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A study on the efficiency behavior of Limitorque Actuators for Motor Operated Valves

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1. Introduction

A motor operated valve (MOV) consists of a motor, an actuator, and a valve, and is an essential element to control the piping flow in a nuclear power plant. In fact, the operational failure of a safety-related MOV can have catastrophic results. Therefore, by the regulatory requirement, the operability of the safety-related MOVs should be ensured. The requirement recommends utilities to consider the fact that aging can decrease the thrust/torque output of actuators [1]. Up until now, it has been assumed that the actuator efficiency, one of the most important factors in evaluating the actuator output, does not degrade over time.

The purpose of this paper is to confirm the validation of the design efficiency by analyzing the efficiency behavior over time for Limitorque actuators. The diagnostic field test data are used in the calculation of actuator efficiency and its behavior analysis over time.

2. Calculation of actuator efficiency

2.1. Data acquisition

As described in Section 1, the diagnostic field tests have been conducted to ensure the motor actuator output of safety-related MOVs for 20 units of nuclear power plants from 1999 to the present. For each valve, more than two tests have been conducted. The first test is the design basis test from 1999 to 2004, and the second is the periodic test from 2005 to present. Each test is composed of one 'as-found' and two 'as-left' tests to compare and analyze conditions before and after maintenance jobs, according to the field test procedures. In the tests, the actuator torque and the three phases of currents and voltages were measured from the strain gage type sensor attached on the stem, and current and voltage probes installed at the power lines toward the actuator, respectively. Figure 1 shows the sensors installed to measure currents and voltages at the valve.

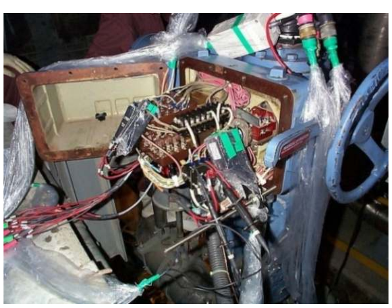

Fig 1: A picture of installed sensors at a field test

2.2. Efficiency calculation

The actuator efficiency is a factor transferring motor torque produced by an electric motor into actuator torque, necessary in rotating actuator inner gears. The typical efficiency can be calculated using the following expression:

$$\eta = \frac{Tq}{MTq \times OVR} \quad (1)$$

Where η is the actuator efficiency, $Tq[ft-lb]$ is the actuator torque, $MTq[ft-lb]$ is the motor torque, and, OVR is the overall gear ratio provided by the manufacturer. In this study, the equation (1) was used to calculate the efficiency. The measured actuator torque in the field tests was applied directly for the equation (1), but the motor torque was not measured directly in the field tests. Accordingly, the motor torque was estimated by a motor torque estimator, NEET, which can estimate the motor torque using the three phases of currents and voltages, and resistance values between phases measured in the field tests [2]. By substituting the three parameters into the equation (1), the efficiency was calculated.

2.3. Efficiency behavior analysis process

As known in equation (1), actuator efficiency is dependent on motor torque, actuator torque, and the overall gear ratio. The most important factors in determining the motor torque output and actuator torque output are motor speed and motor torque rating respectively. Accordingly, the motor speed, maximum motor torque rating, and overall gear ratio were selected as major factors in analyzing the efficiency behavior. The Limitorque design information about those factors is described in Table 1.

Motor Speed (RPM)	Actuator Model	Overall Gear Ratio	Max. Torque Rating	Design Efficiency
1800	SMB-000	33.5~62.5	120	0.4
	SMB-00	23~81.1	260	0.4
	SMB-0	34.9~54.8	700	0.4
	SMB-1	50.4~60.1	1100	0.4
		103.2		0.35
	SMB-2	26.4~67.4	1950	0.4
	SMB-3	53.7~70.9	4200	0.4
		98.6		0.38
3600	AMB-000	36.5	120	0.4
	SMB-00	34.1~41	260	0.45
		67.5		0.4
	SMB-0	31.3~39.1	700	0.45
	SMB-1	27.2~35.9	1100	0.45
	SMB-2	46.6~82.5	1950	0.4
	SMB-3	66.1~70.9	4200	0.4

Table 1: Design information of tested valve

The efficiency behavior by the three factors described above was analyzed according to the following process:

(a) Analyze the distribution of the avg. 'as-left' and 'as-found' efficiencies based on the test-to-test time interval in order to address the potential degradations with the passage of time. The time interval covers the efficiency variations over a period of several years.

(b) Compare the avg. 'as-left' and 'as-found' efficiency with the design efficiency.

