Erosion-corrosion behaviors of FeCrNiAl based high entropy alloys in high-velocity flowing (5 m/s) lead bismuth eutectic (LBE)

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Abstract : In lead-cooled fast reactors (LFRs), structural materials suffer severe erosion-corrosion damage when contact with the flowing circulating coolant lead-bismuth eutectic (LBE). Thus, developing erosion-corrosion resistant alloys to be used in LBE is essential for LFRs. In this work, 7 types of FeCrNiAl based high entropy alloys were prepared, namely HEA-1 (Nb/Ti), HEA-2 (Mo), HEA-3, HEA-5 (Nb/Ti, heat treatment), HEA-4, HEA-6 and HEA-7 have different contents of Si. The erosion-corrosion tests were performed up to 3000 hours in LBE at a relative flow rate of 5 m/s and temperatures of 350 °C and 450 °C. At 350°C, oxidation is the representative corrosion type. The oxide layer formed on the HEA-1 and HEA-2 alloys illustrate remarkable stability in high flow rate LBE compared with 316L stainless steel and P91 steel. At 450 °C, erosion-dissolution dominates the corrosion process. Increasing the temperature leads to an enhance in the solubility of the alloy elements, and the erosion interacting with dissolution accelerates the failure of the alloys. After the optimization in processing and alloy composition, HEA-4 ~ HEA-7 realize high erosion resistance. Among them, few erosion pits and slight impact deformation exist on the surface of HEA-5. While HEA-4, HEA-6 and HEA-7 with the addition of Si elements maintain good macroscopic integrity and possess the best erosion resistance. In particular, the B2-NiAl phase and Laves-Fe_2Nb phase can effectively mitigate LBE erosion. The overall performance of the alloys is ranked as HEA6 > HEA4 > HEA7 > HEA5 > HEA2 > HEA3 > HEA1. The results of this study offer a guideline for alloy designning, especially optimizing the phase distribution as well as the elemental species of new types of nuclear materials that to be used in flowing LBE.

Keywords Lead-cooled fast reactors; High entropy alloy; Erosion-corrosion

[1] Yan-Fei Wang, Ji-Sheng Li, Weifeng Xu, Xian-Zong Wang*, Oxidation and dissolution behavior of FeCrNiAl based high entropy alloy and alumina-forming austenitic steel exposed to lead-bismuth eutectic (LBE), Corrosion Science, 227 (2024) 111693.