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Mechanical Tests Plan after Neutron Irradiation for SMART SG Tube Materials in a Hot Cell

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1. Introduction

An advanced integral PWR, SMART (System-Integrated Modular Advanced ReacTor) is being developed in KAERI. It has compact size and a relatively small power rating compared to a conventional reactor. The main components such as the steam generators, main circulation pumps are located in the reactor vessel. Therefore they are damaged from neutron irradiations generated from nuclear fuel fissions during operation. The SMART SG tubes which are 17 mm in a diameter and 2.5 mm in a thickness will be made of Alloy 690. To ensure the operation safety the post irradiation examinations is necessary to evaluate the deterioration levels of various original properties. Specially the amount of mechanical properties change should be reflected and revised to design data. For that tensile, fracture, hardness test are planned and under preparations.

In this paper the detailed plans are reviewed. Three kinds of materials having different heat treatment procedures are prepared to fabricate specimens. The capsules installed the specimens are going to be irradiated in HANARO. Finally the tests for them will be performed in IMEF, Irradiated Materials Examination Facility at KAERI.

2. Specimen preparations

The specimens to perform PIE's are prepared for tensile, fracture toughness and hardness tests. The specimen dimensions based on the ASTM standards are slightly modified to be fitted to the inner space of a capsule. The main specifications of specimens are shown in Table 1.

Table 1 Specimen dimensions according to test type

Test type	Dimensions [mm]	Remarks
Tensile	108 x 25 x 2.5(t)	Plate
	26 x 5 x 0.5 (t)	Small
Fracture toughness	24 x 25 x 10 (t)	1/2T CT
Hardness	10 x 10 x 2 (t)	

3. Neutron irradiations in HANARO

The fast neutron fluence of the specimens was required to be 1×10^{19} n/cm^2, 1×10^{20} n/cm^2, and 1×10^{21} n/cm^2 (E>1.0 MeV), considering the lifetime neutron fluence of the SMART steam generator. To obtain these neutron fluences, 3 different irradiation capsules will be irradiated in the OR5 and CT test holes of HANARO, as shown in Figures 2 and 3. Irradiation tests will be performed according to the SMART R&D schedule which was decided to be developed by 2011.[1]

Figure 1 The capsules ready for irradiations

4. PIE's in IMEF

All tests after neutron irradiations will be performed in IMEF. The casks shipped into the capsules after irradiations will be loaded to a vehicle and transported to IMEF. The cask is unloaded in a pool at IMEF and finally the capsule is moved to a hot cell. In hot cells the capsule is dismantled and the specimens are classified into test types. Each test is executed in the hot cells where the test machines are operated.[2]

4.1 Capsule transportation and unloading

After the cask is transported to the entrance of IMEF on the vehicle, the hoist lifts up it and loads to the transfer cart to move in the near area of the unloading pool. In pool the cask is opened to pull out the capsule in it. The capsule is transferred up to M1 hot cell by cart from a pool to hot cell. Fig 1 shows the working sequence in a pool and hot cell.

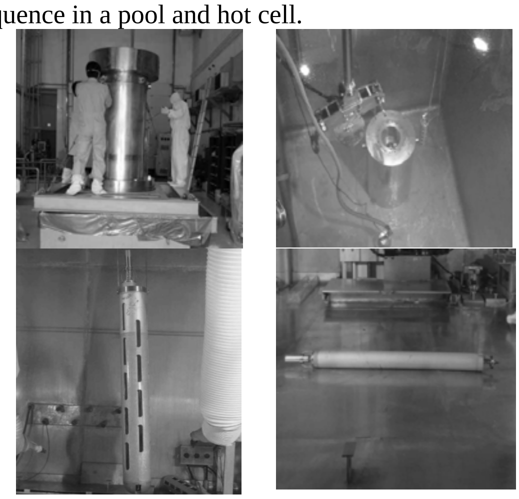

Fig. 1 Capsule transportation procedures

4.2 Capsule Dismantling

In a M2 hot cell the capsule is dismantled to pull out the specimen from the inside of it. The capsule cutting machine is used to do it. It has 1,100 (W) x 1,000 (D) x 400 (H) in a external dimension. The abrasive wheel, which has a diameter 205 ~ 300 mm, will cut to the radial direction with the speed of 150 rpm. The cutting speed is 0.5 ~ 3 mm/min. The area between each thermal media will be cut and finally into 6 pieces. The specimens installed the inner center area are pulled out by the manipulators. The specimens are classified into the type of test. The Figure 2 shows the cutting machine and the capsule pieces.

