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SPEED CONTROL OF PNEUMATIC POWER TRANSMISSION SYSTEMS USING ON-OFF VALVES WITH PULSE WIDTH MODULATION

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Abstract: *To increase the energy efficiency of pneumatic power transmission systems, modern control method for speed control of pneumatic cilinder is applied. This is realised by high speed 2 port valves ON/OFF, digital control by computerand virtual instruments with specialised software. This paper presents the possibility of controlling the speed of a pneumatic rodless cylinder with a controller using Pulse Width Modulation PWM. An electronic block implemented with a PWM and an energy saving amplifier is used for control high speed 2 port valves ON/OFF.*

Practical realization of PWM controlled electro-pneumatic 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.

Keywords: *Pneumatic power transmission system, Energy Efficiency, PWM speed control*

INTRODUCTION

Pneumatic drive systems are widely used in modern industry, they are an integral part of automated production systems. They have a number of advantages related to their good power-to-weight ratio, they are environmentally sound, do not pollute the working environment, have relatively low commercial prices, use compressed air which is readily available in industrial environments, are easy to maintain and install. The disadvantage is the instability of compressed air due to its compressibility, and the relatively high friction in the pneumatic mechanisms which leads to creating difficulties such as variable speed and difficult positioning (Iliev, G., & Hristo Hristov 2023). As a result, the analytical mathematical models describing the dynamics of pneumatic systems are nonlinear and characterized by a large number of unknown parameters that must be identified experimentally to obtain adequate models corresponding to real systems (Gentile A., & Giannoccaro NI, Reina G 2002).

A not small problem remains the design of a controller to control the system, in dynamic mode, which further complicates the model. The use of an energy saving block to control the operation of pneumatic valves is a prerequisite for the realization of energy saving systems in industry (Carducci G., & Gentile A., Giannoccaro NI., Messina A. 2003).

To increase the energy efficiency of pneumatic drive systems, modern control methods are applied. Pneumatic high speed 2-port ON/OFF valves, digital control with pulse-width modulation and specialized software are used. In order to obtain similar linear characteristics as the control of a pneumatic proportional distributor system, the switching time of the valves must be very small during the short cycle time. The control range depends on the valve switching time and the modulation frequency.

EXPOSITION

Investigation of speed control of a pneumatic throttleless cylinder with PWM controller and high speed 2 port valves ON/OFF

A dedicated stand, shown in Fig. 1, has been developed for experimental studies of dynamic processes in pneumatic actuator systems. The stand is equipped with a state-of-the-art DAQ system and a dedicated virtual instrumentq allowing real-time investigation of transients in a pneumatic actuator system.

The objective of the study is to determine the speed of a pneumatic throttleless 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.

