Oxidation Kinetics of the Zr-1Nb-1Sn-0.1Fe at temperatures of 1000-1200℃

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1. Introduction

Zirconium alloys have been used as a cladding material for the fuel rods in Light Water Reactors (LWR) for a long time owing to its superior properties; low absorption cross section, superior corrosion resistance and high mechanical strengths. However, Zirconium alloys have a critical disadvantage that it loses its mechanical stability when it faces an accident condition such as the Loss Of Coolant Accident (LOCA) because of the absorbed oxygen and hydrogen which makes the β layer of the zircaloy brittle. Until now, many experiments have been performed to study the behavior of zirconium alloys on the high temperatures. As a result, NRC issued a regulation Title 10 § 50.46 [1], which imposes maximum cladding temperature of 1204℃ and 17% Equivalent Cladding Reacted (ECR) as the criteria.

To meet the criteria during the accident conditions, it is important to study the oxidation kinetics of the zirconium alloys, so that we can anticipate when the cladding reaches 17% ECR during an accident condition. Most of the oxidation kinetics developed in the past are based on the experiments which uses Zircaloy-4 specimens, which is one of the most popular claddings developed in 1960s. However, the oxidation kinetics data for recent cladding materials such as ZIRLO, M5, E110 and so on are still insufficient, and there are some inconsistencies. For example, the oxidation kinetics of the ZIRLO were studied from ANL and Westinghouse [2,3], the results from each organization show a little inconsistencies with each other.

In this study, the oxidation kinetics are studied using Zr-1Nb-1Sn-0.1Fe cladding. The goal of this study is to explain the inconsistencies found by other experiments by performing the experiments in the well-defined condition. Especially, much efforts has been taken to define the exact temperature of the specimen.

2. Experimental Methods

The experiment was performed using the specimen which is cut into 40mm long using the diamond cutting machine. Then the specimen was located between the Inconel holder and the alumina. The alumina were used to prevent the eutectic reaction between the Inconel and the specimen. The overall schematics of the experiment has already been presented in the previous work [4].

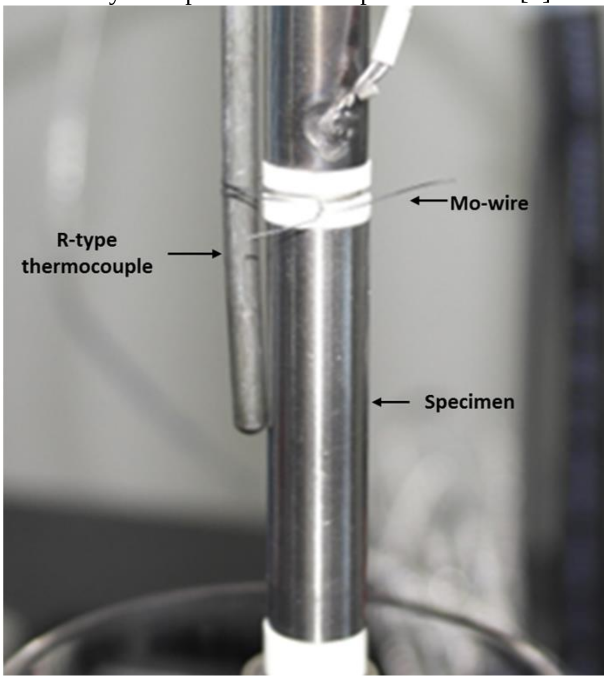

Fig. 1. The picture before measuring temperature of the specimen

The picture of the temperature calibration is shown in Fig.1. To measure the exact temperatures of the specimen, R-type thermocouple which is fixed by the Mo-wire is used. The heating steps were determined, and reproducibility of the temperature measurements was checked by three repeated experiments. The heating steps were determined considering the overshoot and the heating rate criteria which are suggested in the NRC guideline [5], and the reproducibility is satisfied within the temperature range of 1.4℃.

Then, the temperature distribution of the specimens were measured on the 9 different locations of the specimen; axial 10, 20 and 30mm height and circumferential 6, 9 and 12 clock direction. NRC Guideline recommends circumferential temperature variation and axial temperature variation should be within 20 and 10℃. Our results, which are shown in Fig.2 and Table.1, satisfy the criteria which are suggested in the NRC guideline.

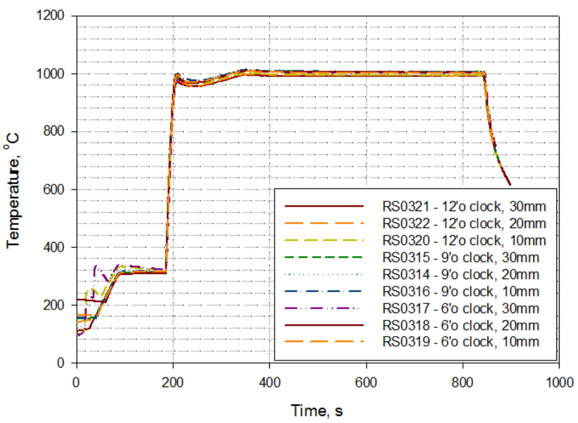

Fig. 2. Temperature distribution of the specimens measured on 1000 ℃

Axial (mm)	Circumferential (Clock direction)		
	6'o clock	9'o clock	12'o clock
10	1001℃	1004.9℃	993.1℃
20	1003.2℃	1007.2℃	991.7℃
30	1001.8℃	1004.5℃	990.4℃

Table 1. The summary of the temperature measurement results shown in Fig.2

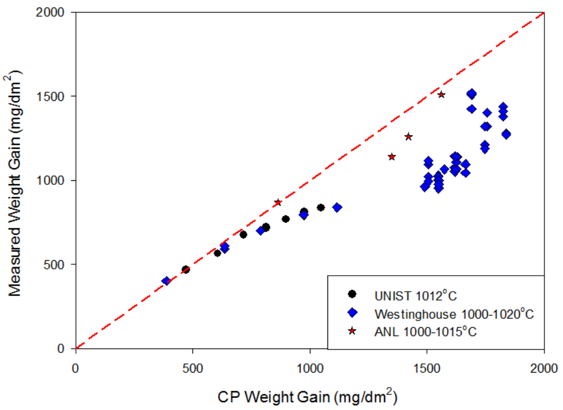

Fig. 3. Comparison of the measured weight gain and CP weight gain

3. Conclusions

Many experiments were performed to study the oxidation kinetics of the Zr-1Nb-1Sn-0.1Fe. Weight gain results at 1012℃ is shown in Fig.3. Our results show similar the oxidation kinetics with the the oxidation kinetics found in the Westing house [3], but several differences were still found. These differences should be discussed by considering many factors such as the experimental methods and the condition of the specimens.

REFERENCES

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