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Verification Tests of a New Capsule Controlling the Neutron Fluence of a Specimen in HANARO

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1. Introduction

Various irradiation devices have been developed at HANARO (High flux Advanced Neutron Application ReactOr) [1]. Among the irradiation facilities, a capsule is the most useful device to cope with the various test requirements.

Extensive efforts have been made to establish design and manufacturing technology for a capsule and temperature control system, which should be compatible with HANARO's characteristics [2,3]. 6,000 specimens from 36 domestic research institutes, 4 nuclear industry companies and 81 universities, have been irradiated in HANARO for 54,000 hours using the irradiation capsule system since 1995 [4].

In an irradiation test using a capsule, the neutron fluence of a specimen is mainly dependent of the reactor operation time. For the required specific fluence of the specimens, the reactor operation period has been controlled in HANARO. However it became difficult because of an increased number of reactor users and a stabilized reactor operation schedule. Therefore, short time irradiation tests such as RPV materials requiring only a 2 day-irradiation for a life time neutron fluence requires new capsule technology.

A mock-up capsule (04M-22K) was designed, fabricated and out-pile tested to confirm the various key technologies necessary for the fluence control of a specimen [5].

Based on the mock-up capsule, a verification capsule (05M-06K) was designed, fabricated and tested for the development of the new instrumented capsule technology for a control of the irradiation fluence of a specimen in HANARO, irrespective of the reactor operation condition. In this paper, the verification test results of the new capsule are described.

2. Capsule Design

Based on the standard capsule system, a fluence control capsule system was designed. The capsule system mainly consists of a main capsule and capsule related systems. In this section the design details of the capsule system are described.

2.1 Capsule Main Body

The basic structure of the 05M-06K capsule was based on the 04M-22K mock-up capsule which was successfully designed and out-pile tested to confirm the various key technologies necessary for the fluence control of a specimen [5]. The capsule consists of three main parts which are connected to each other: protection tube (5m), guide tube (9.5m) and the capsule's main body as shown in Fig. 1. The main body including the specimens and instruments is a cylindrical shape tube of 60mm in diameter and 1,170mm in length. The length of the capsule's main body was determined to be 1,170mm considering the neutron flux and the cask dimension. The main body has 5 stages with independent micro-electric heaters and contains 12 thermocouples and 5 sets of Fe-Ni-Ti neutron fluence monitors to measure the temperatures of the specimens and fast neutron fluences, respectively. Heaters and thermocouples are connected to a capsule temperature controlling system through a guide tube and connection box system. 21 square and round shaped specimens made of STS 304 were inserted into the capsule. Each of the five specimens which were accommodated in the 1st stage (top) of the capsule can be taken out of the HANARO core during a normal reactor operation. The specimen is extracted by a specimen extraction mechanism using a steel wire. Several inner structures including a transfer tube were designed to compare the easiness of moving of the specimen.

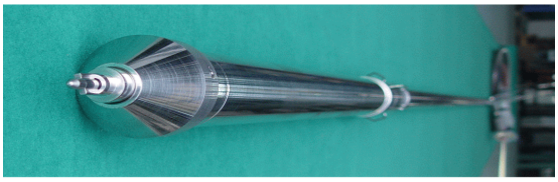

Figure 1. HANARO neutron fluence control capsule.

2.2 Capsule Related System

The fluence control capsule system needs several capsule related systems such as a connection box, a lifting device, and a control system. The specimen should be lifted up by a pulling out mechanism using a steel wire that is bolted to the specimen. The piano steel wire of 1mm in diameter is guided through a stainless guide tube of 2mm in inner diameter. The guide tubes that are penetrating the connection box are connected to the lifting device of a wire rolling rig as shown in Fig. 2. The inner part of the guide tubes are sealed by using swage lock systems and maintained at the same He atmosphere as the capsule's main body during an irradiation test. After a desired neutron irradiation test, the specimen can be lifted up by the handling device, irrespective of a reactor operation.

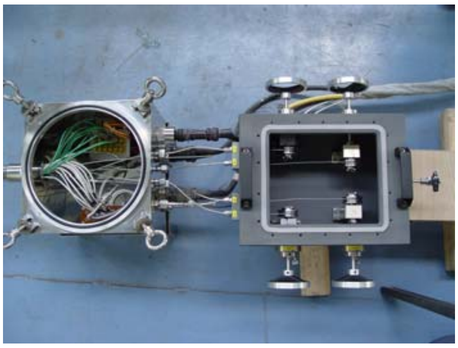

Figure 2. Assembled connection box and a specimen lifting device.

3. Verification Tests

3.1 Performance Tests

To evaluate the soundness of the new capsule design, the capsule was out-pile tested in a single channel test loop. The locking and guiding system of the capsule were proved to be properly designed and the easiness of moving of the specimen was not affected on the inner structure of the aluminum block around specimen. However the system should be strictly maintained in a He gas environment to prevent rusting by moisture included in air.

By a gamma heating, heat is generated in the material inserted into a reactor test hole. This kind of capsule needs a very precise temperature calculation and the temperature of the capsule is complicated by many factors including the gap size, conductivity, and thermal expansion of the capsule structure. Thus, the computer program GENGTC is usually used to calculate the temperature distribution of a capsule. In this thermal calculation, the surface temperature of the outer tube of a capsule in contact with coolant must not cause the coolant to boil. The specimen temperature was basically changed from 118℃ to 201℃ by a gamma heating according to the specimen configuration in the case of 1 atm Helium. The maximum temperature of 201℃ of the specimen is a much lower value than the standard capsule and other capsules having a similar structure. Thus, the temperature of the specimen will be controlled to a specified irradiation temperature by controlling the He gas pressure in the capsule and finally by an electric heater. Therefore, this new capsule is judged to be good enough for irradiation tests at around 300℃ in HANARO.

3.2 Reactor Safety Analysis

The new capsule system should be tested and analyzed to satisfy several reactor requirements concerning the coolant flow and the vibration properties. The pressure drop and vibration properties of the capsule were tested by using the single channel out-pile test loop for simulating reactor coolant flow conditions. The capsule satisfied the pressure drop criteria of 209 kPa in HANARO. The vibration property of the new capsule was measured for 30minites by using a Polytec Laser Doppler Vibrometer as shown in Fig. 3. The new capsule shows a more uniform and less vibration displacement than the standard irradiation capsule, thus it satisfied the HANARO vibration criteria of 1 mm. The vibration frequency of the new capsule with altered dimensions and weight was also found to be lower than that of standard capsule by using ANSYS program.

Figure 3. Single channel out-pile test loop and Laser Doppler Vibrometer.

4. Conclusion

Based on the accumulated irradiation experience and the user's sophisticated requirements, a new instrumented capsule technology for a more precise control of the irradiation fluence of a specimen irrespective of the reactor operation has been developed at HANARO. The new capsule system was successfully verified and evaluated to be applicable to HANARO.

Acknowledgements

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