CONTROL SYSTEM DESIGN FOR PNEUMATIC ACTUATING PROCESS

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Abstract— **Pneumatic actuators are the transforming elements of the control system. Control signal on the real-time machine or system in the form of mechanical or electro-mechanical control movement. Pneumatic valves deal with air pressure. The proposed controller properly manipulated pneumatic directional valves. The performance indicators were analyzed using the performance parameters of the objective function of error criteria. Initially the model-based controller parameter selected based on the mathematical model of Pneumatic systems. Further based on the dynamic behavior, the controller learns themselves to update newer tuning parameters accordingly for external disturbances or servo and regulatory operations. The PID controller provides better setpoint tracking capability and holds the pneumatic valves under specified stable bounds.**

Keywords— **pneumatic valve, PID tuning, pressure.**

I. INTRODUCTION

The technology of fluid power is used to generate, control and transfers forces by means of the use of pressurized fluids in a confined environment and to drive mechanical devices and structures. Pneumatic applications released compressed air into the air. The pneumatic system is more complicated now and a smart pneumatic system has been developed. While pneumatic actuators are employed in many automation industries, they are not easy to control because they have many non-linear features such as problems with the dead zone of the valve, mass flow parameters and compliance variations. System identification is used to obtain the measured experimental data and the plant system's linear mathematical model. The process model for the transfer function has become popular in areas like engineering, computer science, accounting, industrial applications and many others. The architecture of the pneumatic system controller is more complex in position management, power management, compliance, viscosity, etc. The concept of the PID controller for the operation of the pneumatic system was previously proposed. The pneumatic actuator with pulse width modulation (PWM) is also defined by location pulsing algorithms. The mechatronic design has the benefit of replacing more costly servo valves with solenoid valves on / off, and is ideal for a range of practical positions. The above systems are, in most cases, linear process models obtained from experimental data using system recognition and a feedforward location PID controller. Consequently, the purpose of this project is to develop the Intelligent Pneumatic Actuator (IPA) model and methodology to address existing model constraints and improve the performance of the IPA system. System modeling and PID tuning procedures have been performed in the MATLAB environment for IPA simulation.

II. PROCESS MODELLING

A. *Process pneumatic valve modelling*

Every valve has a flow characteristic that defines the relation of the flow rate with the movement of the valve. The flow feature, inherent in the configuration of the chosen valve, permits a certain volume of valve flow at a certain percentage of the bump as a valve opens. It makes a predictable flow control through the valve. The three common types of flux features are:

- Linear
- Equal percentage
- Quick opening

Characteristics of linear valve:

This function provides a linear relation between the location of the valve and the flow rate. The flow through a linear valve and the valve stem location are proportional to each other. When drawn on the straight cords, this flow travel relation approximates a straight line, giving equal variations in volume for the same lifting changes irrespective of the percentage of the valve opening.

Such valves are often used for control of fluid level and certain flow control operations that need a constant benefit.

$$k_v = \pm\frac{1}{100}c_{v,max}\sqrt{\frac{\Delta p_v}{G_f}}$$

Characteristics of Equal percentage valve:

The same percentage valve plug produces the same change in flow per fixed increase of the valve stroke anywhere on its proper curve. For instance, if 30% stem lifts produce 5 gpm and 10% to 40% lifts produce 8 gpm or 60% higher than the previous 5 gpm, then another 10% increases now 60% over the previous 8 gpm, for a total flow of 12.8 gpm.

Such valve types are widely used for pressure control applications and are best suited for applications where the pressure drop is expected to change significantly.

$$k_v = \pm\frac{1}{100}(\ln\alpha)\bar{c_v}\sqrt{\frac{\Delta p_v}{G_f}}$$

Characteristics of Quick opening valve:

A fast opening valve connection results in a significant flow increase for a small initial shift in stem movement. At a relatively low percentage of the average flow is achieved. Quick opening plugs are usually used in two "On-Off" applications, but may be used in some linear valve applications. Thanks to its linear origin at a low percentage of the stem movement, this is likely. The steep slope of this linear area produces a greater initial gain than the linear plug, but also increases the possible instability of the control valve.

