

Impact of Additives on Structural Materials in NaCl-MgCl₂ Molten Salt

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1. Introduction

Material compatibility tests have been conducted since the Aircraft Nuclear Propulsion program at the Oak Ridge National Laboratory in the 1950s, in addition to the Molten Salt Reactor Experiment (MSRE) [1]. In fluoride and chloride systems, common alloying elements that are ranked according to decreasing nobility are molybdenum, nickel, iron, and chromium. Chromium forms the most stable corrosion product salt and is attacked more aggressively than other elements within a given alloy. However, despite the identical ranking order, chloride systems have a smaller Gibbs free energy difference between the salt and alloy formation energies. This is expected to establish a chemical equilibrium in chloride systems, which inherently have a higher tendency to corrode than fluoride systems. In the study of corrosion mechanisms in molten salt environments with Mg(OH)₂ and moisture condition, the use of additives in the salt is also being considered. In this research, Mg(OH)₂ and moisture were added, and corrosion experiments of various alloys were conducted.

2. Experimental

Prepared NaCl-MgCl₂ molten salt electrolyte after preprocessing was utilized for corrosion experiments conducted at a temperature of 650 °C for a total of 500 hours. A reactor and specimen holder, as depicted in Figure 1, were fabricated and utilized for the experiments, where corrosion tests were conducted on SS316 (Named as S), Alloy 600 (Named as A), and C276 (Named as C) specimens under seven different conditions outlined in Table 1.

After a 500 h corrosion experiment, the corroded candidate structural materials are analyzed with scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS).

3. Results and Discussion

In all conditions, SS316 exhibits a faster corrosion rate compared to Alloy 600 and C276. (SS316 at cell #1 = - 110 μm/yr) SS316 shows weight loss in all conditions, while Alloy 600 and C276 exhibit weight gain. Comparing the SS316 cases in Cell #1, #5, #6, #7 (Red arrow), the weight loss continues to increase up to

a moisture concentration of ~30 mol%, after which it tends to saturate.

Comparing the SS316 cases in Cell #2, #3, #4 (Blue arrow), the weight loss continues as the concentration of Mg(OH)₂ in NaCl-MgCl₂ eutectic salt increases. Alloy 600 shows similar weight gain (~2 mg/cm²) in all conditions, while C276 shows significant weight gain (~10 mg/cm²) in all conditions.

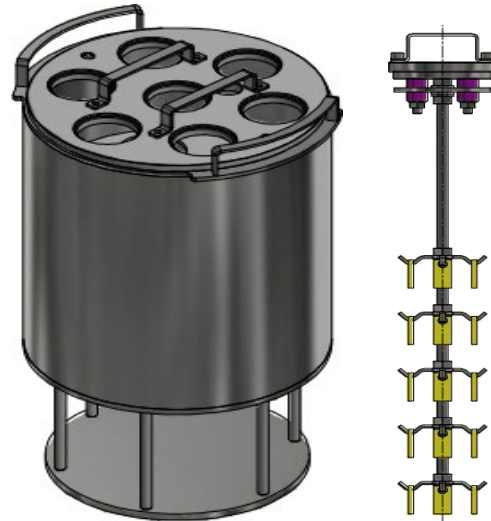


Figure 1. A reactor and sample holder for corrosion experiment

Table 1. Conditions of corrosion experiment with NaCl-MgCl₂ salt

#	Conditions
1	NaCl-MgCl ₂ Pre-treatment salt
2	NaCl-MgCl ₂ + Mg(OH) ₂ 0.1 mol%
3	NaCl-MgCl ₂ + Mg(OH) ₂ 0.2 mol%
4	NaCl-MgCl ₂ + Mg(OH) ₂ 0.5 mol%
5	NaCl-MgCl ₂ with MgCl ₂ ·6H ₂ O 10 mol%
6	NaCl-MgCl ₂ with MgCl ₂ ·6H ₂ O 30 mol%
7	NaCl-MgCl ₂ with MgCl ₂ ·6H ₂ O 50 mol%

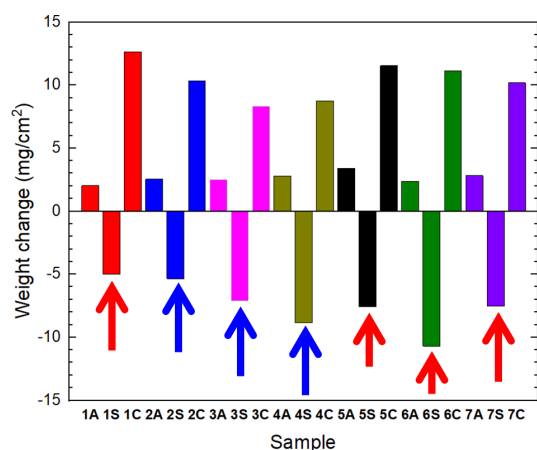


Figure 2. Weight change graph of various samples in NaCl-MgCl₂ with additives

Cr depletion is observed with following the pores and grain boundary of the matrix, as shown in Figure 3. Also MgO is found in the pores. The lower the concentration of Ni in the metal, the faster the rate of corrosion, and weight gain appears to have occurred on the surface of C276 and Alloy 600 specimens due to deposits, while SS316L sample shows weight loss

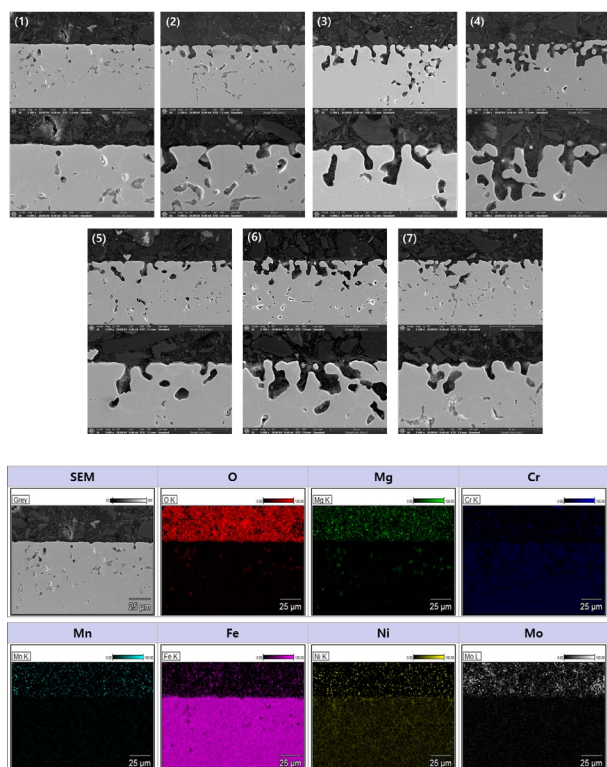


Figure 3. SEM-EDS analysis results of SS316L samples in various cells (Cell #1 ~ Cell #7)

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[1] Gen IV International Forum 2007 annual report, Printed by the OECD Nuclear Energy Agency, 2007.