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Experimental Model for Energy Efficiency Examination of Pneumatic System

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Abstract: In pneumatic systems, which represent large energy consumers, energy saving is very important. Mostly, the costs of the electric power used for feeding the compressors in the production of compressed air amount to around 20% of the overall costs of electrical power for some factory. In order to examine energy efficiency of conventional pneumatic system as well as servo system, no matter on actuator type, in this paper the new experimental model for energy efficiency examination is proposed. It consists of two important parts, such as electric and pneumatic part. The conducted experiments have demonstrated that this new experimental model provides satisfactory results of actuator positioning and energy efficiency as well.

Keywords: Experimental model, amplifier, energy efficiency, positioning

1 Introduction

Pneumatic actuators can offer better alternatives to electrical or hydraulic actuators for great many applications. Pneumatic actuators have the advantages of (a) low cost; (b) high power-to-weight ratio; (c) ease of maintenance; (d) cleanliness; (e) having a readily available and (f) cheap power source. Owing to numerous advantages, pneumatic actuators and systems are widely applied in industrial automation for the so-called sequential control. Nowadays, increasing demands with respect to accurate positioning, especially in robotics, have generated other control techniques.

The energy used in the pneumatic system is that of compressed air which is obtained in special devices called compressors. Mostly, the costs of the electric power used for feeding the compressors in the production of compressed air amount

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to around 20% of the overall costs of electrical power for some factory. For this and many other reasons it is very important to carefully handle the use of compressed air.

Increase of energy efficiency during positioning of pneumatic actuators is very important, and primarily depends on the type of actuator and on the applied position control algorithm. Another problem is that when the piston reverses its movement all the com-pressed air from one chamber is released into the atmosphere and this is a great com-pressed air loss.

There are many papers dealing with the position control of the pneumatic actuators as well as energy efficiency, including the work by Shearer [1–3], Mannetje [4], BenDov and Salcudean [5], Wang et al. [6], Maeda et al. [7], Kagawa et al [8], Bobrow and McDonell [9], and Richer and Hurmuzlu [10, 11], among others.

In order to examine energy efficiency of conventional pneumatic system as well as servo system, no matter on actuator type, in this paper the new experimental model for energy efficiency examination is proposed. To demonstrate the work of the chosen experimental model, some results of actuator positioning and compressed air consumption are shown.

2 Description of experimental model for energy efficiency examination

Concept of experimental model for energy efficiency examination is a modular with the possibility of flexible adjustment for measurement of compressed air consumption at various linear and rotary or swivel pneumatic actuators. The primary purpose of experimental model, besides the measuring the compressed air consumption, is to provide energy efficiency using energy recovery, bypassing the chamber executive element. Such experimental model solution provides the possibility of checking the energy efficiency of conventional as well as servo pneumatic systems.

The experimental model for energy efficiency examination consists of two important parts, such as electric and pneumatic part. Electric part consists of PC, acquisition and control module, amplifier and safety module, position sensor, flow sensor and limit switches. Pneumatic part consists of the necessary components for conventional or servo pneumatic system, such as various actuators, 5/3 way directional and proportional valve, 2/2 way valve and tubes. The block diagram of experimental model for energy efficiency examination, with all their main components, is shown in Fig. 1.

Acquisition and control module is a standard one and in this model it is ED2001. This module is hosted in PC. Programming of acquisition and control module is very easy, in some of standard programming languages like C, C++, Pascal or Ba-

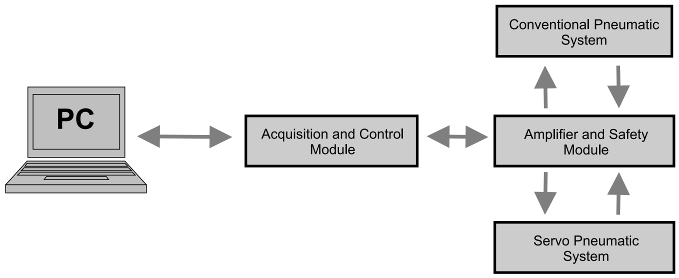

Fig. 1. Block diagram of experimental model.

sic. The key concept of ED2001 is modularity and possibility of using in different applications [12]. It has 32 digital and 16 analogue inputs and outputs. Analogue inputs are very useful for signals that from measure value of the position of actuator and compressed air consumption (flow). Analogue outputs are used for control of proportional vale 5/3 way in servo pneumatic system. Digital outputs are used for activation of by-pass vale 2/2 way and digital inputs are used for signals from electrical limit switches in conventional pneumatic system.

Photography of inputs and outputs interface of ED2001 module is shown in Fig. 2.

