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Experimental Study on Rotation Characteristic by Material Difference of NTD Hydraulic Rotation Device

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1. Introduction

The Korea Atomic Energy Research Institute (KAERI) is developing a new NTD Hydraulic Rotation Device (NTDHRD) of a Neutron Transmutation Doping (NTD) of silicon for new research reactor [1, 2, 3]. The NTDHRD shall provide the constant rotation of the irradiation rigs containing the silicon ingot in the pool by using the hydraulic force to ensure precisely defined homogeneity of the irradiation during irradiation for the NTD process. In the previous studies [1, 2, 3], the NTDHRD was conceptually designed and manufactured by stainless steel. The experimental apparatus for acquisition of the hydraulic rotation characteristic data of the NTDHRD were developed and the data such as the rotation velocity, supplied pressure, and flow rate were taken [1, 2].

The stainless steel can be compared to the aluminum in terms of the strength, weight, machinability, cost etc. These differences of two materials can affect the manufacture and supply of the NTDHRD in the long term. In this study, in order to ensure the rotation characteristic by material difference of the NTDHRD, the additional NTDHRD is manufactured by aluminum material. The experimental measurement and analysis on the rotation characteristic of the NTDHRD manufactured by aluminum material are performed using the same experimental apparatus of our previous works [1, 2].

2. Methods and Results

2.1 Experimental Apparatus

In this study, the rotation velocities as the variation of the torque applied to the NTDHRD are measured at the supplied flow rate from 1.0 to 2.5 kg/s with interval of 0.5 kg/s using the same experimental apparatus with the same NTDHRD geometry described in Park et al. [1, 2]. Since Park et al. [1, 2] contains all details of the test apparatus, NTDHRD geometry and its manufacture, data measurements, instruments etc., their detail description will not be presented again here. An interested reader is referred to Park et al. [1, 2].

Fig. 1 shows a schematic of the experimental apparatus used for the hydraulic data measurements of the NTDHRD. The experimental apparatus is composed of a pump to provide a high flow rate, a flow meter, a pressure transducer, and a torque simulator.

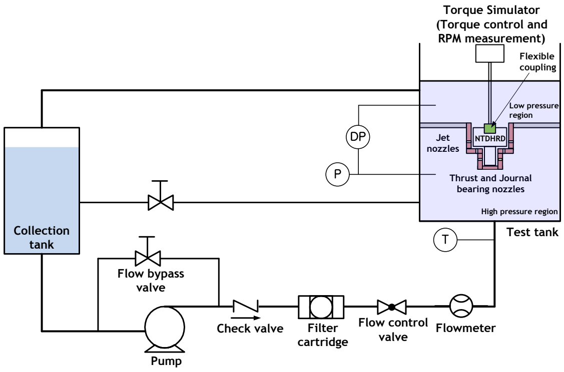

Fig. 1. Schematic of the experimental apparatus for the tests of NTDHRD.

The mass flow rate is measured using precision mass flow meters with 0.5% accuracy at the pump outlet. 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.

Fig. 2 shows the NTDHRD manufactured by aluminum material. 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 [1].

Fig. 2. Picture of the NTDHRD manufactured by aluminum.

2.2 Two Materials of NTD Hydraulic Rotation Device

The stainless steel and aluminum are two most popular materials used in the equipment and structures for the nuclear field. Cost and price are always an essential factor to select when making the product. The price of stainless steel and aluminum is continually fluctuating based on global supply and demand. However, the stainless steel is generally more expensive than aluminum.

The distinctions between the stainless steel and aluminum as the mechanical property are the difference of a density (Stainless steel=7900 kg/m^3 and Aluminum=2700 kg/m^3). The stainless steel is typically 2.5 times denser than aluminum. Since the NTDHRD will be operated in the pool, it is affected by the specific gravity of the material. It is needed to evaluate the effect for the rotation characteristic in the pool by the difference of the material.

2.3 Experimental Results

Before discussing the results, the measured data with aluminum NTDHRD are compared with previous data and pre-calculated results to check the reliability of the experimental apparatus and method since the same experimental apparatus is used for measurement [1, 2]. Fig. 3 shows the comparison of the measured supplied pressure with the pre-calculated results as a function of total mass flow rate. As the total mass flow rate increases, the supplied pressure increases. The pre-calculated results show that measured data are within 20% deviation [4]. From this comparison, the reliability of the test apparatus was confirmed.

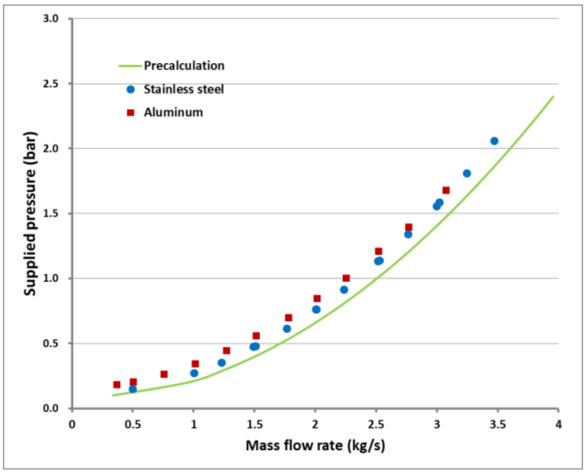

Fig. 3. Comparison of the measured supplied pressure with pre-calculated results.

