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Dynamic characteristic analysis of high pressure natural gas regulating valve with Computational Fluid Dynamic Analysis

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Abstract. Gas pressure regulating valves are devices that maintain constant output pressure regardless of the variations in the input pressure or the output flow. In order to optimum design for regulating valve at the high pressure conditions, the needs to analyze the flow rate according to the working pressure conditions are largely issued. In this study, therefore, analyzed the dynamic characteristic of high pressure natural gas regulating valve with Computational Fluid Dynamic Analysis. And in order to verify the reliability of the results of numerical simulation and performance of pressure regulating valve, experiment on pressure regulating valve operating performance was tested. The numerical analysis results of dynamic behavior of disk can be used to predict flow rate of specific disk lift and calculated flow rate is useful to target disk lift design.

Keywords: Computational fluid dynamic analysis, Dynamic characteristic analysis, Natural gas, Regulating valve

1 Introduction

Gas pressure regulating valves are devices that maintain constant output pressure regardless of the variations in the input pressure or the output flow. They range from simple, single-stage [1,2] to more complex, multi-stage [3,4], but the principle of operation [5] is the same in all. High pressure gas flows through an orifice in the valve and the pressure energy in the gas is converted to heat and flow at the lower, regulated, pressure. The orifice faces a movable disk that regulates the amount of gas flow. When the regulated pressure is too high, the diaphragm and linkage move the disk to close the orifice. When the regulated pressure is too low, the disk is moved to open the orifice and allow more gas pressure and flow into the regulator.

In this study, analyzed the dynamic characteristic of pressure regulating valve for natural gas using computational fluid dynamic analysis. Developed a comprehensive dynamical model for a pressure regulating valve for natural gas from first principles in order to gain a better understanding of its characteristic. In order to verify the reliability of the results of numerical simulation and performance of pressure

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regulating valve, experiments are designed to test the inlet pressure, outlet pressure and outlet flow rate of the pressure regulating valve.

2 Numerical Analysis using CFD

In order to analyze dynamic behavior of disk in the pressure regulating valve is open and close with directly related to the outlet pressure of regulating valve. It can be distributed disk open case with under pressure to the outlet and disk close case with over pressure.

Specifications of pressure regulating valve detail are shown in Table 1. The calculation area is meshed with structural mesh Tetrahedral-type elements using ICEM CFD 12. As shown in Figure 1, 1/2 model is considered symmetric condition for saving calculation time.

Table 1. Specifications of the pressure regulating valve

Type	10" (ANSI Class 600#)
Fluid	Natural Gas
Design Pressure	10 MPa
Design Temperature	RT
Inlet Pressure	Maximum 8.5 MPa
Outlet Pressure	Maximum 3.9 MPa
Maximum Flow Rate	16,000 m^3/h

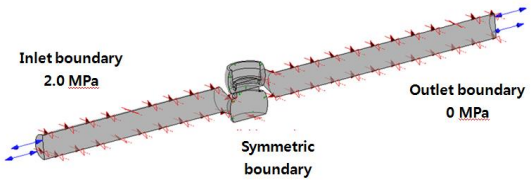


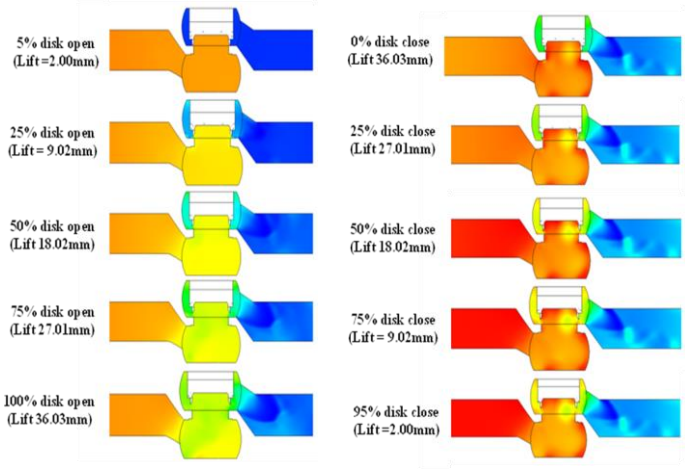
Fig. 1. Boundary conditions of model

The pressure inlet boundary with a gage pressure at 2.0MPa is adopted for valve inlet. The pressure outlet boundary with a known atmospheric pressure value of gage pressure at 0.0MPa is adopted for outlet. No-slip and adiabatic wall type have been used on the pressure regulating valve wall. Automatic near-wall treatment has been applied. The k-e model is utilized for simulating turbulence flow.

