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ANALYSIS OF THE OPERATION OF SELECTED PNEUMATIC CONTROL SYSTEMS IN A VIRTUAL AND REAL LABORATORY

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Abstract – The paper presents possibilities of using VirtualPneumoLab software and Pneumatics TP 101 laboratory workstation for research and testing pneumatic control systems. Examples of laboratory experiments of pneumatic sequential control systems and systems performing logical functions are given. Possibilities of using pneumatic systems in controlling and advantages of both "virtual" character of VirtualPneumoLab software and "real" model of the laboratory workstation Pneumatics TP 101 are pointed out.

Key words – compressed air, electropneumatics, pneumatics, virtual laboratory, pneumatic control systems

INTRODUCTION

Pneumatics is an area of science which deals with construction and practical application of equipment in which power transfer and control are performed by means of pressurized air or some other compressed gas of similar properties as a working medium [4], [10], [12]. In electropneumatic control, the processing and transmission of control signals is carried out on the electrical side, which is the information part of the electropneumatic distribution valve. The transfer of power flow and control of the receiver is carried out on the pneumatic side of the electropneumatic distribution valve. The speed of transmitting electrical signals over considerable distances, combined with the speed of operation of pneumatic drives, enables the use of electropneumatic valves in controlling the course of fast production processes.

Among the many advantages of pneumatic automation devices, the following should be mentioned: the ability to perform all computational operations in automatic control systems, with the implementing elements characterized by simple construction and high operational reliability; obtaining significant forces and powers, sufficient in all control cases or the existence of global standardization of pneumatic signals imposed by the conditions of optimal operation of pneumatic controllers. These advantages of pneumatic control systems are particularly well revealed in performing sets including driving motors.

A traditional laboratory of pneumatic control, where we deal with assembly stations offers a chance to get familiarized with real automatic systems [1], [2].

Commercial firms offer a wide range of pneumatics equipment and software. An example here is a laboratory workstation manufactured by Festo with a wide range of pneumatic equipment satisfying the latest technical and technological requirements, which facilitates combining theory with practice [14].

A possibility taking measurements without time constraints or physical presence is given by the so called "virtual laboratories". An example of such a "virtual laboratory" is the VirtualPneumoLab programme manufactured by Heden Media [11], [13].

This paper presents possibilities of using the Pneumatics TP 101 laboratory workstation and VirtualPneumoLab software for analysis operation of selected pneumatic control systems, presented in publications [3], [5], [6], [7], [8] and [9], in a virtual and real laboratory.

1 GENERAL CHARACTERISTICS OF VIRTUALPNEUMOLAB APPLICATION AND PNEUMATICS TP101 LABORATORY WORKSTATION

VirtualPneumoLab programme is a tool for the researching of pneumatic control systems [13]. It is divided into four applications (Fig. 1.): "Elementy" ("Components"), "Laboratorium" ("Laboratory"), "Sterowanie" ("Controlling") and "PneumoLab".

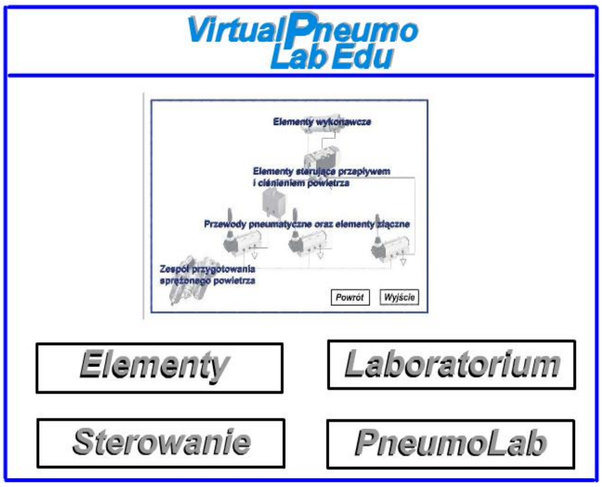

Fig.1. Main window of the VirtualPneumoLab program

In order to simulate the operation of the developed system, should be clicked on the button symbol of the specific distribution valve. During the simulation, the valves are automatically redirected and the actuator piston rods are moved. Visualization of the flow of control signals (displaying the system status) is possible thanks to the change in the color of the active wires.

The VirtualPneumoLab program is a drawing and simulation tool that allows for the development of standardized diagrams of pneumatic drive systems and their controls, as well as the accurate reproduction of the operation of the developed system (Figure 2).

