Nuclear Energy University Programs

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Pulsed Magnetic Welding for Advanced Core and Cladding Steels

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ABSTRACT

We propose to investigate a solid-state joining method, pulsed magnetic welding (PMW), for welding the advanced core and cladding steels to be used in Generation IV systems, with a specific application for fuel pin end-plug welding. Advanced alloys including NF616, ODS variants, and HT-UPS with specially tailored microstructures, have improved high-temperature strength and, in some cases, anticipated improved radiation damage resistance, and they are being considered for the fast reactor cladding, duct, and core materials. A potential issue that directly affects the application of advanced steels is the change in properties associated with welding. Since the superior properties depend on the uniform tempered martensitic microstructure for F-M steels and evenly distributed nano-sized dispersed oxides and ultrafine precipitates for ODS steels and HT-UPS, respectively, any disruptions in microstructures induced by conventional fusion-formed welding may be deleterious. As one of the solid-state welding techniques, pulsed magnetic welding (PMW) has not been extensively explored on the advanced steels. The resultant weld can be free from microstructure defects (pores, nonmetallic inclusions, segregation of alloying elements). For this proposed research, the PMW method will be developed for the fuel pin end-plug welding and optimized for the advanced steels including NF616, ODS, and HT-UPS.

The overall objectives of this project are to:

- Study PWM on NF616, HT-UPS, and ODS F/M steels, including designing a suitable welding apparatus fixture and optimizing welding parameters for repeatable and acceptable joining of the fuel pin end-plug. The welding will be evaluated using tensile tests for lap joint and helium leak tests for the fuel pin end-plug welding.
- Investigate the microstructural and mechanical properties changes in PMW weldments of proposed advanced core and cladding alloys. The residual strain, change of martensitic grain structures, stability of nano-sized MC precipitate in HT-UPS and oxide nanoparticles in ODS will be studied.
- Simulate the irradiation effects on the PWM weldments using ion irradiation (proton and heavy ion), the void swelling, dislocation structure and radiation-induced segregations, and stability of carbide precipitates and oxide nanoparticle will be studied, especially in the vicinity of the welding interface.