Preliminary Test on Characteristics of Canned Motor for Reactor Coolant Pump

Hyuntae Lim[a*], Byeonggeon Bae[a], Tae-Kyoon Kim[a], Jihoon Lee[a]

[a]*Korea Atomic Energy Research Institute, 989, Daedeok-daero, Yuseong-gu, Daejeon, 34057, South Korea*
[*]*Corresponding author: limht@kaeri.re.kr*

***Keywords : canned motor pump, motor efficiency, reactor coolant pump, small modular reactor**

1. Introduction

The Small Modular Reactor (SMR) integrates key components such as the reactor, steam generator, reactor coolant pump, and pressurizer into a single reactor pressure vessel by modularizing these main devices. Unlike conventional large-scale reactors in which each component is connected via piping, all devices in an SMR are housed within one pressure vessel. This design significantly reduces the risk of radioactive release in the event of a loss-of-coolant accident caused by piping rupture. In addition to enhanced safety, SMRs are being developed worldwide in various forms based on their flexibility and cost-effectiveness.

In an SMR, the reactor coolant pump is a critical component that circulates the reactor coolant to transfer the heat generated in the core to the steam generator. The reactor coolant pump is comprised of the hydraulic unit, the motor unit, the pressure casing unit, the cooling unit auxiliary, and the rotating shaft assembly. The electric motor is responsible for converting electrical energy into rotational power. In particular, it is crucial to accurately understand the performance and characteristics of the motor for the stable operation of the reactor coolant pump. In this study, we aimed to determine the characteristics of the SMR coolant pump's motor under various load conditions through experimental tests. The motor under development is a canned motor type motor that is integrated within the pump. As a result, direct measurement of the shaft output is not possible, and the efficiency cannot be directly determined. Therefore, a test setup using a dynamometer and a torque meter was configured to evaluate the motor characteristics. The tests were conducted under fixed frequency conditions. The data thus obtained allowed us to calculate the motor slip, shaft power, and overall efficiency. These results can be used to optimize the motor's operation and confirm the pump performance during hydraulic performance tests, and they are expected to serve as an important basis for future design improvements and enhanced safety of the SMR coolant pump.

2. Experimental facility

To measure the performance of the canned motor type motor, which is integrated into the coolant pump, the upper cover, hydraulic parts(impeller and inlet bell) of the existing coolant pump were disassembled. An assembly comprising an impeller dummy, hydrostatic jig, mechanical seal, mechanical seal housing, and supports was then arranged for the test. The upper cover was removed to connect the shaft of the main coolant pump to the testing equipment (dynamometer and torque meter). Additionally, the hydraulic parts were removed to eliminate the load produced by the pump. After then, these parts were reassembled with the housing and hydrostatic jig to create a coolant pump assembly for the motor performance test. As shown in Figure. 1, the torque meter and shaft are aligned and connected via a coupling to facilitate torque measurement and dynamometer connection. Moreover, to cool the motor, the sealed internal space of the coolant pump is filled with water from a coolant supply source, and continuous circulation is maintained through a chiller. Figure. 2 illustrates the schematic of the test circuit with measured parameters used for the motor performance test.

