CONTROL OF PNEUMATIC SYSTEMS

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Abstract: In any system, regardless of the type of drive used, components of command and control are vital. This paper presents, not strictly the pneumatic element with which the command or control is achieved, but in a much more concrete way, position of these elements in functional schemes and highlighting positive or negative effect of the structure presented.

Keywords: pneumatic systems, control

1. Introduction

Pneumatic actuators play an important role in today's industrial automation. It is a very safe method of operation, economical and easy to use.
The use of pneumatic motor drives leads to a very clean, quiet, low heat loss driving. These advantages make the pneumatic operation very often used in material handling applications for making repetitive movements.

2. Pneumatic systems for position control

Pneumatic position control systems are used in robots and manipulators construction, "pick and place" devices and in other types of material handling equipment.

Position control systems can be classified as:

- Closed loop systems;
- Open loop systems.

In general, open loop pneumatic motor system has mechanical stoppers. In the simplest case, the system has a pneumatic cylinder in which two covers plays the role of maintaining stop positions.

Figure 1 shows the block diagram of such a motor. This construction type has a piston (1) with two cylindrical parts (2, 3), which together with the lid cavities (4, 5) provide air cushion mechanism.

Solenoid distributor (6) connects pneumatic cylinder to air output, according to control algorithm. Control of displacement speed is done using throttles (7 and 8). Piston (1) contains two permanent magnets (9 and 10) and two proximity sensors (11 and 12) positioned outside of the cylinder.

Figure 2 shows the schematic diagram of pneumatic engine, which is able to stop the piston in two adjustable positioning points throughout its stroke.

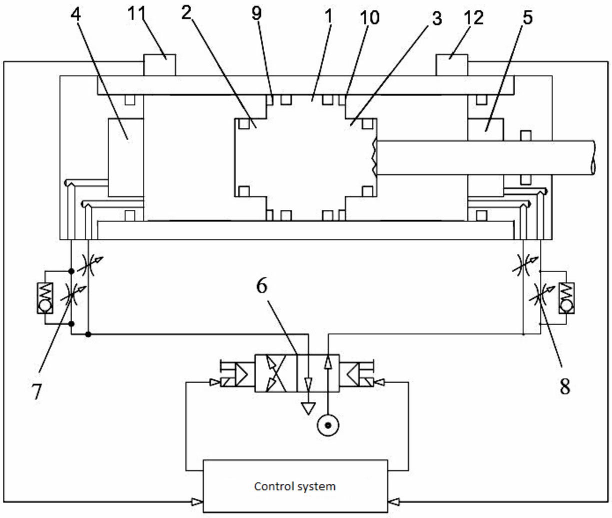

Figure 1. Block diagram of a pneumatic cylinder with two final stops

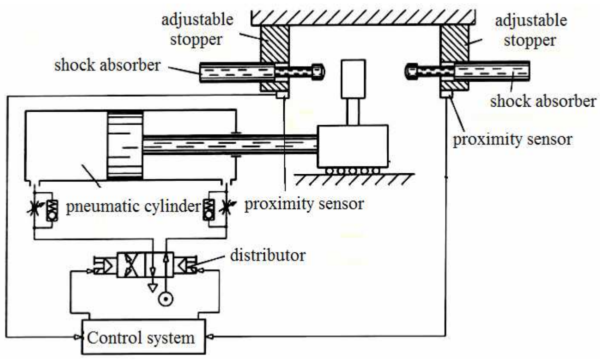

Figure 2. Pneumatic positioning motor with two adjustable stops

The structure of this system is similar to the structure shown in figure 1, the main difference being the use of shock absorbers in place of air cushions. This system can provide high speed and repeatability of positioning. The major disadvantage of the pneumatic motor is insufficient flexibility because shock absorbers are not programmable and they must be manually moved to achieve a desired intermediate position.

Figure 3 illustrates a three-cylinder pneumatic motor with four positioning options. Although this construction is simple and ensures safe operation during the stop phase it appears certain shocks, which sometimes disturb the stability of positioning. In some cases these systems are voluminous because of the high number of used solenoid distributors.

