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Speed Control Of Pneumatic Cylinders Using High Speed 2 Port On/Off Valves With Pulse Width Modulation

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Abstract. **This paper presents the possibility of controlling the speed of a different types of pneumatic cylinder with high speed 2-position valves a controller using Pulse Width Modulation /PWM/. To increase the energy efficiency of pneumatic power transmission systems, modern control method for speed control pneumatic cylinders is applied. This is realised by high speed 2 port ON/OFF valves, digital control by computer and virtual instruments made with specialized software. An electronic block implemented with a PWM and an energy saving amplifier is used for control high speed 2 port ON/OFF valves. Practical realization of PWM controlled electropneumatic power transmission system is shown and experimental characteristics for variable speed of the pneumatic actuator are obtained. The experimental results are shown in few graphs. The presented experimental studies prove the possibility of smoothly adjusting the speed of pneumatic cylinders using two-position valves, controlled with PWM. Using this control method makes it possible to replace expensive servo valves for precise speed control.**

Keywords: Energy efficiency, High speed valves, Pneumatic cylinder, Pulse Width Modulation,

I. INTRODUCTION

Pneumatic drive systems are convenient and easy to apply in industry. In the past they have been used with limited capabilities, usually for two-position control. Disadvantages are the compressibility of the air used in them, and the friction forces in the pneumatic elements. Combining them with electronic controllers, advances in electronics and computer technology, are unleashing innovation in their application for frictionless flow control. Pneumatic servo valves and pneumatic proportional distributors are being developed. Servo valves are used to achieve high linear control in pneumatic actuators, but they have complex designs and are high cost. Proportional distributors do not have the fastest response time due to the piston dead zone and have large internal swells and also have a high commercial cost. Both servo valves and proportional distributors have powerful electrical coils that consume a significant amount of electrical power.

Fig. 1. High speed 2 port valve "SX12F-AH" SMC Japan.

In the last decade, pneumatic high speed 2-position valves with their digital control are becoming more widely used in order to achieve linear flow control characteristics with the fastest possible response.

The application of high speed 2-position valves for the control of pneumatic sawing mechanisms with different design features using digital control and PWM techniques has been under research development in recent years. Which enables the interest for further research in this area [1 - 9].

Main reasons for the use of the PWM control method for fast switching valves are reduction of valve response

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times, miniaturization of the valve control pistons and advanced electronics incorporated. Many researchers used PWM control techniques to drive pneumatic switching valves with good results. PWM signal frequencies used depend on the valve response time and are generally between 20 – 100 Hz.

Currently, PWM is used in electronics, communications, LED lighting and electrical equipment. LEDs are also used in electrical and electronics, motors to control their speed fig1. Applications in hydraulic systems followed as a technique to reduce the non-linearity of solenoid valves and associated dead zones. Some additional advantages in terms of reducing the "stick-slip" phenomenon when hydraulic systems are controlled with PWM signals. As far as pneumatic systems are concerned, the first attempt to apply a PWM-based control technique dates to 1987 and still exists today.

The standard equation of the fluid flow through a pneumatic valve is defined in the ISO 6358 standard (ISO 6358-1, 2013), and is used in this form in almost all mathematical models of pneumatic switching valves [1], [2], [5], [9].

This paper presents a pneumatic experimental rig for obtaining the static flow characteristics of high speed 2-port valves. An electronic controller for energy saving circuit is developed for the operation of the valves. The results obtained are presented in the form of graphs.

II. MATERIALS AND METHODS

To increase the energy efficiency of pneumatic drive systems, modern control methods are applied. This is realized by high speed pneumatic 2-port valves Fig. 1, digital control by computer and specialized software Fig. 2.

A dedicated stand, shown in Fig. 4 has been developed for experimental studies of dynamic processes in pneumatic actuator systems. The stand is equipped with a state-of-the-art Data acquisition /DAQ/ system and a dedicated virtual instrument allowing real-time investigation of transients in a pneumatic actuator system.

