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Design and Simulation of Electro-Pneumatic Motion Control System

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Abstract: *Teaching of technical subjects is an extremely complicate and complex process and it is demand on logical thinking and imagination. Use of computer simulation in education is growing rapidly and has become a major trend in technical education. Design of the educational setting for electro-pneumatic control of the movement of the sheet bending machine is presented in this paper. After designing, the educational set is built with real electrical and pneumatic components in laboratory conditions. The paper also discusses the simulated design of pneumatic systems with FluidSIM software. The outcomes of the simulation show that the pneumatic system parameters can serve adequately.*

Keywords: *design; simulation; electro-pneumatic; FluidSim; educational set.*

1. INTRODUCTION

A modern curriculum in professional education cannot be fully realized if it does not provide the application of modern equipment that enables students to acquire and develop practical skills and at the same time simulate a real work environment. An intense technological development, especially in the field of information technology, has significantly affected the modernization of educational and didactic equipment. Modern teaching equipment is compliant with the industry needs, so that it provides an opportunity for students to develop practical skills of the 21st century.

The application of simulation software is also very important for relating theory with practice, so that the students can develop engineering aspects and understand how process behaviour can be captured using real time simulations. Students need to get a feel for sizes and sensitivities of system parameters, to examine the relationship between and responses of such parameters and to understand the value and limitations of numerical methods used in system solutions. By acknowledging the discrepancies between the model of a physical system and a system in a virtual environment, students can perform optimizations, in terms of cost and time-consumption. [1,2]

Compressed air is one of the oldest man-known form of energy that is used as a substitute for physical labour. Today's modern industry cannot even be imagined without compressed air since every branch of industry uses compressed air devices. That's the reason why knowing the principles of operation of basic pneumatic elements and the correlation of parameters that affect the pneumatic systems operation is very important in teaching of technical subjects. The control of pneumatic components using electrical impulses is known as electro-pneumatics.

Design of the educational setting for electro-pneumatic (EPM) control of the movement of the sheet bending machine is presented in this paper. The system is built using real industrial components and enables the implementing of practical knowledge and skills that are easily applicable in practice.

Simulation of the pneumatic system operation is realized in FluidSim software which is a comprehensive software for simulation of fluid control systems and it is mostly fitted for use in educational purposes. FluidSim software helps students to analyse and solve problems with relevant knowledge and enhance their practical abilities. [3]

2. STRUCTURE OF THE DESIGNED EPM SYSTEM

Motion sequence control is a mandatory step by step process in which the next control is programmed by the previous step. In an electro-pneumatics control system, three major circuits must be identified: a pneumatic circuit, a control circuit (electric) and a power circuit. The control circuit and power circuit are electric. [4]

Fig. 1 shows the design of the electro-pneumatic system for bending of metal elements. Tools and equipment needed for designing this system are compressor, air treatment unit, pressure regulator, pipeline, educational set „Sheet metal bending" and a computer with software.

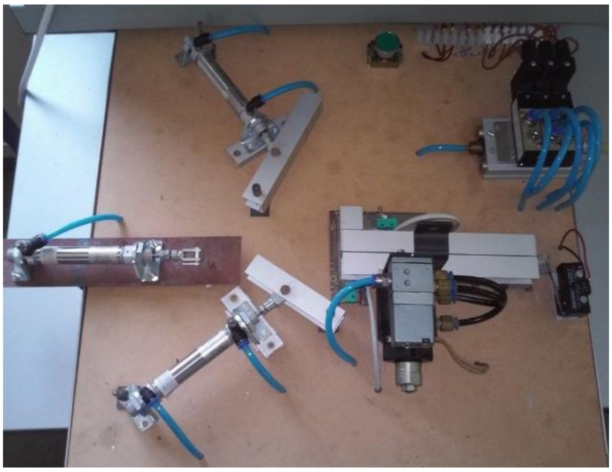

Figure 1. *Electro-pneumatic system for sheet metal bending*

The basic function of a compressor is to convert the supplied mechanical energy into the energy of compressed air.