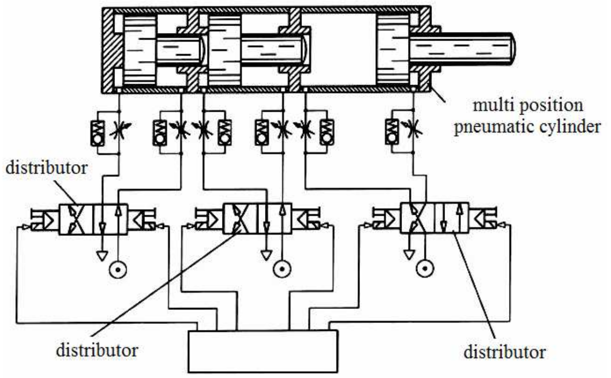

Figure 3. Multi-position pneumatic cylinder motor

The actuator shown in figure 4 may be used to implement the open loop positioning system, obtained by using adjustable stoppers. Each adjustable stopper (in this case it is a single action cylinder) has its own driving system.

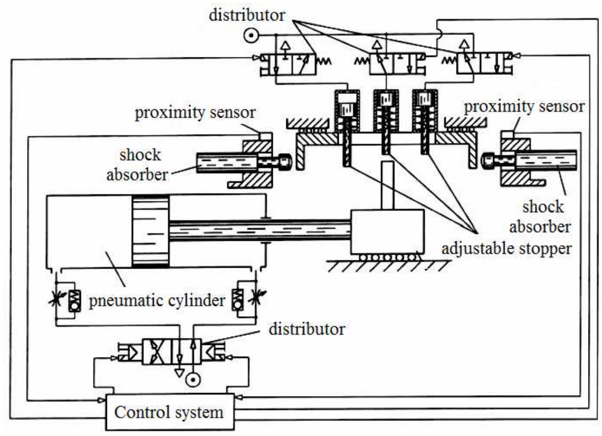

Figure 4. Multi engine-positioning with adjustable brackets

The adjustable stoppers are assembled on a joint base that can move along the displacement axis of the main cylinder. The main movement is limited by two mechanical stoppers that define the shock absorbers. This type of motor is used only when the stops are not more than five or six, otherwise these systems become too voluminous. Positioning repeatability is about 0.03-0.04 mm.

Closed loop pneumatic actuator has a transducer that detects and transforms the output into electric signal. This feedback signal is compared with the command signal, the resulting signal error being used to attain the desired position or track the motion trajectory.

To attain point to point displacement in a closed loop positioning system are widely used two well-known devices:

- servo-valves or proportional valves to control air flow;
- brake device.

Figure 5 shows the general diagram of a positioning motor with pneumatic brake. System contains a pneumatic cylinder (1), a mechanical brake (2), which is controlled by the pneumatic cylinder (3). There are also: a positioning sensor (4) that measures the load displacement, distributors (V_1-V_4), throttles (R_1-R_4) and a control block.

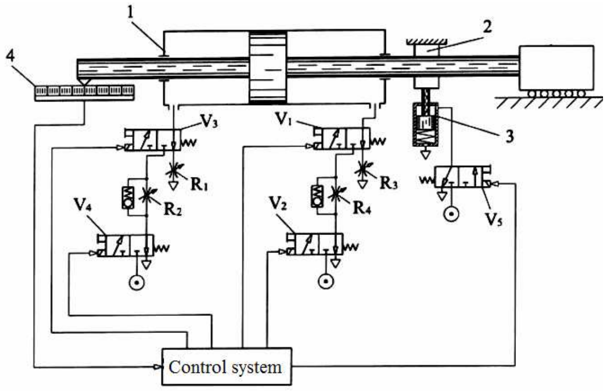

Figure 5. Positioning motor with pneumatic brake

The four distributors (V_1-V_4) are pair series connected and have two functions: to control the pneumatic cylinder (1) and to ensure the maximum and minimum load displacement speed. These controls are done using four throttles (R_1 and R_3 for high speed and R_2 and R_4 for low speed). To control the break of pneumatic cylinder (3) is used the distributor (5).

