NEUP | Nuclear Energy University Program

U.S. Department of Energy

Development of an In-Situ Testing Laboratory for Research and Education of Very High Temperature Reactor Materials

PI: Tasnim Hassan, North Carolina State University

Collaborators: F. Rahman, J. Jones, K.L. Murty, G. Yang, D. Kaoumi, J. Eapen, G. Ngaile, Y. Zhu, North Carolina State University

Program: General Scientific Infrastructure Support

ABSTRACT:

We propose development of a unique in-situ testing laboratory (ISTL) through acquisition of a scanning electron microscope (SEM) and installation of a previously developed miniature thermomechanical fatigue (MTMF) testing system inside the SEM. To obtain in-depth understanding of microstructure-property relationships and micromechanisms responsible for different damage mechanisms and their interactions, in-situ testing is far more advantageous than ex-situ testing. This is because ex-situ testing can provide limited data for us to infer the damage mechanisms, whereas in-depth knowledge on micromechanisms can be obtained through performing in-situ tests with SEM. Because of ISTL's primary objective is to perform long-term in-situ SEM testing with MTMF, it will enable novel research on very high temperature reactor (VHTR) materials towards achieving the DOE-NE Program/Mission Supporting goals.

In order to support the research needs of VHTR materials, a MTMF system has been recently developed at NC State University (NCSU) for in-situ testing of miniature specimens within a SEM. It is capable of prescribing axial-torsional loading to solid specimens and axial-torsional-internal pressure loading to tubular specimens of 1 mm diameter at elevated temperatures up to 1000 °C. MTMF can be used to investigate deformation of microstructure and failure mechanisms under realistic loading conditions in real time. Currently, in-situ SEM testing with the MTMF is performed with a SEM at the Analytical Instrumentation Facility (AIF) at NCSU. However, the SEMs at AIF are utilized by hundreds of different research projects, consequently, only short-term in-situ SEM tests are allowed. The VHTR loading transients with long dwell periods will induce thermo-mechanical creep-fatigue (TMCF) deformations with predominant creep damage. Hence, a test to mimic VHTR loading conditions can span from several days to several weeks. Therefore, a dedicated SEM is required for MTMF to perform in-situ SEM testing for VHTR material characterization. At present, TMCF failure mechanisms of new and existing alloys are investigated through either ex-situ testing or limited in-situ uniaxial isothermal testing. Consequently, micromechanisms responsible for initiation and propagation of many failure mechanisms, especially interactions between creep and fatigue damages remain unknown. Under realistic VHTR loading conditions, interactions between fatigue and creep damage mechanisms significantly reduces component life. DOE-NE categorizes investigations on these damage mechanisms and development of relevant ASME Code material properties and failure criteria for VHTR materials as very high priority Program/Mission Supporting tasks, which can be performed by a dedicated ISTL. Hence, development of the ISTL will allow achieving the high priority DOE-NE program goals. ISTL will give the research community an unprecedented capability to perform fundamental research on long-term microstructure evolution of nuclear materials under uniaxial and multiaxial TMCF loading and educate next generation scientists in real-time. Once the proposed ISTL is developed at NCSU for testing unirradiated materials, efforts will be made to develop another ISTL for the Nuclear Science User Facility (NSUF) for irradiated material testing.