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Development of NTD Hydraulic Rotation System for Kijang Research Reactor

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1. Introduction

The Korea Atomic Energy Reseach 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 (Neutron Transmutation Doping) production, and related research activities [2]. During irradiation for the NTD process, the irradiation rigs containing the silicon ingot rotate at a constant speed to ensure precisely defined homogeneity of the irradiation. A new NTD Hydraulic Rotation System (NTDHRS) is being developed to rotate the irradiation rigs at a constant speed and supply cooling flow for the irradiation rigs and reflector assembly. The NTDHRS requires only hydraulic piping conveniently routed to the rotating devices inside the reactor pool. The resulting layout leaves the pool area clear of obstructions which might obscure vision and hinder target handling for operators. Pump banks and control valves are located remotely in a dedicated plant room allowing easy access and online maintenance. The necessities and major characteristic of NTD hydraulic rotation system are described in this study.

2. NTD Hydraulic Rotation System

2.1 Configuration of NTD Hydraulic Rotation Device

NTD can be used to dope silicon by changing silicon atoms into phosphorous through neutron radiation. NTD doping is superior in its controllability and homogeneity, and is widely used by semiconductor manufacturing industries developing high power devices. The silicon NTD process has been used to produce a high-quality semiconductor with precisely defined resistivity, thereby increasing the efficiency of the silicon in conducting electricity. Semiconductor quality is ensured by a high thermal to fast neutron flux ratio, and high axial and radial neutron flux uniformity over the silicon target. Radial uniformity of irradiation is assured by continuous rotation of the ingot in the rig. Axial uniformity is achieved by the use of a flux flattening device. During irradiation, the rigs containing silicon ingots are rotated by a hydraulic mechanism to ensure the precisely defined homogeneity of the irradiation.

The main role of the NTDHRS is to rotate the irradiation rigs at a constant speed and supply cooling flow for the irradiation rigs and reflector assembly. The NTDHRS requires only hydraulic piping conveniently routed to the rigs inside the reactor pool. The resulting layout leaves the pool area clear of obstructions which might obscure the vision and hinder the target handling for operators. Pump banks and control valves are located remotely in a dedicated plant room allowing easy access and online maintenance.

The NTDHRS consists of hydraulic rotation devices, NTDHRS pumps, control valves, strainer, and all the necessary inter-connecting pipes, isolation valves, and instruments. One NTDHRS pump can supply high-pressure water flow to the outlet plenum assembly. Its role in NTDHRS is providing a common pressure header for the inflow to hydraulic rotation devices. Water transfers its momentum to a hydraulic turbine of the hydraulic rotation device and then cools the irradiation rig and reflector assembly located above the outlet plenum assembly.

The newly developed hydraulic rotation device consists of stationary rig, hydraulic turbine, coupling device, and cooling flow pathes as shown in Fig. 1. For the neutron irradiation, the irradiation rigs are loaded into the irradiation holes using the NTD rig driving device. The irradiation rigs are connected with hydraulic rotation devices through the coupling device. The impulse jet from a stationary rig provides the rotation force on the hydraulic turbine. The impulse jet loses its kinetic energy while passing the rotating rig and enter the cooling path inside and the outside of irradiaiton rig, and reflector assembly.

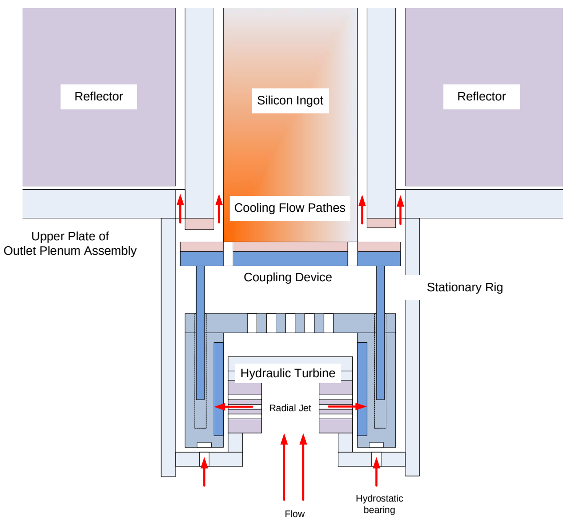

Fig.1. NTD hydraulic rotation device

The coupling device transmits the rotational torque from the rotating rig to the irradiation rig. A hydrostatic bearing is introduced to assure the stable rotation of hydraulic turbine at the low speed. The hydrostatic bearing gives several advantages compared to hydrodynamic bearing such as high bearing film stiffness, low starting torque, high accuracy of location, and good dynamic stability.