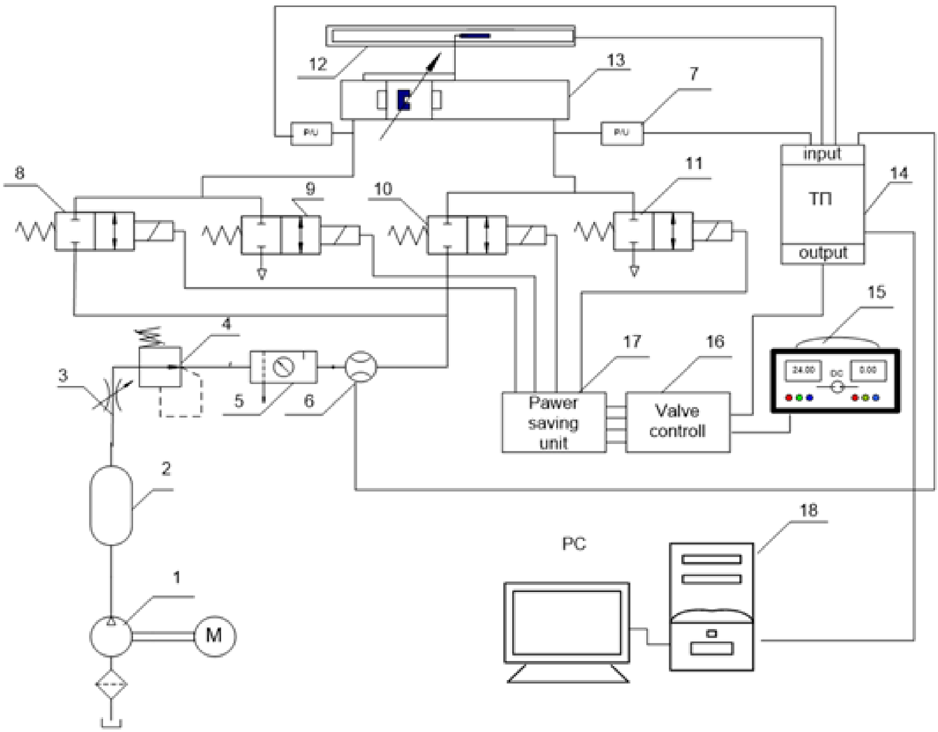


Fig. 1. Scheme of experimental pneumatic stand

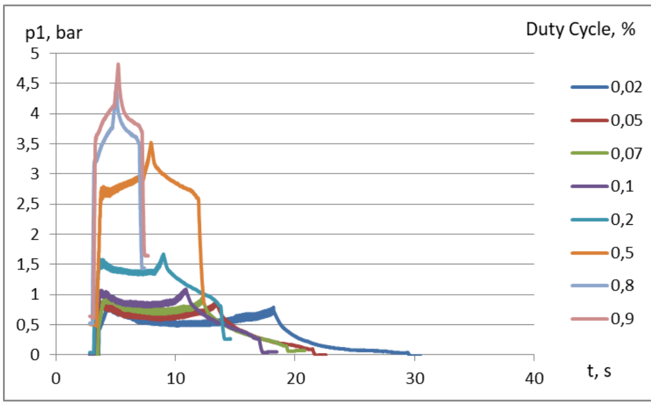
1 - screw compressor; 2 - receiver; 3 - stopcock; 4 - safety valve; 5 - air preparation system preparatory; 6 - flowmeter; 7 - pressure transducer, 8, 9, 10, 11 high speed 2 port on/off valve; 12 - potentiometric sensor, 13 - pneumatic brushless cylinder; 14 - terminal board; 15 - power supply unit;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

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. 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.

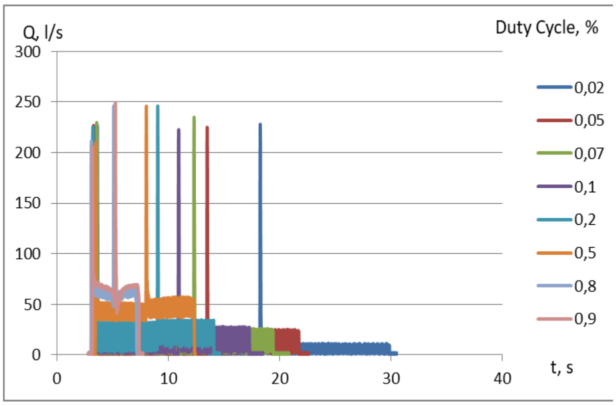
To realize the fast valve operation and the plunger displacement, a high controlled coil power is required: 24 V; 80 W. The control of the high-performance pneumatic quick-acting valves is complemented by a power saving electrical circuit.

EXPERIMENTAL RESULTS

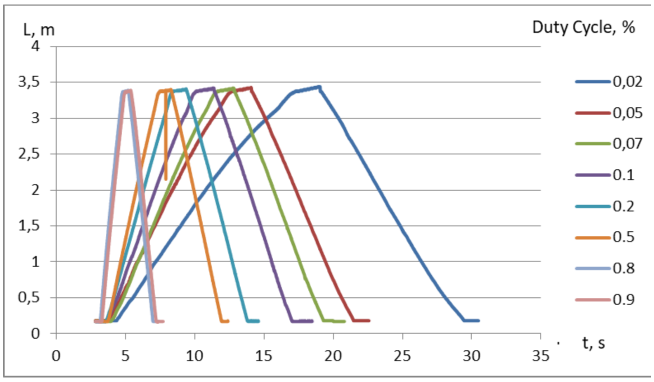
The implemented system for speed variation of pneumatic ramless cylinder model Camozzi-52M2P32A1000 uses four high speed ON/OFF pneumatic valves which are controlled by an electronic module with PWM. Experiments were performed at different PWM frequency and pulse fill. Fig. 2 shows experimental transients with 20Hz PWM and varying duty cycle from 0.02 to 0.9%.



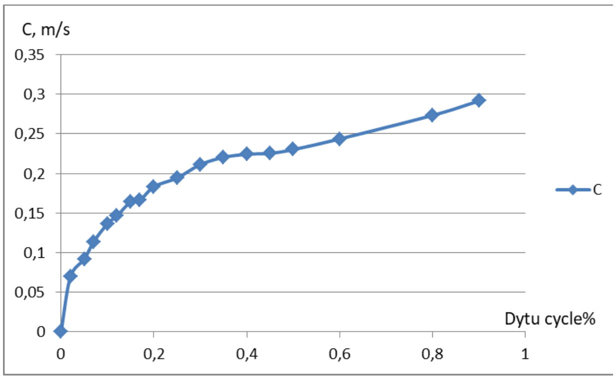
(a) Variation of pressure in the left chamber of the pneumatic ramless cylinder at different values of the duty cycle.



