

Creep crack initiation of Ni-based alloy GH3535 in high temperature molten LiF-NaF-KF salt environment

Wenjun Liang^{1,2}, Xiaoli Li^{1,2,*}, Yumiao Wang^{1,3}, Leng Bin^{1,2}, Tao Wu^{1,2}, Litao Chang^{1,2,*}

¹*Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China*

²*University of Chinese Academy of Sciences, Beijing 100049, China*

³*School of Materials Science and Chemistry, University of Shanghai for science and technology, 20093, China*

*Corresponding authors: Xiaoli Li (lixiaoli@sinap.ac.cn), Litao Chang (chanlitaotao@sinap.ac.cn)

Abstract Ni-based alloy GH3535 is the main structural material for the thorium-based molten salt reactor of China. The service environment for the alloy is very harsh because it has to be in direct contact with the high temperature molten salt, to bear the stresses and also to face the neutron from the fission reaction. Creep and corrosion are two main degradation mechanisms for the structural materials used in the molten salt reactor, and both are important factors to be considered during the design of the reactors. Numerous researches have been done to understand the creep behavior of the alloy in air and also the molten salt corrosion behavior, it can be expected that molten salt corrosion will also affect the creep of the alloy. However, the creep behavior of the alloy with the assistance of molten salt corrosion has not been investigated before. Therefore, this study will investigate the impact of molten salt corrosion on the creep behavior of the alloy with an emphasis on the crack initiation by conducting interrupted creep experiments in both argon and molten FLiNaK salt environments.

The results showed that the specimens underwent significant creep deformation in both argon and FLiNaK environments under the test conditions of 700°C/190 MPa/167 hours. The elongation of the specimens in the molten FLiNaK salt was notably higher than that of samples in the argon environment (6.9% vs 5.3%). The cracks observed in the specimens were intergranular dominant, however, most of the cracks were found only in the sub-surface region with an depth of ~100 μm. The average crack depth for the specimens tested in the argon environment was ~36 μm, however, most of these cracks were existed in the region with was 5-10 μm beneath the surface of the specimens, and only a few of them were connected to the sample

surface. The average depth the cracks identified on the specimens tested in the molten FLiNaK salt was $\sim 71 \mu\text{m}$, and most of these cracks extended to the surface of the specimens. A recrystallized fine-grained layer was identified on the surface of the specimens tested in both environment. Additionally, Cr depletion occurred on the surface and along the cracks in samples exposed to the molten salt environment. The Cr depletion layer on the sample surface was about $9 \mu\text{m}$, which also led to the formation of nano-pores in the surface recrystallized fine-grained region. It is concluded that initiation of the creep cracks was promoted by the sub-surface deformation induced by the sample turning, and was accelerated by active Cr elements dissolution.

Keywords Molten salt reactor; Nickel-based alloy; High temperature creep; Crack initiation; Molten salt corrosion.