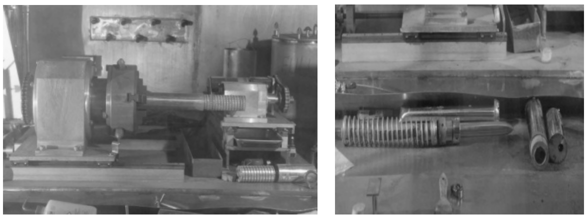

Fig. 2 The cutting machine in a hot cell

4.3 Tensile test

The tensile tests [3] are planned to perform using the static universal testing machine (UTM) in a hot cell. It has 5 ton in a loading capacity and 75 mm in a displacement. The specially designed furnace will control the temperature of a specimen. The load cell and the furnace are calibrated and certified the measured load and temperature before tests simultaneously. For the test of the small sized specimen the jigs to connect it to the loading rods. The fixing device of the pins to a specimen are invented to connect them easily

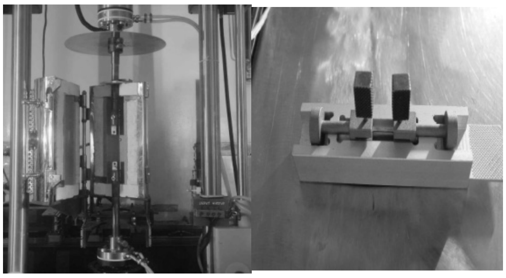

Figure 3 The static UTM and a tensile jig

4.4 Fracture test

The fracture tests will be performed using dynamic UTM in a hot cell. It has 2.5 ton in a loading capacity and 100 mm in a displacement. The chamber will control the temperature of a specimen. Because the specimen dimensions is non standard compared to an ASTM standard the jig are specially designed and fabricated to attach the specimen to the load. The load to the specimen will be pulled with the uniform displacement speed. During loading the amount of a load and a displacement will be stored to the control computer simultaneously. After test the load and displacement curve is plotted and the fracture toughness will be decided by the method of load ratio method. This method is newly developed to decide the toughness based on the load and the load line displacement alone. It is widely used to the fracture test in a hot cell because of the difficulty to get the crack opening displacement required in the test standards. Figure 4 shows the UTM and the jig for fracture test.

Figure 4 The UTM and the jig for fracture tests

4.5 Hardness test

The hardness test will be performed using the micr hardness tester attached to the microscope, TELATOM-III, LEICA. It is MICRO DUROMAT 7 model which has the load range 0.05 ~ 200 gram and 500 micron in a diagonal size. It has VICKERS type indenter. Before test the specimen is prepared to the surface grounding with the molded in the resin devise. Figure 5 shows the hardness tester attached to the microscope

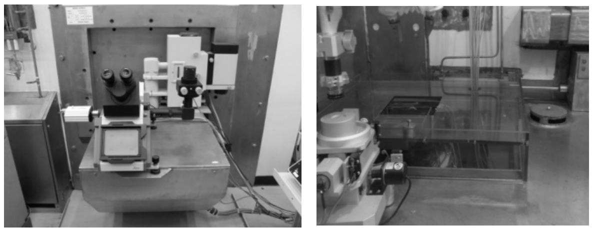

Figure 5 The hardness tester in the microscope

4. Conclusion

The mechanical test plan for SMART SG tube materials after neutron irradiations in HANARO is introduced. To produce the high reliable test data in a hot cell the plan to check the test flow, machine, method, and obstacles etc before tests. Through this study all factors for the tests in a hot cell are reviewed and the tests is confident to be performed successfully

REFERENCES

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[3] ASTM E8M “Standard Test Method of Tension Testing of Metallic Materials”

[4] Xiaoguang Chen et al. Special Application and Advanced techniques for Crack Size Determination ASTM STP 1251, 1995, pp 83-103