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Modeling for assessing the dynamic performance of pneumatic valve

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ABSTRACT – The fundamental control system for an electro-pneumatic valve is explained where this work discusses of the mathematical model and MATLAB program used in controlling system of pneumatic valve. This paper presents an approach to assessment of the dynamics performance of pneumatic valves.

1. INTRODUCTION

Pneumatic is one of preferred power source in industries due to it is simple, cheap, easy to handle and maintenance and has a high degree of controllability. Within the pneumatic system, valve plays a significant rolein controlling fluid flow into different paths from one or more sources. In getting a good results in pneumatic system operation, users need to monitor and control the valve operating condition. Therefore, this requires the development of suitable control techniques in order to deal with nonlinearities that are common in valve[1].

2. BACKGROUND

Pneumatic valve commonly consists of a body with ports that are connected to internal flow passages by spools inside a cylinder. It is can be controlled either mechanically or electrically controlled. The movement of the spool restricts the flow of fluid. Thus the valve controls the fluid flow. Anothertypical application of this valve is to control the rate of air flow under a given set of pressure condition[2]. The pneumatic valve works when it is actuated either by actuator, followed by movement of spool or end with emission of gaseous.

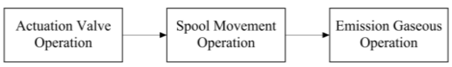

Figure 1 Main working principle of pneumatic valve

3. BASIC CONTROL SYSTEM

The basic mathematical model and control block diagrams will be utilized in modeling control system of pneumatic valve.

3.1 Mathematical Models

Mathematical models relating the various physical parameters may predict and improve the performance of the valve. This paper focuses on electro-pneumatic valve and the mathematical model involved can be separated into three major distinct parts, which are magnetic circuit, mechanical subsystem and air flow path (see Figure 2).

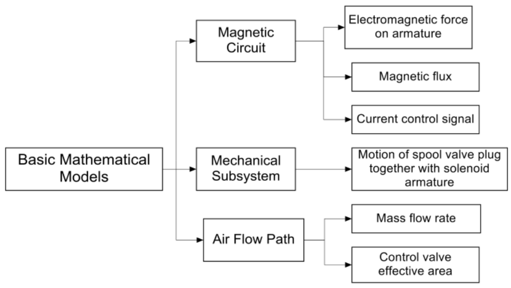

Figure 2 Basic mathematical model

3.1.1 Magnetic Circuit

In general, the mathematical model of the magnetic circuit can be concentrated to the electromagnetic force, magnetic flux and air gap[3]. Below are the mathematical model for the magnetic circuit.

a) Electromagnetic force on the armature

$$FM = \frac{B^2.A_\delta}{2.\ \mu_A} \qquad (1)$$

where

B = the magnetic flux density
A_δ = the cross-sectional area of the air gap
μ_A = the magnetic permeability of air

b) Magnetic flux

$$B = \frac{\emptyset}{A_\delta}\ ;\ \emptyset = \frac{\mu_A.A_\delta.I.\eta_C}{L_M} \qquad (2)$$

where

Φ = magnetic flux
A_δ = the cross-sectional area in the air gap
μ_A = the magnetic permeability of air
I = the current of the control signal
n_C = the number of turns in the solenoid coil
L_M = the magnetic circuit length

c) Current control signal

$$FM = \frac{\delta F}{\delta I}.(I - I_I) + \frac{\delta F}{\delta y}\ y \qquad (3)$$

where

$\partial F/\partial I$ = the electromagnetic stiffness by a control signal current
$\partial F/\partial y$ = the electromagnetic stiffness by an armature movement
I = the current of the control signal
I_1 = the value of the control signal current when the valve armature begins to move
y = the stroke of the armature

3.1.2 Mechanical Subsystem

The mathematical model of mechanical subsystem can be concentrated on the motion of the valve plug together with solenoid armature.

