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Load Test of Motor Equipment Qualification and Associated Test Apparatus

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1. Introduction

Equipment qualification(EQ) of Class 1E motor used in nuclear power plant is performed in compliance with such standards as IEEE Std 323[1], 334[2] and 112[3]. IEEE Std 323 is the general standard of EQ, IEEE Std 334 the specific qualification standard about motor, and IEEE Std 112 the standard for motor functional test. All these standards describe the general test contents and sequence for EQ but do not include the details for test execution method, test device specifications and performance criteria.

Functional test of motor EQ consists of insulation resistance test, winding resistance test, no-load test and load test. Considering that these tests should be performed in the test chamber during LOCA(Loss of Coolant Accident) test, the load test is the most difficult test due to loading the motor by a mechanical or pneumatic loading device.

In this study, we have developed two types of test apparatuses for the load test of Class 1E motor and performed the load test with a couple of motors. We have confirmed the suitable applicability of the developed apparatuses for EQ functional test and performance characteristics of those test specimens.

2. Load Test of Motor

Load test of motor is to measure temperature rise of motor windings under the maximum operating current and loading condition. The temperature rise means temperature difference between surrounding and winding when the temperature of winding is saturated. The load test may evaluate degree of performance degradation of motor, because the temperature rise represents a sum of various losses such as windage loss, friction loss, stator loss, rotor loss, core loss, stray-load loss and brush-contact loss of motor. Operating current of motor will increase if the loading apparatus retards the rotating force of motor driving shaft.

Schematic diagram of the test device for load test is presented in Figure 1. The shaft of motor is extended to loading apparatus by extension shaft because all devices except motor specimen are located out the LOCA test chamber. The motor driving shaft is then carefully aligned with the extension shaft to decrease driving power loss and shaft vibration. Multi-meter, torque meter and tachometer are equipped for measuring operating current & voltage, torque and rotating speed of the shaft. Data acquisition(DAQ) system reads and writes measured signals from those. The no-load test is also possible to perform with only the equipment in dotted line in Figure 1.

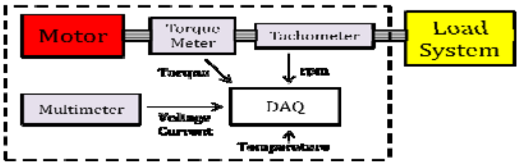


Figure 1. Schematics of load test

We have devised two types of loading apparatus; the electrical loading apparatus and the mechanical loading apparatus.

2.1 Electrical Loading Apparatus(ELA)

ELA uses magnetic force to load motor by resisting to rotating force of motor shaft. General equipment generating electrical load is a powder brake which uses a concept to transfer the magnetic force into magnetic powder with alloy of Fe, Al, Cr. The current passing through the coil in the brake generates a magnetic field, which changes the property of the powder, thus producing a braking torque through friction. The powder brake is suitable for operating range in low to middle speed less than 1,000 rpm and in middle to high torque less than 200 N·m. The developed ELA with the powder brake is presented in Figure 2.

2.2 Mechanical Loading Apparatus(MLA)

MLA uses a frictional force or a dynamic force as the load source. The frictional loading apparatus uses a physical contact method that a brake pad with rough surface clutches, directly or indirectly, rotation of a motor shaft. On the other hand, the dynamic loading apparatus(DLA) uses method to transfer rotating force of motor into dynamic force of other equipment such as a hydraulic pump. As increasing fluid pressure in the pump, the load applied to motor also increases. In MLA, attention should be paid to suppress the excessive temperature rise by a friction. A cooling system for heat removal has been designed considering thermal property of the main materials such as the brake pad or the fluid employed.

In this study, we developed the DLA as presented in Figure 3. Main equipment of the system are a oil pump, oil & water reservoir, cooler, water pump and relief valve.

