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#4-259 In-core Real-time Mechanical Testing of Structural Materials Project Instrumentation

Idaho National Laboratory (INL), in collaboration with the Electric Power Research Institute (EPRI), Nuclear Regulatory Commission (NRC), French Atomic and Alternative Energies Commission (CEA), Joint Research Centre (JRC), Nuclear Research and Consultancy Group (NRG), and Research Center Rez (CVR), is the operating agent of a joint experimental program (JEEP) project that operates within the Nuclear Energy Agency's (NEA) Framework for Irradiation Experiments (FIDES II) program. The first objective of the INCREASE project is to design a shared capsule that can house a variety of in-core real-time mechanical testing instrumentation for enabling smart irradiation experiments for most material test reactors (MTRs). The second objective is to collect in-core real-time stress relaxation data pertaining to high priority stainless steel (SS) materials under light water reactor conditions. The shared capsule design produced under this project will, for phase one, be demonstrated in the Massachusetts Institute of Technology Nuclear Research Reactor (MITR), and for phase two in the Petten High Flux Reactor (HFR). Currently, irradiation-induced stress relaxation is assessed both pre- and post-irradiation, thanks to complex and costly pre- and post irradiation examination efforts. A shared conceptual design was produced between INCREASE core group members and Institute for Energy Technology (IFE) based on the MITR and HFR position constraints, along with their pressure, neutron fluence and temperature distributions. The MITR irradiation test will have four fully instrumented (LVDT bellows pre-loaded configuration) SS specimens, four passively instrumented pre-loaded (pre-loaded and static configuration) SS specimens, and four or more passively instrumented non-loaded SS specimens (total number of passive specimens based on the final available space in the capsule). The target temperature for the MITR irradiation is 340℃ +/-20℃ and a minimum neutron damage of 2 dpa, with a preference of achieving 4-5 dpa or until stress relaxation saturation is achieved. The initial stresses for both, four fully instrumented SS specimens and four passively instrumented pre-loaded SS specimens, are about 80% of the nominal yield strength of each material at target temperature. Only the fully instrumented SS specimens will produce in-core real-time stress relaxation, temperature, and neutron fluence data that will be analysed as received during the MITR irradiation. The passively instrumented pre-loaded and non-loaded SS specimens will have to be analysed during PIE. In core stress relaxation measurement data will be collected using a new hybrid type-3.5 LVDTs supplied by IFE, where they will build and supply six of these LVDTs: four for the irradiation test and two for out of core verification testing in a flowing autoclave. Prior to the irradiation, INL will use its in house LVDT calibration system, located at the Measurement Science Laboratory (MSL), to characterize, optimize, and do final sensor validation of each LVDT prior to irradiation. INL also figured out a way to read temperatures using the IFE's LVDT in addition to displacement values without any physical change to the sensor—something critical for obtaining accurate LVDT calibration data and replacing the need for use of additional thermocouples (i.e. additional sensor feedthroughs). The temperature of each fully instrumented specimen will be monitored via two type K thermocouples for axial distribution within each capsule. Additionally, all the specimens (instrumented, passive pre-loaded, and unloaded) will have passive silicon carbide temperature monitors that can measure averaged peak irradiation temperatures during PIE. Additionally, HFR uses gas gaps between experiment capsule and reactor position to control and implement target temperatures, which create larger temperature gradients and uncertainties within length and axial positions than in the MITR. This will require implementation of fiber optics within the shared capsule design to validate thermal models for better temperature estimation. Lastly, the capsule will be placed in the top half of the MITR core length to accommodate long-term irradiation needs, creating neutron fluence (neutron damage rates) gradients between the top and bottom of each capsule. This requires the use of active (self-powered neutron detectors) and passive (neu-

tron dosimeters and retrospective dosimetry) instrumentation to measure more precisely neutron fluence at various locations within each capsule. As a conclusion, this shared capsule design within INCREASE project can be easily and cost effectively leveraged to meet future in-core mechanical testing needs for various MTRs and different types of materials; furthermore, implement and verify advanced instrumentation techniques for better understanding of the measurements collected during irradiation.

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