Preliminary Test on Hydraulic Rotation Device for Neutron Transmutation Doping

Ki-Jung Park*, Han-Ok Kang, 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) of Si is one of the important applications in the utilization of a research reactor. The Korea Atomic Energy Research Institute (KAERI) is developing a new Research Reactor (KJRR) which will be located at KIJANG in the south-eastern province of Korea [1]. The KJRR will be mainly utilized for isotope production, NTD production, and the related research activities [2]. During the NTD process, the irradiation rig containing the silicon ingot rotates at the constant speed to ensure precisely defined homogeneity of the irradiation [3]. A new NTD Hydraulic Rotation Device (NTDHRD) is being developed to rotate the irradiation rigs at the required speed. In this study, the preliminary test and the analysis for the rotation characteristic of the NTDHRD, which is developed through the conceptual design, are described [4].

2. Methods and Results

2.1 NTD Hydraulic Rotation Device and Experimental Apparatus Design

An important design concept for the 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 the 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 design and picture of the NTDHRD. The NTDHRD is composed of a thrust bearing part, a journal 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 NTDHRD. In order to calculate the thrust load, the weight of the 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 more than 0.3 mm. The nozzle diameter and quantity for the thrust bearing are determined 1.8 mm and 24 by pre-calculation, respectively [5]. The journal bearing part is designed for the support of NTDHRD during thrust and rotation.

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

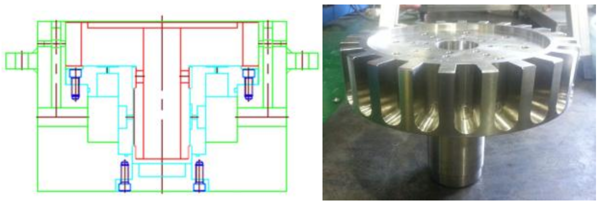

Fig. 1. Design and picture of the NTDHRD.

To evaluate the stable operation for the NTDHRD, an experimental apparatus was developed. Fig. 2 shows a schematic of the experimental apparatus for the tests of NTDHRD. The experimental apparatus is composed of 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.

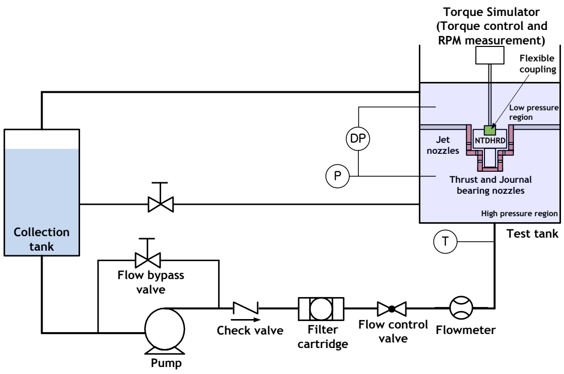

Fig. 2. Schematic of the experimental apparatus for the tests of NTDHRD.

The test tank containing the NTDHRD is manufactured with a stainless steel of 600mm diameter and 765 mm height, 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 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 filter cartridge, which is an inserted 0.01 mm filter element, is installed at the pump outlet. 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 globe 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 speed (RPM) and torque of the NTDHRD are measured by the torque simulator, including the hysteresis break and the torque transducer. Also, the required torque for the NTDHRD is controlled by the hysteresis break. A thermocouple of 0.1 ℃ accuracy is used to measure the fluid temperature. All data are collected by a computer controlled data logger.

2.2 Experimental Results

To verify the design of the NTDHRD, the mass flow rates of the thrust bearing part, the journal bearing part, and impulse jet part are measured through separate tests by the sequential drilling processes of the nozzles. Fig. 3 shows the mass flow rate at each nozzle as a function of supply pressure. As the supply pressure increases, the mass flow rate at each nozzle increases. The pre-calculation results predicted for all measured data with less than 20% deviation.

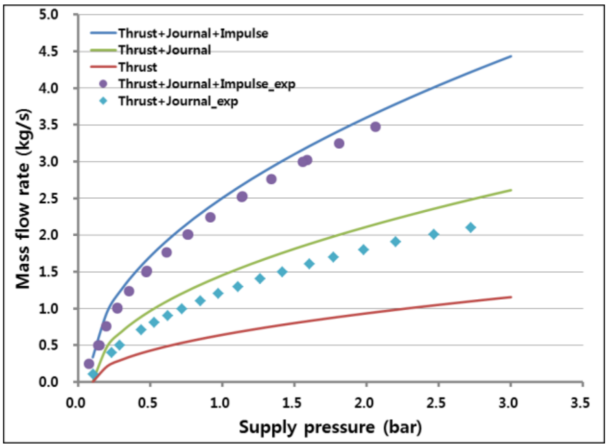

Fig. 3. Mass flow rate at the each nozzle (thrust bearing, journal bearing, and impulse jet).

In order to determine the minimum required supply pressure and mass flow rate, it needs to measure the film thickness, which is the levitation height of NTDHRD, by the thrust bearing. An accurate height-measuring instrument of 1/100 mm accuracy is used to measure the film thickness.

