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Preliminary Modeling of Corrosion/Oxidation Properties of CrAl Alloy-coated Cladding

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1. Introduction

Accident tolerant fuel (ATF) cladding has been being developed globally after the Fukushima accident with the demands for the nuclear fuel having higher safety at normal operation conditions as well as even in a severe accident conditions. Korea Atomic Energy Research Institute (KAERI) has been developed some of remarkable ATF cladding candidates [1-3].

The surface modifications of conventional Zr-based alloy with corrosion-resistant alloying elements (CrAl alloy) are as a promising method and some results on their corrosion resistances of CrAl-coated Zr based alloys (hereinafter denoted as “CrAl alloy”) in previous studies [1-3]. They showed a superior oxidation/corrosion resistance in water and steam conditions to the commercial Zr alloys and totally different behaviors from commercial Zr alloys. Therefore, new model is needed to explain oxidation/corrosion behaviors. To evaluate entire fuel performance collectively, preliminary models of corrosion and oxidation characteristics for CrAl fuel cladding has been proposed from the preliminary results and described.

2. Previous Experimental Results

In this section, the experimental procedures and results of oxidation/corrosion test for CrAl alloy cladding are described.

2.1 Water-side Corrosion Test

Corrosion tests of the CrAl alloy specimens were performed in simulated PWR water under normal operation using the static autoclave [4]. Temperature and pressure of autoclave were 360°C and 18.5 MPa, respectively. The pH of water was measured to vary between 7.0 and 7.5.

Corrosion characteristics of commercial Zr alloys such as Zry-4 show the two stages which are cubic rate law (pre-transition) and linear rate (post-transition). But CrAl alloy shows linear kinetics for the whole tested period, as shown in **Fig. 1**. Also, it has significantly enhanced corrosion resistance than commercial claddings.

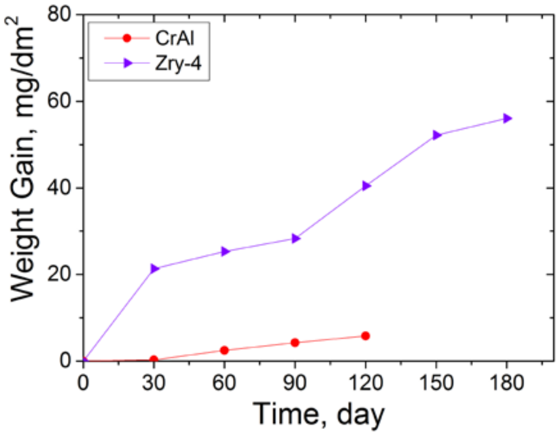

Fig. 1. Results of water-side corrosion test of CrAl alloy at 360°C

2.2 High Temperature Oxidation Test

CrAl alloy samples were oxidized at 900~1400°C for up to 7200s. Thermo-gravimetric analyzer (TGA) and a radiant heating furnace incorporating infrared lamps and a quartz chamber that simulates LOCA conditions were used to conduct the high temperature oxidation tests [4]. They showed the parabolic oxidation kinetic behaviors as shown in **Fig. 2**.

