HIP Cladding and Joining to Manufacture Large Dissimilar Metal Structures for Modular and GEN IV Reactors

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ABSTRACT:

The manufacturing of dissimilar metal reactor structures remains challenging to meet the demand for cost-effective development and deployment of small modular reactors (SMRs) and GEN IV advanced nuclear units. **The proposed project will take an integrated experimental and modeling approach to develop and commercially demonstrate the cost/time reduction and quality improvement by implementing powder-based hot isostatic pressing (HIP) cladding and joining strategy (powder-to-solid or powder-to-powder) into manufacturing large-size and thick-section dissimilar metal pressure retaining components of SMRs and GEN IV reactors.** The current manufacturing of such components like reactor pressure vessel (RPV) involves multiple lengthy and costly steps, including PM-HIP structure fabrication, capsule removal, surface cladding and welding of dissimilar metals materials to improve corrosion and temperature resistance. A significant cost and time reduction is expected when integrating all these process steps into one or two-step PM-HIP, such as replacing post-HIP cladding by utilizing the HIP capsule as a corrosion protection layer or creating bimetallic joint through HIP joining. As a solid-state process, the HIP bonded interface has its intrinsic advantage to avoid issues that transitional arc welding is facing, like dilution zone, heat affected zone (HAZ), heterogeneous microstructure, solidification defects associated with residual stress. It also has a promise to join dissimilar metals that are hard to weld, which supports many design innovations for reactor internals and fuel components.

With the extensive research and business experience of this team, the project aims to achieve the following goals to meet the near-term applicability in nuclear manufacturing:

- Establish a general standard practice for robust HIP based manufacturing for dissimilar metal cladding and joining;
- Explore innovative joint configurations, e.g. compositionally graded transition joint, to eliminate the traditional design of buffer layer;
- Create HIP modeling tools to improve the prediction accuracy of part quality, geometry distortion, process optimization, and long-term reliability for large-size dissimilar component with complex material transition, which can further reduce the manufacturing cost;
- Develop the understandings of feedstock powder quality control;
- Demonstrate the technology on the selected GE and Westinghouse components per OEMs' requirements ;
- Demonstrate the feasibility and cost/time benefit of HIP cladding and joining for commercial-scale dissimilar metal component fabrication in SMRs and GEN IV reactors;
- Evaluate the long-term risk of material degradation due to thermal aging and corrosion.