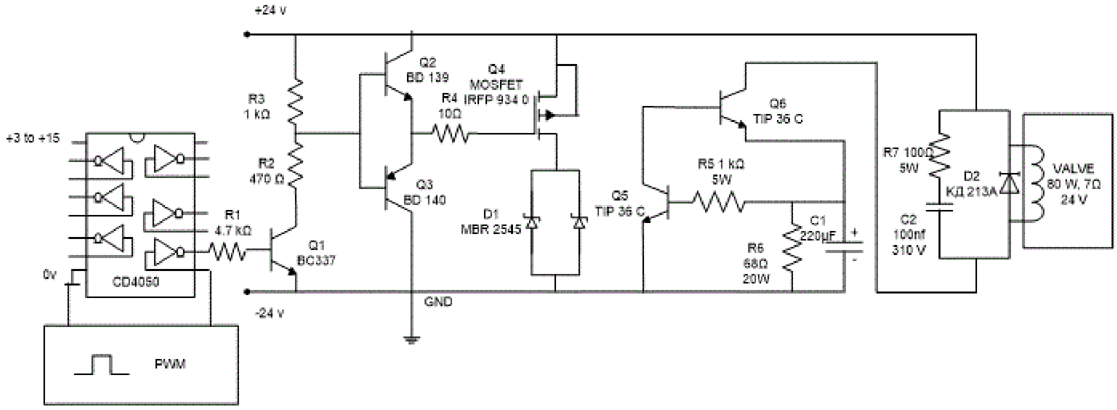

Fig. 2. Combined control circuit with PWM signal and MOSFET transistors and energy saving block for one valve.

The objective of the study is to determine the speed of a pneumatic cylinder with a width-induction modulated governor. The governor consists of SMC Japan model SX12F-AH high-speed pneumatic 2-port valves, an electronic control unit, and an energy saving unit.

To realize the fast valve operation and the plunger displacement, a high controlled coil power is required: 24 V; 80 W. The control of the high-performance pneumatic quick-acting valves is complemented by a power saving electrical circuit.

For the purpose of the study, digitally generated PWM signals obtained using specialized “LabView” software and hardware from “NI” were used. An output driver implemented with a dedicated integrated circuit is used to control the high-speed valves.

The use of CMOS for direct control of MOSFET transistors is suitable due to a number of simplifications in the selection of the operating circuit and the power supply. A disadvantage is that there are limitations on the output current that is produced by the CMOS scheme. For this, circuit solutions of output drivers built mainly with dedicated CD 4050 ICs are suitable. These provide bipolar pulses to the controlled MOSFET transistor with unipolar control pulses applied to their input Fig. 2. A characteristic of the circuit is that it enables unblocking and blanking of the transistor at different rates and optimization of switching losses. MOSFET transistors operate at high output current and can be driven by PWM signals.

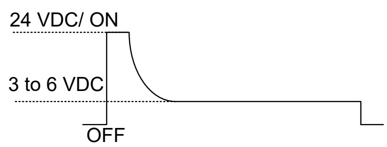

Fig. 3. Starting and operating voltage of the pneumatic high speed valve.

To realize the high-speed operation of the valve and the displacement of the spool, high power of the controlled spool and high electrical power consumption are required. The technical solution for the pneumatic high-speed valve to have a powerful coil 80 W; 24 VDC which enables the fast control [8].