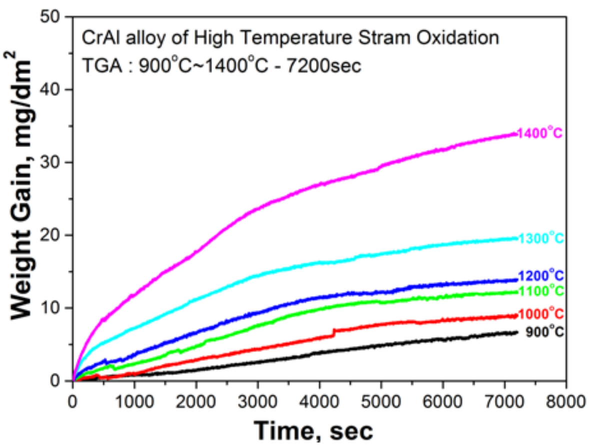

Fig. 2. High temperature steam oxidation characteristic of CrAl alloy

3. Preliminary model of CrAl Alloy Cladding Corrosion Properties

3.1 Water-side Corrosion

Fig. 3 shows the prediction of waterside corrosion for CrAl alloy cladding with comparison to commercial Zry-4. Oxide thickness is predicted with condition that a composition of oxide is proportional to the alloy composition. The prediction by preliminary model is achieved by simple linear correlation and consistent with experimental results (0.95111 of Adj. R-Square), as shown in **Fig. 3**. The predicted oxide thickness of CrAl alloy has 3 order lower than Zry-4 and formed oxide is protective, thus the degradation of mechanical properties would be minimized by reduction of hydrogen uptake. This characteristic is attributed to protective oxide formation. Meanwhile, the prediction of corrosion for Zry-4 was performed by FRAPCON model.

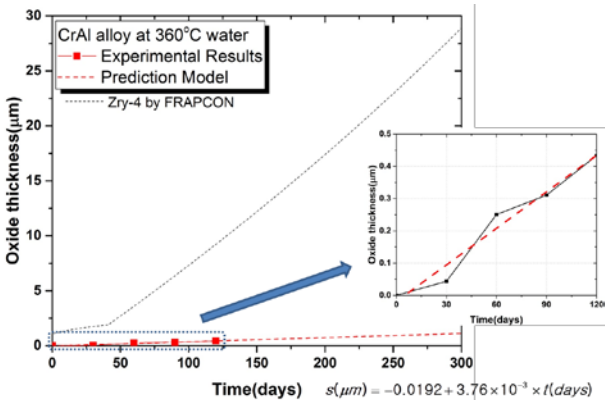

Fig. 3. Prediction of oxide thickness for CrAl cladding at 360°C by water-side corrosion

Still, there is limitation that could not reflect the effects of temperature and neutron irradiation due to limited experimental data. This model gives conservative predictions of oxide formation by water side corrosion, because 360°C is highest temperature under normal operation condition.

3.2 High Temperature Oxidation

Fig. 4 shows the predicted oxide thickness for CrAl cladding by high temperature oxidation. The prediction by preliminary model is achieved by simple linear correlation and consistent with experimental results, as shown in **Fig. 3**. It is considered that they have the parabolic oxidation kinetic behaviors with superior characteristic than existing fuel claddings as shown in **Fig. 4**. It is attributed to dense and uniform oxide formation by protection of oxygen ingress. Also, it is consistent with experimental results (0.90418 of Adj. R-Square).

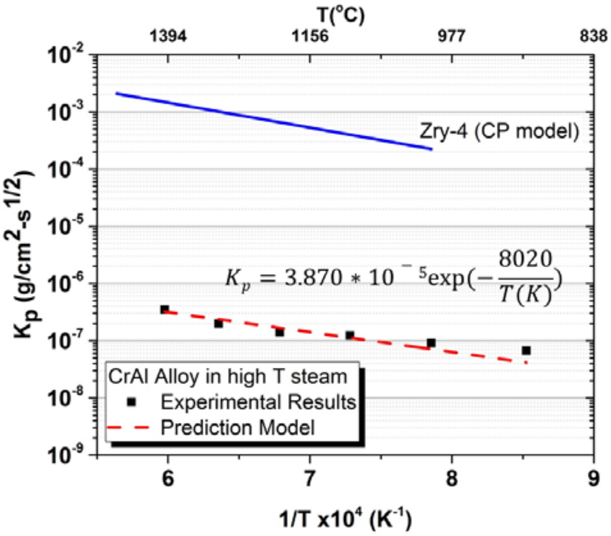

Fig. 4. Prediction of oxide thickness for CrAl cladding by high temperature oxidation

4. Conclusions

Prior to evaluate entire fuel performance of newly developed CrAl alloy cladding by KAERI collectively, preliminary model of water-side corrosion and high temperature oxidation model were proposed. They were highly consistent with experimental results. Also this model is useful for the quantitative analysis with given with relative superior characteristics to existing commercial fuel claddings.

ACKNOWLEDGMENT

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