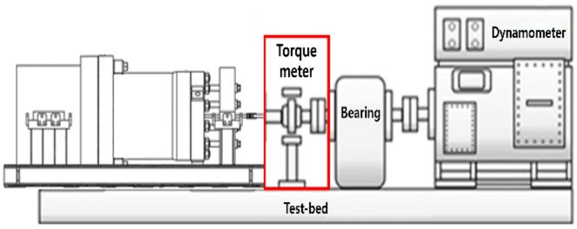


Fig. 1. Schematic Diagram of the Motor Performance Test

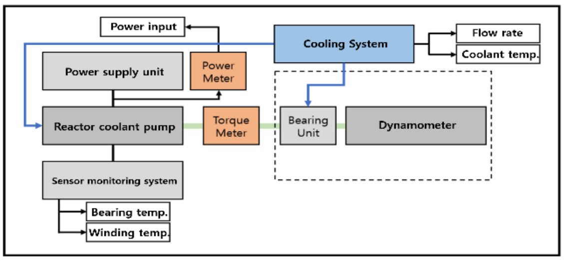


Fig. 2. Schematic Diagram of the Test Apparatus Circuit

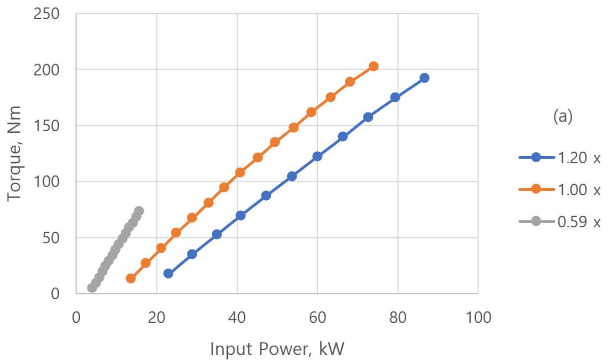
3. Experimental conditions

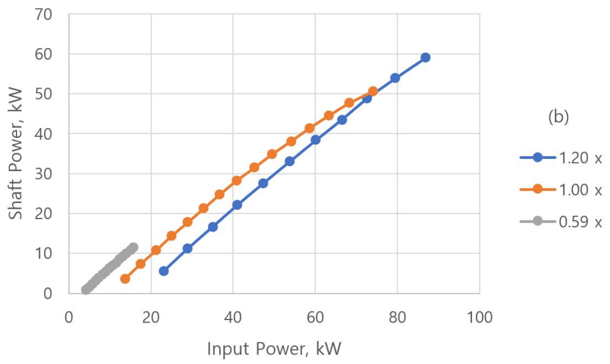
The motor performance test for the pump involved measuring various parameters such as frequency, rotational speed, current, voltage, power, input power, and torque to determine the slip, shaft torque, and motor efficiency. The tests were conducted for three fixed rotational speed conditions. For each case, the test was conducted by applying the predetermined frequency via the power supply unit. The dynamometer system was then used to incrementally adjust the load in 10% steps up to the maximum torque and data were acquired at 20 measurement points per case. To ensure reliability, each test case was repeated three times and the corresponding measured values were cross-verified.

4. Experimental results

The actual rotational speed of the motor is determined by the slip caused by the load depending on the characteristics of the induction motor. Slip is defined as the difference between the synchronous speed and the actual speed. As the load increases, the rotational speed decreases, leading to higher slip. Consequently, the motor requires additional input power to generate the necessary torque, which in turn affects both the overall efficiency of the motor and the shaft power. The overall efficiency in Figure 3(c) shows a rapidly increase from 0.6 to 0.7 before converging. This behavior reflects the motor's response to increase load, where at a certain point, the motor demands additional torque and the resulting increase in slip reaches its limit. Changes in efficiency in relation to slip accurately reflect the characteristics of the induction motor. On the other hand, the shaft power increases gradually as the input power increases relative to torque. This is because as the input power and slip increases, the actual rotation speed decreases, which affects the shaft power, which is product of torque and rotational speed.

As a result, the observed variations in efficiency and shaft power with respect to slip accurately reflect the engineering characteristics of motors. These findings serve as valuable baseline data for evaluating the performance and determining the optimal operating conditions of the motor in the coolant pump for the SMR.





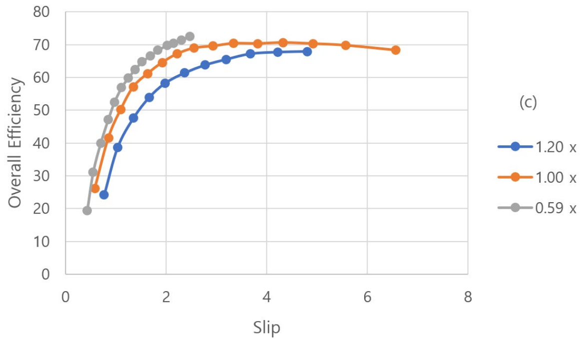


Fig. 3. Test Result for Motor Characteristics:
(a) Torque vs. Input power, (b) Shaft power vs Input power,
(c) Overall Efficiency vs. Slip

5. Conclusions

A performance test was conducted for the pump motor of a novel small reactor. In this study, the performance of the canned motor built in reactor coolant pump for the SMR was measured and analyzed through experimental methods. By measuring and analyzing multiple parameters including current, voltage, power, input power, and torque under the fixed frequency conditions, the motor slip, shaft power, and overall efficiency were obtained.

The test results showed that the motor efficiency increases rapidly at low slip values and then stabilizes gradually once the slip reaches approximately 0.6 to 0.7. This characteristic reflects the process whereby the motor consumes additional power for energy conversion as the rotational speed decreases and slip increases with higher loads. Furthermore, the observed relationship between input power and shaft power under various load conditions confirmed the expected performance characteristics, thereby attesting to the reliability of the test system. These findings can be utilized as fundamental data for the efficient design and stable operation of SMR coolant pumps. In the future, the results are expected to contribute significantly to performance improvements and enhanced safety of these systems.

REFERENCES

[1] Development of RCP Characteristic Models for the ATLAS Facility, Ki-Young Choi, 2008