Advanced Multi-Scale Modeling and Experimental Tests on Fuel Degradation in Severe Accident Conditions
(5) Model of Reaction between Control Rod and Channel Box

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Abstract. In this study, soaking experiments of pre-oxidized zry plates in molten mixture of stainless steel and 5 mol% boron carbide were conducted at 1200-1250°C. Thickness of oxide layer, ZrO_2 was measured before and after the soaking test to investigate the ZrO_2 thickness recession in the molten mixture. Results of the study indicated that the thickness recession of ZrO_2 was mainly caused by the diffusion of oxygen from oxide layer to metallic-Zr region.

Keywords: loss-of-coolant accident, zircaloy, control blade, fuel assembly degradation

1. Introduction

Loss-of-coolant accidents in nuclear energy industry have attracted much attention since the Fukushima dai-ichi incident in March 2011. The control blade composed of stainless steel and B_4C (hereafter referred as SS-B_4C) could be the first component liquefied at approximately 1200ºC. The molten mixture of SS- B_4C then attacks the channel box and fuel cladding which are made of Zircaloy (Zry). To understand the relocation behavior of the molten materials toward nuclear decommissioning, interactions between the components such as channel box and control blade in early stage of the accident must be investigated. In this study, soaking experiments of pre-oxidized zry plates in molten mixture of SS-B_4C were conducted at 1200-1250°C.

2. Experimental procedure

Zry plates were pre-oxidized at 600°C for 12 h in Ar-10%H_2O to create 50 μm of ZrO_2 scale. The molten mixture of SS-5 mol%B_4C was prepared by heat-treatment at 1400°C in Ar gas. The temperature of the molten mixture was then lowered to 1200-1250°C of testing temperatures. After introducing Ar-1%H_2-0.6%H_2O gas mixture to test vessel, zry plate was soaked into the melt for 5-1200 s. Thickness of oxide layer, ZrO_2 was measured before and after the soaking test to investigate the ZrO_2 thickness reduction. Heat treatments of pre-oxidized zry plates in Ar gas at the same conditions were also carried out to clarify the reduction mechanism.

3. Results

Fig. 1 plots the thickness reduction of oxide scale in SS-B_4C melt (solid lines). After soaking in molten SS-B_4C at 1200ºC for 20 min, the ZrO_2 layer (50 μm) almost disappeared completely. Heat treatment in Ar gas (dashed lines) at 1200ºC for 20 min also resulted in thickness reduction of ZrO_2 layer from 50 μm to 35 μm. In conclusion, ZrO_2 layer formed on zry plate can be declined at high temperatures in environments with low oxygen potential such as in Ar gas or when ZrO_2 surface covered by the molten mixture.

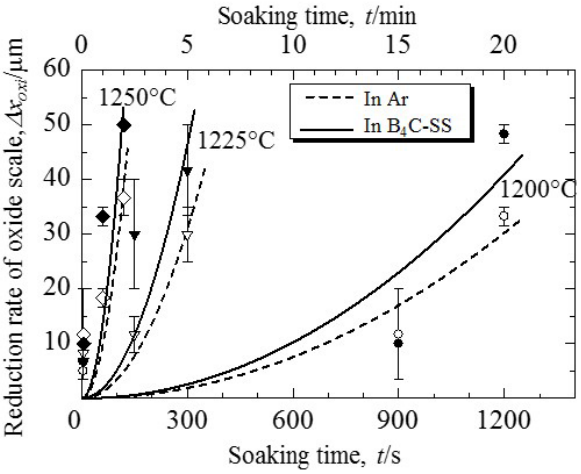

Fig. 1 Reduction rate of oxide scale of zry plate by soaking in SS-B_4C melt or heat-treatment in Ar gas.

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