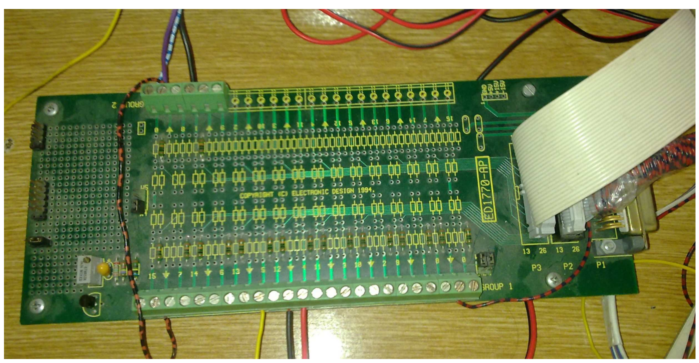

Fig. 2. Photography of inputs/outputs interface of ED2001.

Other components of experimental model for energy efficiency examination are explained in following chapters and they are unique.

3 Pneumatic system of experimental model for energy efficiency examination

As it was explained in previous chapter, the experimental model for energy efficiency examination can be used for both conventional and servo pneumatic system.

In whole pneumatic system the pneumatic components are used and their type, especially valves, depends of the system type and they are different in conventional and servo systems.

Conventional pneumatic system consists of various actuators (linear and rotary or swivel), directional valve 5/3 way as supplying valve designated as 1.1, by-pass valve 2/2 way designated as 1.2, electrical limit switches, flow sensor and tubes.

Fig. 3, shows the conventional pneumatic system as well as pneumatic servo system with rodless cylinder designated as 1.0 as actuator.

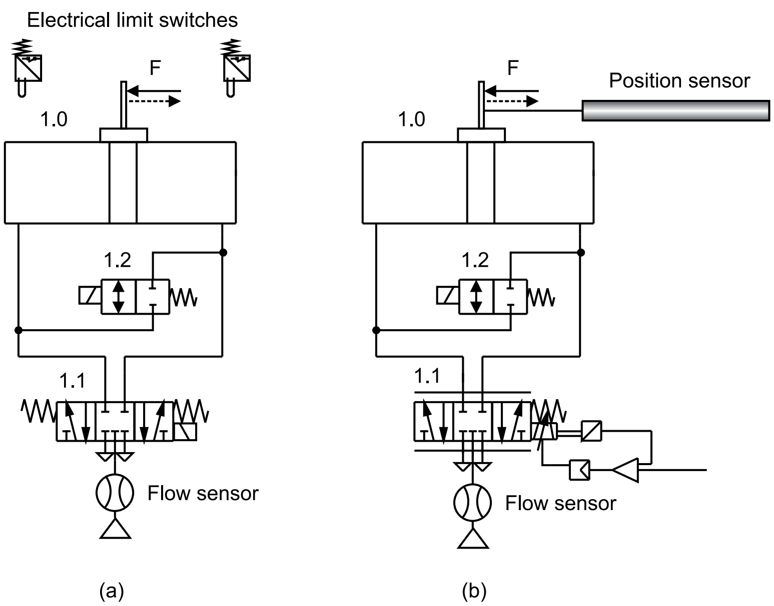

Fig. 3. Pneumatic scheme of experimental model for energy efficiency examination: a) conventional system, b) servo system.

Servo pneumatic system consists of various actuators, by-pass valve 2/2 way designated as 1.2, flow sensor and tubes, too. In servo system, instead valve 5/3 way as supplying valve and electrical limit switches, there are proportional valve 5/3 way designated as 1.1 and position sensor, for continual measurement of position.

Experimental model for energy efficiency examination can be used for both ways of control of pneumatic system. The first way of control means traditional pneumatic system control when by-pass valve 1.2 is not in use and the whole control is depending on activation of supply valve 1.1, no matter on the system type, conventional or servo. In such way of control, during the direction change of piston motion, all the compressed air from the previous working chamber is released, and a new quantity of air is introduced into the new chamber. Hence, in traditional method of controlling pneumatic rodless cylinder, there is an irreversible loss of the compressed air energy. The second way of control means energy efficient pneumatic system control when by-pass valve 1.2 and supply valve 1.1 are used, no matter on the system type, conventional or servo. Such way of control enables the air from the previous driving chambers not to be vented irreversibly to the atmosphere but to be used, in part or entirely, for the reverse (retracting) motion of the actuator piston. This energy efficient control is explained in detail in earlier papers [13–18].

4 Amplifier and safety module

Amplifier and safety module is very important component for properly and safe work of experimental model for energy efficiency examination of pneumatic system. The photography of the amplifier and safety module is shown in Fig. 4.

