Corrosion Characteristics Evaluation on Structural Materials in NaCl-MgCl₂ Molten Salt

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1. Introduction

Molten salt is a chemical compound in a liquid state, formed by the fusion of alkali and acid at high temperatures. It is typically transparent and has an appearance similar to water. There are various types of molten salts due to the combination of different alkalis and acids. Molten salts exist as high-temperature liquids with ionic bonds, where cations and anions are held together by strong electrostatic forces [1]. The molten salt reactor was developed at ORNL (Oak Ridge National Laboratory), and molten salt fuel was chosen for its chemical stability. Molten salt reactors can operate at very low pressure due to their low vapor pressure and high boiling point [2,4]. Since the Molten Salt Reactor Experiment in the 1950s, alongside the Aircraft Nuclear Propulsion program, material compatibility tests have been conducted at ORNL [3]. 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 [1,5]. 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

After pretreatment, a NaCl-MgCl₂ molten salt electrolyte was used in corrosion experiments carried out at 650°C for a total of 500 hours. The experiments utilized a custom-built reactor and specimen holder, as illustrated in Figure 1. Corrosion tests were conducted on three different materials: Pure Nickel 201 (referred to as N), Alloy 800 H (referred to as H), and Alloy 625 (referred to as A), under seven distinct conditions detailed in Table 1. Following the 500-hour experiment, the corroded materials were examined using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) for further analysis.
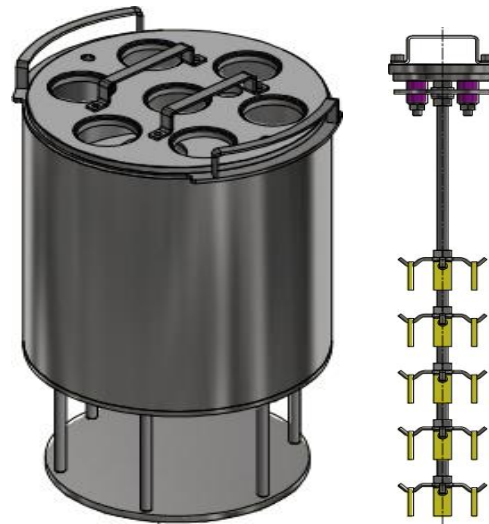

Figure 1. Schematic of reactor and sample holder for corrosion experiment

Cell number	Condition
#1	NaCl-MgCl₂ eutectic salt
#2	NaCl-MgCl₂ eutectic + 0.1 mol% Mg(OH)₂
#3	NaCl-MgCl₂ eutectic + 0.5 mol% Mg(OH)₂
#4	NaCl-MgCl₂ eutectic + 1.0 mol% Mg(OH)₂
#5	Replace 10 % MgCl₂ with MgCl₂*6H₂O
#6	Replace 30 % MgCl₂ with MgCl₂*6H₂O
#7	Replace 50 % MgCl₂ with MgCl₂*6H₂O

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

3. Results and Discussion

In Figure 2, In all conditions, Alloy 800 H exhibits a faster corrosion rate compared to Pure Nickel 201 and Alloy 625. Alloy 800 H shows weight loss in all

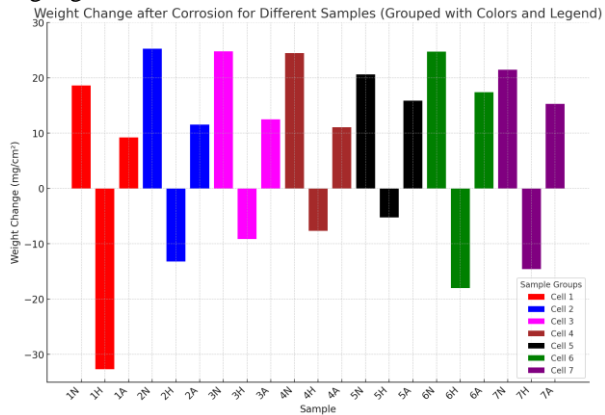conditions, while Pure Nickel 201 and Alloy 625 exhibit weight gain.