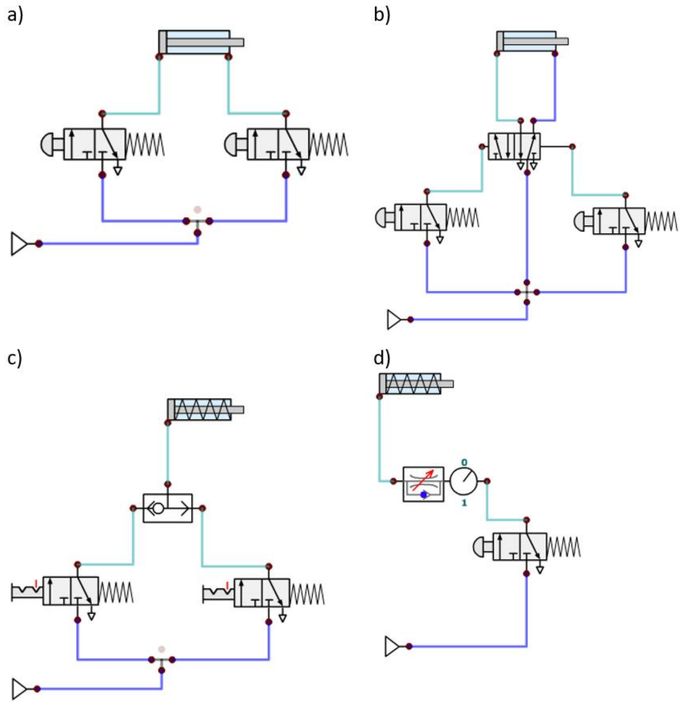

Fig.2. Examples of implementation of pneumatic systems in VirtualPneumoLab: a) Direct control system of a double-acting actuator with two 3/2 valves; b) Indirect control system of a double-acting actuator with a bistable 5/2 main valve; c) Control system of a single-acting actuator using an alternative; d) System for reducing the speed of the actuator piston during backward movement - throttling at the outlet

The program can also be used to detect and eliminate control errors in pneumatic systems. The development of diagrams in the program is easy and effective thanks to the use of the "drag and drop" method, direct access to element symbols, and automatic drawing of standardized lines.

The “Components” block includes animations of performance principles of individual components. The programme enables quick (direct) access to specific components of pneumatic control. Cylinders, manifolds, logical and controlling components are grouped in respective individual groups. “Controlling” provides interactive animations of pneumatic control systems of equipment. “PneumoLab” is an application used for creation and simulation of performance of standardized diagrams of the systems designed by students. Thanks to the simulation option it is possible to check correctness of the structure, performance and control of the developed system.

Festo's Pneumatics TP 101 (Figure 3) is a lab workstation enabling to researches, learn design, building and maintenance of pneumatic modules and sub-assemblies, equipment and pneumatic control systems [14].

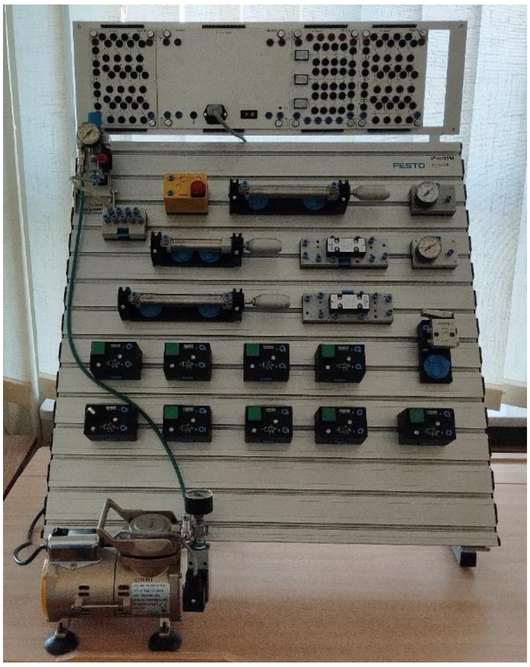

Fig.3. View of the Pneumatics TP 101 laboratory workstation

The workstation is a set of different industrial pneumatic components which allows for quick and convenient assembly and dismantling of compressed air systems. These components, owing to special grippers, are attached to the profile plate.

