Experimental Investigation on Rotation Characteristic of 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 commercial applications in the utilization of a research reactor. During the NTD process, the irradiation rig containing a silicon ingot rotates at a constant speed to ensure a precisely defined homogeneity of the irradiation [1]. A new NTD Hydraulic Rotation Device (NTDHRD) is being developed to rotate the irradiation rigs at the required speed in the Korea Atomic Energy Research Institute (KAERI) [2]. In this study, experimental investigation and analysis on the rotation characteristic of the NTDHRD through the case study of the blade length and flow path variation are described.

2. Methods and Results

2.1 Experimental Apparatus

Fig. 1 shows a schematic of the experimental apparatus used for the testing of the NTDHRD. To evaluate the stable operation of the NTDHRD, an experimental apparatus was developed [2]. The experimental apparatus is composed of a pump to provide a high pressure flow rate, a flow meter, a pressure transducer, and a torque simulator.

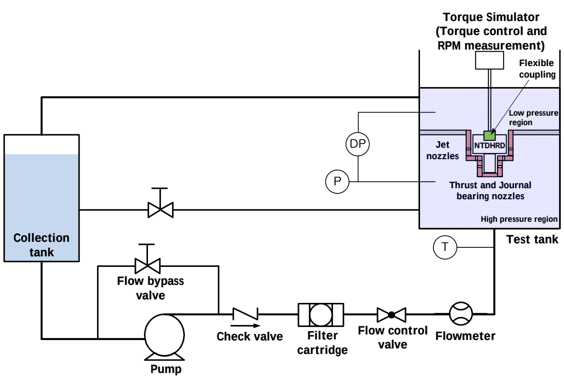


Fig. 1. Schematic of the experimental apparatus for the tests of NTDHRD.

The mass flow rate is measured using precision mass flow meters 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. The rotation velocities (RPM) and torque of the NTDHRD are measured by a torque simulator, including the hysteresis break and the torque transducer. All data are collected by a computer controlled data logger. More details are available elsewhere [2].

2.2 NTD Hydraulic Rotation Device for Case Study

Fig. 2 shows the reference design and image of the NTDHRD for the case study. The NTDHRD, which was developed through the conceptual design, is composed of a thrust bearing part, a journal bearing part, and an impulse jet part [2].

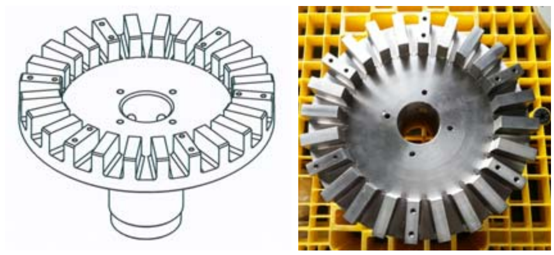
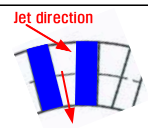
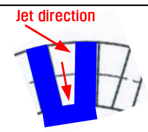
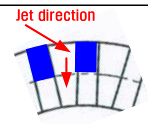
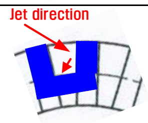


Fig. 2. Reference design and picture of the NTDHRD.

Table I: Test cases as the blade length and flow path between two blades

Test cases	Description	Blade length (mm)	Flow path between two blades
Case 1 (Reference case)		50	Open
Case 2		50	Close
Case 3		25	Open
Case 4		25	Close

The thrust bearing part was designed for a stable levitation of the NTDHRD. The journal bearing part was designed for the support of NTDHRD during thrust and rotation.

The impulse jet part was designed for a uniform rotation of the NTDHRD. In order to determine the blade length and flow path of the NTDHRD, the rotation characteristic of the NTDHRD as the blade length and flow path variation shall be investigated.

To investigate the rotation characteristic of the NTDHRD, the test cases were divided into four cases as the blade length and flow path between two blades as shown in Table I. The blade length was divided into two types, 50 mm and 25 mm. As another case, the flow path between two blades was divided into two types, open and close.

2.3 Experimental Results

To verify the design of the NTDHRD, the total mass flow rate is measured. Fig. 3 shows the comparison of the measured total mass flow rate with pre-calculation as a function of supply pressure. As the supply pressure increases, the total mass flow rate increases. The pre-calculation results showed that measured data are within 5% deviation [3].

