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Embrittlement effect of liquid lead-bismuth eutectic on irradiated ferritic/martensitic steels

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Ferritic/martensitic (FM) steels have been selected as structural materials for applications in liquid metal spallation targets, such as the MEGAPIE (megawatt pilot experiment) target, and in the future accelerator driven systems (ADSs). Liquid lead–bismuth eutectic (LBE) is a candidate target and coolant material for such systems. Apart from the serious degradation of the mechanical properties induced by intensive proton and/or neutron irradiation, liquid metal embrittlement (LME) is another factor of great concern for the components made of FM steels and used in a LBE environment.

In this work, LBE embrittlement effect on ferritic/martensitic (FM) steels T91, F82H, HT9 and EP823 after irradiation in a mixed spectrum of spallation neutrons and high energy protons in a target of Swiss Spallation Neutron Source has been studied. Slow-strain-rate tensile (SSRT) testing at a strain rate of 1 × 10-5 s-1 was conducted on T91 and F82H steels irradiated to doses up to 20 dpa in either Ar or liquid LBE at temperatures between 150 and 500 ℃. Tests in Ar showed significant irradiation-induced hardening and embrittlement effects (loss of ductility) as compared to the unirradiated ones. Tests in LBE revealed an additional embrittlement effect induced by LBE, which increased with irradiation dose. Consequently, the fracture strain of irradiated specimens was reduced from above 5% to 2-3%. 3-point bending (3PB) testing was performed on pre-cracked T91, HT9 and EP823 steel specimens irradiated to 6-14 dpa in either Ar or LBE at 150-250℃ and different strain rates. Similar to the SSRT test results, the 3PB test results show that the irradiated FM steels exhibited both irradiation-induced embrittlement effect and LBE induced embrittlement effect on fracture toughness of the steels. The LME effect is more pronounced at a lower strain rate. Scanning electron microscopy revealed an enhanced cleavage fracture mode for specimens tested in LBE.

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