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Mechatronic Solution for Low Cost Closed Loop Control of Pneumatic Cylinder for Accurate Position Control with on-off Solenoid Control Direction Control Valve

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Abstract- Most vital part of the automation is the control of the automatically operated devices. Basic forms of automation are Hydraulics, Pneumatics, Electronics, Electrical and Mechanically operated automatic systems.

Out of these systems the cheapest system is pneumatic system and also it is less intricate system. It can be readily used anywhere but the inherent limitation of the automation available through this system is the lack of perfect control especially for position and velocity control. This problem prevails due to the typical characteristics of the air defined as compressibility. Air being the medium for transmitting the motion not controllable due to compressibility.

Modern studies propose to achieve similar performances to that of conventional systems (hydraulics & electric) servo pneumatics system, that overcome the problem encountered in controlling these actuators by using advance control techniques.

Application of pneumatic circuits are vital for position control in case of transferring fluid, robotic manipulators and it can be extended in many applications where they are not being used because of the inherent incapabilities of air.

On the other hand, it is a complex task to model pneumatic system as they are highly non-linear, subjected to high level of friction with stiction and also due to compressibility of air, which cannot be neglected, especially during slow movement. These non-linearities make accurate position control of pneumatics actuator more difficult; as a consequence, control algorithms are more complex than other system.

There are lots of research work is going on for development of servo pneumatic system for position control, Many of them has got success using expensive servo valve.

The objective of the paper is to develop inexpensive system for position control of pneumatic actuator using simple direction control valves. The servo valves are very costlier than stepper motor operated flow control valve and also servo valve tend to bulky compared to compact and lightweight stepper motor operated flow control valve. Some researchers have tried to achieve inexpensive position control of pneumatic actuator using ON/OFF solenoid valve. But by ON/OFF solenoid valve method fine control of pneumatics actuator is difficult to achieve because of the limitation of the valve response time and its discrete ON/OFF nature and compressibility of the air.

The paper provides the newly developed circuit and algorithm for fine control of pneumatics actuator by overcoming previous problem discuss with ON/OFF solenoid valve. The paper includes the detail of hardware design and design of controller.

INTRODUCTION

A simplified pneumatic circuit using on-off direction control valve is shown in fig 1 and it works on a very simple principle as illustrated below.

A double acting Pneumatic cylinder (1) having two ports is connected to a 4/2-direction control valve (2) via the flexible pipes (3).

Compressed air source 4 is also connected to one of the port of the four-port direction control valve. Direction control valve is controlled through two solenoids. One solenoid is energized the compressed air enters the cylinder through port from the piston side and when the opposite solenoid is energized the compressed air enters the cylinder through the opposite side port i.e. the port of the piston rod side. So one solenoid does the extension of the cylinder whereas the second solenoid does the retraction of the cylinder.

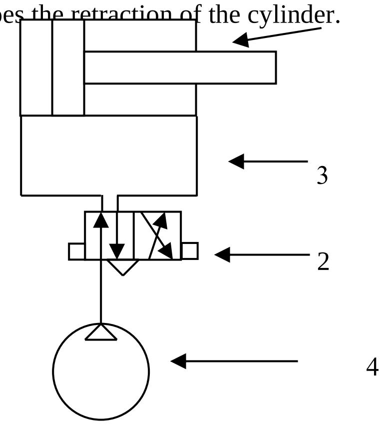

Figure1: pneumatic circuit used in typical pneumatically controlled device for motion control

As it is evident from figure 1 that the control signal is given to the solenoid of direction control valve which block the passage for the compressed air towards the cylinder in either case. But as the motion of the cylinder is available due to the force exertion of the compressed air on either side of the piston. The air will expand and its pressure will drop until a value which will not be sufficient for the air pressure to further push the piston. This working has got a sufficient time lag which most of the time lets the piston move to either of the extreme towards which it was moving. But from the control point of view, the exact braking of the piston is must to perform some intricate and accurate jobs.

When the error will be zero that time the microcontroller will send the signal to the solenoid of the auxiliary direction control valve. So the air, which is leaving the cylinder, will be fed to the piston side of the auxiliary piston. So the air will not find any path due to which first of all the air will tend to push the piston but the piston will also be subjected to a differential force of the auxiliary cylinder piston. Even the slight movement of the piston after the signal will tend to move is back because there will be continuous pressure force from the piston side of the auxiliary piston cylinder. Even if any error is left out in the movement LVDT will produce the output signal, which will generate the electrical signal, and the signal will be fed to the solenoid of the direction control valve for the correction.