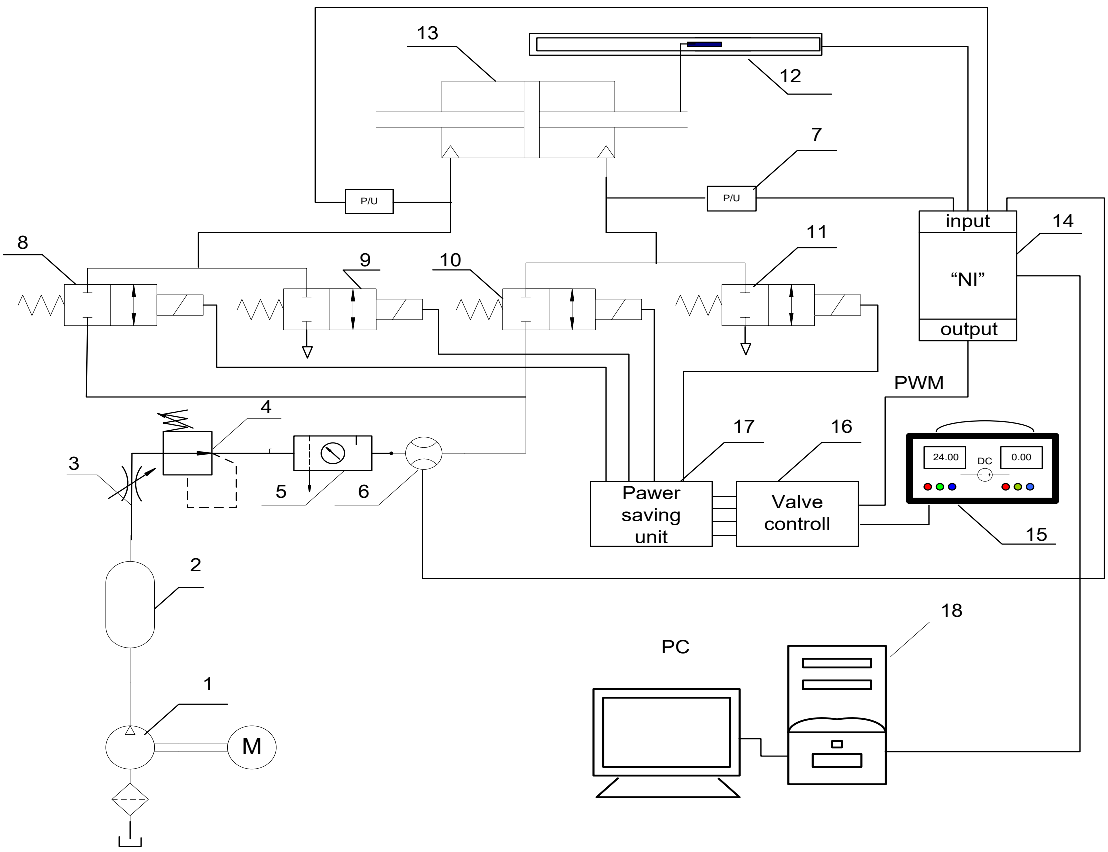

Fig. 4. Scheme of experimental pneumatic stand.

1 - screw compressor; 2 - receiver; 3 - stopcock; 4 - safety valve; 5 - air preparation system preparatory; 6 - flowmeter; 7 - pressure transducer, 8, 9, 10, 11 high speed 2 port on/off valve; 12 - potentiometric sensor, 13 - pneumatic cylinder with double out rod 14 - terminal board (NI); 15 - power supply unit; 16 - regulator, 17 - energy saving unit, 18 – PC,

Once the pneumatic valve is energized at 24 VDC, its spool is moved to switch from the "OFF" position to the "ON" position, but to hold it in this position usually not the full power is needed, but only part of it to hold the spool in the operating position, usually this is 70/75% less power than the rated Fig. 3.

When operating with energy saving driver, continuous energization with the holding voltage of 3 to 6 VDC is possible.

III. RESULTS AND DISCUSSION

The implemented system for speed variation of „Camozzi 61M6P040A0500“ pneumatic cylinder with double outrigger rod uses four high speed pneumatic valves which are controlled by an electronic module with PWM.

Experiments were performed at different PWM frequency and pulse fill.

Selected working pressure 5 bar.

Fig. 5 to 7 Shows experimental transients with 20Hz PWM and varying duty cycle from 0.02 to 0.9.

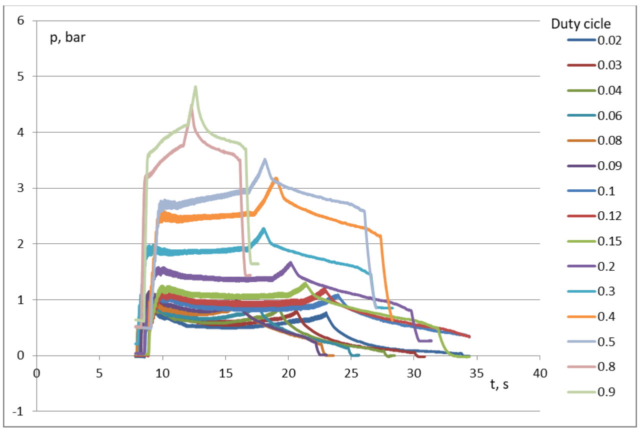

Fig. 5. Variation of pressure in the left chamber of the pneumatic cylinder with double out rod at different values of the duty cycle 20 Hz.

