Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

Neutron Research in HANARO

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Abstract

HANARO (High-flux Advanced Neutron Application Reactor), which was designed and constructed by indigenous technology, is a world-class multi-purpose research reactor with a design thermal power of 30 MW, providing high neutron flux for various applications in Korea. HANARO has been operated since its first criticality in February 1995, and is now successfully utilized in such areas as neutron beam research, fuel and materials tests, radioisotopes & radiopharmaceuticals production, neutron activation analysis, and neutron transmutation doping, etc. A number of experimental facilities have been developed and installed since the beginning of reactor operation, and R&D activities for installing more facilities are actively under progress. As new experimental facilities are added up, rapid growth in utilization has been observed in terms of the number of users as well as fields of applications. Internationally competitive experimental facilities based on the high flux reactor and the strong support of government to the HANARO users have promoted researchers to include the use of neutron in their own research activities, which is confirmed by annually growing record of HANARO utilization every year.

Three flux traps in the core (CT, IR1, IR2), providing a high fast neutron flux, can be used for materials and fuel irradiation tests. They are also proper for production of high specific activity radioisotopes. Four vertical holes in the outer core region, abundant in epithermal neutrons, are used for fuel or material tests and radioisotope production. In the heavy water reflector region, 25 vertical holes with high quality thermal neutrons are located for radioisotope production, neutron activation analysis, neutron transmutation doping and cold neutron source installation. The two largest holes named NTD1 and NTD2 are for neutron transmutation doping, CNS for the cold neutron source installation, and LH for the irradiation of large targets. HTS is equipped with a hydraulic transfer system for short half-life radioisotope production, three NAA holes are equipped with pneumatic transfer systems (PTS) for neutron activation analysis, and 17 IP holes are for various targets irradiation.

Horizontally there are 7 beam ports of different types available for researches in neutron scattering, neutron radiography, prompt gamma neutron activation analysis (PGAA) and medical applications. All the beam ports are tangentially arranged and their beam noses except the NR are located at the peak areas of thermal neutron flux in the reflector. Five beam ports (ST1~4, CN) are for neutron scattering experiments, the IR is for ex-core neutron irradiation experiments such as boron neutron capture therapy (BNCT) and dynamic neutron radiography, and the NR is for neutron radiography.

Since the commencement of HANARO operation in 1995, a series of neutron scattering instruments have been developed and installed. The neutron radiography facility (NRF) was installed in 1996 as

the first experimental facility. The high resolution powder diffractometer (HRPD) became operational in 1998, followed by the four circle diffractometer (FCD) in 1999, the residual stress instrument (RSI) in 2000, and the small angle neutron spectrometer (SANS) in 2001, respectively.

HRPD and SANS became the most popular instruments these days, attracting wide range of users from academia, institutes and industries. NRF is becoming a practical tool for industrial and scientific applications as neutron tomography and dynamic radiography capabilities are available. FCD is a quite classical single crystal diffractometer whose beam time has been equally allocated for single crystal studies in academic side and texture works in industrial one. This instrument is now also under major upgrade phase. RSI is an instrument to measure residual stress on industrial materials. It was commissioned lately and upgraded with relocation from beam port ST2 to ST1. Along with these instruments development, various sample environments have been developed to meet various users' demand and internal needs. Several low temperature environments based on closed-cycle refrigerator down to 10 or 4K are available for HRPD, FCD, and high temperature furnace up to 1000K for HRPD and a special furnace fitted into the Euler cradle for the FCD can be used up to 800K. Several sample stages including heat blocks are available for SANS.

We have made a lot of efforts during the last 10 years to develop some key components such as monochromators, collimators, and precision motion units with its motion controller specific to heavy load neutron instruments, etc. The development and application of position sensitive detector (PSD) was a great success. In 2003, we started development of neutron mirror techniques and devices, which would be successfully utilized to develop neutron guides for the cold neutron research facility project. All of these efforts together make us enable to develop high performance neutron instruments and researches in cost-effective way.

Instrument under commissioning phase is the reflectometer with vertical sample geometry (REF-V). Instrument at the beam port ST1 PNS is the only one instrument at present in HANARO, which can change its take-off angle, i.e., wavelength, and using this characteristic we will use this instrument for various testing and development purposes. We are developing additional instruments complying with users' demand, the high intensity powder diffractometer (HIPD), the reflectometer with horizontal sample geometry (REF-H), and the triple axis spectrometer (TAS).

The result of demand survey on cold neutron in October 2002 showed that more than 50% of neutron beam users wanted to use cold neutrons for their researches, which is quite an increase compared to 24% in 1998. Consequently, the project of constructing the cold neutron research facility (CNRF) at HANARO was re-initiated in July 2003. The first phase duration of CNRF project is five years, and the project envisions installation of cold neutron source, related systems, 3 neutron guides, and 6 cold neutron scattering instruments to satisfy the imminent needs of cold neutron beam. 6 neutron instruments include the relocation of 3 reactor hall instruments (8m-SANS, REF-V, REF-H) and the installation of 3 new instruments (40M-SANS, Cold-TAS, DC-TOF). The cold neutron source is being designed based on liquid hydrogen as the moderator, which will be naturally circulated in two-phase thermo-siphon mode within an in-pool assembly consisting of a cavity type moderator cell and a condenser. The full-scale thermo-siphon test is in progress to confirm the design and to develop an operation procedure. The basic layout of neutron guides and instruments and the basic design of 3 new instruments have been peered through instrument development teams and reviewed by the international advisory group. The Ni guide manufacturing technology has been developed, and the super-mirror and the large area 2D detector are being developed. The design of the cold neutron laboratory building has been completed, of which safety analysis report has been submitted to the regulatory body, too.