$$k_v = \pm\frac{1}{100}(\ln\alpha)\bar{c_v}\sqrt{\frac{\Delta p_v}{G_f}}$$

TABLE 1

TIME (s)	LINEAR	EQUAL PERCENTAGE	QUICK OPENING
0	0	0	0
1	0	0	0
2	1.501688	1.551401302	36.86163589
145	14.76	39.56261325	57.64
146	14.76	39.56759254	57.64
147	14.76	39.5723772	57.64
198	14.76	39.67460581	57.64
199	14.76	39.67520754	57.64
200	14.76	39.67578575	57.64

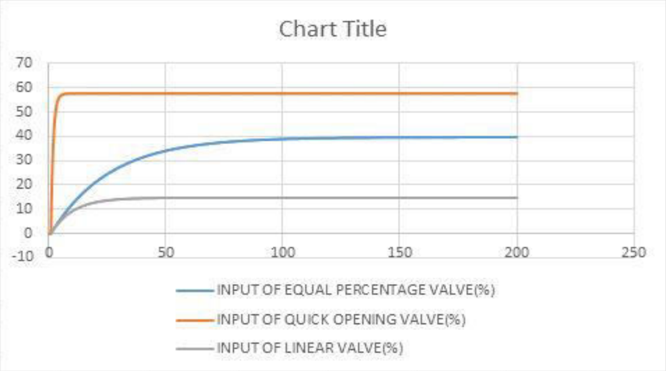
Three Valve Characteristics with Respect to Time

Fig.1 Valve characteristics with respect to time

An open loop test has been conducted for the three valves, values has been tabulated and plotted in the form of graph as shown in table 1 and Fig.1 respectively.

Inherent Characteristics:

The relationship between flow under constant pressure and valve opening conditions is an inherent flow characteristic. When a pressure drops over the



valve for all valve positions, the intrinsic feature of a valve is achieved: the process fluid doesn't flanged, caviting or approaching sonic velocity (choked flux); and the actuator is linear (valve stem movement is proportionate to the controller output).

III. CONTROLLER PROCESS

A. PID Tuning

The tuning process of a controller gains based on the plant data is called automatic PID tuning. Simulink model can be used for tuning the PID gains using Simulink controller design. The method used here is Model – based PID controller tuning and its tools includes PID tuner. This helps us to validate system performance by interactively tuning PID gains. A linear plant model is required for working of PID tuner [8]. If the plant model is non-linear then the PID tuner works against the data response that was measured.

A single – loop PID controller can be tuned in both simulation and real time with the help of the close-loop PID auto-tuner block. The plant output during the closed loop experiment was measured by injecting sinusoidal perturbation signals. The block computes the PID gain when the experiment stops and that is near the desired bandwidth.

The general formula for PID control which combines Proportional control, Integral control and Derivative control in parallel is,

$$C_{PID}(s) = K_p \ (k + \frac{k_i}{s} + k_d s)$$

Where,
K_p = PID control gain
k = constant
k_i = integral gain
k_d = proportional gain

The tuning methods of PID controller are,

- Zeigler – Nichols method
- Cohen coon method

Zeigler – Nichols Tuning:

The procedure for Zeigler –Nichols (Z-N) tuning are as follows,

- The plant should be set up with a very small gain under Proportional controller.
- The gain is increased until the loop starts oscillating.
- The critical gain of the controller (i.e) $K_p = K_c$ and oscillation period of controller output (i.e) P_c are recorded.
- The process parameter of the controller should be adjusted in accordance with the table as follows.

	K_p	T_r	T_d
P	$0.50K_C$	-	-
PI	$0.45K_C$	$\frac{P_c}{1.2}$	-
PID	$0.60K_C$	$0.5P_c$	$\frac{P_c}{8}$

- The Z-N method was developed in-order to eliminate some controversies in PID parameterization.

$$C_{PID}(s) = K_p \left(1+\frac{1}{T_r s} + \frac{T_d s}{T_d s+1}\right)$$

Thus, the undammed response for the step input was in the form,

$$G_0(s) = \frac{K_0 e^{-ST_0}}{v_0 s+1}$$

Cohen And Coon Tuning:

- If the process is performed at manual mode, we should until the process reaches the steady state.
- A step change is introduced in the input.
- A first order process is obtained based on the output with the time constant t delayed by t_{DEL} units.

