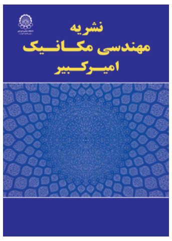

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The Experimental Study of Effective Characteristics on Differential Pressure Value Setting of Quarter-turn Actuator in Gas Transportation Pipelines

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ABSTRACT: Actuators with line-break detection system can be used in the zones with no access to national electricity network, hazardous or impassable area enclosure, for passive defense conditions or to protect different ecosystems such as rivers and ground water, forests and fertile land and etc. In this paper, the effects of orifice diameter, pipeline initial pressure and pipeline pressure drop rate on the setting differential pressure in a quarter turn Scotch-Yoke actuator have been studied by 81 tests. The nitrogen gas was used in this experimental study. The actuator differential pressure is increased by the growth of pipeline pressure drop rate or reduction of orifice diameter or pipeline initial pressure. The occurrence time of maximum differential pressure of diaphragm valve depends just on orifice diameter. This time is independent of pipeline pressure drop rate or pipeline initial pressure. It increases with the decrease of orifice diameter. The curves of actuator differential pressure which is generated by different pipeline pressure drop rates are proposed for different pipeline initial pressures and orifice diameters. The values of curves in this diagram with 10 percent safety factor can be used in differential pressure value setting of quarter-turn actuator installed on gas transportation pipelines.

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1- Introduction

Gas pipeline systems employ quarter-turn actuators to close valves and prevent the release of oil in the rupture of a pipeline. When a pipeline ruptures, a large pressure drop occurs and the corresponding rate of pressure drop can be observed at the adjacent valve location. The rate of pressure drop value is measured over a pre-set period of time and is used to determine whether a pipeline rupture has occurred. In Iran, the rate of pressure drop settings (including rate of pressure drop values and their corresponding durations) are usually adopted based on domestic or foreign experiences or on estimated values derived from pipeline steady flow over a long time [1, 2]. If the quarter-turn valve actuators in the entire pipeline use a common rate of pressure drop setting, the valves may either mistakenly shut down when there is no rupture or not shut down when a rupture occurs.

Multiple factors, such as pipeline diameter and length and initial oil operating pressure and flow rate, complicate the process of determining the appropriate rate of pressure drop value setting. In addition, the risk of downstream valves shutting down in sequence after an upstream valve has been closed, makes this problem even more complex. Furthermore, an appropriate rate of pressure drop setting for the quarter-turn valve actuator must reflect the accuracy and timeliness of the valve's mechanical action. Several studies on leak detection in oil pipelines have been reported [3], also some studies focus on pipeline ruptures [4]. However, there are only a few studies on setting the rate of pressure drop value of quarter-turn valve actuators [5], especially relating to how the value settings might differ between oil pipelines.

In this study, these parameters were studied which associated with quarter-turn valve actuators. The final significant diagram is obtained which shows the effect of these parameters on differential pressure value between two sides of diaphragm valve. The differential pressure is the main parameter in quarter-turn actuator setting for different conditions. The method developed in this study can be applied to other type of pipeline fluids such as petroleum gas.

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2- Experimental Setup

Generally speaking, the quarter-turn actuators are divided into three different categories [1]: Scotch-Yoke (Fig. 1), rack and pinion and rotary vane. In this paper, Scotch-Yoke actuator was investigated for quarter-turn valve actuator type. In this study, the Scotch-yoke actuator is selected.

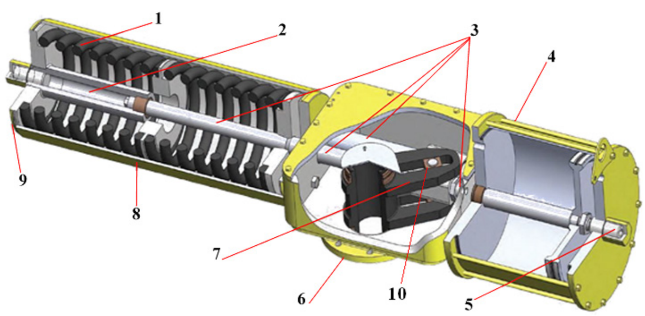

Fig. 1. The automatic actuator

The schematic of test setup is shown in Fig. 2. The test setup is shown in Fig. 3. Three pressure transmitters are used to measure pressures in points called PC, PR and PS in Fig. 2.

The pressure drop rate settings for quarter-turn valve actuators in gas pipelines were determined through simulations based

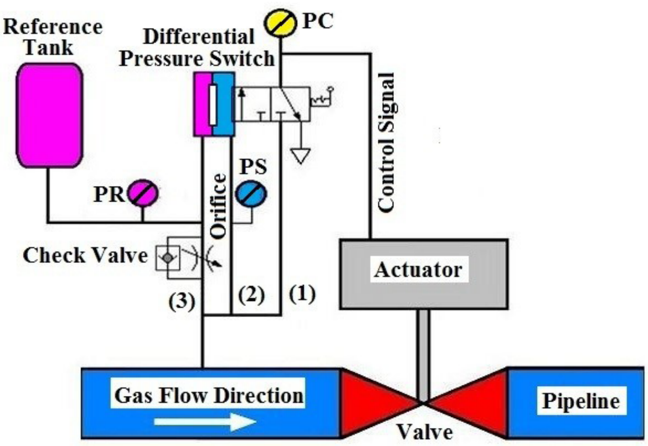

Fig. 2. The schematic of setup.

