DEPARTMENT OF ENERGY UNITED STATES OF AMERICA

Project Title

Radiation Tolerance of Controlled Fusion Welds in High Temperature Oxidation Resistant FeCrAl Alloys for Enhanced Accident Tolerant Fuel Cladding Applications

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Program: NEET-3

ABSTRACT:

The objective of this work is to accelerate the development of nuclear grade FeCrAl alloys for enhanced accident tolerant cladding applications through guided experiments on the weldability and radiation stability of welds in FeCrAl alloys. Ferritic structured FeCrAl alloys have shown an increased oxidation resistance at relevant accident scenario conditions for fuel cladding applications. Increased oxidation resistance has been deemed critical to the performance of fuel-clad systems in a loss of coolant accident (LOCA) and key to developing cladding with enhanced accident tolerance. In order for full adoption of FeCrAl alloys as cladding materials, the performance of irradiated fusion welds must be demonstrated. Failure of welds on cladding can lead to costly fuel failures. Historically, FeCrAl based alloys have been reported to have poor weldability due to hydrogen embrittlement although many of these studies did not utilize controlled fusion welding techniques such as laser welding in a cover gas to reduce hydrogen uptake or composition refinement to manage free hydrogen and increase the weldability of the alloy. Furthermore, FeCrAl alloys with high Cr contents have exhibited phase instability under neutron irradiation with the formation of coherent α' (Cr-rich ferrite) particles in the matrix at elevated temperatures. The formation of α' has been observed to cause severe loss of ductility in iron based alloys with high Cr additions; this effect is known as "475 °C embrittlement."

The scope and objective of this work is two fold: (1) explore the use of controlled fusion welding and alloy composition refinement to reduce or eliminate cracking in FeCrAl weldments and (2) explore the effects of α' formation under irradiation on the mechanical properties of the FeCrAl weldments. A detailed, scientific approach will be utilized to accomplish this goal including a systematic alloy development and fabrication stage, an irradiation campaign, and an extensive post irradiation examination phase. Several different composition refined alloys will be investigated which have shown promise as materials which could mitigate cracking in weldments as well as manage/control α' formation under irradiation. This work will be completed using world class facilities including the High Flux Isotope Reactor (HFIR), the Irradiated Materials Examination and Testing (IMET) hot cell facility and the Low Activation Materials Development and Analysis (LAMDA) laboratory housed at Oak Ridge National Laboratory. The demonstration of controlled fusion welds and radiation tolerance of the weldments will elevate the technology readiness level of FeCrAl alloys. This research will continue to push the FeCrAl alloys to commercialization and if so, could significantly enhance the safety of the current fleet of light water reactors.