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Comparison of Loss Coefficient using 1-inch Ball and Glove Valve Opening Ratio

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1인치 볼 밸브 및 글로브 밸브에 대한 개도율에 따른 손실계수(K) 비교에 관한 연구

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ABSTRACT

This study aims to determine the flow characteristics of a one-inch small ball valve and glove valve used in industrial plants. The flow was changed through an experimental equipment, and the internal flow characteristics of the valves were compared. Considering the pressure drop, the decrease in the slope of the ball valve based on the degree of the valve opening was relatively greater than that of the glove valve; further, the slope of the glove valve was gentle while the pressure drop was high. The flow velocity of the ball valve remains consistent after the valve was opened by 70%, whereas the flow velocity of the glove valve constantly increased. The valve loss factor of the ball valve was relatively low compared with that of the glove valve. When the valve was opened by 20%, which is the beginning stage of the valve opening, the valve loss factor of the ball valve was high and gradually became low. This is a structural problem of the ball valve, and the loss factor is significant because the flow path installed at the ball valve has a considerably small area. However, the overall loss factor of glove valve is high because it has a complicated structure of flow path.

Key Words : Ball Valve(볼밸브), Glove Valve(글로브 밸브), Valve Loss Coefficient(밸브 손실계수)

1. Introduction

Continuous research is being conducted on valves, both domestically and internationally. In particular, advanced research, including flow, structural, and vibration analyses, is actively being performed at the design stage.

Most of the computational valve analyses at the design stage involve flow analysis and structural analysis. Such analyses can also be used to verify the performances of valves that have already been

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developed. On the other hand, experiments are designed and developed based on international standards such as ANSI and API, and then carried out from a structural design perspective. These include internal pressure and air tightness tests.

Experiments involving the flow are mainly conducted to measure the flow coefficient (Cv), pressure differential between the valve inlet and outlet, and flow rate. In addition, many studies have verified flow fields by comparing the results of a computational analysis with experimental results.

Taewook Byun et al.[1] compared experimental and computational analysis results on the effects of the flow rate and discharge pressure on a decompression valve. Changwon Kang et al.[2,3] measured the Cv value through an experiment measuring the flow coefficient of an instrumentation ball valve, and provided data comparing the measured flow coefficient of ball valves applied to thermal power plants with the results of a computational analysis.

Valves such as solenoid valves, electric valves, and pneumatic control valves are used to control the valve opening rate, and the importance of valves is increasing with the recent acceleration of automation. Currently, the role of valves in onshore plants such as power plants is very important, and their performances vary with their characteristics[4~8].

It is necessary to identify the characteristics of a control valve in response to its operating variable because the flow rate and pressure vary with the valve opening[9,10].

This study had the goal of determining the relationship between the loss coefficient and the change in valve opening for 1-inch ball valves and globe valves.

2. Valve Flow Measurement

2.1 Experimental setup and equipment

The main framework for the valve flow coefficient measuring device had a width of 45,000 mm, depth of 2,500 mm, and height of 1,600 mm. The experimental device was configured as shown Fig. 1 to allow measurements using various pipe sizes, including 1/4″, 1/2″, and 1″. SUS-based materials were used in the piping to prevent corrosion, and a valve adaptor was used in the design to accommodate various pipe sizes.

In order to provide a continuous supply of water, which was the operating fluid, the experimental device was designed as a closed-circuit circulation structure, and the water tank had a width of 35,000 mm, depth of 1,500 mm, and height of 900 mm.

A filter was installed to remove foreign substances from the operating fluid flowing from the water tank to the pipe, and the water tank was made of an SUS-based material to prevent corrosion. A vertical multistage pump with a power rating of 18 kW, flow rate of 341 LPM, and head of 65 m was used.

In order to test the performances of various control valves and manual valves, the loss coefficient was calculated using measurements of the flow rate passing through the valve and the pressures at the inlet and outlet.

