tests after post-irradiation heat treatment at 550 °C on Eurofer97 irradiated up to 15 dpa [3] can thus be correlated with the present results.

The final design of the new instrumented indentation device working at high temperatures is also presented. The device is adapted for force application up to 200 N. The heating system relies on the use of cartridge resistors integrated both at the sample and the indenter in order to minimize substantial heat flow due to temperature gradient when contact occurs. An optical sensing system based upon a laser illumination of manufactured line markers was conceived for a long working distance measurement of indentation depth at high temperature. The optical setup is associated with the Differential Digital Image Tracking (DDIT) analysis method [4] delivering a sub-micrometer displacement resolution. The final design of the whole testing machine takes into account the constraints of remote handling in a hot cell.

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