2.2 Performance Improvement of NTD Hydraulic Rotation Device

The NTD hydraulic rotation devices are located inside the outlet plenum assembly. Works requiring the access to the device directly such as the maintenance and replacement of the components are limited due to the high radiation level. It is necessary to design the device with higher durability to minimize any corrective action and maximize the replacement period. The hydrostatic bearings are introduced to cope with the load from the thrust and radial directions. Using reactor pool water as the working fluid, the hydrostatic water bearing system ensures no physical contact between the moving parts during operation thereby minimizing or eliminating mechanical wear and tear.
The NTDHRS consists of hydraulic rotation devices, NTDHRS pumps, and control valves. The design goal of NTDHRS is to minimize the necessities of the operator intervention or complicated control logic for stable operation. There are two types of irradiation holes in the Kijang research reactor: one for 6 inches and the other for 8 inches. The required flow rate for each device is maintained through the adequate nozzle diameter design. The variation of the number of operating devices depending on the customer demand can change the inflow to each device due to the overall system flow-resistance characteristics variation. The decrease of inflow to each device can induce the deterioration of cooling capability of silicon ingot and reflector assembly and so its occurrence has to be prevented. The flow rate to each device is maintained to be constant without dependency on its operational status. Even though the irradiation can is not loaded, pool water is injected into the corresponding device. Through this approach, we can guarantee the cooling capability of the silicon ingot and reflector assembly regardless of the number of rotating devices.
The device itself is designed to minimize the rotational resistance through the hydrostatic bearing and careful manufacturing procedure. The clearance between rotational and stationary parts is minimized for the stable rotation with the minimum eccentricity. It is also important to keep the surface roughness within the design limit through the adequate surface treatment. The orthogonality between the thrust and radial surfaces can have an effect on the rotational performance and durability of the device.

The irradiation rigs are connected with hydraulic rotation devices through the coupling device. The major rotational resistance is transferred from the irradiation rigs. The external rotational resistance of the irradiation rig consists of the 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 NTD hydraulic rotation device should be designed to be insensitive to the applied external torque. The concept can be described as shown in Fig.2. The external torque can vary depending on the manufacturing method and operational history of the irradiation rig. The blue line with less sensitivity to the applied external torque shows a better performance. To achieve this trend, the following approaches are pursued:

- Jet nozzle pressure drop increase
- Jet velocity increase
- Jet shading fraction decrease
- Larger number of blades
- Thrust bearing stiffness increase
- Journal bearing stiffness increase

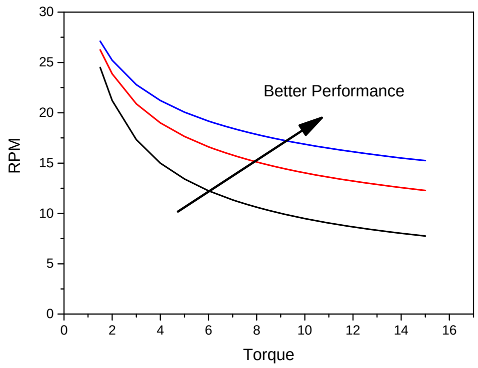

Fig.2. The relationship between the rotational speed and external torque in the NTD hydraulic rotation device

4. Conclusions

A new NTD hydraulic rotation system are being developed to rotate the irradiation rigs at a constant speed and supply cooling flow for the irradiation rigs and reflector assembly. The configuration of the NTD hydraulic rotation device is discussed and practical methods to improve the rotational performance are suggested.

ACKNOWLEDGEMENT

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