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Test Method for the Analysis of High Temperature Oxidation Behavior of Fuel Cladding in High Pressure Steam Environments

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1. Introduction

After the Fukushima nuclear power plant accident that occurred 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 [1-3].

According to the state-of-the- art report on ATF, large break loss-of-coolant accident(LB-LOCA, low pressure condition) and station black-out (SBO, high pressure condition) were selected for the evaluation of ATF candidates among the various accident scenarios [4]. The research on LB-LOCA has already been conducted since the zirconium cladding and many infrastructures have been established, however, the test facility of the high pressure condition was insufficient. KEPCO NF recently constructed new test facility to evaluate accident tolerance for ATF candidates in SBO condition. And in this study, high temperature oxidation property of pressurized steam environment were evaluated for the advanced ferritic steel (AFS), which is iron-based alloy under developing as accident tolerant fuel 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 degree of C. Weight measurement 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.

Fig. 1. HP-TGA

2.2 Test Results

Fig. 2 shows the results of evaluating the high temperature oxidation resistance of Fe-based alloy in the pressurized water-vapor environment. The test was performed for 4 hours in pressurized steam/argon mixture atmosphere at 1300 degree of C and exposure pressure was maintained at 50 bar. For the test alloys, AFS alloy, Kanthal® APM alloy and 310s stainless steel were conducted in plate form. And the test results of the AFS alloy performed at atmospheric pressure were also shown in order to confirm the effect of environmental difference between normal pressure and pressurization.

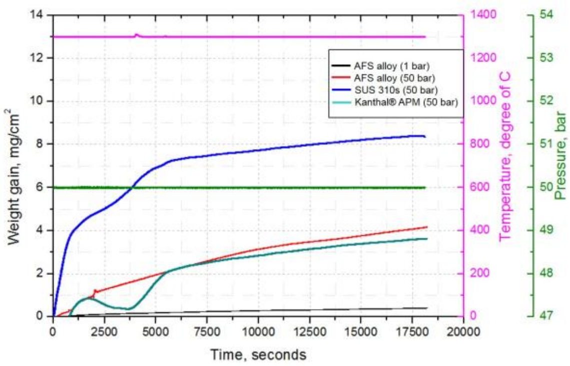

Fig. 2. Results of high temperature oxidation test

In the pressurized environment of the AFS alloy, the high temperature oxidation resistance was slightly lower than the APM alloy. However, considering the initial weight loss in the APM alloy, similar characteristics were obtained when the high temperature oxidation amount was analyzed. 310s stainless steel forming the chromium oxide was confirmed to have low resistance of high temperature oxidation compared to another alloys forming aluminum oxide. In the case of AFS alloy, amount of weight-gain was increased about 10 times when the exposure pressure was pressurized to 50 bar.

3. Conclusions

In this study, the test equipment was constructed to simulate the 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 Fe-based alloys, it was confirmed that high temperature oxidation rate was accelerated about 10 times compared with the atmospheric pressure in the pressurized environment of 50 bar. 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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