SOLUTION

Fig. 2. shows the same circuit with certain modifications for the position control of the cylinder. One more direction control valve is added and an LVDT is introduced. The function of LVDT is to produce the output signal according to the displacement of the piston so there is a continuous monitoring from the output side for the displacement. An input signal from the keypad is introduced to define the displacement This can not be achieved using this simple circuit. So the solution for this type of situation can be a closed loop circuit as described below. A microcontroller will compute the corresponding output in terms of the electric signal and will compare this value with the value of the LVDT feedback.

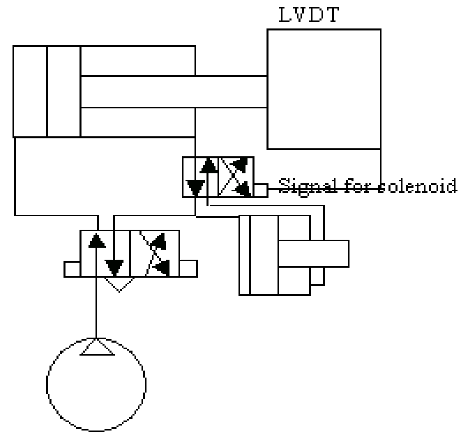

Figure2: pneumatic circuit used in typical pneumatically controlled device for motion control using closed loop circuit which controls the output displacement.

ELECTRICAL CIRCUIT

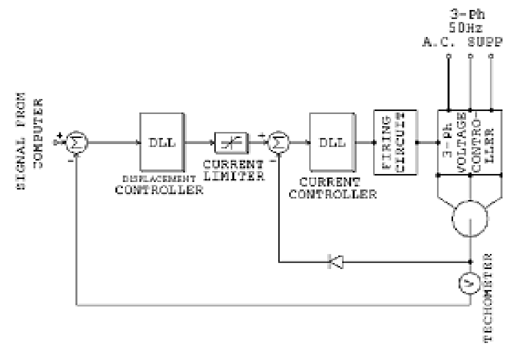

Figure3: Electronics circuit used in typical pneumatically controlled device for motion control using closed loop circuit which controls the output displacement.

As shown in figurer 3 the input signal from the keyboard or any input device is entered in the form of desired displacement. This signal is processed by Distance Controller. Output of which is fed to current controller. This output is compared with the feedback and the error current signal is fed to again another current controller which triggers the firing circuit. This in turn gives the signal to the 3 phase voltage controller which gives the output to the solenoid valve.

Capacitive gages (capacitance sensors) are the nanometrology system of choice for the most demanding precision positioning, scanning and measurement applications. Two plate capacitive displacement sensors ensure highest linearity and long term stability. These absolute-measuring, non-contact devices detect motion at sub-nanometer levels directly (direct metrology). They provide accuracy, linearity, resolution, stability and bandwidth superior to conventional sensors such as LVDTs, strain gauge type sensors (piezo resistive sensors), and incremental encoders (glass scale type encoders). The output voltage of LVDT is low. We have to put one amplifier circuit to increase the voltage level for the comparisons of voltage to generate proper pulse signal to the voltage controller to control the position of pneumatic valve. The amplify voltage is proportional to the generated voltage by LVDT.

The main difficulty in integrating optical position sensors on the same substrate of the printing head is concerned with the limited available space and the large feature size of the power CMOS technology used for printing head fabrication. Two different approaches have been followed for the print head position detection. The first is related to a position-to-delay conversion algorithm and requires two couple of photo sensors with proper shape. The position of the light spot impinging on the sensor is extracted by simply measuring the delay between the transitions of the two couple of sensors.

Resolution is achievable with short-range, two-electrode capacitive position sensors. Theoretical measurement resolution is limited only. In practical applications, stray radiation, electronics-induced noise and geometric effects are the limiting factors. This translates to 0.2 nm at 100 Hz bandwidth. The maximum standard bandwidth (jumper selectable) is 3 kHz.

