Potential solid-state welding processes of advanced Ferritic-Martensitic steels in the nuclear industry

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Advanced Ferritic-Martensitic (FM) steels are targeted as potential core materials for TerraPower's Traveling Wave Reactor designs because of their promising swelling resistance and attractive thermomechanical properties. The weldability and cost-effective fabrication methods of advanced FM steels are still being assessed. The nature of joining can significantly change the material microstructure and the joint properties, causing concern about failures during service in a nuclear environment. Therefore, robust welding processes for advanced FM steels must be developed to provide assurance of joint reliability for extended performance in a sodium fast reactor. Tungsten arc welding, laser welding, and capacitive-discharge welding processes were all evaluated during the time of EBR-II and FFTF. Continued study on fusion welding of FM steels for reactor applications has prevented the loss of expertise during the past decades, and has increased the process reliability. At the same time, recently matured solid-state welding processes, such as friction welding, pulse magnetic welding, and resistance pressure welding, promise to provide joints with optimized weldment microstructure and desirable mechanical properties. The largest benefit of the solid-state welding processes is the lack of high heat input and complicated thermal cycles, which are required for the fusion welding processes. This promises to maintain the post-welding microstructure stability for FM steels without complicated post-weld heat treatment, and provide better weld performance between dissimilar metals for FM steels compared to traditional fusion welding. However, there are limited data on advanced FM steel components joined by solid-state welding processes relevant to nuclear applications, such as swelling resistance, compatibility with sodium, and long-term in reactor performance. If positive results were acquired, the total cost of constructing and maintaining sodium fast reactors may reduce significantly. Here, a detailed literature review of the available solid-state welding processes for FM steels relevant to reactor component fabrication is presented, including some early scoping work on resistance pressure welding compared to fusion welds performed at TerraPower. The results of this initial exercise will inform the direction of a comprehensive welding development program for the Traveling Wave Reactor.