Corrosion fatigue behavior of T91 steel in liquid lead bismuth eutectic

Jibo Tan[1], Baoquan Xue[1], Xinqiang Wu[1]

[1]*CAS Key Laboratory of Nuclear Materials and Safety Assessment, Liaoning Key Laboratory for Safety and Assessment Technique of Nuclear Materials, Institute of Metal Research, Chinese Academy of Sciences, Shenyang 110016, PR China*

Presenter's e-mail address: jbtan10s@imr.ac.cn

Abstract: T91 steel has been considered a promising structural material of lead-cooled fast reactors (LFRs) for fuel cladding and other core internal materials, due to its good strength and creep properties at elevated temperatures and resistance to irradiation swelling. T91 steel may be subjected to liquid metal corrosion (LMC) and liquid metal embrittlement (LME) when stressed in liquid LBE, causing a great safety hazard to the service equipment. The corrosion fatigue behavior of T91 steel in liquid lead bismuth eutectic is a main concern for its application in LFR. The liquid LBE encironment factor is not considered in the current ASME code fatigue design curve. The effect of temperature (150~550 ℃) and strain rate (0.004~4%s^{-1}) on fatigue behavior of T91 steel in oxygen saturated liquid LBE was investigated. The temperature dependent "fatigue endurance peak and trough" was found.The crack propagated along the prior or deformed sub- grain boundaries (GBs) at 150 °C and 350 °C, which was characterized by quasi-cleavage cracking. The intergranular oxidation and Pb/Bi permeation into the deformed GBs significantly degraded the fatigue properties at 550 °C.The fatigue life of T91 steel decreases by about 85 % with decreasing strain rate from 0.4 to 0.004 %/s at 550 ℃, while it is almost independent on strain rate at 350 ℃. The intergranular oxidation resistance of T91 steel at 550 ℃ decreases at lower strain rates, leading to fatigue failure mode changes from quasi-cleavage to cleavage cracking. Notably, the cracks (>200 μm) propagate along the recrystallization grain boundaries with Pb/Bi segregation but without oxides detected at 0.004 %/s. The LMC (oxidation) and LME (quasi-cleavege cracking) paly an important role in fatigue crack initiation and propagation for T91 steel in liquid LBE.

Keywords: T91 steel, lead bismuth eutectic, corrosion fatigue, liquid metal corrosion , liquid metal embrittlement