All-position surface cladding and modification by solid-state friction stir additive manufacturing (FSAM)

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ABSTRACT:

Oak Ridge National Laboratory (ORNL) and the Electric Power Research Institute (EPRI) have strategically teamed up for the proposed research, which aims at developing a novel solid-phase additive manufacturing employs frictional heat input to overcome technical challenges and issues of nowadays fusion cladding technology for nuclear reactor component production. This novel solid-phase technology will enable to clad and modify low alloy structural steel surfaces using stainless steel and nickel-based alloys in reactor pressure vessel (PRV), steam generators and pressurizers with high productivity, low heat input, minimal chemical dilution ratio, and excellent claddability to resist corrosion, erosion and wear in nuclear plants operation. Many technical issues exist in today's melting cladding technologies, such as low productivity, high chemical dilution ratio, solidification cracking, primary water stress corrosion cracking (PWSCC), Ductility-dip cracking (DDC), cladding disbonding, carbon diffusion/migration, and creep failure in HAZ. All those cladding problems are related with the non-equilibrium melting and solidification processes in fusion cladding technologies and cost industries millions of dollars each year in repair or replacement.

The proposed project aims at overcoming those shortcomings through a solid-state cladding process, which follows the same physical and metallurgical principles with friction stir welding (FSW). Meanwhile, solid-state additive manufacturing can be achieved by cladding metals layer by layer. More importantly, the feasibility of such solid-state process has been demonstrated at ORNL recently. Through this project, the scientific and technical basis of the proposed technology innovations will be systemically developed and demonstrated on cladding and additive manufacturing low alloy structural steel with stainless steel and nickel-based alloys. The solid-state cladding process innovations will be integrated with advanced computational modeling (integrated computational welding engineering, ICWE) and comprehensive microstructure characterization and property testing, to achieve fundamental understanding on how the cladding and additive manufacturing process conditions will influence the microstructure and property in the bonding region. These fundamental understanding, assisted by the effective ICWE modeling tool, will be then used to effectively develop and optimize cladding and additive manufacturing conditions and parameter space that will be tailored to different families of structural materials and high alloyed materials to maintain or improve the cladding properties and performance for the intended services in nuclear reactors.

The solid-phase cladding and additive manufacturing would be truly revolutionary and transformational, as they would greatly improve cladding productivity with high quality and reduced manufacturing cost in nuclear reactor component production and beyond.

The proposed research is fully supportive of the NEET program goal of crosscutting manufacturing technology and innovations that directly support and enable the development of new and advanced reactor designs and fuel cycle technologies, which will advance the state of nuclear technology, improving its competitiveness and promoting continued contribution to meeting our Nation's energy and environmental challenges. Specifically, it addresses the objectives of NEET-1 in this FOA – the development of advanced cladding and surface modification modular construction methods with accelerated deployment schedule, reduced component fabrication cost, and high quality to resist erosion, corrosion and wear.