A Study on the Distortion of Air Operated Valve Flow Characteristics in the System

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1. Introduction

In order to meet the diversified needs of different industries, various valves are developed to fit specific needs. In particular, many types of valves are operated in nuclear power plants. For valves designed to control fluids, the trim shape determines the characteristic of the valve, which dictates the places the valve appropriate for. Globe valves have wide range of applications for general use; commonly found characteristics in these valves are quick-opening, linear, and equal-percentage. In this paper, we study how distortion effects occur using the data obtained from operation for the control valve with equal-percentage flow characteristics.

2. Methods and Results

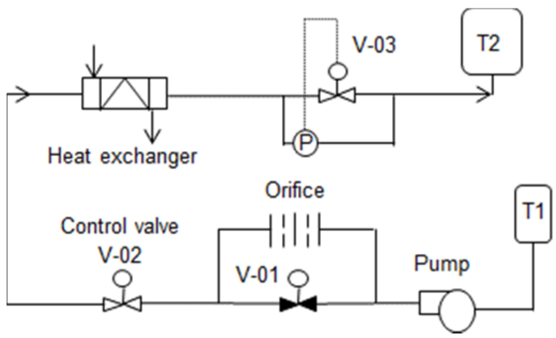

Fig. 1 Overview of system

System (Fig. 1) involves a pump that provides upto 189 kg/cm^{2}g of driving force and two separate tanks are laid at the boundary surface; The pressure of the first tank (T1) is 3.5 kg/cm^{2}g while the second tank (T2) is kept at atmospheric pressure. The fluid is controlled by the control valve (V-02) with the operating range of 166 Lpm ~ 500 Lpm. For V-01, orifice bypass valve is closed while V-03 is opened and used as back pressure control valve. The main focus of the study is to identify the causes of distortion effect from equal percent flow characteristics of V-02 valve when passing through the orifice and then through V-02 control valve at the flow rate specified by the pump.

2.1 Flow characteristics of control valves

The flow characteristic of a control valve is determined by the travel distance of trim and the flow rate; the characteristics can be defined as either inherent flow characteristic and installed flow characteristic under operation condition.

The relationship between the trim travel distance and the flow rate is as follows:

$$Q = Q_m R^{[(x/T)-1]}$$

Q = Flow rate (GPM)
Q_m = Maximum flow rate (GPM)
R = Rangeability
x = valve position (in.)
T = Maximum valve travel (in.)

2.2 Properties of equal-percentage control valve type

The flow rate of the system is adjusted by the linear control method, a commonly used type of control system. Equal-percentage control valves experiences gradual increase in the flow path cross-sectional area as per the distance travelled by the trim. In centrifugal pump system, the pump provides the pressure, while the valve controls the flow rate. The equal-percentage flow characteristic is used to emulate the linear control in response to the H-Q curve produced by the pump.

Fig. 2 Trim of V-02 Control valve

2.3 Distortion of flow characteristics

The equal-percentage flow characteristic of V-02 control valve produces distortion due to pressure loss in the system. Hence, due to the rate of pressure loss in the system the actual flow rate is different, ultimately distorting the flow characteristic of the control valve.

The system pressure loss rate (P_s) is defined as follows and calculation shows 0.17 for the system in Fig. 1.

$$P_s = \frac{\Delta P_{valve}}{\Delta P_{system}}$$

Then, the actual flow rate affected by the system pressure loss is then calculated using the following equation :

$$Q_{install} = \sqrt{\frac{\frac{1}{P_s}}{\frac{1}{P_s} - 1 + \frac{1}{k}}}$$

$Q_{install}$ = Actual installed flow rate
P_s = System pressure loss rate
$k = \frac{Q}{Q_M}$= Inherent flow rate

2.4 Results

a) Inherent valve characteristics
The control valves with equal-percentage characteristics provided by the supplier can be combined with centrifugal pump to allow for linear flow rate control. Fig. 3 is a valve characteristic curve of the valve provided by the supplier; flow coefficient (Cv) is determined to choose appropriate valve opening to allow desired control of flow.

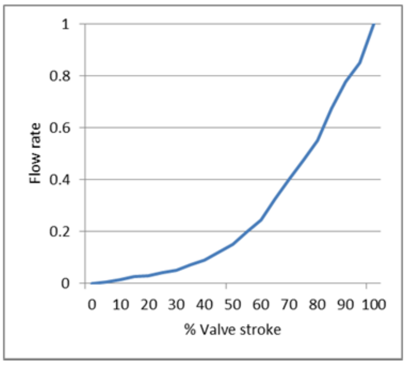

Fig. 3 Equal-percentage characteristic curve of supplier-provided valve

b) Installed valve characteristics
Fig. 4 depicts the case where flow characteristic of the valve suffers distortion due to friction loss in the system. Flow characteristic now displays quick-open response due to the distortion in the valve, which is a deviation from the expected flow characteristic.

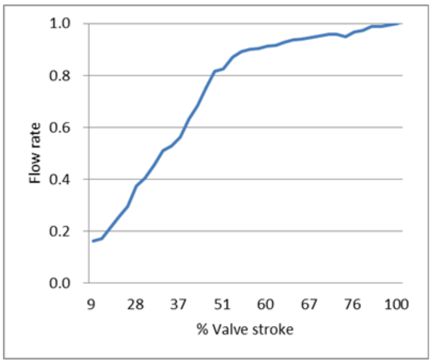

Fig. 4 Distorted valve flow characteristic in the system

c) Failed valve characteristics
A faulty valve actuator unable to function properly will suffer an improper production of valve flow characteristic. Fig. 5 displays the case when valve actuator suffers continuous leak of injected control air.

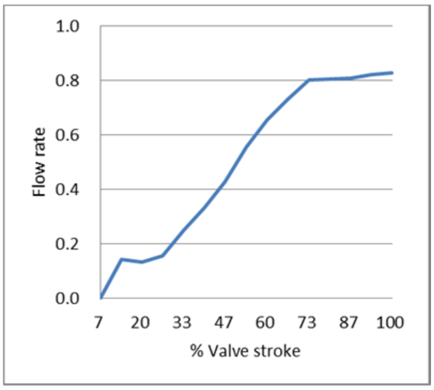

Fig. 5 Characteristic curve of the control air leaking valve

In the case of control air leakage, stable control of flow rate is not achievable due to the hunting of the control valve stem. Fig. 6 shows the turbulence felt in the flow rate due to leaking of control air.

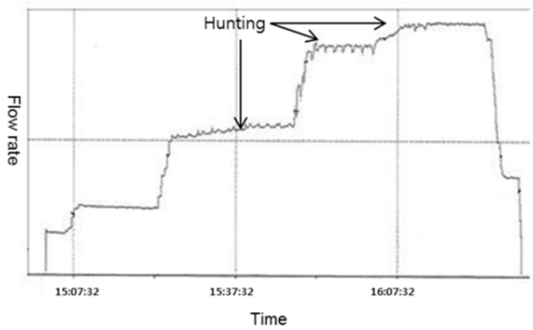

Fig. 6 Hunting effect due to leaking of control air

3. Conclusions

A. Excessive system pressure loss rate is a major contributor to the variation of flow characteristic of control valve.

B. Changes in valve flow characteristics will affect the gain, hindering the efficiency of valves that require fine control and ultimately reduce the performance of the system.

C. Leakage of control air, as well as variation in flow characteristic can cause hunting effect on fluid control, which can present serious issue to the safety of the system.

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