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Consideration on abnormal signal graphs during diagnostic testing of air-operated valves (AOVs) in NPPs

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1. Introduction

In nuclear power plants, there are air-operated valves (AOVs) that perform safety functions in the event of an accident. Since these valves perform a very important role in stabilizing the power plant after an accident, their performance must be evaluated on a regular basis. Therefore, periodic valve diagnostic tests should be performed to identify factors that impede valve performance and remove these obstacles to improve performance margins. By analyzing abnormal signal graphs during diagnostic tests, you can identify obstacles. The purpose of this study is to analyze the mechanical condition of the valve through abnormal signal graphs.

2. Main subject

2.1 Typical graph for Valve/Actuators

The valve/actuator graph will typically show the results of the actuator air pressure plotted on the Y-axis versus valve stroke displacement on the X-axis (Fig 1). Figure 1 shows the relationship between the opening and closing of the valve according to the air pressure of the actuator. 'Point a' is when the air supply begins, and at 'point b' the air pressure exceeds the actuator piston spring preload and the valve begins to open. As the air pressure gradually increases to 'point c', the valve opens fully and increases to the rated air pressure (point d). The air pressure difference between point c and d is margin to open. The air pressure is gradually reduced, and as the spring force increases, the valve begins to close (point e). 'Point f' is the air pressure in a completely closed state, and the diagnostic test is completed by lowering the air pressure to 'point a' where the air pressure becomes '0'. [1], [2]

The difference between the parallel open/close air pressure curves represents the friction force during the valve stroke. Since the friction force of the opening stroke and the closing stroke are added, the actual friction force of the valve is half.

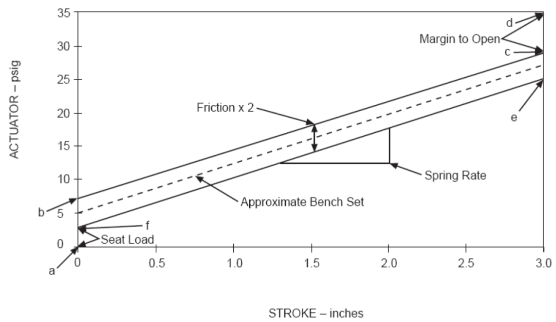

Fig 1. Typical graph for valves/actuators

2.2 Abnormal signal graph for Valve/Actuators

The abnormal signal graph that occurs during the diagnostic test shows the mechanical condition of the valve. Through comparison with the typical graph explained earlier, problems with the current valve can be identified. There are many factors that impede the performance of the valve (packing sticking, stem wear/ misalignment /bending, high friction, etc.).

Fig 2 shows the saw tooth type of wave form due to excessive packing clamping force or sticking. Excessive valve packing clamping force places excessive load on the stem and causes the valve to vibrate during stroke. Therefore, the stem friction force (solid black line, right axis of the graph) appears in an irregular sawtooth shape. This problem reduces the performance margin of the valve and requires maintenance. It can be solved by easing the packing clamping force or replacing the packing.

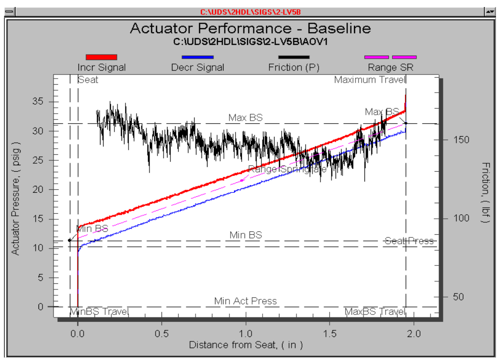

Fig 2. Example graph of packing sticking

Fig 3 is a graph resulting from stem wear. The friction force applied to the stem (solid black line) increases at the point where wear is presumed to have occurred. In the sections before and after, the friction force is relatively small, and a wave shape like the one above appears. Additionally, the supply pressure of the actuator (red line, blue line) also appears irregularly due to locally increased friction. Because large local loads occur on the actuator, valve performance margins are reduced and maintenance is required.