Another construction diagram for positioning actuators includes a magneto-rheological brake system mounted parallel to a pneumatic cylinder or an actuator.

The force given by the magneto-rheological brake is proportional with the current input. Close loop of positioning sensor ensures an accurate and robust movement control.

Figure 6 represents the general diagram of such a positioning actuator. The desired position of the cylinder is attained using the three slides solenoid distributor. Such a linear positioning system offers a wide range of controlled speeds (for example, a pneumatic cylinder with 32 mm inner diameter and 160 mm stroke may have a range of constant speed between 20 and 500 mm/s and a positioning repeatability of ± 0.15 mm).

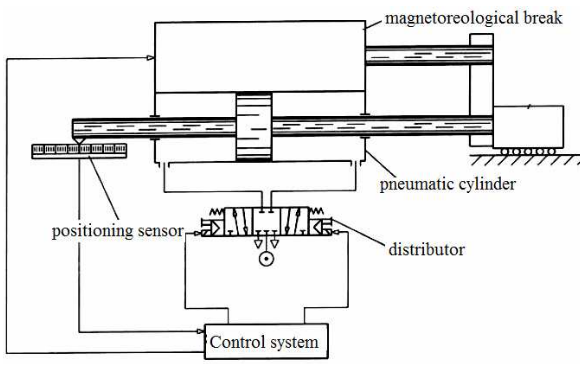

Figure 6. Positioning motor with magneto-rheological brake

3. Pneumatic systems for speed control

Figure 7 presents the general diagram of a rotational pneumatic actuator with a speed control circuit incorporated. The three positions distributor ensures the desired rotation sense. Actuator stop position corresponds to middle position of distributor. The driving element rotates the shaft on which is mounted magneto-rheological brake, load and speed sensor.

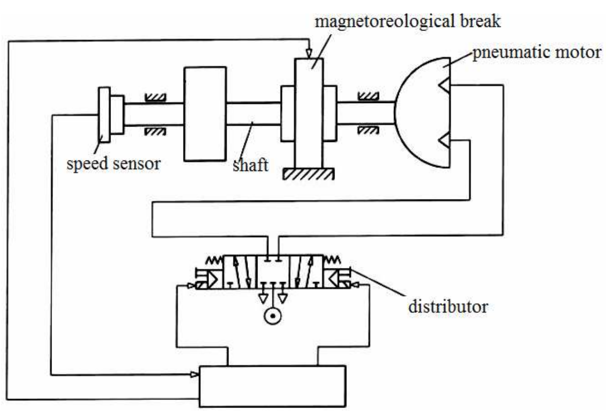

Figure 7. Rotary motor with magneto-rheological brake

Angular position of the shaft is control by changing the torque of brake impedance. For this system, control precision is around 15% of desired value. Pneumatic actuator for speed control using servo-valve or proportional valve generates the error signal analogue to positioning servo-actuator, except that rather is detected the output speed than load position. When speed loop is active the error signal is applied to position the load.

Most pneumatic applications require both position and speed control. The easiest way to add the position control is to design a cascade loops structure (position loop includes speed loop).

In the last years there were achieved great progresses in this field. Thus, today, there are different pneumatic cylinders with better friction and lubrication characteristics.

4. Pneumatic systems for force control

In a circuit is commonly used a pressure regulator to control pressure and a pneumatic cylinder or a motor to transform this pressure into a force or torque accordingly. Also, a directional control valve can be used in certain cases.

To detect force it may be used either a strain gauge, mounted between load and pneumatic cylinder shaft, or a pressure transducer, used for motor's chambers.

Response signal is analysed by the system and used to control pressure regulator or control distributor. The response pressure of the circuit controls forces without considering the friction characteristics of the cylinder. The two pressure transducers have as output, with no contact, the piston position.