Figure 2. Weight change graph of each samples

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. In Figure 4, Fe enriched layer was found on the sample surface, and line-EDS analysis confirmed the Ni and Cr depletion as well as the Fe enriched layer. In Figure 5, pores were observed within the matrix and along the grain boundaries. 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 Pure Nickel 201 and Alloy 625 specimens due to deposits, while Alloy 800 H sample shows weight loss.
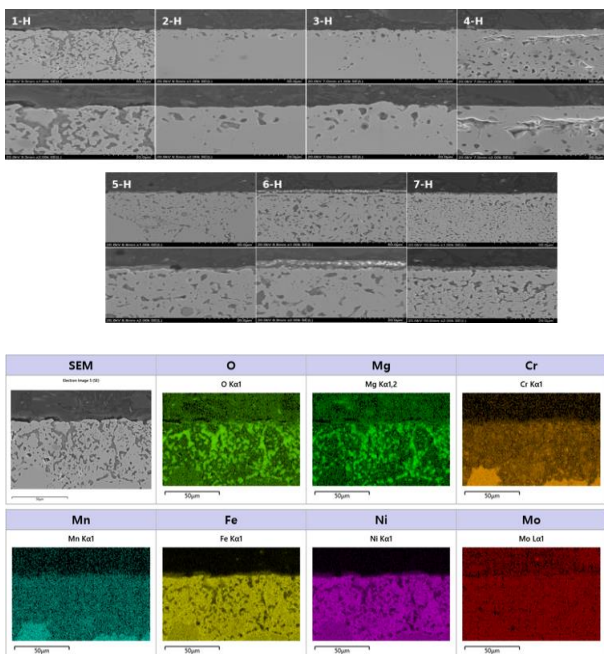

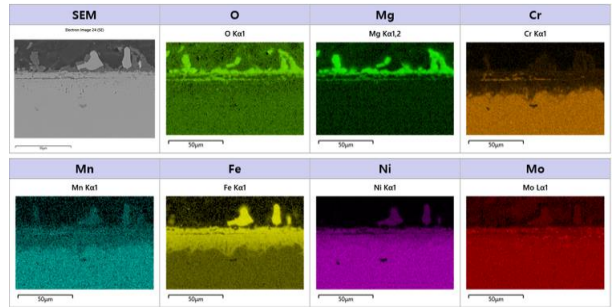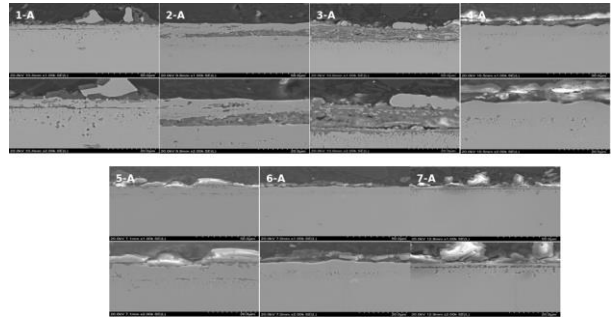Figure 3. SEM-EDS data of Alloy 800 H sample after corrosion test

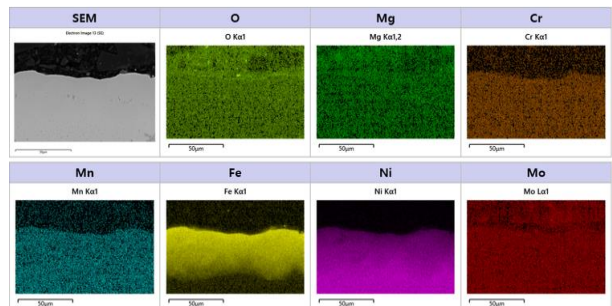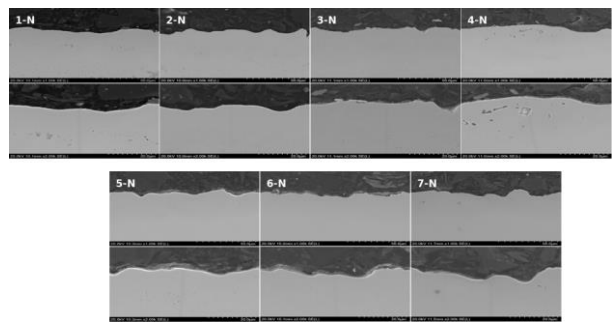Figure 4. SEM-EDS data of Alloy 625 sample after corrosion test

Figure 5. SEM-EDS data of Pure Nickel 201 sample after corrosion test

4. Conclusion

Candidate materials were exposed to NaCl-MgCl$_2$ eutectic salt for 500 hours in a corrosion chamber, where the maximum temperature reached 650 ℃. To investigate the effect of additives on the corrosion of structural materials, Mg(OH)$_2$ and MgCl$_2$*6H$_2$O were added to the eutectic salt. The prepared chloride salt was injected into an autoclave within a glove box. The Alloy 800 H samples experienced the most significant

corrosion in NaCl-MgCl$_2$ eutectic salt without any additives. Additionally, typical corrosion patterns characterized by the depletion of Cr near the surfaces were detected. And, Alloy 625 samples exhibited good corrosion resistance under all conditions.

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