Behavior $ZrCl_4$ in Molten Salt and Its Effect on the Corrosion of Inconel Alloy

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1. Introduction

Molten salt reactor(MSR), one of the 4th gerneation reactor is widely investigated for its heat efficiency and safety. However, by the aggressive corrosive property of molten salt is the most important issue in material compatibilty. Moisture and actinides are known to accelerate corrosion in MSR, which is widely being investigated for its prevention. However, fission products which can be generated during operation were not researched on its effect to material. Also, as the liquid fuel type MSR is considered nowadays in Korea, its importancy gets bigger. In this study, one of the major fission products, $ZrCl_4$ was investigated for its single behavior and effects to corrosion behavior of Inconel alloy.

2. Methods and Results

2.1 Electrochemical Approaches

Cyclic voltammetry methods was applied for defining electrochemical property of $ZrCl_4$ in 700 ℃ NaCl-KCl molten salt. Scan rate of 0.5V/sec was adopted and data collecting was on scan rage of 0.2V to -0.7 V~ -1.5 V for identifying each redox reaction. Concentration of $ZrCl_4$ was 1 wt.% and whole cases were done in 500 sec for avoiding concentration change by volatilization of $ZrCl_4$. Tungsten WE, CE were adopted and electrode area was 0.314 cm^2 with NaCl-KCl-1.0 wt.% AgCl reference electrode in mullite membrane. Whole system was set in glove box which is controlling moisture and oxygen level below the 0.1 ppm. Potentiostat(VersaSTAT 3F, Princeton Applied Research) was utilized for collecting data.

2.2 Corrosion Test

Immersion corrosion test was conducted for corrosion effect of $ZrCl_4$ on Inconel alloy. Inconel 600 and Inconel 625 alloy were selected, which are candidataes on MSR material. Coupon with locking neck was designed and installed on allumina crucible with cover, for preventing galvanic corrosion or effect of crucible on corrosion. Also, L-shape horizontally installed specimen was applied for inducing more reaction with Zr(s) particle. Specimen area and total applied salt was 1.52 cm^2 and 11g fixed. Corrosion tests were done for 7 days and 28 days in 700 ℃, w/ or w/o 1 wt.% of $ZrCl_4$. Before the test, surface of specimens were polished down to 1 μm suspension with cleaning by DI water ultrasonic.

Corroded specimens were analyzed by SEM and SEM-EDS on surface and cross-section. And weight loss was measured to calculate corrosion rate along ASTM G1-03[1].

2.4 Powder-Alloy Reaction Test

Powder type Zr metal and Inconel 625 was tested for defining its metallurgical reaction in high temperature. In allumina crucible, Inconel 625 specimens was installed inside the Zr powder with slight tempering. After 100 hr in 700 ℃, specimen was collected and analyzed for surface and cross-section.

2.5 Cyclic Voltammetry Results

From cyclic voltammetry, two couples of redox peak was observed. And first reduction peak near -0.6 V was expected to react with Cr oxidation which ranging along -0.7 V to -0.4 V. From this result, it was expected that Zr^{4+} would oxide chromium in material and reduced to Zr^{2+}.

2.6 Corrosion Test Results

As expected from cyclic voltammetry results, it was observed that huge corrosion acceleration was occur with Inconel 600 specimen. Its corrosion rate was almost doubled, calculated by ASTM G1-03. Also, disproportionation was observed by particles collected after-salt, which was identified as pure Zr.

It had opposite results from Inconel 625, which was corrosion resistant with $ZrCl_4$, by enriching surface Mo layer. It was clarified by powder-alloy reaction test, which showed Zr particle can leach out Ni and Nb from Inconel 625. And it's calculated that around 40 % of corrosion resistance.

3. Conclusions

Behaviors of $ZrCl_4$ and corrosion effect was investigated by cyclic voltammetry and immersion corrosion test on Inconel 600/625 specimen. By redox reaction with Cr, $ZrCl_4$ accelerated corrosion of Inconel 600 however, Inconel 625 was observed to resist

against corrosion by enriching Mo on surface. These behavior was identified as Ni, Nb leaching out of Zr particle, produced after disproportation reaction of Zr^{2+}, which can be formed by redox reaction with Cr. By this study, some experimental evidences were investeaged for corrosion resistance of Inconel 625 in molten salt.

REFERENCES

[1] ASTM G1-03, “Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimen”, 2012

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