When the piston is closed to a transducer it is induced a magnetic field that generates electric signal. The main role of the air cushion is to absorb and dissipate the kinetic energy. This adjustable impact cushion is used for pneumatic cylinders with speeds greater than 0.2 m/s. This air cushion has also the role of reducing the phonic pollution, very noxious both for employers and environment.

Figure 8 presents a schematic diagram of a pneumatic linear motor force control that contains an electronic closed-loop proportional pressure.

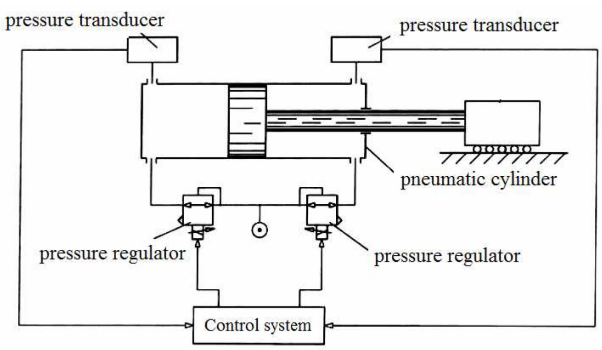

Figure 8. Pneumatic actuator with pressure regulator to control force

This system uses a pressure transducer to close the control loop. The major disadvantage in this case is the small response time and response time variation depending on the load position. Therefore, such systems can be used in applications where these disadvantages can be tolerated.

Figure 9 presents the general diagram of pneumatic actuator with force control. Distributor control de force desired between the cylinder shaft and load. Force is measured using a strain gauge. Even if it is changed the analogue controller with a digital one, there are no significant advantages in force control. The precision of a force control system is primary determined not by the used signal processing method but by the transducer quality and kinematic aspects regarding force appliance.

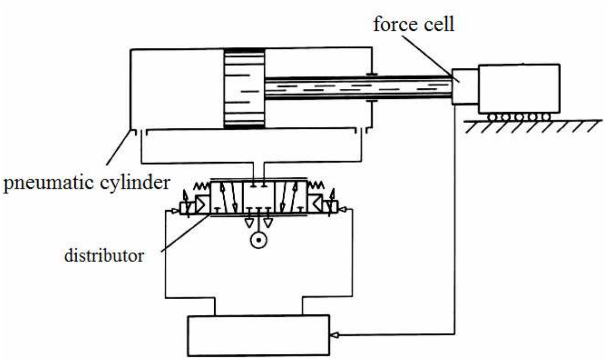

Figure 9. Pneumatic motor with force adjustment distributor

5. Conclusions

Control systems are analyzed in this paper in terms of two broad classes: open loop and closed loop.

Open loop control depends on human reasoning and must be estimated. An important disadvantage registered by the open-loop systems is that they cannot adapt to environmental changes.

From pneumatic point of view, open loop control systems include, besides pneumatic motor, which in most cases is a simple effect pneumatic cylinder, some stoppers: mechanical, air cushion, permanent magnet.

These stoppers allow limiting the movement either at the end of stroke or in intermediate positions, but their great disadvantage is that they must be manually set after the movement and analysis of system response.

The disadvantage of open-loop control is removed by using closed-loop control, which has the great advantage given the reaction system. Closing the control system determines the error and thus controls the movement of the whole system.

If the disturbances are measurable, control function will based on these inputs attaining a direct control. When the goal is to attain both direct control of disturbance and force control relative to reference, it should be implemented a combine control method. One of the most used combined methods is cascade one. This method allows decomposing the system into sub-processes, casually interconnected; the number of controllers is equal to measured variables.

Pneumatic speaking, a closed-loop control system contains a motor (most common is linear), a transducer for each desired output variable, one or more distributors for the reverse movement or to stop its movement (mounted upstream of the cylinder) and flow control systems / pressure.

The main parameters controlled by pneumatic control systems are: position, speed and motor force, control can be achieved either directly or combined or simultaneous position and speed control, which involves a cascade control with speed loop included into the position loop.

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