The Impact of Directional Control Valves on Pneumatic Circuits

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Abstract: *The article presents the new trend in pneumatic circuits. It also presents two pneumatic circuits equipped with directional control valves. Since pneumatic installations with directional control valves offer numerous advantages in industrial environments—such as precise motion control, high speeds, and high force—they can be effectively used both as a working medium and as a control medium to facilitate various movements: rotational, linear, or rapid changes of direction in a wide range of technical applications. Moreover, this paper includes material on the study of the basics of pneumatics: Bernoulli's equation and the valve flow coefficient (Kv). The first pneumatic circuit consists of the following parts: a single-acting cylinder (SA 1), a throttle valve, a 3/2-way normally closed valve, and a compressed air supply. In contrast, the second circuit consists of six components: a single-acting cylinder (SA 2), an operated 3/2-way valve, a 3/2-way normally closed valve, a manifold, a start-up valve with filter, and a compressed air supply.*

Keywords: *Simulation, coefficient, spring, operator*

1. Introduction

Directional control valves are used to control the direction and movement of pneumatic air through a circuit. A pneumatic circuit operates using compressed air from a compressor. The compressor compresses the air to the desired pressure, and this is made possible by hoses that connect the compressor to various valves.
These pneumatic valves ensure that the compressed air is directed to the correct parts through the connected hoses. In addition, safety and pressure relief valves ensure that the compressed air is introduced into the system at the correct pressure [1].
Directional valves, also known as directional control valves (DCVs), are devices that control the start, stop, and direction of air in a pneumatic circuit. These devices operate by opening, blocking, or changing the path of air through ports. In this case, directional valves use a spool or slide valve, which is actuated by a lever or solenoid, Fig .1.

Fig. 1. 3/2-way valve

Anyway, the pneumatic valves are classified according to the number of ports (ways) and operating positions: a 3/2-way valve has three ports and two positions, a 4/2-way valve has four ports and two positions, a 5/2-way valve has five ports and two positions, and a 5/3-way valve has five ports and three positions, Fig. 1.
But, in this paper, we only study 3/2-way valves, Fig. 2.

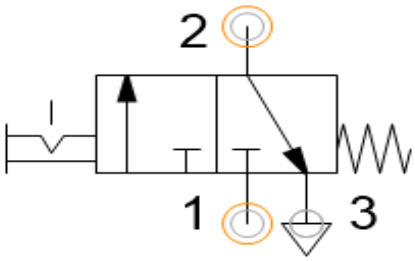

Fig. 2. Symbol of pneumatic device: 3/2-way valve with spring

Pneumatic valves in circuits are configured according to:
- the number of possible flow paths or switching positions
- the number of inlet and outlet ports they have
- the mechanism used to open or close the ports
- the state of the valve when not actuated.

In practice, several types of valves are used: solenoid valve, pneumatic valve, mechanically operated valve, electrically actuated valve, and manual valve [2].
The operation of a solenoid valve is represented by a specific symbol. This symbol generally consists of the following components:
· The square frame that represents one switch position (multiple squares mean multiple switch positions).
· The lines in the frame represent the connections. These lines are indicated in the box that shows the normal/rest position (usually right).
· The arrows in the frame indicate the direction of flow.
Properties of a directional control valve:
- Normally closed (NC): In the idle or unactuated position, the valve is closed. When the operator actuates the directional control valve, it opens, and air flow through the circuits is possible, Fig.3.

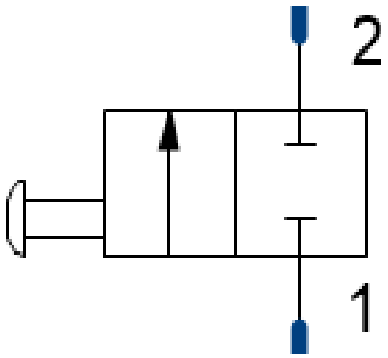

Fig. 3. Normally closed (NC)

-Normally open (NO): In the unactuated position, the directional control valve is open. When the operator actuates the pneumatic valve, it closes and no air can flow through the installation, Fig. 4.

