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Molten Salt Corrosion of Structural Materials for Applications in MSRs

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1. Introduction

Molten salt reactors (MSRs) is one of the GEN IV nuclear systems. Korea Atomic Energy Research Institute has recently started to develop the chloride salt-cooled reactors for applications in transportable nuclear power systems. However, poor chemical compatibility of structural materials with the molten salt limits the lifetime of reactors. Even though the alloys contain a high Cr content, it does not promote the formation of the protective oxide layer. Instead, alloying elements tent to dissolve into the high-temperature molten salts [1]. In this study, several candidate structural materials were studied in the molten salt for the material selection for MSR applications. This paper reports the preliminary results of corrosion test.

2. Methods

2.1 Materials

Four high-temperature alloys were selected for their potential to be qualified in ASME BPVC code. Among them, Alloy 800H and Type 316H SS are qualified as class A materials in ASME BPVC Section III, Division 5 - "High Temperature Reactors". Alloy 617 will be qualified within 2023. Hastelloy N is qualified as ASME Section VIII and there is an effort to add to the ASME BPVC Section III, Division 5.

The compositions of test materials were listed in Table I.

Table I. Chemistries of candidate alloys for MSR.

	Alloy 617	Hastelloy N	Type 316H	Alloy 800H
Ni	Bal.	Bal.	10.29	30.18
Fe	1.26	3.66	Bal.	Bal.
Cr	22.20	7.66	20.43	20.43
Mo	9.52	16.0	2.12	-
Si	0.14	0.273	0.57	0.42
Co	12.30	0.253	-	-
Mn	0.08	0.414	0.59	0.98
Al	1.09	0.441	-	0.49
V	-	-	-	-
Ti	0.37	-	-	0.54
Cu	0.01		0.22	0.45
N	-	-	0.023	-
C	0.090	0.072	0.049	0.07

2.2 Corrosion Test

The salt used for corrosion tests is composed of 57 mol% $MgCl_2$ and 43 mol% NaCl. Test chamber is made of Type 304 SS and placed in the glove box. 8~9 kg of the mixed salt was loaded in the chamber and gas purification system was attached to the glove box to reduce oxidants. Test environment was maintained in Ar gas. Oxygen and water vapor were maintained below 4 ppm and 20 ppm, respectively. Before inserting test specimens, the salt was treated at 400ºC for 3 days and 650ºC for 6 days to reduce oxidants further.

3. Results and Discussion

Fig. 1 shows the weight changes of high-temperature materials after 100 hours corrosion test at 650ºC in 57 mol% $MgCl_2$–43 mol% NaCl. All specimens lost weight after corrosion test. In particular, Alloy 617 and 800H were severely corroded. Hastelloy N and Type 316H SS have a relatively low corrosion rate but are still quite fast. In the case of Type 316H SS, weight loss was underestimated because the deposits adhered to the surface of the specimens.

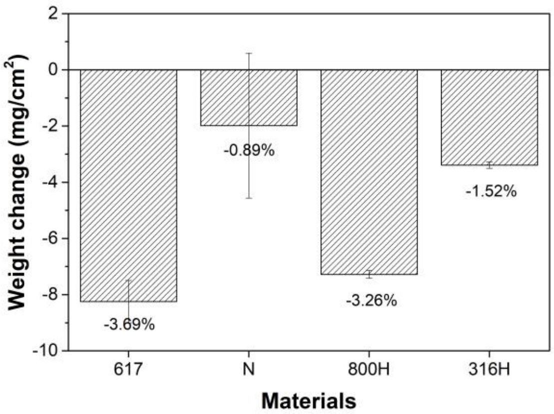

Fig. 1. Weight loss of four high-temperature structural materials at 650ºC in 57 mol% $MgCl_2$ – 43 mol% NaCl for 100 hours.

Fig. 2 shows weight changes of materials as a function of initial wt% Cr in alloys. Weight loss strongly depends on Cr contents. In the molten salt, the chemical activity of the major elements of alloys is highest in the order of Cr, Fe, Co, Ni, and Mo. Therefore, it can be seen that the corrosion rate depends on the only Cr content among the elements in alloy listed in Table I.

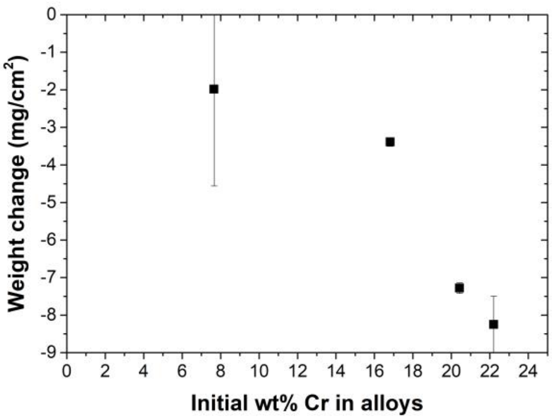

Fig. 2. Weight loss of four high-temperature structural materials as a function of initial wt% Cr in alloys.

4. Summary

Corrosion tests of several high-temperature structural materials were carried out at 650°C in the molten chloride salt environment for 100 hours. Among tested materials, Hastelloy N, which has lowest Cr content, has the highest corrosion resistance. However, despite short-term corrosion test, significant weight loss was observed for all materials. In order to use the high-temperature structural materials qualified in ASME code to MSRs, it seems necessary to have better corrosion resistance by applying corrosion resistant coating or cladding materials.

REFERENCES

[1] S. S. Raiman, and S. Lee, Aggregation and data analysis of corrosion studies in molten chloride and fluoride salts, Journal of Nuclear Materials, Vol.511, p. 523, 2018.