# Experimental Study on Hydraulic Rotation Device for Neutron Transmutation Doping

Ki-Jung Park*, Han-Ok Kang, Yongsoo Park, Seong Hoon Kim, Cheol Park
*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 305-353, Republic of Korea*
**Corresponding author: pkijung@kaeri.re.kr*

## 1. Introduction

NTD (Neutron Transmutation Doping), a silicon irradiation method, is one of the important items in the utilization of a research reactor. As the commercial needs for NTD in a research reactor are increasing, all research reactors constructed recently or under the design stage have an NTD irradiation facility. For uniform irradiation, the most important factor for the production of NTD-silicon, it is necessary to rotate the silicon ingot at a uniform speed at a certain position in the NTD irradiation holes. [1] In this study, a new NTD hydraulic rotation device to rotate the silicon ingot with a uniform speed was developed for the purpose of application to the KJRR research reactor.

## 2. Methods and Results

In this section the design characteristic for the NTD hydraulic rotation device (NTDHRD) and experimental apparatus are described.

### *2.1 NTD Hydraulic Rotation Device Design*

A motor-driven rotation system, which is widely used for the rotation of NTD irradiation, has a weakness due to the space utilization and the failure probability of the mechanical component. In addition, it is necessary to consider the heat removal from a silicon ingot as the size of that is lager. Plural hydraulic-driven rotation devices were proposed to make up for the weakness of the motor-driven rotation system which is necessary to enhance the reliability of the NTD system.

The important design concept for NTDHRD is a combination of stable hydrostatic bearing and uniform rotation drive. Using the reactor pool water as the working fluid, the hydrostatic bearing system ensures no physical contact between the fixed part and rotation part during NTD irradiation. A high-pressure impulse jet supplied from the reactor lower structure assembly provides rotation force on the NTDHRD. One of the important design focuses of the hydrostatic bearing and the rotation should be achieved using the same supply pressure.

Fig. 1 shows the conceptual design for NTDHRD. The designed NTDHRD is composed of a thrust bearing part, a radial bearing part, and an impulse jet part. High-pressure water jets are supplied through each nozzle. The thrust bearing part is designed for the stable levitation of the silicon ingot and NTDHRD. In order to calculate the thrust load, the weight of the silicon ingot and NTDHRD in the pool is applied. The thrust bearing area is the shape of the annular circle, and the film thickness by the thrust bearing will be less than 0.1 mm. The radial bearing part is designed for the support of NTDHRD during thrust and rotation.

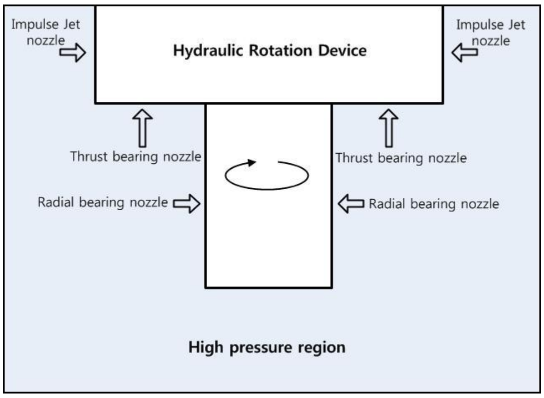


Fig. 1. Conceptual design for NTD Hydraulic Rotation Device.

The impulse jet part is designed for a uniform rotation of the NTDHRD. The target rotation velocity for the optimum irradiation is 10-30 RPM. To determine the nozzle size, the minimum rotation force is calculated by the absolute weight of the silicon ingot and NTDHRD.

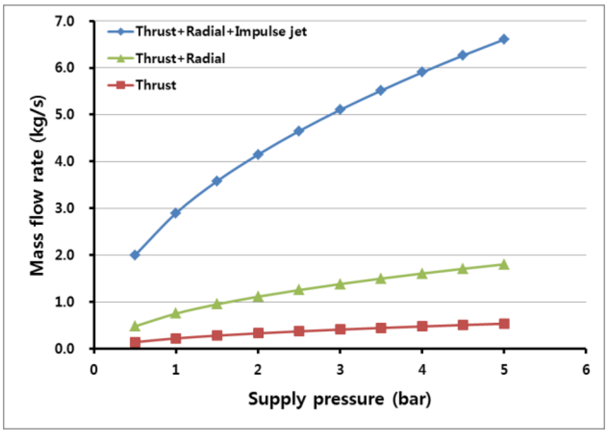


Fig. 2. Mass flow rate at the each nozzle (thrust bearing, radial bearing, and impulse jet).