Fig. 3. The test setup

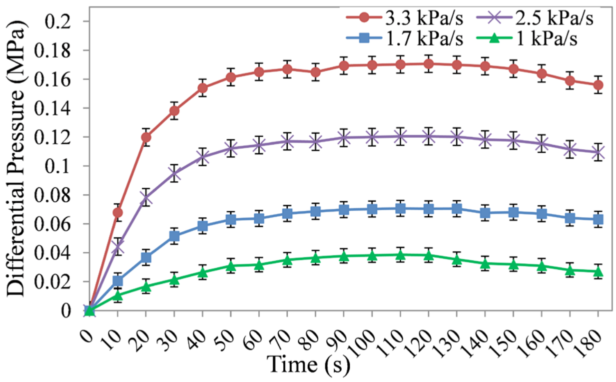

Fig. 4. The differential pressure versus time for P_i=3.5 MPa and orifice diameter of 0.5 mm

on the principle that closing an upstream valve should not cause the sequential shutdown of the downstream valves. The differential pressure can be determined in various pressure drop rate for different orifice diameters and initial pressures by Fig. 7. This figure is the base of commissioning of this type of actuator valve installed on gas pipelines. It is a practical diagram for this purpose.

3- Results and Discussion

The results of the work and discussions are presented here for

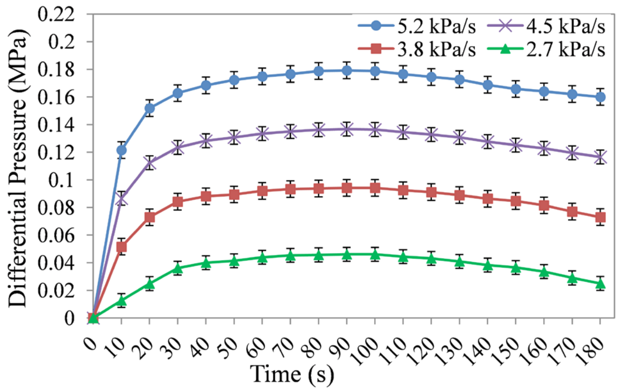

Fig. 5. The differential pressure versus time for P_i =3.5 MPa and orifice diameter of 1 mm

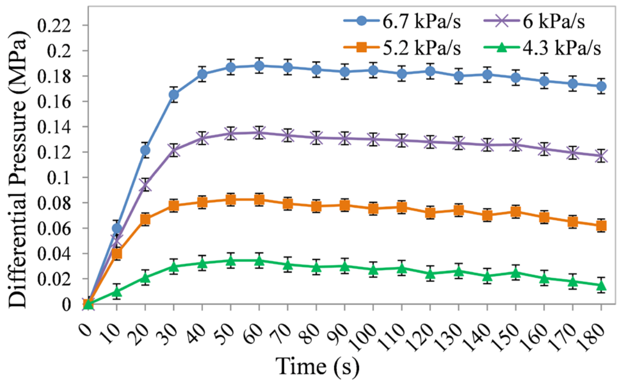

Fig. 6. The differential pressure versus time for P_i =3.5 MPa and orifice diameter of 1.5 mm

three orifice diameters, twenty pressure drop rates and three initial pressures.

The equations of three lines in Fig. 7 for 3.5 MPa initial pressure and different orifice diameters are:

$$OD = 0.5mm, \Delta P = 0.057\dot{P} - 0.019; R^2 = 0.99 \quad (1)$$

$$OD = 1mm, \Delta P = 0.056\dot{P} - 0.112; R^2 = 1 \quad (2)$$

$$OD = 1.5mm, \Delta P = 0.063\dot{P} - 0.233; R^2 = 0.99 \quad (3)$$

The non-dimensional diagram is shown in Fig. 8.

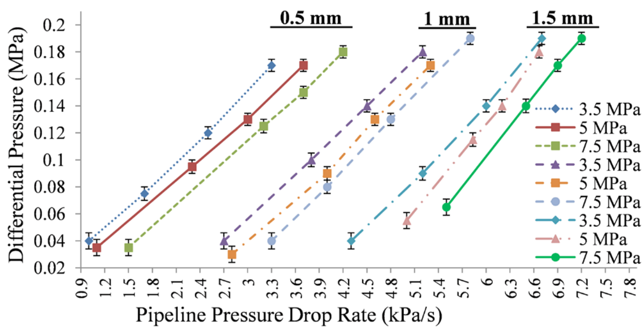

Fig. 7. The differential pressure versus pressure drop rate for different initial pressures and orifice diameters

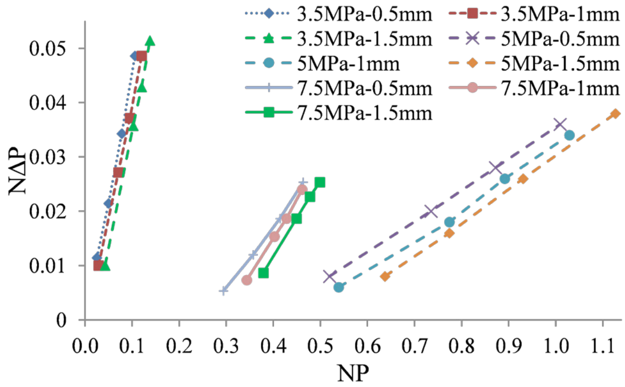

Fig. 8. The differential pressure versus pressure drop rate for different initial pressures and orifice diameters (non-dimensional)

4- Conclusions

In this study, rate of pressure drop, orifice diameter and initial pressure of pipeline parameters were studied experimentally which is associated with quarter-turn actuator. The differential pressure is the main parameter in actuator setting for different conditions. The final significant diagrams (dimensional and non-dimensional) are obtained which show the effect of these parameters on differential pressure value between two sides of diaphragm valve. The final significant diagrams are the basis of commissioning of this type of actuators installed on gas pipelines.

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