Fig. 4 shows film thickness of the NTDHRD as a function of mass flow rate. As the mass flow rate increases, the film thickness increases. The film thickness by the thrust bearing should be more than 0.3 mm for stable rotation of the NTDHRD [5]. As seen in Fig. 4, the minimum required mass flow rate for rotation should be more than 1.0 kg/s for the NTDHRD under this study. Also, the minimum required supply pressure should be more than 0.2 bar.

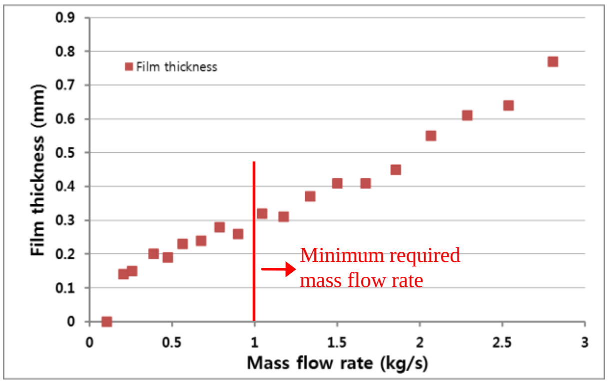

Fig. 4. Film thickness of the NTDHRD as a function of mass flow rate.

Fig. 5 shows the RPM of the NTDHRD as a function of mass flow rate at the torque-free state. The measurement is conducted the different way to confirm the hysteresis effect. First, with increase of the mass flow rate, the RPM is measured. And then, as the mass flow rate is decreased, the RPM at the same mass flow rate is measured. As seen in Fig. 5, the hysteresis effect is not presented.

Test results show that the rotation is started at a specific mass flow rate and the RPM is proportionally increased as the mass flow rate increases. On the same as the results of Fig. 4, the minimum required mass flow rate for stable rotation exists, and the threshold value is around 1.0 kg/s.

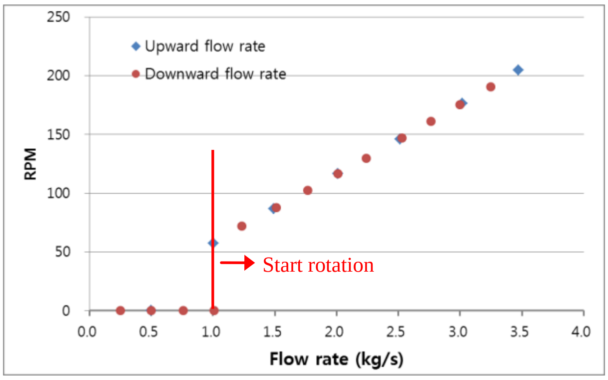

Fig.5. RPM of the NTDHRD as a function of mass flow rate.

In addition, with the increase of the torque simulated from the torque simulator, the rotation velocities (RPM) are measured at a constant mass flow rate. Fig. 6 shows the RPM of the NTDHRD at the constant mass flow rate as a function of the torque. As the simulated torque increases, the RPM gradually decreases.

The irradiation rig is connected with NTDHRD through the coupling device. The major rotational resistance is transferred from the irradiation rig. The external rotational resistance of irradiation rig consists of startup, upper bearing, and shear friction resistances. Each of these values has some uncertainty with long-term operation. To achieve the operational simplicity the rotational speed of the NTDHRD should be designed to be insensitive to the applied external torque. The external torque can vary depending on the manufacturing method and operational history of the irradiation rig. The requirement of the external torque for the optimum irradiation can be predicted in the range of 0.2 ~ 0.8 Nm. As seen in Fig. 6, the target region can be the red block.

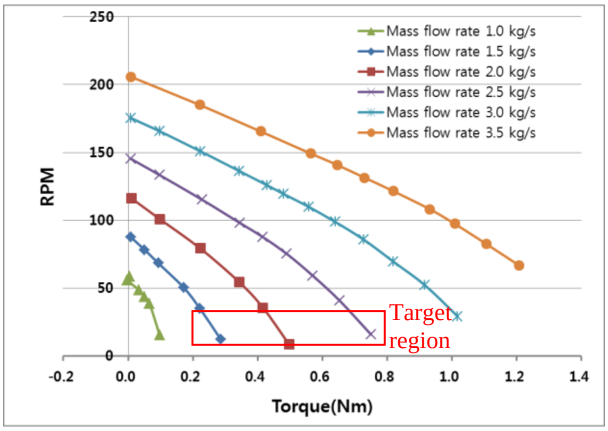

Fig. 6. RPM of the NTDHRD as a function of the torque at the constant mass flow rate.

3. Conclusions

A new NTD hydraulic rotation device is being developed for the purpose of application to the KIJANG research reactor (KJRR). The preliminary test and analysis for the rotation characteristic of the NTDHRD, which is developed through the conceptual design, are conducted in experimental apparatus.

The film thickness by the thrust bearing is measured and the minimum required mass flow rate for stable rotation is determined. The RPM variation as the torque increase is taken. These results will be used as a further design database of the NTDHRD. A further study is necessary to develop an analytic model.

ACKNOWLEDGEMENT

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