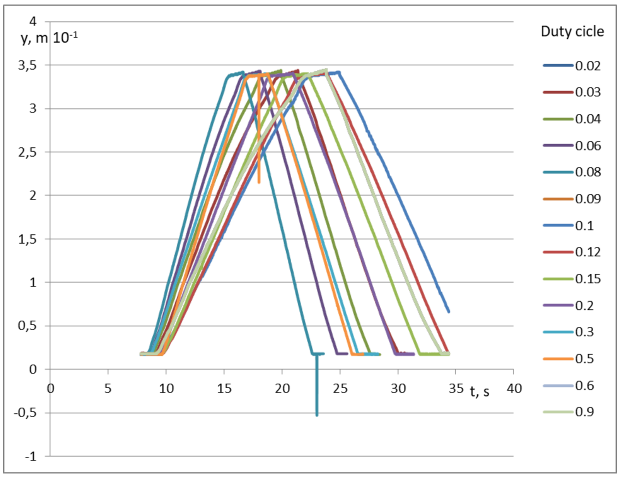

Fig. 6. Displacement of the piston of the pneumatic cylinder with double out rod at different values of the duty cycle 20 Hz.

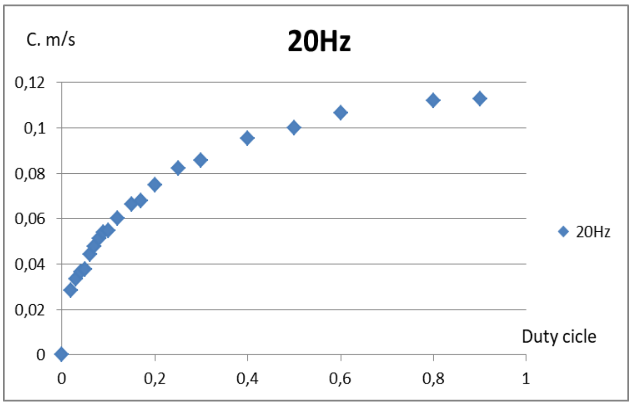

Fig. 7. Variation of the piston speed of pneumatic cylinder with double out rod different duty cycle values.

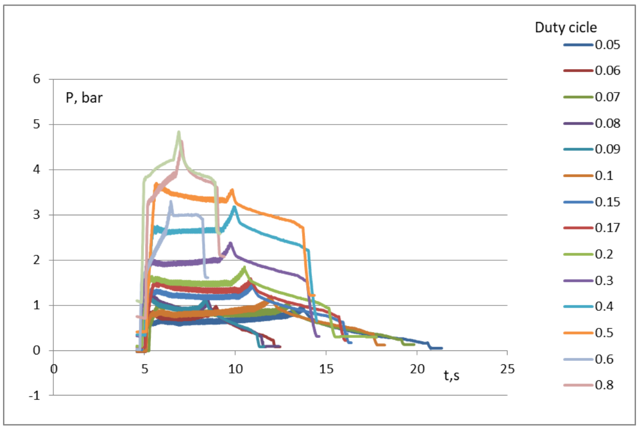

Fig. 8. Variation of pressure in the left chamber of the pneumatic cylinder with double out rod at different values of the duty cycle 30 Hz.

Fig. 8 to 10 Shows experimental transients with 30 Hz PWM and duty cycle variation from 0.02 to 0.9.

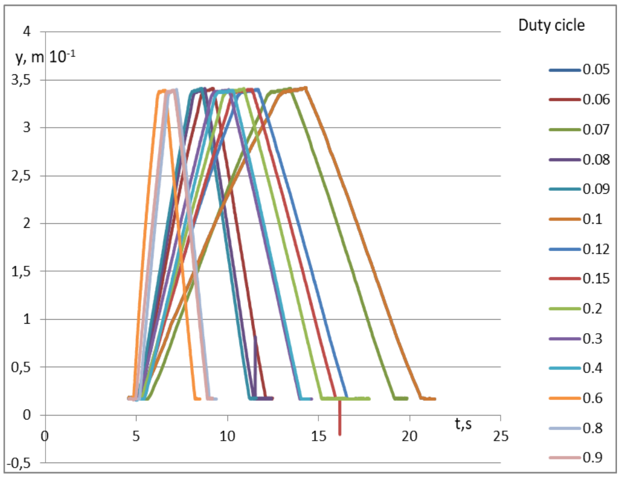

Fig. 9. Displacement of the piston of the pneumatic cylinder with double out rod at different values of the duty cycle 30 Hz.