2.2 Test Valve

Fig. 2 shows the full-bore type 1-inch ball valve and globe valve used in the experiment to determine the loss coefficient. The sizes of the flange and pipe

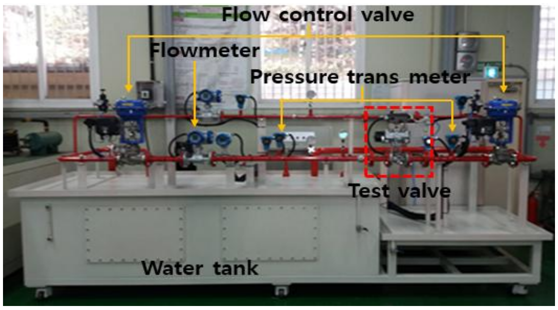
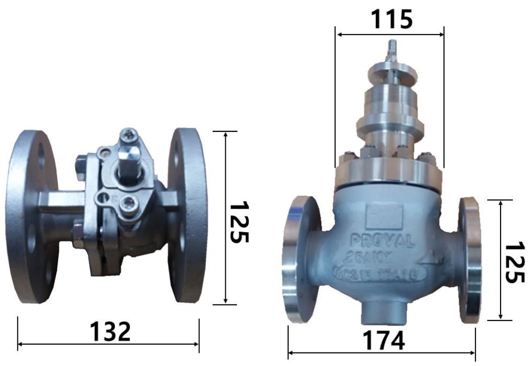


Fig. 1 Experimental setup for valve flow coefficient measurement

connected to the valve were the same at 1 inch.

Fig. 3 shows a 1-inch ball valve installed to the experimental device, and Fig. 4 shows a 1-inch globe valve installed to the experimental device where the flow rate and pressure were measured. The pipe extending from the flow control valve to the test valve was straight, with a length of more than 30 times the diameter of the valve to allow the flow to fully develop. In addition, a pressure gauge was installed across the inlet and outlet of the test valve to measure the pressure differential. Both the flowmeter and pressure gauge were calibrated by an accredited institution before the actual measurements.



(a) ball valve **(b) glove valve**

Fig. 2 Configuration of 1-inch valves

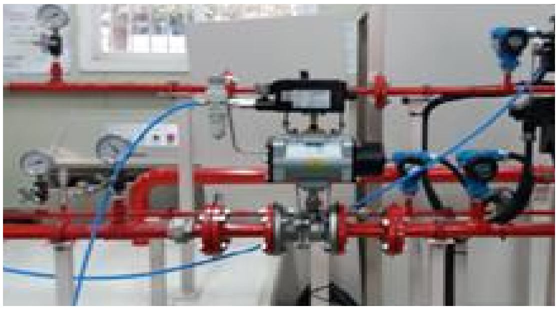


Fig. 3 Experiment setup for 1-inch control ball valve

Fig. 4 Experiment setup for 1-inch control glove valve

2.3 Experiment Method

A valve is similar to a control orifice with an opening that is easily adjusted. Thus, the loss caused by the fluid as it passes through the valve can be expressed in Equation (1).

$$v \approx (\triangle P)^{\frac{1}{2}} \tag{1}$$

The correlation between the flow rate and flow resistance at any valve position is established using experimentally determined resistance (loss) or flow parameters. As shown in Equation (2), loss coefficient K defines the friction loss caused by the valve as the velocity head or velocity pressure.

$$\triangle P = K\frac{v^2\rho}{2} \tag{2}$$

The above equations are valid for both turbulent and laminar flows of Newtonian fluids. When the Mach number reaches 0.2 at the valve inlet, the compression effect becomes substantial, but it may not be significant until the Mach number reaches 0.5.

Even with the same type of valve, if the manufacturers are different, and even with the same pipeline, if the specifications are different, two valves will not be geometrically similar. Thus, the valve loss coefficient varies depending on the valve specification, type, and manufacturer. Equation (3) shows loss coefficient K, which this study attempted to confirm. The experiment was conducted by measuring the pressure differential and flow rate in relation to the opening of each valve.

$$K = \frac{1}{2}\frac{\Delta P}{v^2 \rho} \quad (3)$$

3. Results and Review of Valve Flow Rate Experiment

3.1 Comparison of Pressure Drop

In order to reduce the error in the experiment, the results of five repeated experiments for each experimental variable were collected, it was determined that the experiments were consistently conducted because the results showed an error of less than 2%. Fig. 5 compares the pressure drop caused by a flow rate change in relation to the opening amount of the ball valve. As shown in the figure, the pressure drop decreased as the valve opening increased. In addition, it was confirmed that the pressure drop decreased drastically up to a 60% opening, and thereafter decreased gradually.