Based on the above parameter the formulas are described below:

	K_c	t_I	t_D
P	$\frac{1}{Kr}(1+\frac{r}{3})$	-	-
PI	$\frac{1}{Kr}(0.9+\frac{r}{12})$	$\tau_{DEL}(\frac{30+3r}{9+20r})$	-
PID	$\frac{1}{Kr}(\frac{4}{3}+\frac{r}{14})$	$\tau_{DEL}(\frac{32+6r}{13+8r})$	$\tau_{DEL}(\frac{4}{11+2r})$

where, $r = \frac{\tau_{DEL}}{\tau}$

TIME (sec)	LINEAR VALVE	EQUAL PERCENTAGE	QUICK OPENING
0	0	0	0
1	0	0	0
2	1.017049817	1.03802015	0.999824794
491	1	1	1.000054804
492	1	1	1.000042746
493	1	1	1.000060646
998	1	1	1.000026001
999	1	1	1.000053434
1000	1	1	1.000081336

IV. RESULT AND DISCUSSION

TABLE 2
PID tuning of three valve characteristics

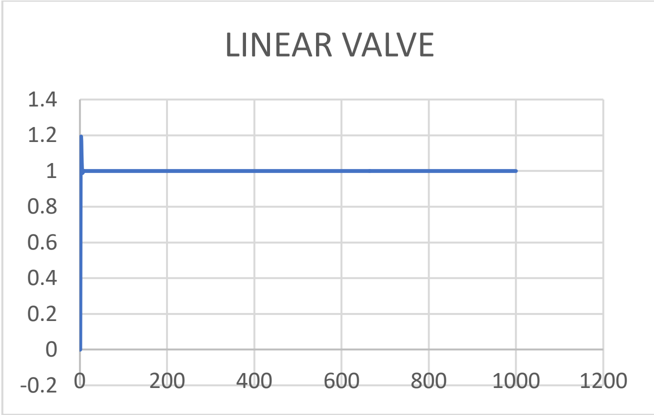


Fig.2 PID tuning of Linear valve characteristics with respect to time

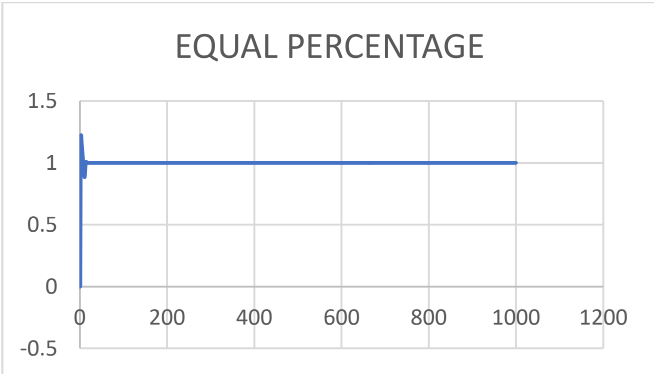


Fig.3 PID tuning of Equal percentage valve characteristics with respect to time

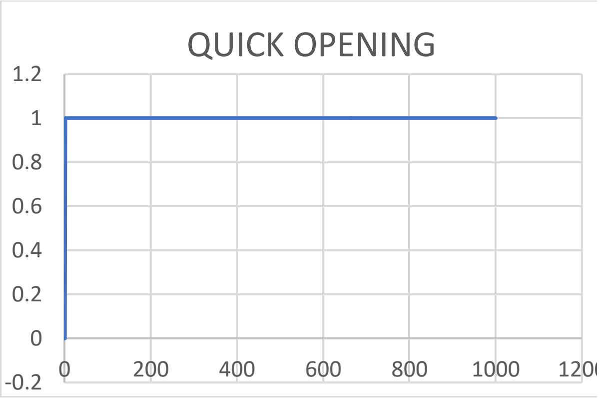


Fig.4 PID tuning of Quick opening valve characteristics with respect to time

The open loop test has no accurate results and so we have conducted closed loop test using Ziegler Nichols PID tuning the three valve characteristics and the values of closed loop tuning has been tabulated and plotted as shown in table.2 and Fig. 2,3,4 for linear, equal percentage and quick opening valve characteristics respectively.

V. CONCLUSION

Based on the experimental and simulation response, it is observed that conventional PID controller provides steady state and larger settling point. So, this project provides suggestion for the pneumatic actuating process is that to make use of Ziegler-Nichols PID controller, thecost function has been minimized and the end product quality has been maximized.

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BIOGRAPHY

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