2 AREAS OF POSSIBLE LABORATORY RESEARCH

Both VirtualPneumoLab programme and Pneumatics TP 101 laboratory workstation enable to conduct the following laboratory experiments:

- Basic manual control systems
- Logic operations
- Control systems enabling changes in the piston movement parameters
- Simulation of pneumatic sequential control systems
- Simulation of pneumatic control systems with time relays
- Simulation of pneumatic systems with operation counters
- Simulation of basic electro-pneumatic control systems

The pneumatic system should consist of the following elements:

- Compressor (compressor) – power source
- Compressed air preparation unit
- Elements controlling air flow and pressure – separating valves of various types
- Actuating systems – actuators
- Pneumatic lines and connecting elements

Sample applications investigating

No. 1

The simulated pneumatic sequential control system is shown in Figures 4 and 5. Pneumatic systems giving an exactly specified sequence of cylinder performances are used to control technological equipment. In the case of devices equipped with several pneumatic servos, the sequence of their performance refers mainly to such operations as: tool feeding, fastening/clamping and withdrawing; pushing an object closer to the tool or withdrawing a feeder. The said operations, as a work cycle, are performed semi-automatically (when each work cycle is initiated) or automatically (the work cycle is repeated automatically). Development of sequential control systems necessitates application of self-activating sensors which signal position, time and force. The following varieties of sequential control are distinguished: path-, time- or pressure-dependent control. Figure 4 shows the implementation of the system in a virtual laboratory implemented in the VirtualPneumoLab program and Figure 5 shows the implementation of the system in a real laboratory using Festo components.

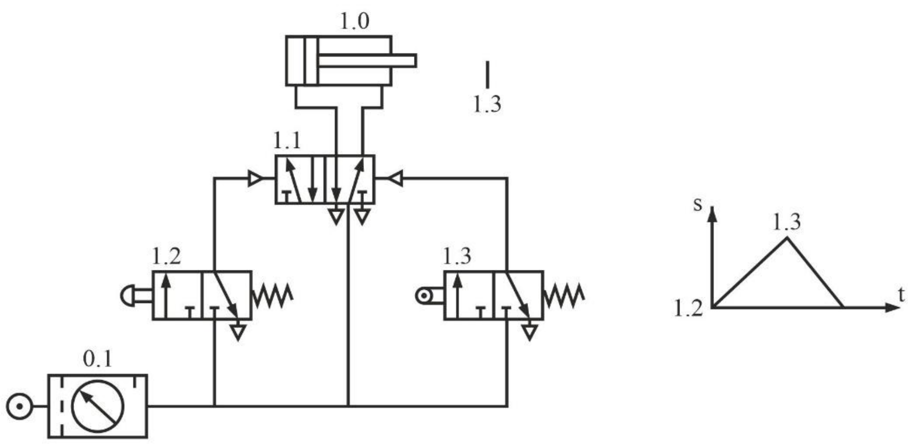

Fig.4. Execution of the control system for the intermittent double-acting cylinder with the use of a 3/2 way roller lever valve and work cyclogram in the application of VirtualPneumoLab: 0.1 – air supply block; 1.0 – double-acting cylinder; 1.1 - 5/2-way double pilot valve, pneumatically actuated, both sides; 1.2 - 3/2 valve with pushbutton actuator, normally closed; 1.3 – 3/2 way roller lever valve with idle return, normally closed

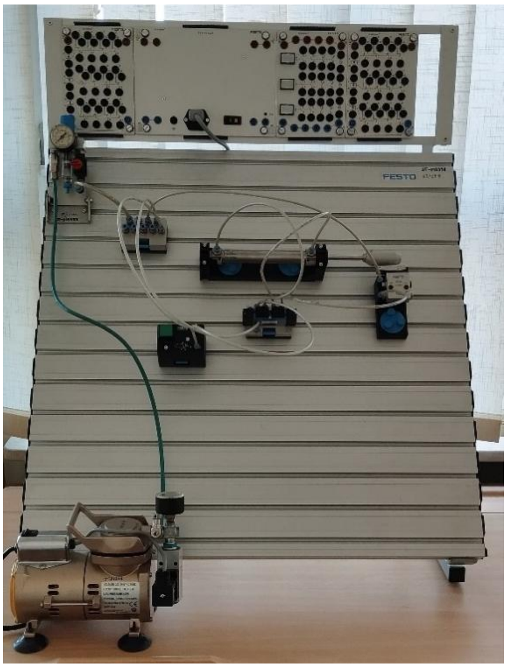

Fig. 5. Execution of the control system for the intermittent double-acting cylinder with the use of a 3/2 way roller lever valve and work cyclogram at the laboratory workstation Pneumatics TP 101

A short-time push of the 1.2 valve button results in changing the position of the main valve 1.1 and the air flows from the air supply block 0.1 to the cylinder chamber 1.0. As a result of increased pressure in the cylinder chamber, the cylinder piston rod extends. The piston rod's retracting motion will occur automatically after the extreme position has been reached when the main valve changes its position due to the signal from the 3/2 way roller lever valve with idle return, normally closed 1.3.