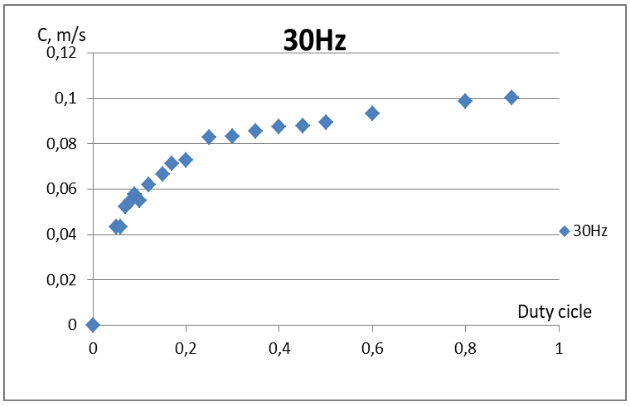

Fig. 10. Variation of the piston speed of pneumatic cylinder with double out rod different duty cycle values.

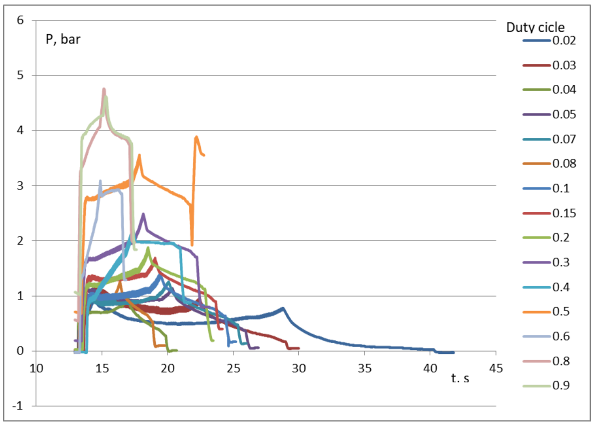

Fig. 11. Variation of pressure in the left chamber of the pneumatic ramless cylinder at different values of the duty cycle 50 Hz.

Fig. 11 to 13 Shows experimental transients with 50 Hz PWM and duty cycle variation from 0.02 to 0.9.

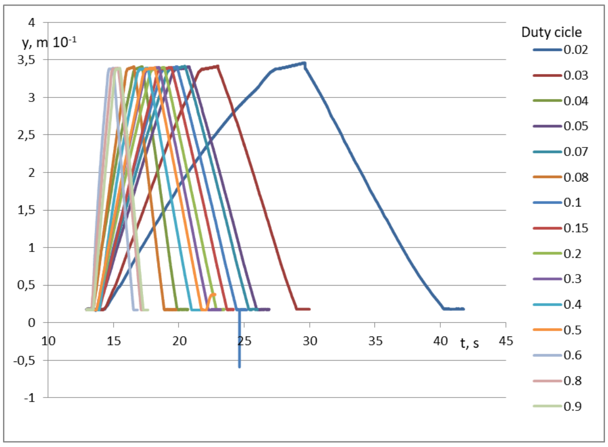

Fig. 12. Displacement of the piston of the pneumatic pistonless cylinder at different values of the duty cycle 50 Hz.

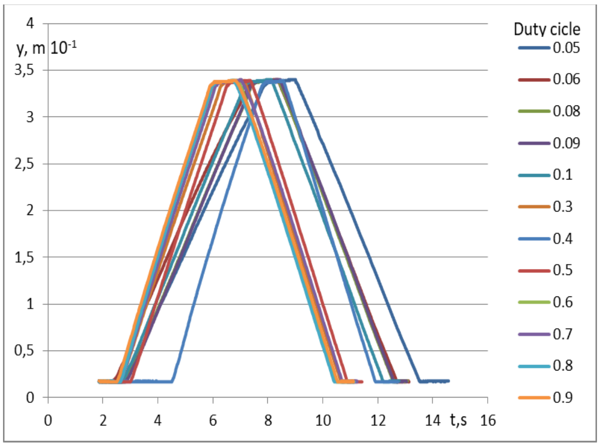

Fig. 15. Displacement of the piston of the pneumatic pistonless cylinder at different values of the duty cycle 70 Hz.

