World Academy of Science, Engineering and Technology
International Journal of Nuclear and Quantum Engineering
Vol:11, No:03, 2017

Functional Plasma-Spray Ceramic Coatings for Corrosion Protection of RAFM Steels in Fusion Energy Systems

Authors : Chen Jiang, Eric Jordan, Maurice Gell, Balakrishnan Nair

Abstract : Nuclear fusion, one of the most promising options for reliably generating large amounts of carbon-free energy in the future, has seen a plethora of ground-breaking technological advances in recent years. An efficient and durable “breeding blanket”, needed to ensure a reactor’s self-sufficiency by maintaining the optimal coolant temperature as well as by minimizing radiation dosage behind the blanket, still remains a technological challenge for the various reactor designs for commercial fusion power plants. A relatively new dual-coolant lead-lithium (DCLL) breeder design has exhibited great potential for high-temperature (>700oC), high-thermal-efficiency (>40%) fusion reactor operation. However, the structural material, namely reduced activation ferritic-martensitic (RAFM) steel, is not chemically stable in contact with molten Pb-17%Li coolant. Thus, to utilize this new promising reactor design, the demand for effective corrosion-resistant coatings on RAFM steels represents a pressing need. Solution Spray Technologies LLC (SST) is developing a double-layer ceramic coating design to address the corrosion protection of RAFM steels, using a novel solution and solution/suspension plasma spray technology through a US Department of Energy-funded project. Plasma spray is a coating deposition method widely used in many energy applications. Novel derivatives of the conventional powder plasma spray process, known as the solution-precursor and solution/suspension-hybrid plasma spray process, are powerful methods to fabricate thin, dense ceramic coatings with complex compositions necessary for the corrosion protection in DCLL breeders. These processes can be used to produce ultra-fine molten splats and to allow fine adjustment of coating chemistry. Thin, dense ceramic coatings with chosen chemistry for superior chemical stability in molten Pb-Li, low activation properties, and good radiation tolerance, is ideal for corrosion-protection of RAFM steels. A key challenge is to accommodate its CTE mismatch with the RAFM substrate through the selection and incorporation of appropriate bond layers, thus allowing for enhanced coating durability and robustness. Systematic process optimization is being used to define the optimal plasma spray conditions for both the topcoat and bond-layer, and X-ray diffraction and SEM-EDS are applied to successfully validate the chemistry and phase composition of the coatings. The plasma-sprayed double-layer corrosion resistant coatings were also deposited onto simulated RAFM steel substrates, which are being tested separately under thermal cycling, high-temperature moist air oxidation as well as molten Pb-Li capsule corrosion conditions. Results from this testing on coated samples, and comparisons with bare RAFM reference samples will be presented and conclusions will be presented assessing the viability of the new ceramic coatings to be viable corrosion prevention systems for DCLL breeders in commercial nuclear fusion reactors.

Keywords : breeding blanket, corrosion protection, coating, plasma spray
Conference Title : ICNMNF 2017 : International Conference on Nuclear Materials and Nuclear Fuels
Conference Location : Rome, Italy
Conference Dates : March 05-06, 2017