Irradiation Influence on Alloys Fabricated by Powder Metallurgy and Hot Isostatic Pressing for Nuclear Applications

PI: Janelle P. Wharry (Boise State University)

Collaborators:
David W. Gandy (Electric Power Research Institute)
Assel Aitkaliyeva (Idaho National Laboratory)
Louis Lherbier (Carpenter Technology, Inc.)
Myles Connor (GE Hitachi Nuclear Energy, LLC)
Steve Lawler (Rolls-Royce Power Engineering, PLC)
Clinton Armstrong (Westinghouse Electric Company)
Daniel Ingersoll (NuScale Power)
Michael Preuss (University of Manchester)

Program: NSUF-1 (ATR-NSUF Access Only)

ABSTRACT:

Manufacturing processes have considerable influence over the safety and integrity of nuclear reactor vessels and internal components. Established processes such as casting, plate rolling-and-welding, forging, drawing, and extrusion, have been used to fabricate structural and pressure-retaining materials used in the nuclear power industry for the past 60 years. However, issues of weldability, inspectability, and casting defects such as porosity, continue to challenge the manufacture of reactor vessels and internals, enhancing their susceptibility to degradation and failure. Reactor vessels and internals are subject to harsh service environments that combine high radiation fluence, high temperature, and mechanical stress, which accelerate material degradation. The most extreme degradation often occurs in weldments and poor-quality components that were inadequately inspected. Advanced reactor designs and life extensions to the existing fleet of light water reactors (LWRs) will further exacerbate materials degradation issues by increasing the duty on reactor internals. Thus, developing reliable manufacturing processes to ensure high-quality weldments and inspections can be performed, is of great importance to the continued safety and operation of nuclear power plants.

Recently, alloys produced by powder metallurgy and hot isostatic pressing (PM-HIP) have successfully been developed and introduced for structural pressure-retaining applications in the electric power industry [1]. These PM-HIP components exhibit excellent structural uniformity, no chemical segregation, superior mechanical properties, and enhanced weldability. In addition, PM-HIP components are produced near-net shape, which offers the distinct advantages of minimizing machining and enhancing the ease of component inspectability. Components fabricated by PM-HIP are also lower-cost and higher quality than those fabricated by casting, owing to their reduced porosity and weight. Because of their exceptional properties, PM-HIP alloys have attracted the interest of the nuclear power industry as potential structural materials for LWRs, advanced light water reactors (ALWRs), small modular reactors (SMRs), and advanced (e.g. Generation IV) reactors. But little is known about the irradiation response of PM-HIP alloys, and even more critically, existing data do not elucidate the differences in irradiation response between PM-HIP and conventional alloys. This project seeks to understand these irradiation effects through a systematic neutron irradiation campaign and post-irradiation microstructural and mechanical assessments. The objective of this project is to assess the viability of using alloys manufactured by PM-HIP for nuclear reactor internals, in order to enhance the quality, weldability, and inspectability of these components.

Improving the manufacturing processes for reactor internals will have crosscutting impact across all DOE-NE programs. This project will compare the irradiation response of six PM-HIP and conventionally manufactured alloys commonly used in LWR internals, or which are candidates for ALWR and SMR internals, having relevance to all DOE-NE base programs. This project will also supplement ongoing DOE Nuclear Energy Enabling Technologies (DOE-NEET) research on *Innovative Manufacturing Process for Nuclear Power Plant Components via Powder Metallurgy and Hot Isostatic Processing Methods (DE-NE000054)*. Several original equipment manufacturers (OEMs) are exploring PM-HIP techniques for reactor internals. Along with additional industry and university partners, they have provided input to the proposed workscope and will serve on the Industrial Advisory Board for this project. Furthermore, use of PM-HIP technology will help re-establish nuclear manufacturing in the United States.