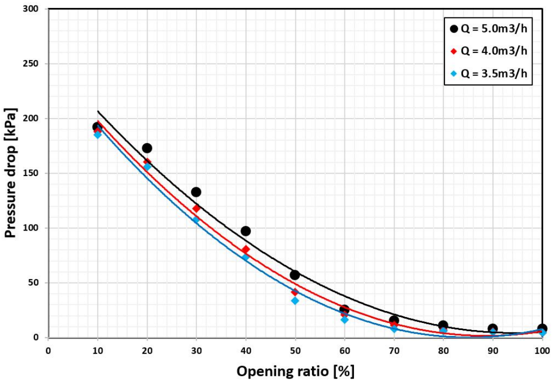


Fig. 5 Comparison of pressure drop according to valve opening ratio at 1-inch ball valve

유량변화에 따른 압력강하를 보면 유량이 증가할수록 압력강하가 높게 나타나는 것을 확인할 수 있었다. 이는 유량의 증가함에 따라 밸브의 입구측에서 압력이 증가하기 때문에 압력강하가 상대적으로 높게 나타남을 확인할 수 있었다.

Fig. 6은 글로브 밸브 열림량에 따른 압력강하를 유량변화에 따라 비교한 것이다. Fig. 5와 비교해보면 밸브 열림에 따른 압력강하 기울기가 상대적으로 완만한 것을 확인할 수 있었다. 반면, 글로브 밸브의 경우 볼 밸브에 비해 상대적으로 압력강하가 높은 것을 확인할 수 있었다. 이는 글로브 밸브 구조 특성상 바디 하부에서 상부로 연결된 구조를 가지고 있고, 유체 이동통로가 플러그의 상하 이동량에 따라 결정되기 때문에 압력강하는 높은 대신

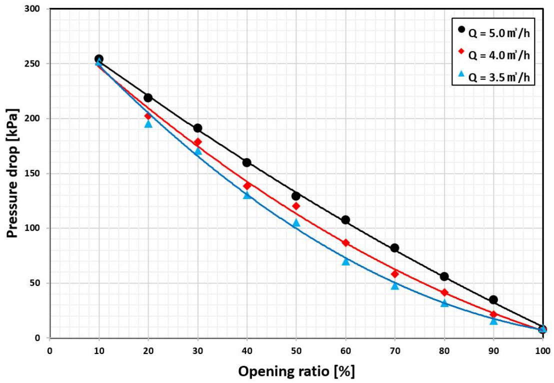


Fig. 6 Comparison of pressure drop according to valve opening ratio at 1-inch glove valve

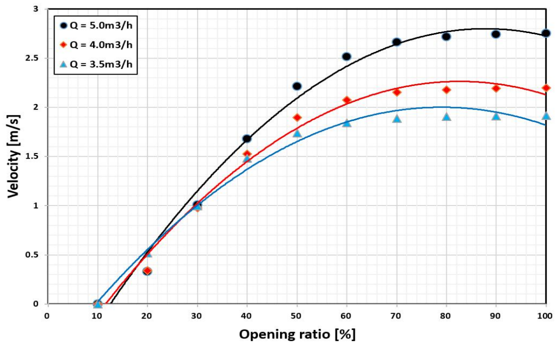


Fig. 7 Comparison of velocity according to valve opening ratio at 1-inch ball valve

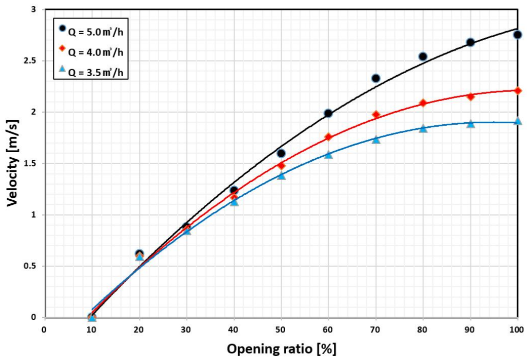


Fig. 8 Comparison of velocity according to valve opening ratio at 1-inch glove valve

3.2 Velocity Comparison

Fig. 7 shows the velocity distribution in relation to the opening amount of the ball valve. Basically, as the flow rate increased, the velocity increased, and as the valve opening increased, the flow rate increased. However, with a valve opening of more than 70%, the flow rate stopped increasing and remained constant. This was because the path of the ball was almost fully open as a result of the characteristics of the ball valve.

