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Development of Irradiation Capsule Technology in HANARO

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1. Introduction

A material capsule system including a main capsule, fixing, control, cutting, and transport system were developed for an irradiation test of non-fissile materials in HANARO [1-3]. The capsule system has been actively utilized for the various material irradiation tests requested by users from research institutes, universities, and the industries. Based on the accumulated irradiation experience and the user's sophisticated requirements, development of new instrumented capsule technologies for a more precise control of the irradiation temperature and fluence of a specimen and for an IP/OR irradiation test and high temperature irradiation test have been performed in HANARO.

2. Development of Capsule Technology

2.1 Standard Irradiation Capsule

The 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. For the development of an instrumented capsule system, the capsule related systems such as a supporting, connecting, and controlling system were also developed.

13 instrumented capsules and 2 non-instrumented capsules have been successfully irradiated in the HANARO CT and IR test holes since 1995. The capsules were mainly designed for an irradiation of the RPV (Reactor Pressure Vessel), reactor core materials, and Zr-based alloys. Most capsules were made for KAERI material research projects, but 6 capsules were made as a part of national projects for the promotion of the HANARO utilization for universities. 6,000 specimens from domestic research institutes, nuclear industry companies and universities, were irradiated in HANARO for 54,000 hours by using the capsule irradiation systems. The metallic material specimens were mainly irradiated at around 300℃ up to a fast neutron fluence of 1.3×10^{21}(n/cm^2) (E>1.0MeV).

2.2 Development of a Temp. Control Capsule

The irradiation temperature of the specimen is determined by the micro-heater output and He gas pressure of the gap in the capsule as well as the neutron flux of the capsule itself. However, during a reactor power transient such as a start-up, the irradiated specimen is subjected to a change of the temperature as well as of the neutron flux. Such simultaneous changes of the temperature and neutron flux, both of which affect an irradiation damage on the material, makes it difficult to elucidate the radiation damage mechanism. The results of previous researches clearly show that temperature changes during a reactor startup and shutdown affect the microstructures of the irradiated specimens [4]. To avoid such undesirable effects, the temperatures of the specimens during a reactor start-up and shut-down should be kept as uniform as possible with that of a specimen at a normal operation of a reactor. Thus it was necessary to keep a sample at a specified temperature by heating the sample using auxiliary devices before a reactor power increase in order to eliminate the effect of a temperature transient in the recent irradiation tests. The temperature control is done by an electric heater and by controlling the He gas pressure in the capsule. First temperature control capsule (03M-06U) irrespective of the reactor operation was designed, manufactured and irradiated in HANARO. The specimen temperature was successfully raised up to the target temperature of 300℃ before a reactor start-up.

2.3 Development of a Fluence Control Capsule

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.

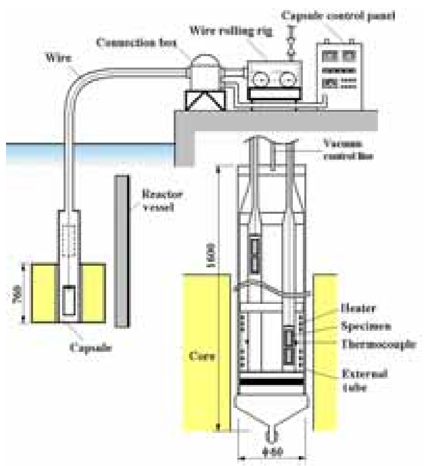

Figure 1. Schematic diagram of the fluence control capsule

Figure 1 shows the conceptual design of the fluence control capsule. The system mainly consists of a main capsule, a protecting tube, a junction box, and a lifting device. Five subcapsules simulating square and round bar type specimens are accommodated in one stage of the capsule and each sub capsule can be taken out of the HANARO core during a reactor operation. The subcapsule could be lifted up by a pulling out mechanism using a steel wire. To take the subcapsule out of the reactor core, the length of the capsule main body would be increased more than in the conventional 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 an expensive irradiation cost for several capsules to carry out a systematic irradiation at different temperatures with different neutron fluences.

A mock-up capsule(04M-22K) was designed, manufactured and out-of-pile tested to confirm the capsule technology. To compare the easiness of moving for different designs, several designs were installed in the capsule. The mock-up capsule was successfully tested under air environment at room temperature and a temperature of 300℃ [5]. Through the parametric out-of-pile tests of the capsule, an optimal design of the fluence control capsule (05M-06K) according to the HANARO reactor characteristics and available manufacturing techniques was suggested. Lots of technical tests and safety analyses should be performed to apply this capsule in HANARO.

2.4 Development of New Capsule Technologies

For the next research stage starting from 2007, we are planning to develop new capsule technologies for a irradiation test in the IP/OR test holes and for a high temperature irradiation test.

The fast neutron fluxes of the OR and IP test holes are much less than the CT/IR holes [6]. Therefore these test holes are more adequate for the irradiation tests of RPV, SMART, and ceramic materials. Based on the standard irradiation test system, the possibility and safety problems should be examined thoroughly.

Another research is to develop a higher irradiation temperature capsule. Generally, the standard irradiation capsule is mainly tested at around 300℃. However, the research on the VHTR core materials requires a 400~500℃ irradiation temperature. To achieve the high irradiation temperature of the VHTR core materials, the basic design of the standard capsule system might be changed for the irradiation test at the OR5 test hole.

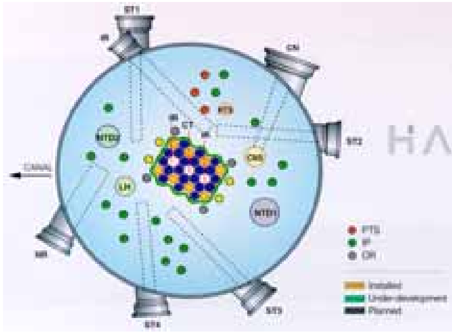

Figure 2. Core configuration of the HANARO.

3. Conclusion

Based on the accumulated irradiation experience and the user's sophisticated requirements, new instrumented capsule technologies for a more precise control of the irradiation temperature and fluence of a specimen irrespective of the reactor operation has been developed in HANARO. New capsule technologies for an irradiation test in the IP/OR test holes and for a high temperature irradiation test will be performed for the next research stage starting from 2007.

Acknowledgement

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