

## Effects of Preformed Oxide on Enhancing High-Temperature Oxidation Resistance of a Zirconium Alloy Cladding Tube

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### 1. Introduction

Zirconium alloys are widely used as the cladding tube in light water reactors owing to their good mechanical strength, acceptable corrosion resistance, and low thermal neutron absorption cross section. However, after the Fukushima accident, concerns have arisen over their performance during an accident condition such as a loss-of-coolant accident (LOCA). According to a LOCA scenario, the temperature of a cladding can increase up to approximately 1080 °C [1]. In this temperature range, the oxidation rate of a cladding becomes so high that brittle phases such as zirconium dioxide (ZrO<sub>2</sub>) and oxygen stabilized alpha zirconium ( $\alpha$ -Zr(O)) are formed rapidly. In addition, a phenomenon called as breakaway oxidation can take place in a relatively short time. The breakaway oxidation causes rapid absorption of hydrogen to the metal substrate, and the absorbed hydrogen increases the concentration of oxygen in the metal substrate, causing the cladding to rapidly become brittle.

In previous studies [2-5], it was reported that a zirconium alloy cladding tube with the high-temperature preformed oxide shows enhanced oxidation resistance during subsequent oxidation at 1000–1100 °C. However, it has not been clearly accepted that how this kind of oxidation resistance enhancement can take place. Studying and understanding why these phenomena occur can give us a new solution to enhance the oxidation resistance of zirconium alloys at high-temperature. Hence, in this study, several tests were performed to analyze the oxidation resistance enhancement by preformed oxides.

### 2. Methods and Results

#### 2.1 Experimental Method

Zr-1Nb-1Sn-0.1Fe cladding tube specimens were oxidized in the system shown in Fig. 1 [1-5]. Three different types of tests were performed. First, non-pre-oxidized specimens were oxidized at 1100 °C. Second, specimens were pre-oxidized at 1100 °C for 270 s, and the pre-oxidation tests were stopped by not supplying steam to the system for 100 s; the temperature was maintained as 1100 °C in this period. Then the specimens were oxidized again at 1100 °C. Third, specimens were pre-oxidized at 1100 °C for 65 and 265

s, and the specimens were cooled to the room temperature by air cooling. Then, the pre-oxidized specimens were oxidized again at 1100 °C. The purpose of these tests was to confirm whether the cooling of the pre-oxidized specimens is essential for the oxidation resistance enhancement.

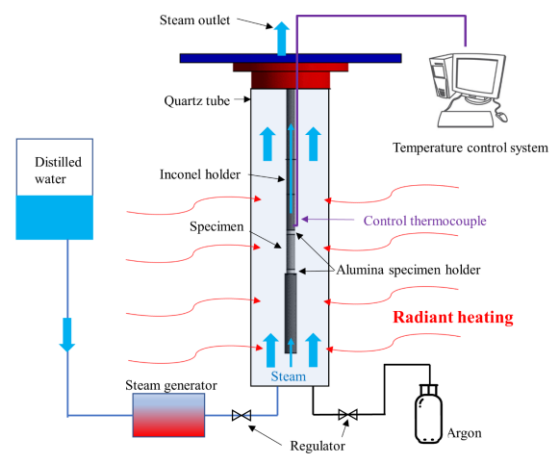


Fig. 1. Schematic of oxidation test system [2-6].

#### 2.2 Weight Gains

The weight gain results of the specimens are shown in Fig. 2. Total weight gain and total oxidation time are the sum of the values from pre-oxidation and subsequent

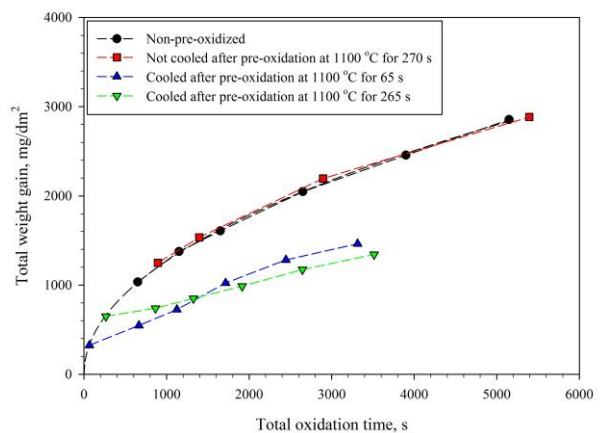


Fig. 2. Weight gains results of the non-pre-oxidized and pre-oxidized specimens; total weight gain and total oxidation time are the sum of the values from pre-oxidation and subsequent oxidation.

oxidation. The specimens which were not cooled after the pre-oxidation showed similar total weight gains with the non-pre-oxidized specimens. However, the specimens which were cooled to the room temperature after the pre-oxidation showed lower total weight gains than the non-pre-oxidized specimens. It appears that cooling of the preformed oxide is essential for the preformed oxide to enhance high-temperature oxidation resistance.

### **3. Conclusions**

Three different types of tests were performed to confirm whether the cooling of the pre-oxidized specimens is essential for the oxidation resistance enhancement. Based on the weight gain results, it can be concluded that the cooling of the preformed oxide is essential for the preformed oxide to enhance high-temperature oxidation resistance.

### **Acknowledgments**

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