3 Numerical Analysis using CFD

Figure 2(a) shows that the pressure distribution on the flow region with disk lift variation by the pilot pressure. It means that the flow pressure decreases gradually inlet of the regulating valve with disk open. Figure 2(b) shows that the pressure

distribution on the flow region with disk lift variation by the pilot pressure. It means that the flow pressure increases inlet of the regulating valve with disk close.



(a) disk open (b) disk close

Fig. 2. Pressure distribution with disk open and close

By the numerical analysis results of dynamic behavior of disk, it can be found that outlet flow rate of natural gas according to disk lift variation as shown in Figure 3. Initial stage on disk open, holding flow rate is about 200 m^3/h. It can be seen that flow rate is rapid increase about 0.0211m disk lift and flow rate is abruptly increased until disk is full open. This results can be used to predict flow rate of specific disk lift and calculated flow rate in Figure 3 is useful to target disk lift design

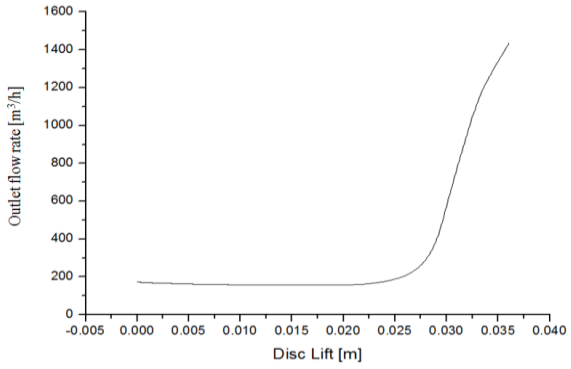


Fig. 3. Outlet flow rate with disk lift variation.

4 Experimental Test

In order to verify the reliability of the results of numerical simulation and performance of pressure regulating valve. Figure 4 shows the results of holding outlet pressure is 3.0MPa and outlet flow rate is 250 m^3/h for 20 minutes on steady-state levels. By the results of outlet pressure and outlet flow rate, it can be found that the pressure regulating valve developed in this study provides satisfactory operating performance.

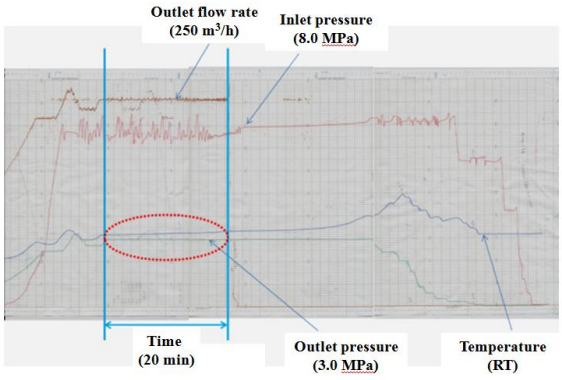


Fig. 4. Results of experiments

5 Conclusions

This paper has been analyzed the dynamic characteristic of pressure regulating valve for natural gas using computational fluid dynamic analysis and experiment on pressure regulating valve operating performance was tested. The conclusions are summarized as follows.

(1) By the numerical analysis results of dynamic behavior of disk, it can be found that outlet flow rate of natural gas according to disk lift variation.

(2) This results can be used to predict flow rate of specific disk lift and calculated flow rate is useful to target disk lift design.

(3) By the results of outlet pressure and outlet flow rate, it can be found that the pressure regulating valve developed in this study provides satisfactory operating performance.

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