The main characteristics of the compressor are airflow rate, i.e. the amount of compressed air and the pressure achieved after compression. A reciprocating compressor with rectilinear piston movement, which is most often used in practice today, is used in this educational set. Compressed air and moisture increase the wear rate of surface and sealing, and it is reducing the efficiency and service life of pneumatic components. Also, unstable pressure poorly affects the operation of the complete system.

Therefore, before entering the pneumatic devices, it is necessary to prepare compressed air, i.e. to perform air purification, lubrication and to regulate the air pressure. An air treatment group consists of a filter, a lubricator and a pressure regulator. The filter is used to eliminate impurities from the air, such as water, steam, compressor oil, dust and corrosion products. A lubricator is used to inject oil in the form of a fine mist into the air stream. The role of the pressure regulator is to provide a stable desired operating pressure. The pressure regulator dampens the pressure oscillations due to the variable air consumption that occurs as a disturbance on the outlet side of the regulator and reduces the air pressure from the main line to the required value of the working pressure.

„Sheet metal bending" educational set consists of the following pneumatic and electrical components: single-acting and double-acting pneumatic actuating cylinders, solenoid impulse valves, pushbutton, limit switches and PC with software. Pneumatic linear motors - cylinders convert the energy of compressed air into mechanical work. In pneumatic systems, the cylinder is usually the executive element. They can be with one-way (single acting cylinder) or two-way (double acting cylinder) operating mode. Single acting cylinders have the working fluid supplied only from one side of the piston and push it, whereby the connecting rod is pulled out and perform the mechanical work. Return of the piston to its starting position is done either with a spring or its weight. Double acting cylinders have the working fluid supplied from both sides of the piston so that the cylinder has a working stroke in both directions. A pneumatic distributor is used to control the double acting working cylinder.

Distributors are valves that pass, close and direct the flow of working fluid. Distributor type is determined by the number of connections, number of positions (states), activation method, return method and connection sizes. The label of distributor corresponds by the number of connections and distribution positions. In the realization of described educational set, electromagnetic controlled air distributors type 5/3 and 3/2 were used. Type 3/2 means three ports and two positions: one port connects to the source of compressed air; second port serves as outlet and the third port connects to the cylinder. The valve has two positions: filling or emptying the cylinder. The required valve size can be calculated once the cylinder and application properties are known.

By working on this educational setup, students get familiarized with the principles of operation of applied pneumatic components. They learn to design pneumatic systems and simulate their operation, and most importantly they learn to implement this type of systems. [5]

The task needed to be solved using this educational setting is to bend the sheet metal to make a "J" profile. A complete sequence for solution of the metal sheet bending task is shown in the Fig. 2.

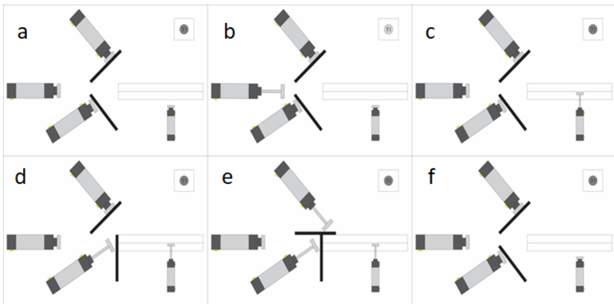

Figure 2. *Sequencing of sheet metal bending operations*

The control sequence consists of the following steps: (a) Manually place the sheet metal in the form of a strip in the machine. The cycle starts by pressing the T1 pushbutton; (b) single acting cylinder C pushes the sheet metal strip until the position CX is reached; (c) Cylinder C then returns to the home position; (d) One-way cylinder D clamps the sheet metal into the tool; (e) Then the double acting cylinder A bends the strip until it reaches AX position, the two-way cylinder B then bends the sheet metal to the limit position BX; (f)

At the end of the cycle, all cylinders return to the home position.