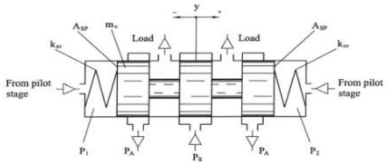

Figure 3 Spool valve schematic diagram (source: [3])

a) Motion of the valve plug together with solenoid armature[3]

$$m_V.\ddot{y} + b_{vv}.\dot{y} + k_{sv}.(y_0 + y) + F_{VF} = (P_1 - P_2).A_{VE} + F_M \quad (4)$$

where

A_{VE} = valve effective area
$(P1 - P2)$ = differential pressure across the plug
m_V = the armature and plug assembly mass
b_{VV}= the viscous friction coefficient
k_{SV} = the valve spring constant
y_0 = the valve spring compression in the valve closed position
y = the valve plug displacement
F_{VF} = the coulomb friction force
A_{VE} = the valve plug effective area
F_M = the solenoid electromagnetic force

3.1.3 Valve Flow Ability

The most important parameters of control valves are their flow ability and control valve effective area[3].

a) Mass flow rate (flow capacity)

$$G = A_V.\beta.P_{in}.\sqrt{\frac{2.k}{R.T_{in}.(k-1)}}.\varphi(\sigma) \quad (5)$$

where

A_V = valve area
β = the degree to which the control valve is open
T_{in} = Test medium air temperature
k = constant
σ = critical value
P_{in} = the upstream pressure

b) Control valve effective area

$$A_V = \frac{G}{\beta.P_{in}.\varphi(\sigma)}.\sqrt{\frac{R.T_{in}.(k-1)}{2.k}} \quad (6)$$

$G = Q_n \times \rho_{an}$,

where

ρ_{an} = the density of air under standard conditions
T_{in} = Test medium air temperature
k = constant
β = the degree to which the control valve is open

3.2 Control System Block Diagrams

The control diagram below represents free body diagram and block diagram of pneumatic valve.

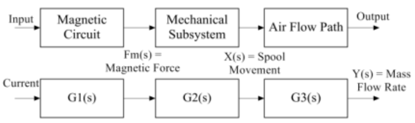

Figure 4 Control diagram of electro-pneumatic valve

4. METHODS

Figure 5 depicts the process flow for identifying result in this project. Begin with identification of the DCV basics. Next, modeling the control system of DCV. Lastly, evaluate response of DCV control system.

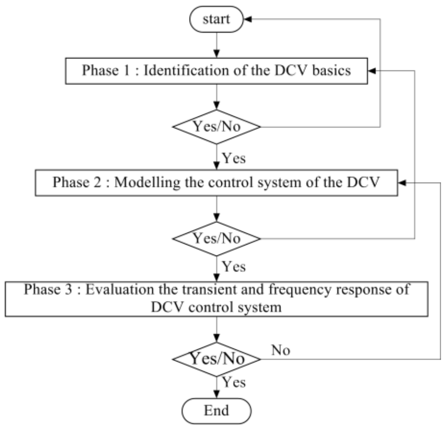

Figure 5 Project process flow

Dynamic performances of electro-pneumatic valve are illustrated below. Graph A represents mechanical part and graph B represents electrical part while graph C represents the air flow rate part.

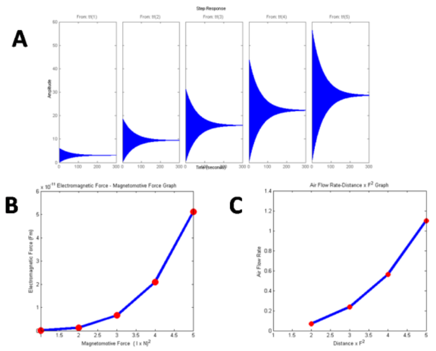

Figure 6 Dynamic performance of electro-pneumatic valve

5. SUMMARY

Mathematical model control system of pneumatic control valve has been identified. To account the control system, we have to analyze the underlying mathematical model with respect to the selected valve. Examining the control system through the mathematical models is the most efficient method whereby this work suggests it is possible to analyze and evaluate the dynamic performance of an electro-pneumatic valve.

6. REFERENCES

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