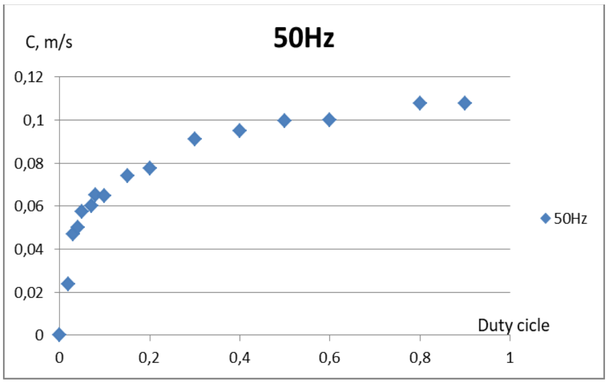

Fig. 13. Variation of the piston speed of pneumatic cylinder with double out rod different duty cycle values.

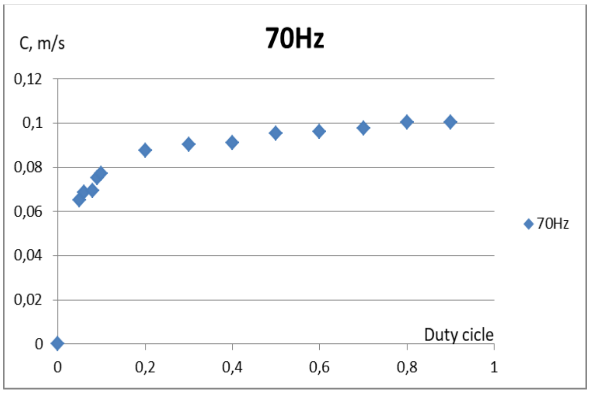

Fig. 16. Variation of the piston speed of pneumatic cylinder with double out rod different duty cycle values.

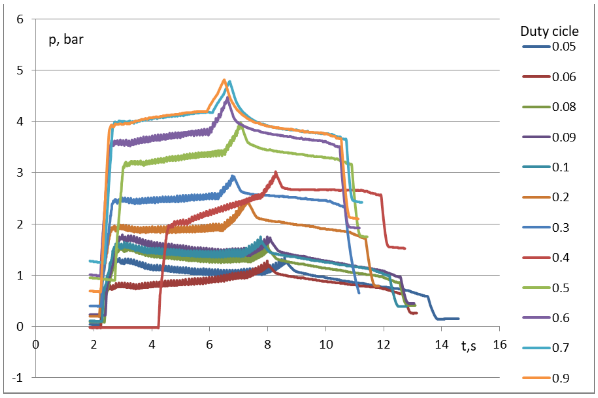

Fig. 14. Variation of pressure in the left chamber of the pneumatic cylinder with double out rod at different values of the duty cycle 70Hz.

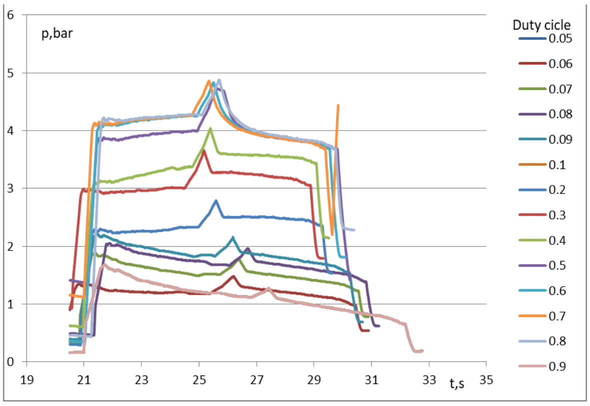

Fig. 17. Variation of pressure in the left chamber of the pneumatic cylinder with double out rod at different values of the duty cycle 100H.

Fig. 14 to 16 shows experimental transients with 70 Hz PWM and duty cycle variation from 0.02 to 0.9.

Fig. 17 to 19 shows experimental transients with 100 Hz PWM and duty cycle variation from 0.02 to 0.9.