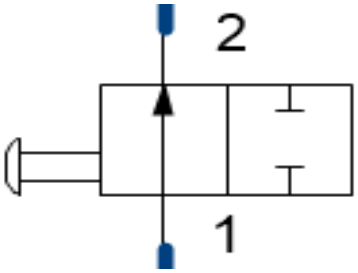

Fig. 4. Normally Open (NO)

2. Study of directional control valves

A pneumatically operated directional control valve, also known as a pneumatic valve, is a type of valve that uses air pressure to perform a function similar to a solenoid. As the air pressure increases, the compressed air begins to push against the walls of the piston or diaphragm, which causes the valve to actuate [3].
On the other hand, these technical applications with directional control valves are found in a wide range of industries, such as food and chemical processing, material handling, etc.
The methods of actuating directional control valves depend on the pneumatic installation. The methods of actuating valves can be manual, mechanical, pneumatic, electric and combined.
The pneumatic installations have one or more directional control valves.
Thus, the first pneumatic circuit contains only one valve [4].
In pneumatic installations, a 3/2-way valve flow coefficient (Kv) is a measure of a valve's flow capacity, more precisely how much fluid can pass through it at a given pressure drop when the valve is fully open. In this case, for a 3/2-way valve, which has one inlet and two outlets, the flow coefficient indicates its ability to direct fluid between one inlet and one outlet and to evacuate the system [5].

$$K_V = Q\sqrt{\frac{SG}{\Delta P}} \tag{1}$$

Where:
K_V – valve flow coefficient
Q – Flow rate
SG – Specific gravity of fluid at 16 ^{0}C
ΔP – Pressure drop across valve inlet and outlet.

Bernoulli's equation gives the relation between mean velocity and static pressure:

$$p_1 + H_1 \cdot \rho_1 \cdot g + \frac{1}{2} \cdot v_1^2 \cdot \rho_1 = p_2 + H_2 \cdot \rho_2 \cdot g + \frac{1}{2} \cdot v_2^2 \cdot \rho_2 + \Delta p_h \tag{2}$$

Where:
- 1 – refers to upstream conditions
- 2 - refers to downstream conditions
- v – mean velocity
- P – static pressure
- ρ – density
- Δp_h – pressure loss
- H – relative height
- g – acceleration of gravity.

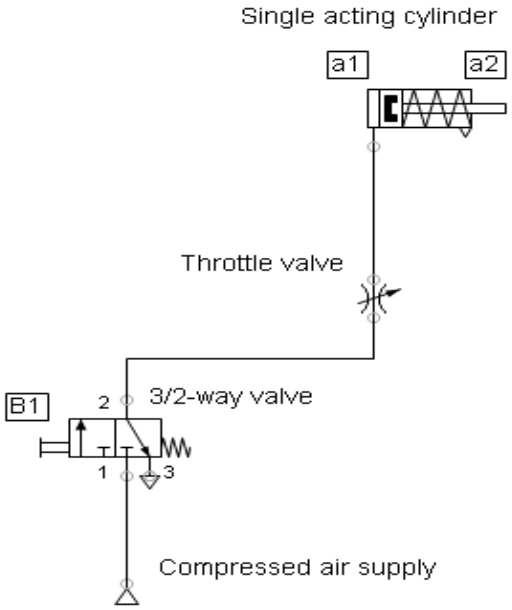

Fig. 5. Pneumatic circuit with one 3/2-way valve

The first pneumatic circuit consists of four devices, which are shown in the table below [6].

Table 1: Devices of the first pneumatic scheme

Description	Number of components
Single acting cylinder	1
Throttle valve	1
3/2-way valve normally closed	1
Compressed air supply	1

If the operator pushes the lever on the 3/2-way valve to the right, then the piston moves from point a1 to point a2. After that, the piston moves back because the 3/2-way valve has a spring on the right side, Fig. 6.

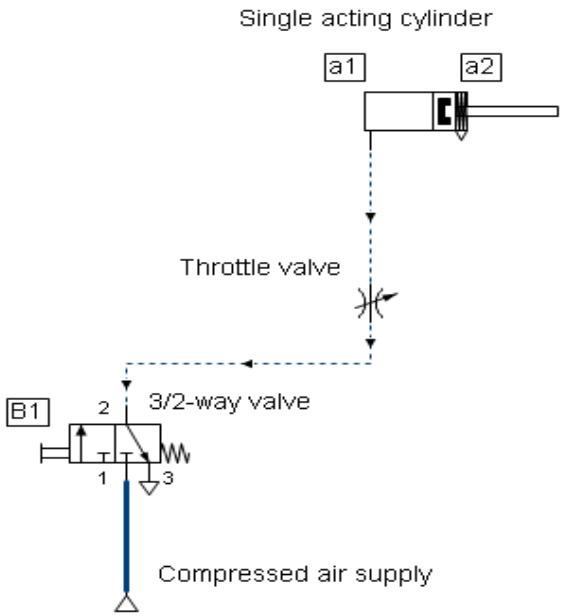

Fig. 6. Pneumatic circuit with a valve. Simulation

The second circuit is equipped with two 3/2-way valves, Fig. 7.