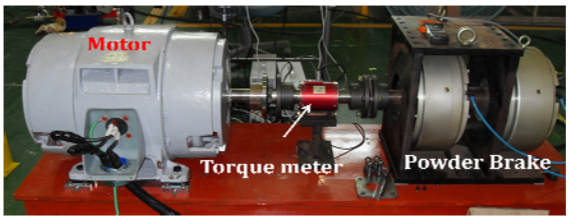


Figure 2. Electrical loading apparatus

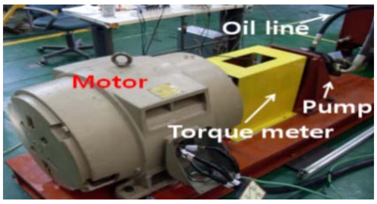


Figure 3. Dynamic loading apparatus

3. Experiment and Results

We performed the load tests for motor EQ with above-mentioned loading apparatuses in compliance with IEEE standards. Two test specimens, M-1 and M-2, are presented in Table 2. The load test of the M-2 was only performed by DLA due to capacity limitation of a powder brake. The general procedure of the load test is as follows;

1. Install the motor in the load test system.
2. Operate the motor with rated voltage and no-load condition.
3. Increase the load by the loading apparatuses until the operating current of motor increases to maximum value presented in Table 1.

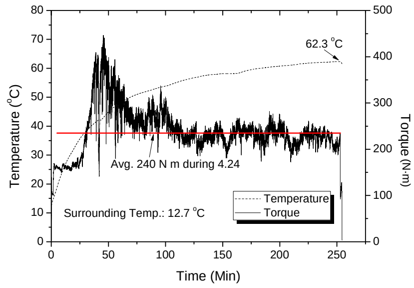
The developed apparatus have continuously measured the speed of revolution, torque and temperature of windings throughout the test. Figure 4 shows the test results which are temperature of windings and torque with elapsed time of testing. In case of the M-1, the temperature of windings attained the peak condition after operating during 4.24 hours under the average load of 240 N·m. In case of the M-2, the saturated time and average load were 1.98 hours and 492 N·m, respectively. The temperature rises are 49.6 ^{o}C and 44.4 ^{o}C, respectively. During the test with DLA, the surface temperature of oil reservoir increased to approximately 70 ℃ and 100 ℃ in case of M-1 and M-2, respectively, due to heat generation. In ELA, the surface temperature of a powder brake increased to about 70 ℃.

4. Conclusion

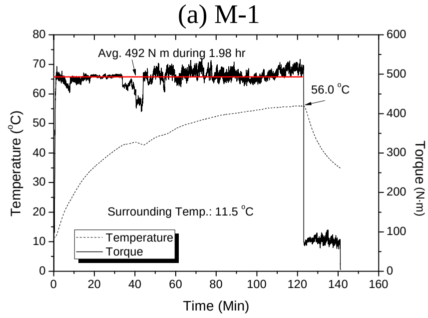
For load test in functional tests of industrial and Class 1E motor, two types of loading apparatuses, electrical and dynamic apparatus, have been developed. The loading apparatus successfully performed the load test of two motor specimens. Figure 4 shows that the developed loading apparatus is suitable for motor load test and the performance characteristics of the motors can be used as baseline functional data for EQ test.

Table 1. Specification of motors for load test

Specification \ Specimen	M-1	M-2
Power [kW]	30	75
Max. current [A]	45.5	17.9
Rated voltage [Vac]	460	4,160
Speed [rpm]	1,800	1,800
Type	Hermetic	Semi-hermetic



(a) M-1



(b) M-2

Figure 4. Measured winding temperature and torque with elapsed time for motor load testing

The ELA is easy to install with motor and operate on testing. The DLA needs to decrease temperature of oil and equipment due to limitation of thermal property of them. This limitation makes the apparatus complicated. The pump noise due to operating in condition of high pressure(about 200 atm) is another obstacle. However, the DLA is cheaper and available to perform the load test of the motor with larger capacity and higher rotating speed than the ELA. Characteristics of two load system are described in Table 2.

Table 2. Characteristics of electric and dynamic loading apparatus

	Electric	Dynamic
Good	•Easy to installing and operating •Low heat generation	•Cheap(1,000 $<) •Available to high capacity motor
Weak	•Expensive(2,000 $>) •Limitation of rpm, capacity • Periodic replacement of magnetic powder	•Complexity due to heat removal system (pump, oil, cooler, oil and cooling water reservoir, relief valve) •Noise on operating •Large occupancy •Difficult maintenance

REFERENCES

[1] IEEE Std 323, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations" (1974,1984,2003).
[2] IEEE Std 334, "IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating stations" (1974,1994,2006).
[3] IEEE Std 112, "IEEE Standard Test Procedure for Polyphase Induction Motors and Generators" (1984, 1991, 1996, 2004).