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Study on the Faults of the Worm Gear in the Actuator

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1. Introduction

The actuator of the motor-operated valve (MOV) is the system which transfers the torque from the electrical motor to the stem. It is composed of the spur gear set, the worm-worm gear set, bearings and so on. Among them, the condition of the worm-worm gear set affect most on the performance of the actuator such as the efficiency. Therefore, the diagnosing defects and maintaining the performance of the worm-worm gear set contributes to the safe operation of power plants. However, it is very difficult to inspect it without disassembly.

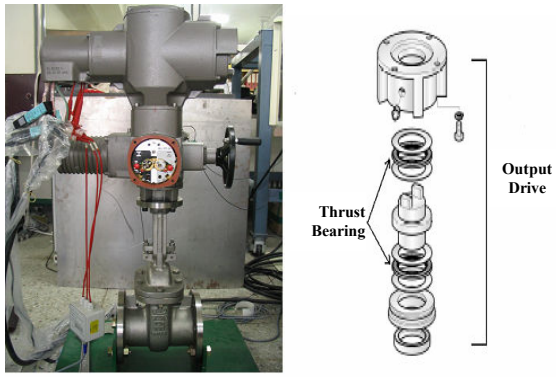
In this paper, non-intrusive diagnostic methods are developed to identify the defects which commonly occur: the wear of the gear teeth, broken teeth and the eccentricity of the assembly. Motor torque signals are used as the basic diagnostic signatures and the methods are verified with the various experiments.

2. Experiment

A fault simulator is designed and manufactured to provide the MOV with known defects on purpose. It can simulate not only the component defects such as broken gear teeth, worn gear teeth or eccentricity of the worm gear but also the assembling defects such as misalignment and so on. Using the simulator, we can examine the signature change according to each defect.

2.1 Fault Simulator

There are many actuators which are used in the power plants. AUMA SAM 07.5 is one of the widely used actuators. Therefore, the fault simulator uses the AUMA SAM 07.5 as the actuator. For valves, it can be assembled with various kinds of valves: rising stem type gate or glove valves and rotating stem type butterfly valves. Figure 1(a) shows the simulator with the gate valve.



(a) Simulator with gate valve (b) Output drive
Figure 1 Simulator

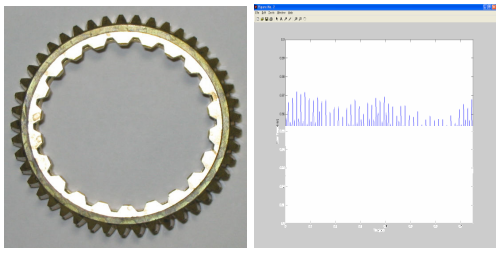
Additional gear boxes can be attached to the simulator to change the torque or the direction. The bevel gear box, spur gear box and worm gear box are used. The output drive is placed between actuator and valve. Stem nut is in output drive. Figure 1(b) is output drive. To estimate the motor torque, current probes and voltage probes are connected. Various sensors can be attached to measured torque, thrust and vibration. All the data are stored in digital format and the data are further processed to eliminate noise.

2.2 Eccentricity of worm gear

Figure 2(a) is the worm gear and figure 2(b) shows the motor torque of the one period of the worm gear rotation. In figure 2(b), there are 45 peaks in motor torque which represent gear teeth engagement. As the worm and worm gear engages, the number of engaging teeth varies which makes the contact stiffness changes. As the contact stiffness changes, so the contact force does. Therefore, there is cyclic variation of the motor torque signal and the pattern of the motor torque provides lots of information regarding the shape of the worm gear and gear teeth.