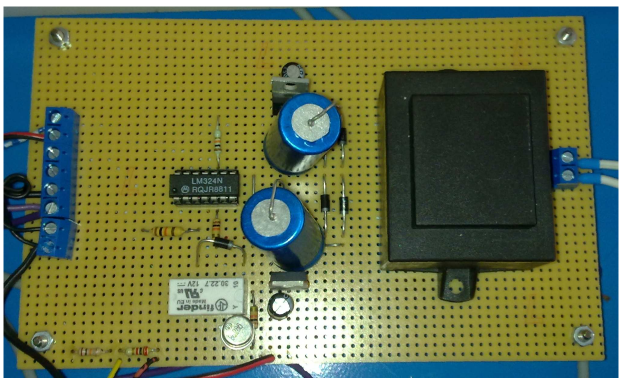

Fig. 4. Photography of amplifier and safety module.

This module is one of the most important components of the measurement and control chain. It has two purposes: amplifier and safety purpose.

Amplifier purpose. The module has to increase the signals from PC, more precisely from outputs of interface ED2001, to match the level of activating signals for by-pass vale 1.2 and supply valve 1.1. The output signals from interface ED2001 are from -10 to 10 V DC. Activating signals for by-pass vale and directional supply valve 5/3 way in conventional system are 24 V DC and for proportional vale 5/3 way in servo system is form 0 to 10 V DC.

Safety purpose. The module has to enable the safety operation of ED2001 and PC. It has to convert and decrease signals from sensors to a safety level that is suitable for further processing. The suitable level of inputs of interface ED2001 is from -10 to 10 V DC, the same as outputs.

The electric scheme of amplifier and safety module is shown in Fig.5.

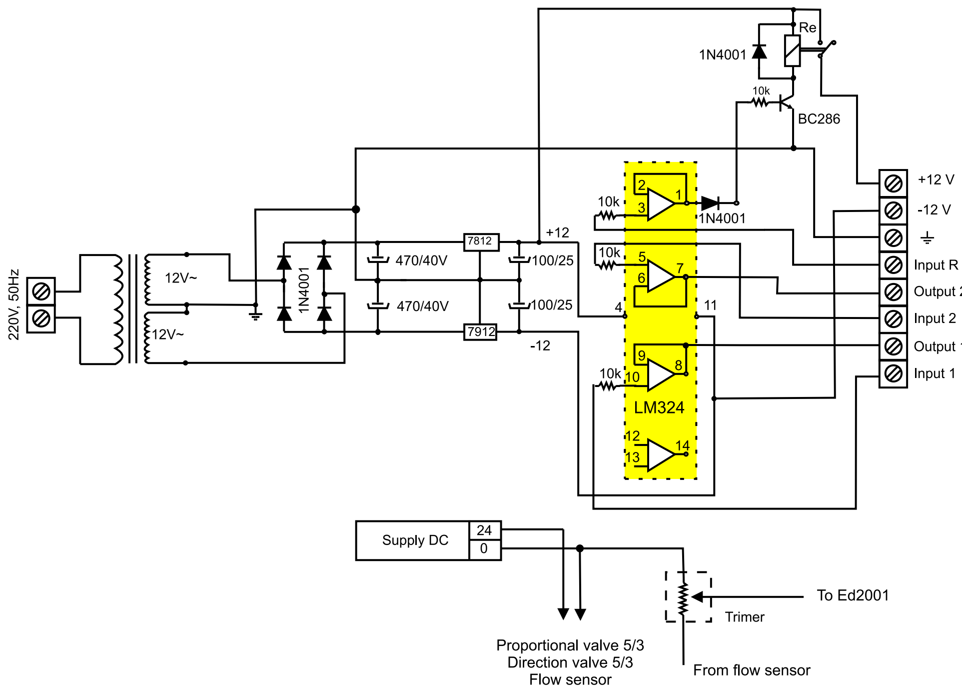

Fig. 5. Electric scheme of amplifier and safety module.

The Inputs 1 and 2, figure 4, are used for control signals from ED2001 which are result of control algorithm implemented in PC. Generated control signal for proportional valve 5/3 way is connected to Input 1, and for directional supply valve 5/3 to Input 2. Activation signal for by-pass vale from ED2001 is connected to Input R.

The Outputs 1, 2, 3 and 4, figure 4, are directly connected to devices. The Outputs 1 and 2 are used for proportional vale 5/3 and directional supply valve 5/3. Outputs 3 and 4 are directly connected on by-pass valve. Output 3 gives +12 V DC and output 4 gives -12 V DC. A signal from flow sensor is indirectly connected to ED2001 via electronic Trimmer. This device enables converting signal form flow sensor to acceptable value from 0 to 10 V DC.

A signals form position sensor and electrical limit switches are connected to ED2001 via special amplifier that is not a part of amplifier and safety module.

