Revealing the Mechanical Degradation in a 3D-Printed Chemical Complex Alloy after High-Temperature Oxidation through Advanced Characterization

Zhao Shen*, Xiaoqin Zeng
School of Materials Science and Engineering, Shanghai Jiao Tong University, Shanghai 200240, China

Corresponding author: Z. Shen shenzhao081@sjtu.edu.cn;

Abstract Using selective laser melting (SLM) and hot isostatic pressing (HIP) techniques, the Ni50Co20Cr10Al15Ti2 complex concentrated alloy (CCA) was fabricated. Subsequent investigation into high-temperature oxidation revealed a significant decrease in the ductility of the CCA. To address this issue, measures were taken to regulate the alloy composition, aiming to prevent the formation of depleted zones during oxidation. This approach successfully enhanced the mechanical performance of the CCA under high-temperature service conditions. After 2000 hours of oxidation at 700°C, the CCA exhibited a dramatic 62.4% reduction in elongation. In contrast, specimens subjected to 2000 hours of aging treatment at the same temperature showed no significant alteration in elongation. Selective oxidation of CCA, particularly targeting the L12 phase, occurs at elevated temperatures, leading to the depletion of L12 particles near the oxide layer and the formation of depleted zones. This phenomenon substantially diminishes the anchoring effect of the HEAs/CCAs, facilitating the rapid propagation of intergranular oxidation cracks. The absence of the L12 phase results in a significant decrease in the tensile strength of the depleted zone, suggesting that oxidized CCA exhibits a propensity for abrupt loss of ductility under relatively low strains, culminating in brittle fracture rather than undergoing significant plastic deformation. Utilizing advanced techniques such as ECCI and HRDIC, we observed and analyzed the expansion and internal tearing of oxidation cracks within the depleted zone with precision and clarity. Simulation outcomes highlight the exacerbation of stress concentration at crack tips within the metal matrix in the presence of depleted zones, significantly contributing to the propensity for brittle fracture in the material. To address these challenges, we propose an optimized solution focused on the composition of the L12 phase to mitigate selective oxidation at high temperatures. By preventing the formation of depleted zones, this strategy aims to preserve the ductility of CCA under high-temperature conditions, thereby enhancing its mechanical integrity and longevity.

Keywords: Selective laser melting; Complex concentrated alloy; Oxidation; Cracking; HRDIC