3. PNEUMATIC SYSTEM DESIGN

Pneumatic system design contains two parts: pneumatic and electrical. FESTO FluidSim software is used for simulation of pneumatic power system (Fig. 3). FluidSIM is a comprehensive software for the creation, simulation, instruction, and study of electro-pneumatic, electro-hydraulic, digital and electronic circuits. All the program functions interact smoothly, combining different media forms and sources of knowledge in an easily accessible manner. FluidSIM unites an intuitive circuit diagram editor with detailed descriptions of all components, component photos, sectional view animations and video sequences [6]. Pneumatic components are explained with textual descriptions, figures, and animations that illustrate underlying working principles [7].

Electrical part of the design should be done in different ways. Each student can apply their logic by designing their own circuit diagram for the system to do the required sequence. This electrical design stays only in simulation, so students can use all electrical component they think they need. One of the electrical schematics is shown on the Fig. 4.

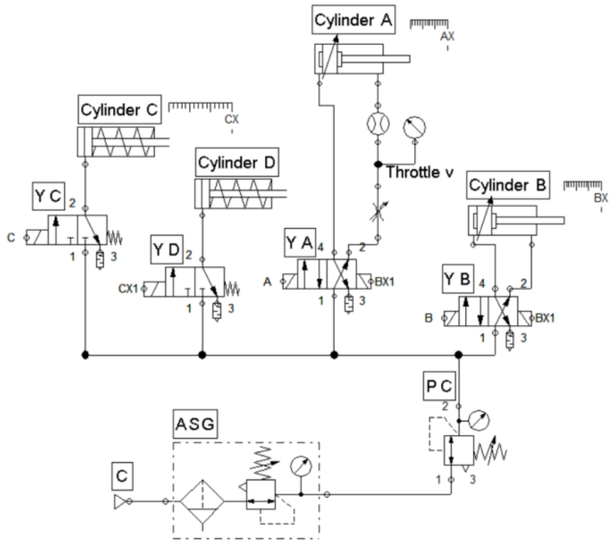

Figure 3. *FluidSim schematic diagram of the pneumatic circuit*

Pressing the button (F9) starts the simulation while button T1 is used to start the sequence that is being simulated. This simulation helps students to see if their logic is working or not. After their logic is working in simulation, pneumatic and electrical schematics can be implemented on a real system.

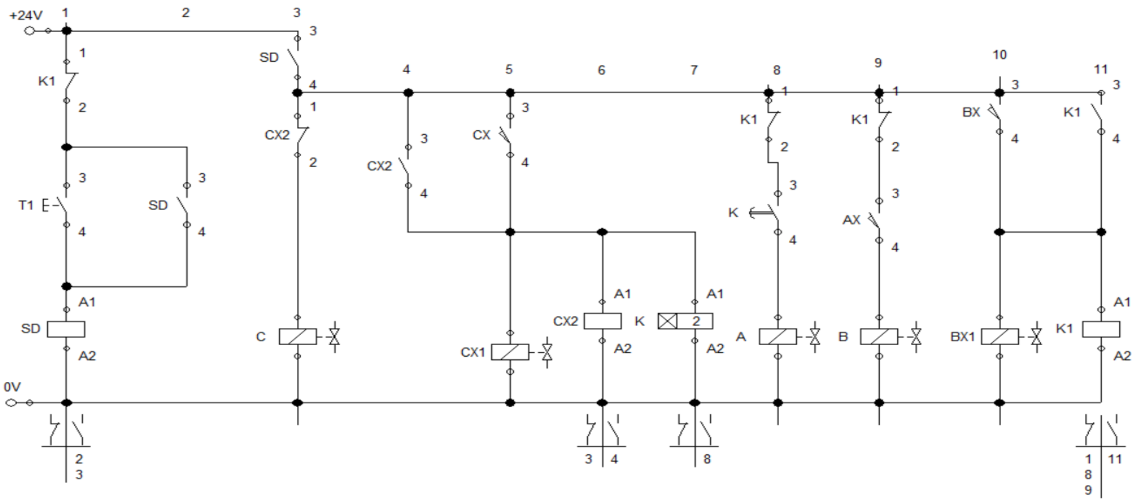

Figure 4. *Electrical schematic of the system*

The component part of the EPM system is as shown in Table 1, for pneumatic and electrical circuit of the system.