Fig. 2 shows the mass flow rate at each nozzle as a function of supply pressure as the preliminary computational result [2]. As the supply pressure increases, the mass flow rate at each nozzle increases. The higher mass flow rate of the impulse jet as compared with that of the thrust bearing and the radial bearing is required. The supply pressure is determined at the required minimum film thickness of the thrust bearing.

*2.2 Experimental Apparatus Design*

To evaluate the stable operation for the NTDHRD, an experimental apparatus was developed. Fig. 3 shows a schematic of the experimental apparatus for the tests of NTDHRD. The experimental apparatus is composed of mainly the pump to provide the uniform flow rate, the flow meter, the pressure transducer, and torque simulator to simulate the torque transferred from the silicon ingot through the coupling device.

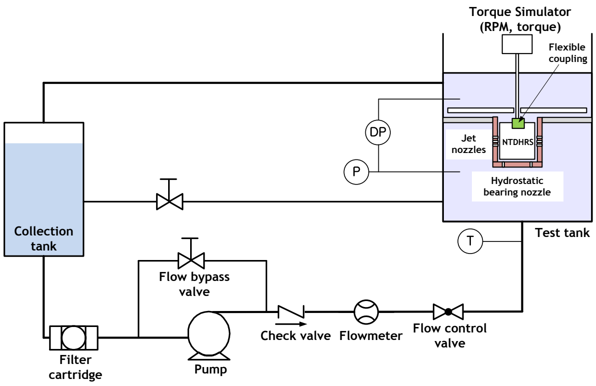


Fig. 3. Schematic of the experimental apparatus for the tests of NTDHRD.

The test tank included the NTDHRD is manufactured with a 700 mm height stainless steel of 500mm diameter, and divided into two parts of the high pressure region in the lower section and the atmosphere region in the upper section. A sight glass is installed in the side of the test tank to see the rotation of NTDHRD and the water level. The fluid from the test tank is collected in collection tank of 2700 mm in height, which is high enough to provide the critical submergence. The fluid through the filter cartridge, which is an inserted 0.01 mm filter, from the collection tank is supplied to the pump, which is a centrifugal type. At the pump outlet, the Swing type check valve is installed to prevent a reverse flow to the pump. The mass flow rate of the supplied fluid is measured by precision mass flow meters of 0.5% accuracy at the pump outlet. To control the supply pressure, a bypass line at the inlet and outlet of the pump is connected. A glove valve at the inlet of the test tank is installed to control the mass flow rate.

An accurate pressure transducer and differential pressure transducer of 0.05% accuracy are used to measure the supply pressure at the lower section of the test tank and pressure drop across the NTDHRD, respectively. The rotation velocity and torque of the NTDHRD are measured by the torque simulator, including the hysteresis break and the torque transducer. To measure the fluid temperature, a thermocouple of 0.1 ℃ accuracy is used. All data are collected by a computer controlled data logger. Fig. 4 shows the experimental apparatus made for the tests of NTDHRD.

Fig. 4. Experimental apparatus for the tests of NTDHRD.

To verify the design of the NTDHRS, the mass flow rates of the thrust bearing part, the radial bearing part, and impulse jet part are measured through separate tests by the sequential drilling processes of the nozzles. These results will be compared with the preliminary computational results. In addition, as the torque simulated from the torque simulator is increased, the rotation velocities (RPM) are measured at a constant supply pressure. These results will be used as a further design database of the NTDHRS.

## 3. Conclusions

The conceptual design of the hydraulic-driven rotation system and experimental apparatus was proposed to make up for the weakness of the former motor-driven rotation system which is needed to enhance the reliability of an NTD system. Through the proposed design, the potential for application to a new NTD rotation system will be verified. It is necessary to conduct a further study to establish this new method completely.

## ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. NRF-2012M2C1A1026909).

## REFERENCES

[1] J.H. Park, Feasibility Study on the Hydraulic-driven NTD Facility, KAERI Internal Report, KAERI/TR-4867, 2013.
[2] W. Brian Rowe, Hydrostatic, Aerostatic and Hybrid Bearing Design, Elsevier, 2013.