No. 2

Figures 6 and 7 show the automatic control system employing the oscillating movement of the piston rod of a double acting cylinder. A short-term push of the 3/2 way valve button 1.2 results in an alternating motion (forth and back) of the cylinder's piston rod 1.0. A repeated push of the valve 1.2 causes that the cylinder's piston rod stops.

Figure 6 shows the implementation of the system in a virtual laboratory implemented in the VirtualPneumoLab program and Figure 7 shows the implementation of the system in a real laboratory using Festo components.

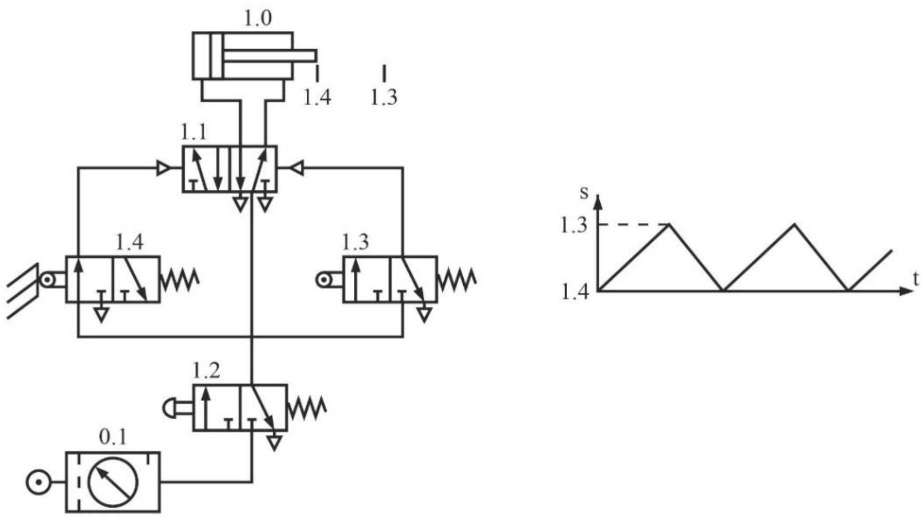

Fig. 6. The system executing the oscillating movement of the double-acting cylinder's piston rod performed in the VirtualPneumoLab application: 0.1 – air supply block; 1.0 – double-acting cylinder; 1.1 - 5/2-way double pilot valve, pneumatically actuated, both sides; 1.2 - 3/2 valve with pushbutton actuator, normally closed; 1.3 – 3/2 way roller lever valve with idle return, normally closed

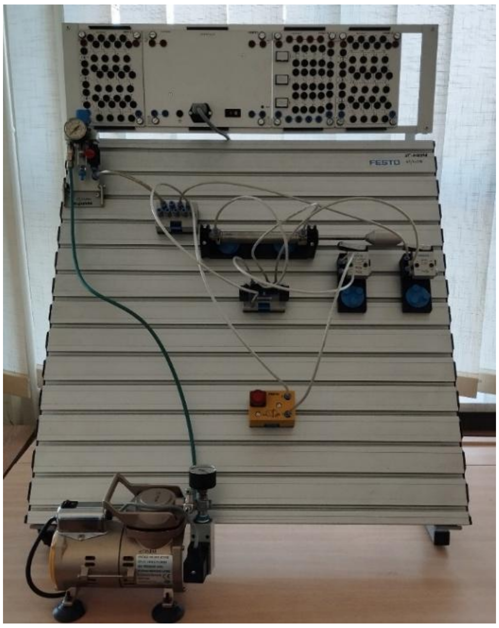

Fig. 7. The system executing the oscillating movement of the double-acting cylinder's piston rod performed at the Pneumatics TP 101 laboratory workstation

No. 3.

Another example of applying both the VirtualPneumoLab programme and Pneumatics TP 101 laboratory workstation in our research of pneumatic control systems is development of logical functions. In pneumatic control systems the OR and AND functions are most frequently implemented.