Each symbol can be parametrized as physical component in the system. For example, double-acting pneumatic actuating cylinder A (PCU-16-50-DD-A) has 50 mm maximum stroke, 16mm piston diameter and 5mm rod diameter [8]. Those parameters must be configured in cylinder configurator software section shown in the Fig. 5.

Table 1. *Description part list for EPM system*

Number of items	Designation	Description
1	C	Compressed air supply
1	ASU	Air service unit, simplified representation
2	Cylinder A, B	double-acting actuating cylinders
2	Cylinder C, D	single-acting actuating cylinders
2	AY, BY	4/2-way valves
2	CY, DY	3/2 -way valves
1	T1	Pushbutton

3	AX, BX, CX	Limit switch
1		Electrical connection 24V
1		Electrical connection 0V
1	SD	Self-holding relay
8	C, CX1, A, B BX1	Valve solenoid
2	K, K1	Relay
1	K	Time delay relay

Solenoid valves must be configured in the same way as cylinders (Fig. 6). The parameters must be in accordance with the documentation for every valve in the system. Each component must be properly configured for the simulation to be done properly.

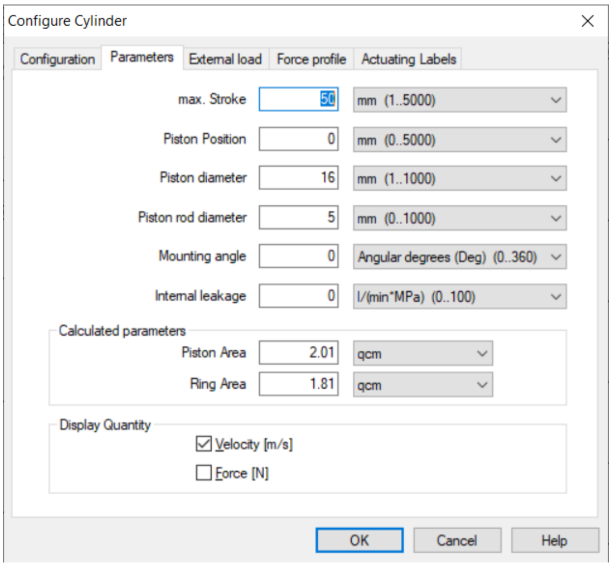

Figure 5. *Configuration of the double-acting cylinder A*

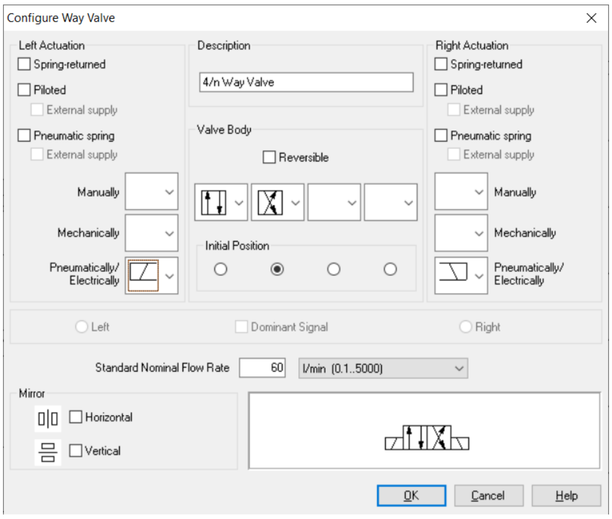

Figure 6. *Configuration of the solenoid valve*

4. FLUIDSIM SIMULATION ENVIRONMENT

Advantages of using FluidSim for simulation of the system is seen through easy access modelling and user-friendly options. Different computer simulations and experimental process ware carried out by means of the developed model shown in Fig. 3. The following results were obtained to ascertain the workability of the system. In addition to simulating logic, the program FluidSim can also simulate states of the system on the time axis. Those states can be speed and position of cylinder, pressure and flow rate on the desired component. In this paper cylinder acting with flow change in his one input is simulated. Flow has been changed with decrease from 1% to 20% in steps (1%, 2%, 3%, 5%, 10%, 20%). Graph with position and velocity of cylinder A and B as well as graph of pressure and flow if throttle valve are shown in the Fig. 7.