5 Experimental demonstration

A good example for presenting possibilities of experimental model for energy efficient examination of pneumatic system is examination of pneumatic servo system with rodless actuator, Fig. 3b. In this example, the pneumatic components are: rodless pneumatic cylinder designated as DGPL-18-150-PPV-A-B-KF-SH, 5/3 way proportional valve designated as MPYE-5-1/8-LF-010-B and 2/2 way bypass valve with designation MC-2-1/8, all manufactured by FESTO Company. The flow sensor is SFE1-LF-F200-WQ8-P2I-M12 with measuring range from 0 to 200 l/min, also made by FESTO Company. The HBM position sensor is used for position purposes and it has a range 200 mm.

In the first test, the traditional way of control was used, without activation of by-pass valve 1.2. The test was performed with load force F = 30 N and when the roofless cylind-er piston was moving from 50 mm to the desired 100 mm, after which it was retracted into the initial position 50 mm, again. After achieving the positions along the stroke length, the rodless cylinder piston should hold the position during 1 s. The supply pressure was 600 kPa.

In Fig. 6, the results of positioning of the rodless cylinder piston when traditional control are used, are shown.

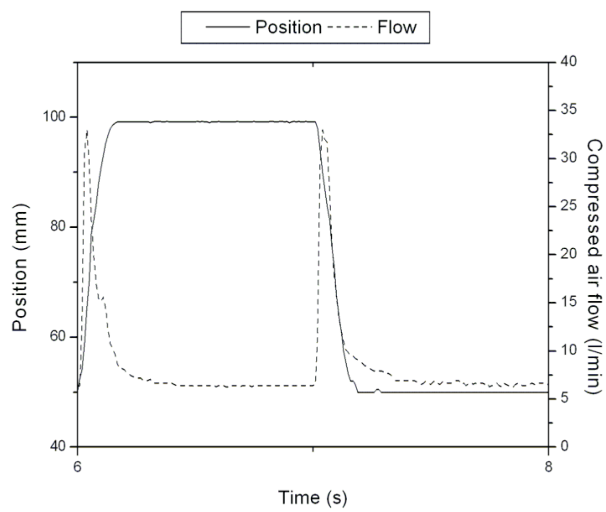

Fig. 6. Diagram of the rodless cylinder piston position and compressed air flow with traditional control.

The second test has been performed with energy efficient way of control, when by-pass valve 1.2 is used and for the same conditions and durations as in the first measurements. The conditions for by-pass valve activation are explained in detail in our previous papers [15, 16, 18].

In Fig. 7, the results of positioning of the rodless cylinder piston when energy efficient control are used, are shown.

The results show that energy efficient control of the rodless cylinder exhibits

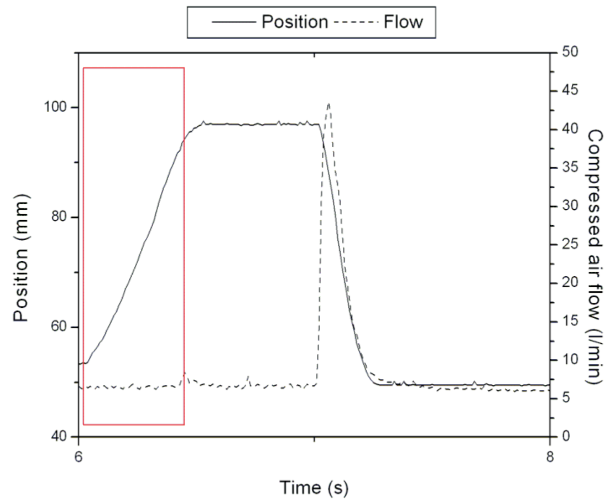

Fig. 7. Diagram of the rodless cylinder piston position and compressed air flow with energy efficient control.

superior performance of energy consumption in comparison with the traditional control. When the energy efficient control is used, because the by-pass valve was activated, the reaching of desired position is slower but in that period there is no need for any energy from supply. It is shown by rectangle in Fig. 7.

Using the experimental model for energy efficient examination of pneumatic system, in this example, the energy efficient control uses about 35% less compressed air than traditional control at the same condition.

6 Conclusion

The paper presents a new experimental model for energy efficient examination of pneumatic system. Architecture of experimental model for energy efficiency examination is a modular with the possibility of flexible adjustment for measurement of compressed air consumption (flow) at various linear and rotary or swivel pneumatic actuators. One of the main purposes of experimental model is to provide energy efficiency using energy recovery. This is the result of bypassing the chambers actuator, which enables the air from the previous driving chambers not to be vented irreversibly to the atmosphere but to be used, in part or entirely, for the reverse (retracting) motion of the actuator piston. Also, experimental model solution provides the possibility of examination the energy efficiency of conventional and servo pneumatic systems as well.

The advantages of experimental model for energy efficient examination of pneumatic system are shown in Chapter 5, where its performance is used for experimental verification of energy efficient way of control superiority compared with traditional way of control.

According to conducted experiment, the main conclusion of paper is that application of experimental model for energy efficient examination of pneumatic system provides satisfactory results of actuator positioning and energy efficiency as well.

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