Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 22-23, 2025

Tensile Properties of Materials after Molten Salt Corrosion in $MgCl_2$-NaCl

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Keywords : molten salt reactor, chloride, corrosion, tensile, degradation

1. Introduction

Molten salts can cause severe material corrosion under various conditions, leading to mechanical property degradation and limiting the lifespan of reactor components. In this study, materials were subjected to short-term corrosion in a molten chloride environment, followed by high-temperature tensile testing to investigate the mechanical degradation behavior caused by corrosion.

2. Methods and Results

2.1 Materials

Type 316H stainless steel and Alloy 625, two candidate materials for MSR structural applications, were evaluated. Type 316H is classified as a Class A material under ASME BPVC Section III, Division 5, making it a strong candidate for MSR structural components. Alloy 625, known for its superior corrosion resistance compared to stainless steel, is often considered a protective coating material for structural components exposed to molten salt corrosion. The chemical compositions of the two materials are shown in Table I.

Table I: Chemical compositions of candidate alloys for MSR.

	Type 316H SS	Alloy 625
Ni	10.29	Bal.
Fe	Bal.	3.07
Cr	20.43	21.53
Mo	2.12	8.94
Si	0.57	0.08
Co	-	0.13
Mn	0.59	0.08
Nb	-	3.51
Al	-	0.08
Ti	-	0.17
Cu	0.22	-
N	0.023	-
C	0.049	0.02

2.2 Corrosion and Tensile Tests

Before the corrosion test, $MgCl_2$ and NaCl were mixed at a ratio of 57 mol% to 43 mol%, followed by the addition of magnesium. The mixture was purified by first exposing it to 300°C for 24 hours in an argon-filled glove box and then maintaining it at 550°C for 48 hours. The corrosion tests were conducted in a glove box where O_2 and H_2O levels were maintained below 5 ppm. Small plate-type tensile specimens were immersed in purified molten salt inside alumina crucibles and subjected to 650°C for 200 hours. The volume-to-surface area (V/S) ratio of the crucible salt and specimens was approximately 0.05 mL/mm^2. Tensile testing was conducted at 650^{o}C in ambient conditions at a strain rate of 0.5 mm/min.

2.3 Molten Salt Corrosion

After 200 hours of corrosion, the mass loss of Type 316H stainless steel and Alloy 625 was -6.03 mg/cm^2 and -1.75 mg/cm^2, respectively, indicating that Type 316H exhibited a corrosion rate approximately three times higher than that of Alloy 625. As shown in Fig. 1, Type 316H primarily experienced grain boundary corrosion, whereas Alloy 625 exhibited intragranular corrosion.

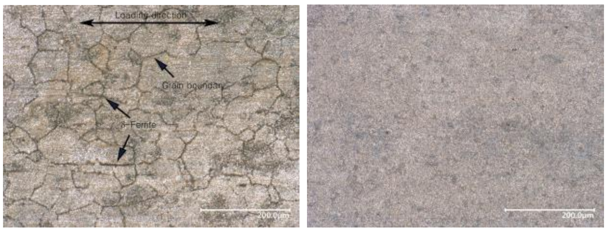

Fig. 1. Surface microstructure of Type 316H stainless steel(left) and Alloy 625(right) after corrosion at 650oC for 200 hours in $MgCl_2$-NaCl.

2.4 Tensile Properties

Fig. 2 presents the high-temperature tensile test results at 650°C for Type 316H and Alloy 625. After corrosion, Type 316H exhibited reductions in yield strength, tensile strength, and elongation. Conversely, while Alloy 625 showed a significant decrease in ductility, its strength actually increased. Both materials experienced not only microstructural damage due to corrosion but also thermal aging during high-temperature exposure.

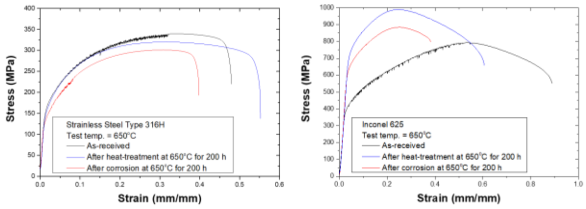

Fig. 2. Tensile properties of Type 316H stainless steel(left) and Alloy 625(right) at 650°C.

Comparing specimens exposed to an inert environment at 650°C for 200 hours with those subjected to corrosion, both materials exhibited reductions in yield strength, tensile strength, and elongation due to corrosion. In Alloy 625, thermal aging-induced embrittlement was particularly pronounced, and dynamic strain aging (DSA) was completely suppressed after both corrosion and heat treatment. This suppression is attributed to the precipitation of Nb and Mo, which were initially in solid solution [1].

3. Conclusions

After 200 hours of short-term corrosion in $MgCl_2$ - NaCl at 650°C, the strength and elongation of Type 316H stainless steel and Alloy 625 decreased. Notably, Alloy 625, despite its relatively superior corrosion resistance, exhibited severe embrittlement, likely due to the combined effects of thermal aging and corrosion damage.

REFERENCES

[1] A.M. Beese, Z. Wang, A.D. Stoica, and D. Ma, Absence of Dynamic Strain Aging in an Additively Manufactured Nickel-Gase Superalloy, Nature Communications, Vol. 9, p.2083, 2018.