The 3-phase circuit can provide forward motoring and reverse plugging operations. The use of class D design squirrel cage motor allows higher torques to be produced, with reduced currents, for low speed motoring and high speed braking operations. In firing circuit, while changing from one set of thyristor pairs to another care should be taken to ensure that the incoming pair is activated only after the outgoing pair is fully turned off. Failure to satisfy this condition will cause short-circuiting of the supply by the conducting thyristors of the two pairs. The protection against such a fault can be provided only by the fuse links and not by the current control. Therefore, when changing from one set of thyristor pairs to another, firing pulses are withdrawn to force the current to zero. After the current zero is sensed by the zero current sensors, a dead time of 5 to 10ms is allowed to ensure that all the thyristors of the outgoing pair have in fact turned off. Now the pulses are released to the incoming set of thyristor pair. For closed loop speed control, the inner current control scheme described in the circuit. It consists of a speed controller, current limiter, current controller and firing circuit. A closed loop scheme for the single quadrant control results are shown in the figure. A four quadrant closed loop drive can be realized by using the voltage controller.

Computer input sets the speed reference. A signal proportional to the motor speed is obtained from the speed sensor. The speed sensor output is filtered to remove the ac ripple and compared with the speed reference. The speed error is processed through a aped controller. The output of the speed controller adjusts the rectifier firing angle to make the actual speed close to the reference speed. The speed controller is usually a PI controller and server three purpose-stabilizes the drive and adjusts the damping ratio at the desired value, makes the steady state speed error close to zero. Sometimes in close loop control system PD & PID controllers are often used. But they are not preferred in converter drives because of the presence of substantial noise and ripple in the current and speed feedback signals. The output current control overrides the speed control and the speed error is corrected essentially at a constant current equal to the maximum permissible value. When the speed reaches close to the desired value the output falls to the rated current. The current control goes out of the action and speed control takes over. Thus in this scheme at any given time the operation of the drive mainly controlled either by the speed control loop or the current control loop and hence it is also called parallel current control loop.

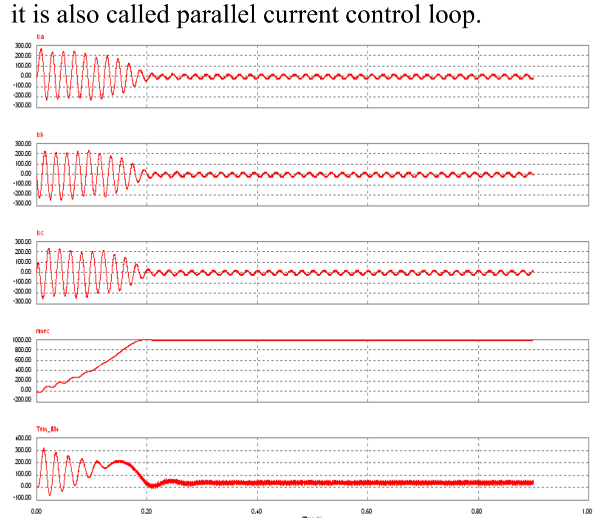

Fig 4.1,4.2&4.3 graphs are of current which will measure by current sensor.
Fig 4.4 graph of speed control
Fig 4.5 graph of torque as speed is constant torque will be constant.

CONCLUSION

It can thereby be concluded that there is a definite possibility of controlling the pneumatically controlled actuators without going for a costlier solutions. Even the suggested circuits do not add up major components and the cost. Further research may prove better results than these ones. What is written in the basic books of pneumatics about the intermediate position control of pneumatic actuators without sophistication is easily possible.

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REFERENCES

[1] B.K. Bose – Power Electronics & A.C. Drives, Prentice Hall New Jersy, 1986.
[2] Ned Mohan et. Al., Power Electronics', John Wiley & Sons 1989.
[3] M. Chilikan 'Electric Drives', Meer Publishers – Moscow 1970.
[4] R. B. Van Varsevald and G. M. Bone, "Accurate Position Control Of A Pneumatic Actuator Using On/Off Solenoid Valves" IEEE/ASME Transactions On Mechatronics, Vol.2, No. 3, pp.195-204,1997.
[5] S. Chillari, S. Guccione & G. Muscato, "An Experimental Comparison Between Several Pneumatic Position Control Methods", proceeding of the 40th IEEE Conference on Decision And Control, Orlando, Florida USA, December 2001.
[6] A. K. Paul, J. K. Mishra & M. G. Radke, "Reduced Order Sliding Mode Control for Pneumatic Actuators", IEEE Transactions Control System Technology, Vol.2 pp.271-276, September 1994.
[7] Control System Engineering, Third Edition by Norman S. Nise Publication: John Wiley and Sons Pte Ltd.
[8] Hydraulics and Pneumatics Manual by Bosch Rexroth Group India Ltd.
[9] Control System Engineering, Third Edition by I.J. Nagrath & M.Gopal, Publication New Age International Publishers.