Fig. 4 shows the rotation velocities (RPM) of the NTDHRDs manufactured by the stainless steel and aluminum as a function of the mass flow rate in a torque-free state. First of all, with an increase of the mass flow rate, the RPMs of the two NTDHRDs are identically increased. The RPMs of the stainless steel NTDHRD are proportionally increased with an increase of the mass flow rate. However, at the mass flow rate range of more than 2.0 kg/s, the RPM increase rate of the aluminum NTDHRD is decreased less than that of the stainless steel NTDHRD. Since the inertia moment of the aluminum NTDHRD is less than the stainless steel NTDHRD in the pool, these results can be guessed that the rotation force of the aluminum NTDHRD is not maintained at the high rotation velocity range of more than about 120 RPM. Therefore, it can be concluded that the stainless steel NTDHRD is appropriate for the proportional increase of the rotation velocity and larger rotation velocity at the high rotation velocity range. However, since the target rotation velocity range for high performance NTD is less than 50 RPM, the rotation performances of two NTDHRDs are similar.

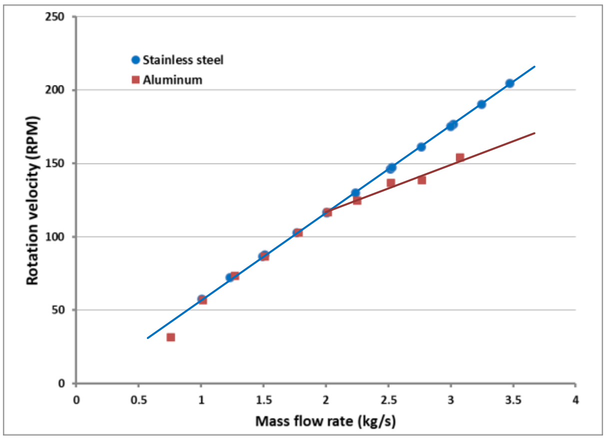

Fig. 4. Rotation velocities of the NTDHRDs manufactured by the stainless steel and aluminum as a function of the mass flow rate in a torque-free state.

Fig. 5 shows the rotation velocities of the NTDHRDs manufactured by the stainless steel and aluminum at a constant mass flow rate as a function of the torque. With the increase of the torque, the rotation velocities are measured at a constant mass flow rate. As the simulated torque increases, the rotation velocities gradually decrease for both of two NTDHRDs.

As shown in Fig. 5, in case the rotation resistance such as a torque force is applied to the NTDHRD, there are no distinct differences of the rotation characteristic such as the rotation velocity and rotation decrease rate between the NTDHRDs manufactured by the stainless steel and aluminum.

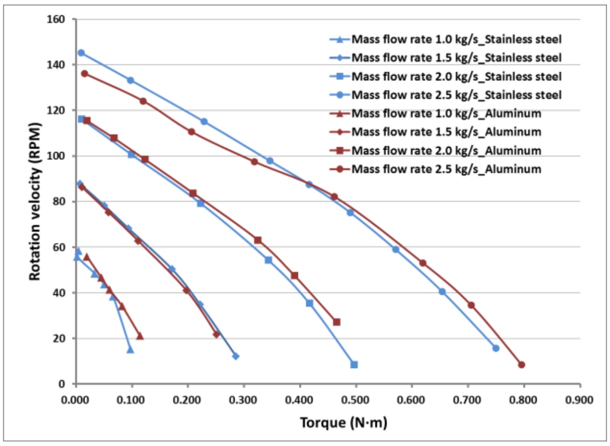

Fig. 5. Rotation velocities of the NTDHRDs manufactured by the stainless steel and aluminum as a function of the torque at the constant mass flow rate.

From these results, it can be concluded that at the range of less than the rotation velocity 50 RPM, which is target rotation velocity, because there is no distinct difference of the rotation characteristic between the NTDHRDs manufactured by the stainless steel and aluminum, the aluminum can be suggested as the NTDHRD material in terms of the weight, machinability, cost etc.

3. Conclusions

The experimental measurement and analysis on the rotation characteristic of the NTDHRDs manufactured by the stainless steel and aluminum material were performed using the same experimental apparatus of our previous work.

In torque-free test, the rotation performances of two NTDHRDs are almost same at the range of less than the rotation velocity 50 RPM. In case the rotation resistance such as a torque force is applied to the NTDHRD, as the simulated torque increases, the rotation velocities gradually decrease for both of two NTDHRDs. However, there is no difference of the rotation characteristic between the NTDHRDs manufactured by the stainless steel and aluminum. These results show that the aluminum can be suggested as the NTDHRD material in terms of the weight, machinability, cost etc.

ACKNOWLEDGEMENT

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