Figures 8 and 9 illustrate the control system of double acting cylinder with the use of AND. The cylinder's piston rod 1.0 extends when 3/2 way valve pushbutton actuators 1.2 and 1.4 are pressed simultaneously. After the manifold pushbutton 1.3 is pressed, the piston rod retracts.

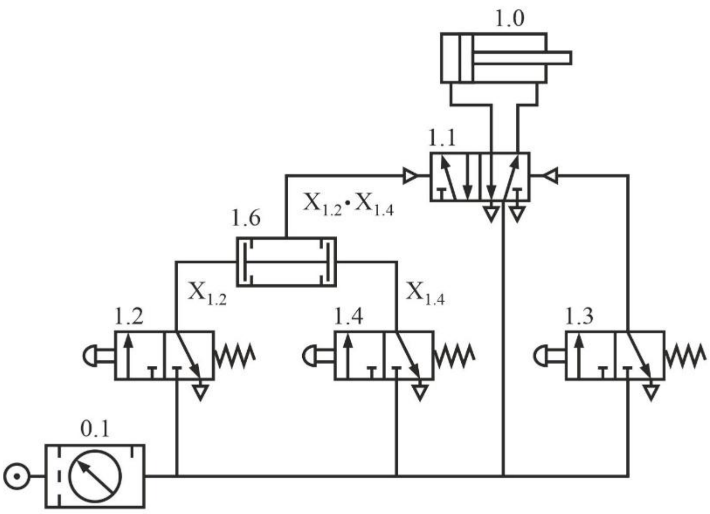

Fig. 8. The control system of double-acting cylinder with the use of AND in the VirtualPneumoLab application: 0.1 – air supply block; 1.0 – double-acting cylinder; 1.1 - 5/2-way double pilot valve, pneumatically actuated, both sides; 1.2, 1.3, 1.4 - 3/2 valves with pushbutton actuator, normally closed; 1.6 – dual-pressure valve

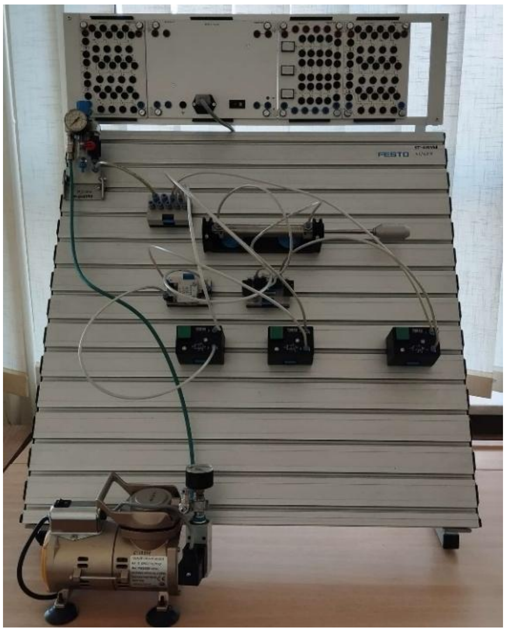

Fig. 9. The control system of double-acting cylinder with the use of AND at the Pneumatics TP 101 laboratory workstation

Figure 8 shows the implementation of the system in a virtual laboratory implemented in the VirtualPneumoLab program and Figure 9 shows the implementation of the system in a real laboratory using Festo components.

3 CONCLUSIONS

The paper presents possibilities of using VirtualPneumoLab software and Pneumatics TP 101 set for research and testing pneumatic control systems.

The experiments carried out in the Mechatronics Laboratory, at the Faculty of Transport, Electrical Engineering and Computer Science of the University of Radom, using the VirtualPneumoLab package and at the Pneumatyka TP 101 laboratory stand allow for familiarization with the structure and operation of pneumatic drive and control components and systems, as well as performing research in the area of mechatronics using pneumatic elements.The advantage of combining virtual and real laboratories in the research process is the ability to test systems in advance in the virtual laboratory without the risk of damaging them or causing a system failure. Thanks to the simulation option in the virtual laboratory, it is possible to check the correctness of the construction, operation and control of the developed system. Checking the connections of the pneumatic system elements and searching for disruptions in its operation allows locating errors in the system control. After locating the causes of disruptions, one moves on to removing errors in the developed pneumatic systems and then testing them in the real laboratory.

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