Development of Irradiation and Creep Resistant High-Cr Ferritic/Martensitic Steels via Magnetic Field Heat Treatment

PI: Haluk Karaca-University of Kentucky

Collaborators: Osman Anderoglu – University of New Mexico

Nan Li- Los Alamos National Laboratory

Program: FC-5: Accelerated Fast Reactor Metal Fuel Cladding Material Development

ABSTRACT:

HT9 steel is one of the most promising candidates for high dose cladding applications for advanced reactor concepts due to good radiation resistance, compatibility with liquid sodium coolant, high thermal conductivity, and low thermal expansion coefficient. However, the harsh neutron irradiation environments at the reactor core region together with temperature gradient along the length of the cladding pose unique limitations for HT9.

The main goal of this proposal is to employ novel magnetic field tempering method to tailor the microstructure of Ferritic/Martensitic (F/M) steels to improve their mechanical properties including creep, and irradiation resistance. The primary objectives are to: (a) gain the ability to control the carbide, carbonitride and subgrain boundary properties by magnetic field tempering method, (b) perform detailed microstructural characterization to relate it to the magnetic field tempering parameters and mechanical properties including creep resistance and (c) reveal the effects of ion irradiation on the microstructure and micromechanical behavior of magnetically tempered samples.

The current proposal aims to improve the creep and irradiation resistance of HT9 steels by engineering the carbide and subgrain boundary characteristics for extended use in extreme irradiation environments at high temperatures. An innovative *tempering* heat treatment under *high external magnetic field* (up to 9T) will be conducted on F/M steel HT9 to engineer the microstructure. It is proposed that magnetic field tempering will result in favorable carbide morphology (e.g. finer and spherical carbides) and subgrain boundary properties. This novel processing will lead to improved mechanical properties including creep and irradiation resistance. In addition to microstructure and mechanical property characterization of magnetically tempered HT9 samples, their irradiation resistance will also be studied using both light (<350°C) and heavy ion irradiations (~ 450°C) followed by micro-mechanical testing.

Expanding the temperature range of cladding will help with reactor design, efficiency, and safety margins. In addition, enhancing the void swelling resistance of HT9 cladding will lead to higher fuel burn up and therefore directly improve the fuel efficiency and fuel cycle.