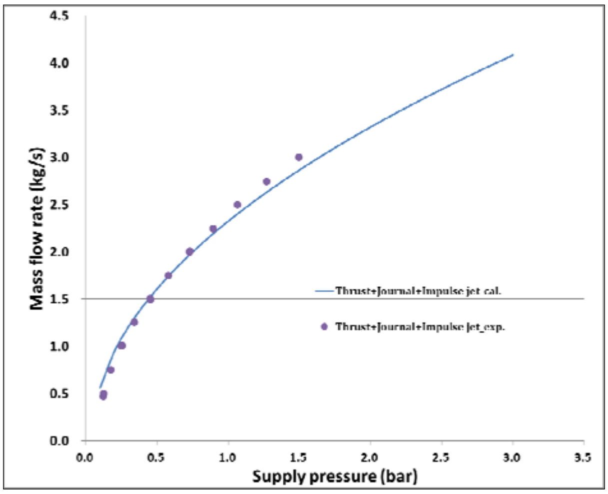


Fig. 3. Comparison of the measured total mass flow rate with pre-calculation.

Fig. 4 shows the RPM of the NTDHRD at a constant mass flow rate as a function of the torque for every test case. With the increase of the torque simulated from the torque simulator, the rotation velocities are measured at a constant mass flow rate. As the simulated torque increases, the rotation velocities gradually decrease for every test case.

Kang's et al. reported that the NTDHRD is operable with low rotation velocity of about 30-50 rpm and the rotation velocity sensitivity for the external torque variation shall be as low as possible to achieve the stable rotation of the irradiation rig [4]. As shown in Fig. 4, initial rotation velocity of case 2 is slower than the result of the case 1 (reference case) and the rotation velocity sensitivity of case 2 for the external torque variation is less than case 1. As these results, in case the flow path between two blades is closed, the rotation characteristic is more stable than open flow path. The rotation velocity and sensitivity of case 3 are similar to the results of case 1. Therefore, the blade length is not related to the rotation characteristic. Also, the rotation characteristic is affected by the nozzle direction of the impulse jet.

The overall rotation velocity of case 4 is slower than the result of the case 1. However, the rotation velocity sensitivity of case 4 for the external torque variation has a same trend with case 1. The rotation velocity sensitivity in case 2 is higher than that in case 4. Therefore, even though the flow path between two blades of two cases is equally-close, the rotation velocity sensitivity is affected by the blade length. The flow stagnant region made by long blade length maintains the rotation power to be less sensitive for the external torque variation

From these results, it can be concluded that the rotation characteristic of case 2 is appropriate for the blade shape of the NTDHRD.

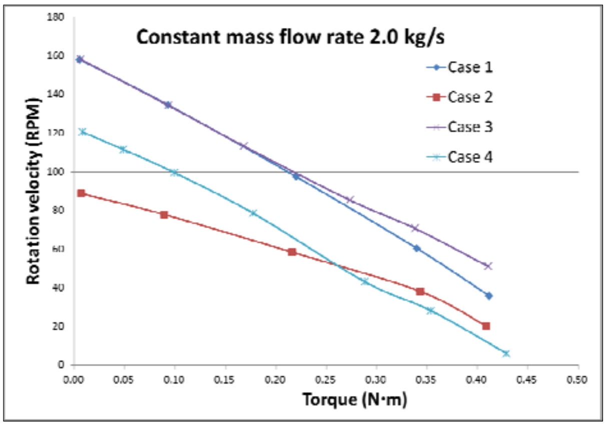


Fig. 4. RPM of the NTDHRD as a function of the torque at the constant mass flow rate 2.0 kg/s.

3. Conclusions

A new NTD hydraulic rotation device is being developed to apply to research reactors. The experimental investigation and analysis for the rotation characteristic of the NTDHRD through the case study of the blade length and flow path variation are conducted in the experimental apparatus.

As the simulated torque increases, the rotation velocities gradually decrease for every test case. In case the flow path between two blades is close, the rotation characteristic is more stable than open flow path. Even though the flow path between two blades of two cases is equally-close, the rotation velocity sensitivity is affected by the blade length. These results will be used as a further design database of the NTDHRD. Further study is necessary to develop an analytic model.

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] K.J. Park, H.O. Kang, Y. Park, S.H. Kim, C. Park, Experimental Study on Hydraulic Rotation Device for Neutron Transmutation Doping, Transactions of 2014 KNS Spring Meeting, KNS, 2014.

[3] W. Brian Rowe, Hydrostatic, Aerostatic and Hybrid Bearing Design, Elsevier, 2013.

[4] H.O. Kang, K.J. Park, Y. Park, Y. Park, S.H. Kim, C. Park, Development of NTD Hydraulic Rotation System for Kijang Research Reactor, Transactions of 2014 KNS Spring Meeting, KNS, 2014.