Design of New Irradiation Capsules for Controlling Temperature and Fluence

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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 various test requirements. Instrumented and non-instrumented capsules have been developed at HANARO for new alloy and fuel developments and the life time estimation of nuclear power plants. Extensive efforts have been made to establish design and manufacturing technology for the capsule and temperature control system, which should be compatible with HANARO's characteristics [2-4]. 9 instrumented and 2 non-instrumented capsules were designed, fabricated and successfully irradiated since the first non-instrumented capsule (96M-01K) for various materials irradiation. In an irradiation test using a research reactor, temperature and fluence are mainly dependent of reactor operation condition such as reactor power mode and operation time. In consequence, the irradiated specimen is subjected to the change of temperature as well as of neutron flux during reactor power transient such as start-up and shut-down. A large difference in the defect structure has been reported to be caused by this transient irradiation from the mechanism of the defect structure development [5,6].

Therefore, the development of new capsule technology has been required to overcome those limitations. In this paper, current status of development of the capsule for controlling temperature and fluence in HANARO is described.

2. Development of Temperature Control Capsule

During the irradiation test in a research reactor, the temperature of irradiated specimen is determined by micro-heater output and He gas pressure of the layer in the capsule as well as neutron flux of capsule itself. However, during reactor power transient such as start-up, the irradiated specimen is subjected to the change of temperature as well as of neutron flux. Such simultaneous change of temperature and neutron flux, both affect irradiation damage of the material, makes it difficult to elucidate radiation damage mechanism [5,6]. Thus it is required to keep sample at specified temperature by heating the sample using auxiliary devices before the reactor power increase in order to eliminate the effect of temperature transient in the recent irradiation tests.

Fig. 1 shows a typical concept of temperature control irradiation in HANARO. The results of previous researches clearly show that temperature changes during reactor startup and shutdown affect the microstructures of irradiated specimens [5,6]. To avoid such undesirable effects, temperatures of the specimens during reactor start-up and shut-down should be kept uniformly as that of specimen at normal operation of reactor. The temperature control is done by electric heater and by controlling He gas pressure in the layer of the capsule. The first temperature control capsule (03M-06U) irrespective of reactor operation was designed and manufactured and will be irradiated in HANARO this year.

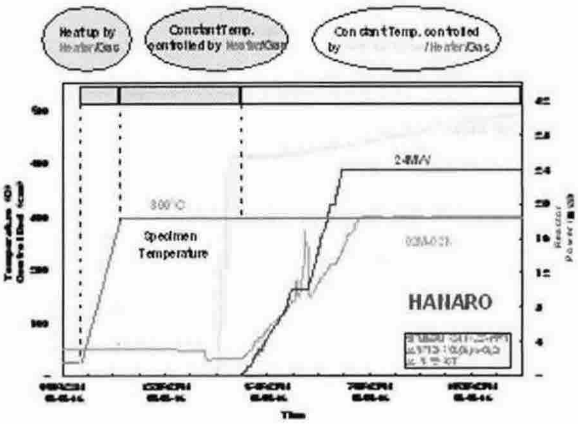

Figure 1. Design concept of temperature control irradiation capsule in HANARO.

3. Development of Neutron Fluence Control Capsule

In HANARO, we have controlled reactor operation period for the required fluence of the specimens. However it becomes difficult because of increased reactor users and stabilized reactor operation schedule. Nowadays, the HANARO is operated at 30MW by several operation cycles a year. An operation cycle for the HANARO consists of about 24 operation days and 11 maintenance days. Therefore, short time irradiation tests such as RPV materials requiring only 2 day-irradiation for the life time neutron irradiation requires new capsule technique.

Fig. 2 shows the conceptual design of fluence control capsule. Five subcapsules are accommodated in the capsule and each subcapsule could be taken out of HANARO core during reactor operation. The subcapsule was pulled out by the pulling out mechanism using a steel wire. To take the subcapsule out of reactor core, the length of capsule is twice as long as that of conventional capsule. Temperature of each capsule is controlled separately by the gap between parts and electric heater.

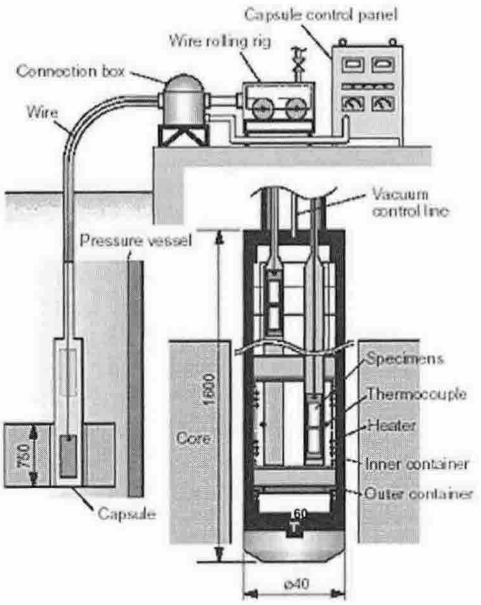

Figure 2. Schematic diagram of fluence control capsule.

Moreover, the fluence control capsule will make it possible to irradiate specimens at different temperatures and with different fluences. With this one capsule, five different total fluences at five different temperatures can be ideally realized. Usually, one capsule realizes only one irradiation fluence at one temperature. Thus, it takes several years and expensive irradiation cost of several capsules to carry out systematic irradiation at different temperatures with different neutron fluences. Such research can be done in only one year using this capsule as shown in Fig. 3.

3. Conclusion

For a research period of 2003-2006, development of new instrumented capsule technologies for more precise control of irradiation temperature and fluence of specimen irrespective of reactor operation has been performed in HANARO. Those technologies will also be effectively applied on the researches of test variables with a capsule.

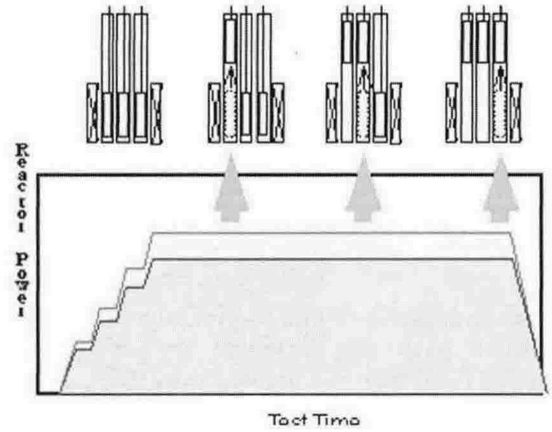

Figure 3. Schematic diagram of effective utilization of the fluence control capsule.

Acknowledgement

This study was supported by Korea Institute of Science & Technology Evaluation and Planning (KISTEP) and Ministry of Science & Technology (MOST), Korean government, through its National Nuclear Technology Program.

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