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High Temperature Oxidation Behavior of the Cr Coated Zr alloy in BDBA Condition

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1. Introduction

After the Fukushima Daiichi station blackout in 2011, many organizations have conducted researches to improve safety and integrity of the nuclear fuel in accident conditions. In the severe conditions of design basis accident (DBA) and beyond design basis accident (BDBA) conditions, the oxidation resistant of accident tolerant fuel (ATF) is one of the crucial subjects trying to achieve in ATF development [1-6]. Therefore, it is necessary to study the effect of higher temperature and pressurized steam environment than the accident analysis of the zirconium based nuclear fuel. KEPCO NF built new test equipment to evaluate accident tolerance for ATF candidates in more severe accident condition. And in this study, high temperature oxidation property of pressurized steam environment were evaluated for the chromium coated zirconium alloy under developing as ATF cladding in KEPCO NF.

2. Methods and Results

2.1 Test Equipment

The test equipment which is the HP-TGA (high pressure steam environment simultaneous thermo gravimetric analyzer) for the high temperature oxidation test in pressurized steam environment is shown in Fig. 1. This equipment was designed to measure the in-situ weighing of sample, under controlled steam/argon mixed environment with max pressure of 150 bar and max temperature of 1600 ^{o}C. Weight measurement was provided for vacuum, inert and humidified atmosphere under static or flowing gas environment. Especially, balance part was kept at room temperature for effective weighing during high temperature test. Temperature accuracy was controlled within 0.3 degree of C, and pressure was controlled within 0.1 bar using a flow-type pressurization system.

2.2 Materials and Test Conditions

The material used for this test was HANA-6 plate with chromium coating using a commercial grade arc ion plating device. The zirconium surface and the coated surface with a thickness of about 15 micrometers were compared. The test was conducted at 1300°C for 12 and 27 minutes, and a sufficient amount of steam was supplied so as not to be affected by the steam starvation.

Fig. 1. High pressure steam environment STA

2.3 Test Results

As shown in Fig. 2, it was confirmed that the weight gain of the coated plate on one side compared to the uncoated plate was about 60%. In addition, as can be seen in Fig. 2, cracks could be identified on the zirconium surface but the coated surface maintained integrity. As shown in Fig. 3 as a result of analyzing the microstructure and EDS line scanning for cross section of the specimen, it was confirmed that the chromium layer served as a protective oxidation layer to 12 minutes and internal oxidation proceeded thereafter. However, when the 27-minute test was performed, it is determined that breakaway may occur due to cracks occurring on the uncoated surface.

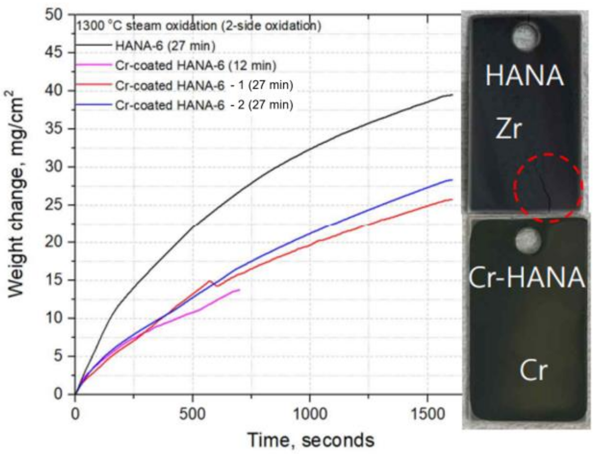

Fig. 2. Test results for in-situ weight gain and appearance

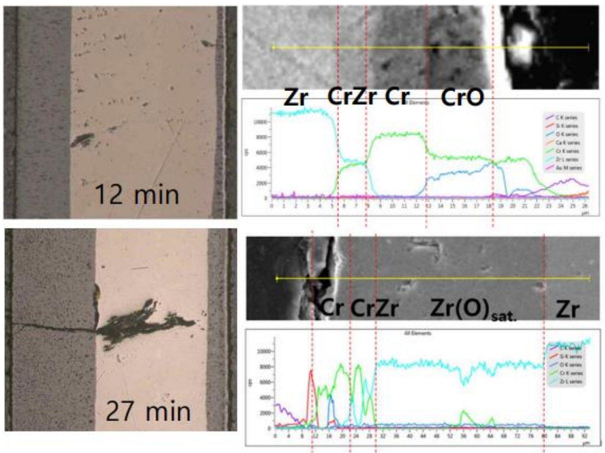

Fig. 3. Analysis results for (a) microstructures and (b) line scanning

3. Conclusions

In this study, the test equipment was constructed to simulate the Station blackout(SBO) scenario and the high temperature oxidation behavior was evaluated in pressurized steam environment of the Fe-based alloy. The HP-TGA was designed to measure in-situ weighing in steam/argon mixed environment of up to 150 bar at up to 1600 degree of C. In the case of Cr coated Zr alloy, it was confirmed that chromium layer served as a protective oxidation layer, however, breakaway may occur due to cracks occurring on the uncoated surface. Based on the test equipment, it is expected that it will be possible to evaluate the high temperature oxidation behavior of pressurized environment of various accident tolerant fuel materials, furthermore, the industry will be able to construct the databases in the conditions of SBO scenario.

4. Acknowledgements

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