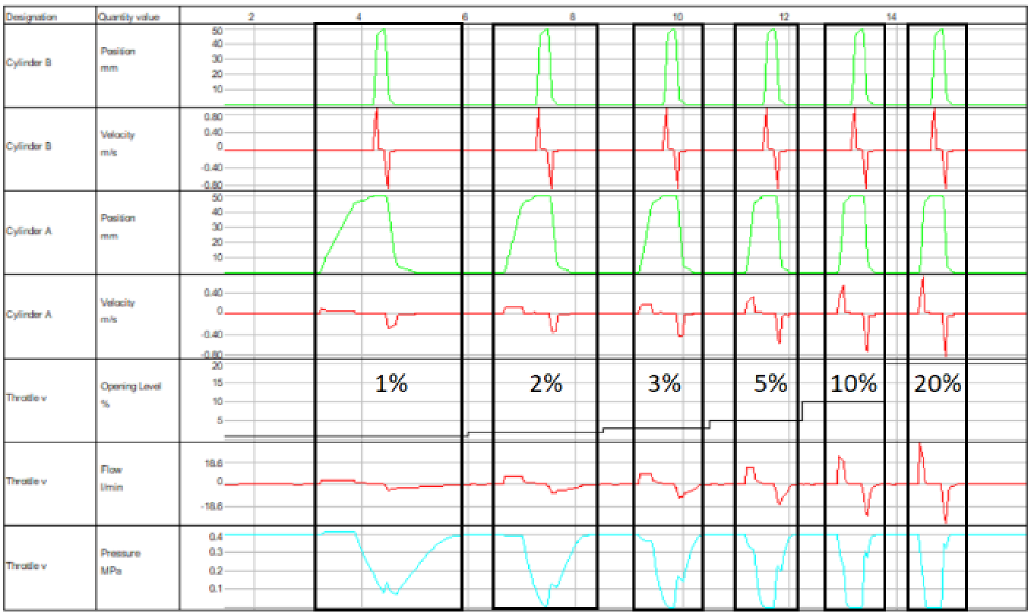

Figure 7. *The simulation diagram result of dependence of position and velocity on different throttle valve openings for cylinders A and B*

This graph shows that acting cylinder speed is proportional with flow through it. As flow is increasing the acting cylinder speed is increasing, and it takes lower amount of time to react. Cylinder A has one input flow regulation, but it impacts on both inputs as graph shows. Throttle valve on one side reduces the flow change in the cylinder on both sides (extraction and retraction).

With this type of simulation, cylinder speed can be adjusted to the value that has to be achieved on a real system. Acting speed of the cylinder A in analysed system is important because if it is not tuned well, it can cause collision with the other cylinder in the system.

5. CONCLUSION

In the past decades, the context of engineering education has changed dramatically. Modelling and simulation can significantly boost the learning and teaching process of electro-pneumatics. In this paper design and simulation of an educational set for electro-pneumatic motion control system is analysed. The simulated pneumatic system is built using the main components of the machine for sheet metal bending. The most important advantages of these computer simulation in education are interactive feature, fostering students' visualization, and enhancing their problem-solving process. The experimental and simulation results show the characteristics and behavior of the air movement within the system. A further upgrade of the system should be adding a PLC controller, and thus make it more flexible. This can be helpful to improve the performance and optimization of the analysed system. By applying the presented educational set in teaching courses, increased motivation of students was noticed, and a higher level of student's practical knowledge and skills was achieved in relation to the traditional model of teaching.

ACKNOWLEDGEMENTS

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