Fig. 8 shows the velocity profile in relation to the opening amount of the globe valve. As shown in the figure, the velocity distribution is relatively linear compared to that of the ball valve. In addition, it was confirmed that the flow velocity increased with the flow rate.

With the globe valve, this was due to the vertically operating valve stem and disk, which resulted in a relatively constant flow path, compared to the ball valve, as the valve opened.

3.3 Loss Coefficient Comparison

Fig. 9 show a comparison of the loss coefficient, K, values in relation to the flow rate change and valve opening amount for the ball valve. As shown in the figure, a loss occurred when the valve was at least 20% open, and it was the highest at a flow

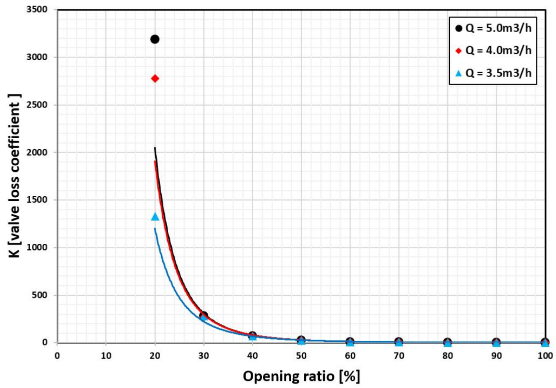


Fig. 9 Comparison of valve loss coefficient according to valve opening ratio at 1-inch ball valve

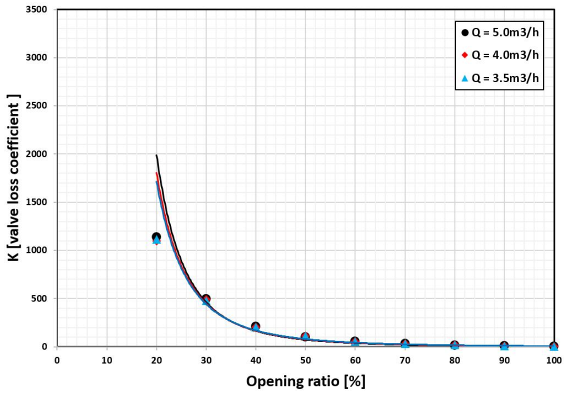


Fig. 10 Comparison of valve loss coefficient according to valve opening ratio at 1-inch glove valverate of 5.0 m^3/h. Overall, a higher loss coefficient resulted from a higher flow rate.

As the valve opening increased, the loss coefficient decreased rapidly until reaching a constant value at an opening of 50%.

Fig. 10 shows a comparison of the loss coefficient, K, values in relation to the flow rate change and valve opening amount for the globe valve. As shown in the figure, a loss occurred when the valve was at least 20% open. However, relative to the ball valve, the loss coefficient was lower. At a flow rate of 5.0 m^3/h, the loss coefficient was approximately three times lower. In addition, at a 30% valve opening, it was approximately twice that of the ball valve. Therefore, in the case of the globe valve, the loss coefficient was low at the initial stage of valve opening, but the subsequent rate of decrease was gradual compared to that of the ball valve, which resulted in a relatively higher loss coefficient.

The relatively complex path structure inside the globe valve increased the loss coefficient compared to the ball valve. On the other hand, with the ball valve, the loss coefficient was high at a 20% valve opening because of its structure, whereby the path opening was at its initial stage, which caused a relatively higher loss coefficient.

4. Conclusion

In order to understand the flow characteristics of the small 1-inch ball valves and globe valves that are commonly applied to plants, the flow characteristics of the valves were experimentally compared in relation to the flow rate change, and the following conclusions were obtained.

The rate of decrease in the pressure drop within the ball valve in relation to the amount of valve opening was relatively higher than that of the globe valve, and with the globe valve, the pressure drop was greater but the subsequent rate of decrease was gradual.

The flow velocity passing through the valve reached a constant value after the valve was 70% open for the ball valve, whereas it continuously increased for the globe valve.

The loss coefficient for the ball valve was relatively lower than that for the globe valve, but at a 20% valve opening, which was the initial stage of opening, the ball valve had a higher loss coefficient, which then decreased. This is a structural issue with the ball valve, whereby the area for the flow path through the ball installed in the valve body is very small at the initial stage, which results in a large loss coefficient. In contrast, the structurally complex flow path of the globe valve relative to the ball valve produced an overall high loss coefficient.

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