From the experimental investigations made on a pneumatic system with "Camozzi" model: „61M6P040A0500" pneumatic cylinder with double out rod, by controlling its speed by SMC Japan model SX12F-AH high speed 2 port pneumatic valves and PWM control with an energy saving block, the following was achieved:

- At a frequency of 20 Hz /fig. 5 - 7/, a supply pressure of 5 bar, and a change in the duty cycle coefficient ranging from 0.02 to 0.9, a pressure variation from 0.8

bar at 0.02 fill to 4.82 bar at 0.9 fill was observed, and the flow rate variation under the same conditions was from 6.33 l/s to 58.31 l/s, The maximum achieved piston speed of the pneumatic cylinder was 0.112 m/s.

- At a frequency of 30 Hz /fig .8 - 10/, a supply pressure of 5 bar and a change in duty cycle ranging from 0.05 to 0.9, there is a pressure variation from 0.98 bar at 0.05 duty cycle to 4.84 bar at 0.9 duty cycle, the flow rate variation under the same conditions is from 17.79 l/s to 61.06 l /s, the maximum velocity is 0.100 m/s.
- At a frequency of 50 Hz /fig.11-13/, a supply pressure of 5 bar and a change in duty cycle ranging from 0.05 to 0.9, there is a pressure variation from 0.92 bar at 0.05 duty cycle to 4.62 bar at 0.9 duty cycle, the flow rate variation under the same conditions is from 4.14 l/s to 59.9 l/s, the maximum velocity is 0.107 m/s. The piston velocity of the cylinder does not change with an increase in duty cycles above 0.8, but the pressure and flow rate increase.

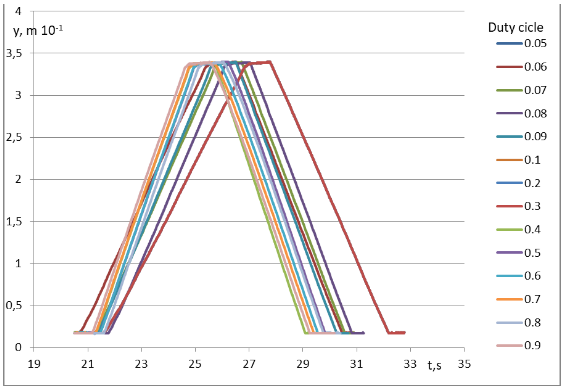

Fig. 18. Displacement of the piston of the pneumatic cylinder with double out rod at different values of the duty cycle 100 Hz.

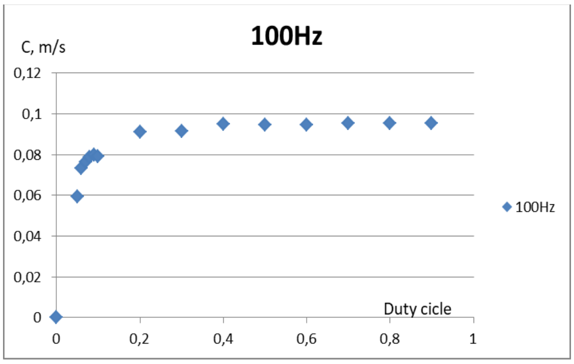

Fig. 19. Variation of the piston speed of pneumatic cylinder with double out rod different duty cycle values.

- At a frequency of 70 Hz /fig. 14 - 16/, a supply pressure of 5 bar and a change in duty cycle ranging from 0.02 to 0.9, a pressure variation from 1.35 bar at a duty cycle of 0.02 to 4.81 bar at a duty cycle of 0.9 is observed, the flow variation under the same conditions is from 29.05 l/s to 60.90 l/s, the maximum velocity reached is 0.100 m/s. The piston velocity of the cylinder does not change with an increase in duty cycle above 0.5, but the pressure and flow rate increase.
- At a frequency of 100 Hz /fig. 17-19/, a supply pressure of 5 bar and a duty cycle variation ranging from 0.02 to 0.9, a pressure variation from 3.4 bar at a duty cycle of 0.02 to 4.86 bar at a fill of 0.9 is observed, the flow variation under the same conditions is from 26.36 l/s to 59.81 l/s, the maximum velocity reaches 0.095 m/s. Cylinder piston velocity does not change with duty cycle increase above 0.4, but pressure and flow rate increase.

CONCLUSIONS

The presented experimental studies prove the possibility of smoothly adjusting the speed of pneumatic cylinders using two-position valves, by changing the frequency and duty cycle of PWM. Using this control method makes it possible to replace expensive servo valves for precise speed control.

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