3. Efficiency behavior

3.1. Motor speed

Figure 2 depicts the actuator efficiency distribution for the avg. 'as-left' efficiency (◇ blue), 'as-found' efficiency (□ red), and △efficiency (△ green). In the figures, the x-axis is the time interval between the design basis test and the periodic test. The y-axis includes the actuator efficiency and △efficiency (-0.2 to +0.2). The figures also include the design efficiency provided by manufacturer.

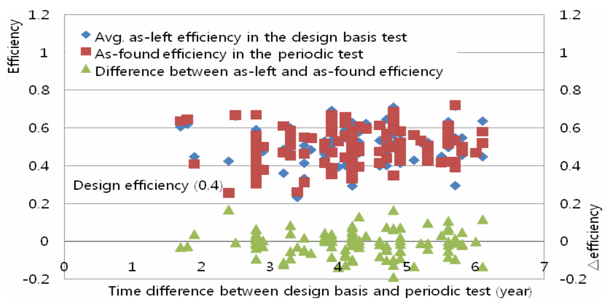

Figure 2a: Efficiency distribution by motor speed 1800 RPM

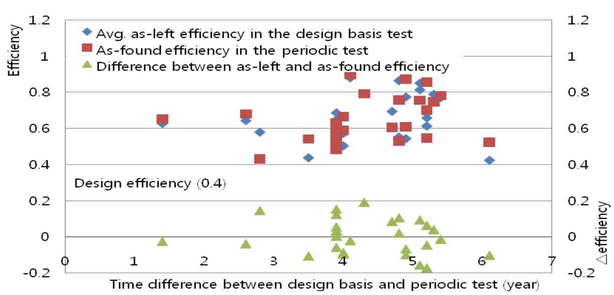

Figure 2b: Efficiency distribution by motor speed 3600 RPM

The efficiency distribution of the actuators with design efficiency, 0.4 was shown in Figure 6 by the motor speed 1800 RPM (Fig. 2a) and 3600 RPM (Fig. 2b). In both figures, △efficiency was distributed in the positive and negative areas evenly over time. The actuator efficiencies have variations in efficiency from test-to-test, but no increasing or decreasing trend over time. However, most of the actuators with 3600 RPM are observed to possess greater efficiency than the design efficiency, 0.4, while some actuators with 1800 RPM have lower efficiency than the design efficiency. From those observations, we concluded that motor speed does not affect the age-related or service-related degradation, while the efficiency of actuators with 1800 RPM can be susceptible to a decrease below the design efficiency.

3.2. Overall gear ratio

In order to analyze if the OVR affects the potential degradation in efficiency, the various OVRs were grouped by 20~40, 40~60, and 60~80. The design efficiency of the groups is 0.4. The △efficiency by group was distributed in the positive and negative areas evenly over time. The actuator efficiencies have variations in efficiency from test-to-test, but no increasing or decreasing trend over time. However, the greater number of actuators was distributed in the area below design efficiency as the OVR increased. From those observations, we concluded that OVR does not affect the age-related or service-related degradation, while the efficiency of actuators with more OVR can be susceptible to a decrease below the design efficiency.

3.3. Maximum motor torque rating

The efficiency distribution of the various actuators was analyzed by the maximum motor torque rating. The △efficiency by motor torque rating was distributed in the positive and negative areas evenly over time. The actuator efficiencies have variations in efficiency from test-to-test, but no increasing or decreasing trend over time. From these observations, maximum motor torque rating does not affect the efficiency degradation over time, but lower motor torque rating could have lower efficiency than the design only, for 120 and 260 of maximum motor torque rating with the 1800 RPM motor.

4. Conclusions

The actuator efficiency has variations in efficiency from test-to-test, but no increasing or decreasing trend over time. In other words, there is no potential degradation in efficiency due only to the passage of time. Under certain conditions, however, decreases in efficiency to below the design efficiency were observed. Specifically, the actuators with low speed, low actuator size, and high gear ratio are susceptible to decrease in efficiency. However, these decreases tend to occur progressively down to a plateau level because those actuators have variations in efficiency from test-to-test, but no increasing or decreasing trend over time.

Accordingly, when it is assumed that design efficiencies are pertinent for some actuators, it can be possible to evaluate the potential degradation in design efficiencies only for the actuators with lower speed motor, lower actuator size, and higher gear ratios based on the results of this paper.

REFERENCES

[1] JOG, Joint Owners' Group (JOG) Motor Operated Valve Periodic Verification Program Summary, 2004.

[2] Shincheul Kang, 2006. Motor Control Center (MCC) Based Technology Study for Safety-Related Motor Operated Valves, Nuclear Engineering and Technology, Vol. 38, No. 2, 155-162.