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Corrosion control of a Fe-based alloy (DMV 310 N) in molten $MgCl_2$-KCl-NaCl for heat storage and transfer at very high temperatures

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Abstract

Next-generation concentrating solar power (CSP) plant with operating temperatures higher than 700°C needs an advanced high-temperature thermal energy storage (TES) system and advanced power cycle (e.g., supercritical CO_2 Brayton) for a higher energy conversion efficiency and lower levelized cost of electricity (LCOE). $MgCl_2$-KCl-NaCl is a promising candidate of such very high-temperature heat storage and transfer due to its low cost (<0.35 USD/kg) and excellent thermophysical properties (e.g., high thermal stability >1000°C). Using Fe-based (Fe: ≥50 wt.%) alloys as the main structural material for the chloride-based TES system is the key to ensuring its cost competitiveness. However, it is universally believed that Fe-based alloys have unacceptably high corrosion rates in unpurified molten $MgCl_2$-KCl-NaCl at such high temperatures. Theoretically, purification with Mg metal can reduce the corrosion rates of Fe-based alloys to acceptable low levels (<30 µm/year) at very high temperatures (≥800°C). In this work, to experimentally verify a commercial highly creep-resistant austenitic stainless steel DMV 310 N (Fe-based, ASME code listed) as the high-temperature structural material for the chloride-based TES at very high temperatures, it was immersed in the Mg-purified molten $MgCl_2$-KCl-NaCl at 800°C for 500 hours. The SEM and EDX results show that after immersion, the typical Cr-depleted corrosion layers on the samples are negligibly thin (only several µm). Based on mass loss and microstructural analysis results, the corrosion rate of DMV 310 N is below 30 µm/year. Therefore, from the perspective of corrosion, the cost-effective Fe-based alloys possess good compatibility with the Mg-purified molten $MgCl_2$-KCl-NaCl even at 800°C. According to preliminary calculation, the cost of TES using chlorides at >700°C could be potentially reduced close to that using commercial nitrates/nitrites at ≤565°C, leading to a significant reduction of the LCOE of CSP with higher operating temperatures.

Keywords: Concentrating solar power (CSP), Thermal energy storage (TES), Fe-based alloy, Corrosion control, Mg corrosion inhibitor.

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