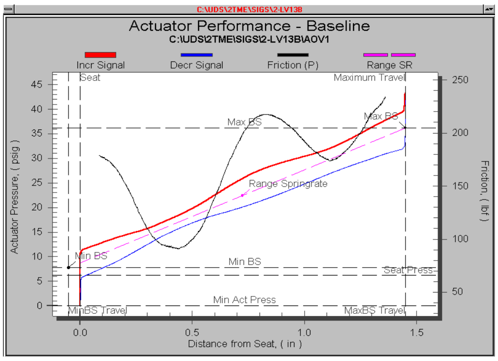

Fig 3. Example graph showing stem wear

Fig 4 is a graph that appears due to excessive friction. (This graph shows an upward left curve because the valve closes when the supply pressure is injected.) A graph like this appears when excessive friction occurs at a specific location due to a bent stem or other factors. At that point, the friction force (black line) increases rapidly, and the air supply pressure (red line and blue line) also increases rapidly.

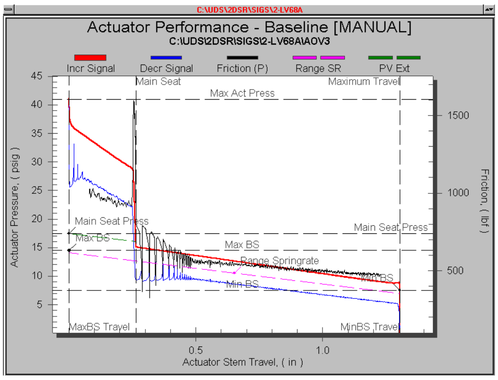

Fig 4. Example graph showing excessive friction

Fig 5 shows an abnormal graph due to a bent valve stem. Because the load on the actuator increases where the stem is bent, the air pressure curve widens.

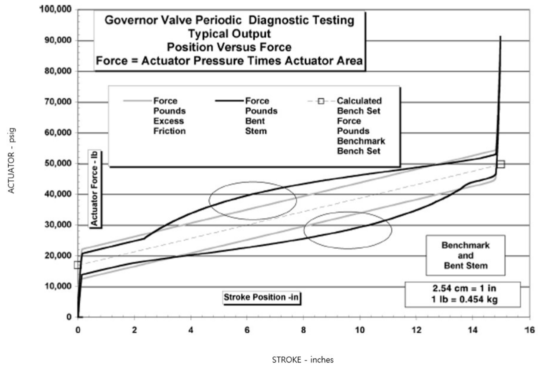

Fig 5. Example graph showing stem bent

Fig 6 is a graph that occurs due to poor axial alignment between the actuator and valve stem. At the point where the valve begins to open, a normal signal is displayed, but at the point when it fully opens, the friction force gradually increases. As a result, the load on the actuator air pressure increases, and the stroke distance increases compared to when the stem is aligned in a straight.

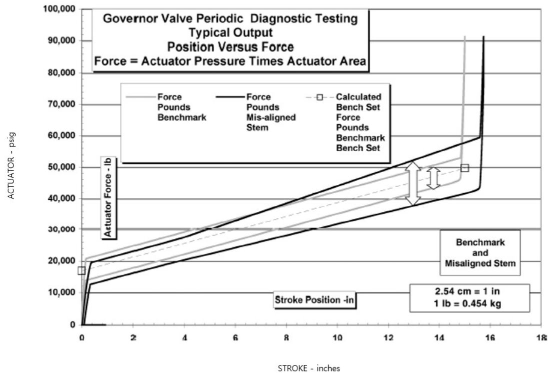

Fig 6. Example graph showing stem misalignment

2.3 Diagnostic test cycle of AOVs

Since AOVs that perform safety functions perform a very important role in stabilizing the power plant after an accident, their performance must be evaluated on periodically. Therefore, these valves must be undergoing diagnostic tests within the five-cycle nuclear power plant overhaul. However, high-safety critical valves and low-performance valves apply shorter periods.

3. Conclusions

Representative examples of abnormal signal graphs that may occur during AOVs diagnostic tests at nuclear power plants are listed. For the safe operation of nuclear power plants, diagnostic tests must be performed every week to check the performance of the value. Through regular and systematic diagnosis and testing, the valve's operating margin can be secured by analyzing abnormal signals of the valve and detecting and resolving mechanical problems.

REFERENCES

[1] Nuclear Maintenance Applications Center: Air-Operated Valve Diagnostic Testing Guide, 2011 Technical report, Electric Power Research Institute
[2] A Study of Air-Operated Valves in U.S. Nuclear Power Plants, 0. Rothberg, S. Khencha, J. Watkins, M. Holbrook, 2000.