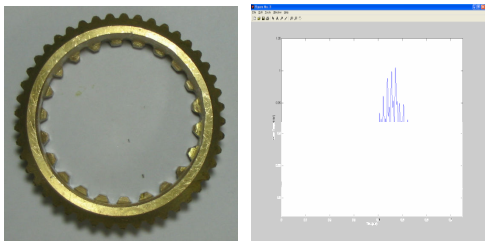
There are two big fluctuations in Figure 2(b) which comes from the eccentric shape of the worm gear. Since there is optimal distance between worm and worm gear, the efficiency of the worm and worm gear changes depending on the distance between them. If the distance becomes shorter than the optimal distance, the teeth of the worm push the worm gear which requires additional toque to rotate the worm gear. Similarly the efficiency reduces when the distance become longer since the contact angle between the gear teeth changes. In Figure 2(b), one fluctuation is caused by the eccentric shape of

outer circle of the worm gear and the other is caused by the eccentric shape of the inner circle of the worm gear.



(a) Worm gear (b) Motor torque
Figure 2 Worm gear and motor torque

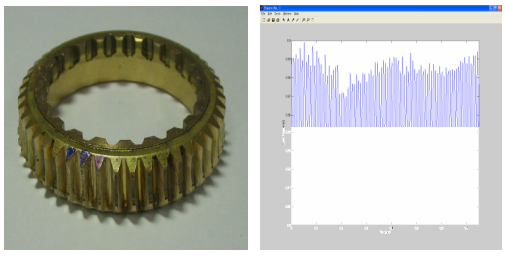
The shorter the distance between worm and worm gear becomes, the more the motor torque increases. The inner circle of the worm gear is worn to make more eccentricity. This lets the teeth of worm push more causing the sudden increase in the motor torque as shown in figure 3(b).



(a) Eccentric worm gear (b) Motor torque
Figure 3 Eccentric worm gear

2.3 Wear of gear teeth

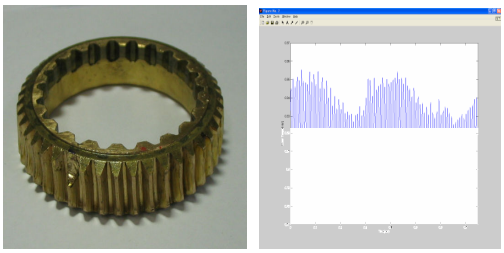
The motor is turned off by the torque switch when the valve is seated in a certain thrust. During seating, high torque is concentrated on some teeth. This leads to wear of the gear teeth. To simulate this, three teeth are worn out. The worn teeth make more gap between the worm and the worm gear. Figure 3(a) shows the worn teeth of the worm gear and figure 3(b) shows the fluctuation of the motor torque due to the worn gear teeth, which represents the effect of the change of the efficiency.



(a) Worn gear teeth (b) Motor torque
Figure 4 Wear of the worm gear

2.4 Broken teeth

Figure 5(a) shows broken worm gear. The half of the teeth is broken. The surface of the broken teeth is very rough and the edge is very sharp. The Broken tooth contacts with the worm not smoothly but roughly and suddenly. Rough and sudden contact affects motor torque increase at that time. So, motor torque is increased suddenly. Sudden increment of motor torque is shown in Figure 5(b). This is opposite of the worn gear teeth.



(a) Broken worm gear (b) Motor torque
Figure 5 Broken tooth

3. Conclusion

Diagnosing MOVs without disassembly would be helpful for the maintenance and the safety of the plants. In this paper, we have studied the worm and the worm gear in the actuator. Since the worm gear set is the most important component affecting the efficiency of the actuator, any change in the worm gear can be detected in the shape of motor torque.

Eccentricity of the worm gear is shown as a large fluctuation of the motor torque during the rotation of the worm gear. The number of the fluctuation represents the number of the eccentricity. In the paper, two fluctuating motor torque comes from the eccentric shape of the outer circle and the inner circle, respectively. The local fluctuation of the motor torque represents either worn or broken gear teeth of the worm gear. The worn gear teeth make the motor torque increase or decrease depending on the initial assembly, in other word, the initial distance between the worm and the worm gear. On the other hand, the broken teeth make always the motor torque increase.

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