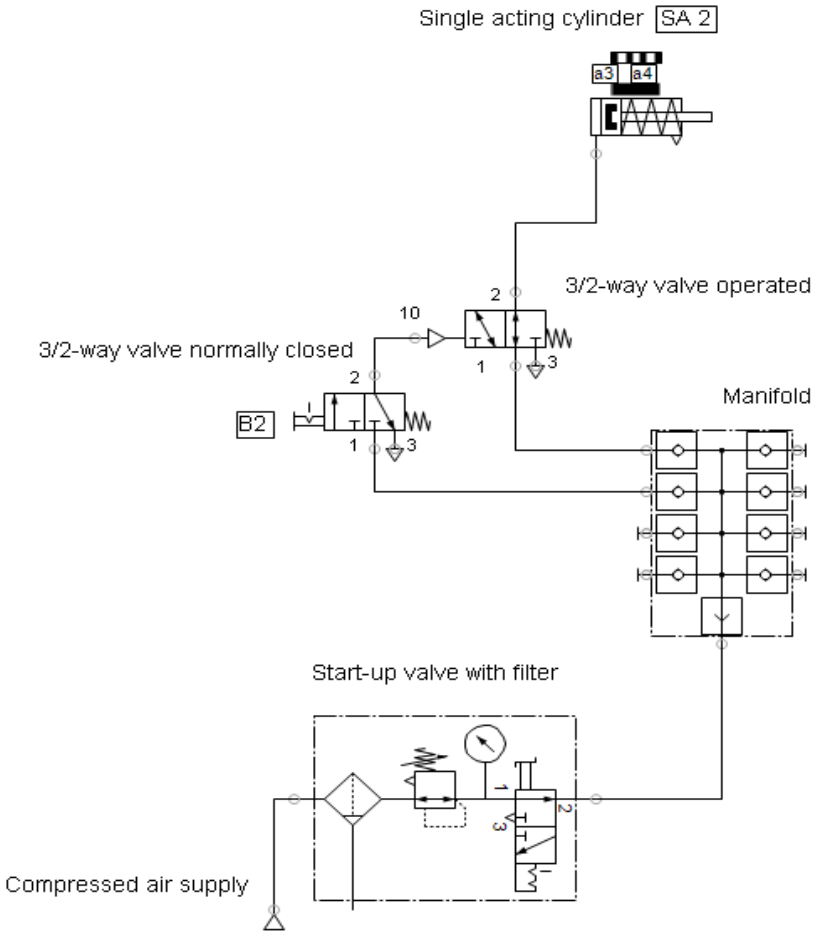

Fig. 7. Pneumatic circuit with 3/2-way valves

When the manipulator presses B2 button, the piston moves from point a3 to point a4, Fig. 7.

Table 2: Devices of the second pneumatic scheme

Description	Number of components
Single acting cylinder (SA 2)	1
3/2-way valve operated	1
3/2-way valve normally closed	1
Manifold	1
Start-up valve with filter	1
Compressed air supply	1

3. Conclusions

These 3/2 valves are used because they offer the following advantages. Moreover, 3/2-way valves are a basic component of pneumatic installations:

a) Control of single-acting cylinders (3/2-way valves are ideal for operating single-acting cylinders).
b) Dynamic flow control (3/2-way valves allow dynamic control of fluid flow, enabling efficient regulation of both supply and release).

c) Pressure and vacuum control (3/2-way valves can be used for specific applications such as purge functions).
d) Fast response time (the internal mechanism of a 3/2 valve is designed to operate quickly, making it suitable for applications where fast action is required).
e) Flexibility and adaptability (the valve's ability to switch flow between an inlet, an outlet, and an exhaust port makes it a flexible component in various machines and systems).

The 3/2-way valves in pneumatic circuits have a longer lifespan compared to those in electro-pneumatic systems.

Acknowledgment

The authors are very thankful to University POLITEHNICA of Bucharest for giving them the proper environment to make this work successful. They would also like to thank Mr. M. Degeratu for drawing pictures and helping to write the paper.

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