(b) Variation of the flow rate at different values of the duty cycle.



(c) Displacement of the piston of the pneumatic pistonless cylinder at different values of the duty cycle.



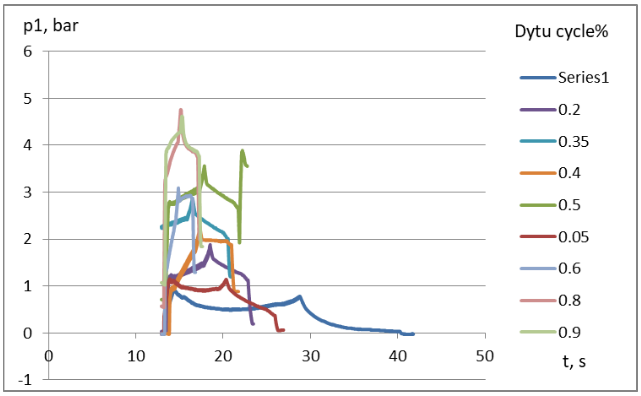
(d) Variation of the piston speed of the pneumatic pistonless cylinder different duty cycle values.

Fig. 2. Experimental transients of pneumatic actuator system with PWM amplitude at 20Hz and change of duty cycle from 0.02 to 0.9%.

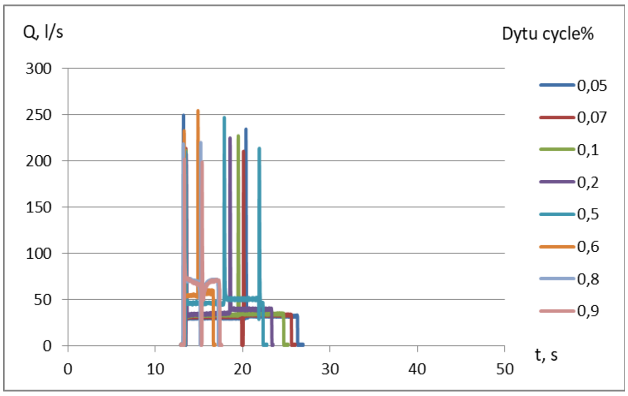
Fig. 3 Shows experimental transients with 50 Hz PWM and duty cycle variation from 0.02 to 0.9 %;

Fig. 4 Shows experimental transients with 70 Hz PWM and duty cycle variation from 0.02 to 0.9 %;

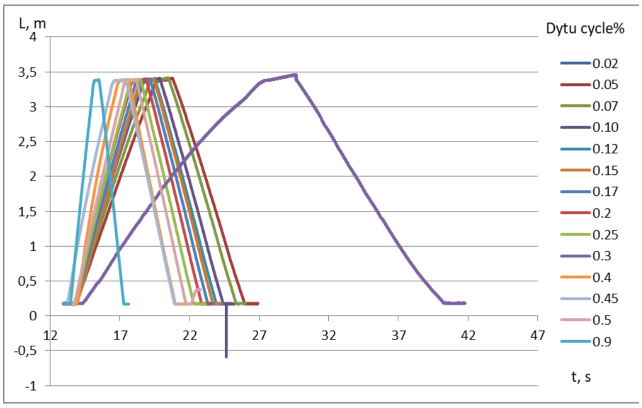
Fig. 5 Shows experimental transients with 100 Hz PWM and duty cycle variation from 0.02 to 0.9 %.



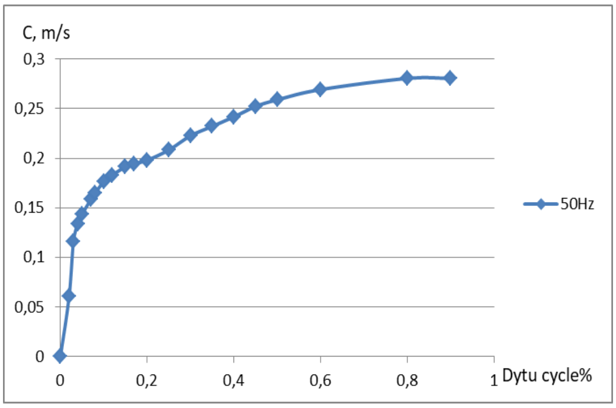
(a) Variation of pressure in the left chamber of the pneumatic ramless cylinder at different values of the duty cycle.



(b) Variation of the flow rate at different values of the duty cycle.



(c) Displacement of the piston of the pneumatic pistonless cylinder at different values of the duty cycle.

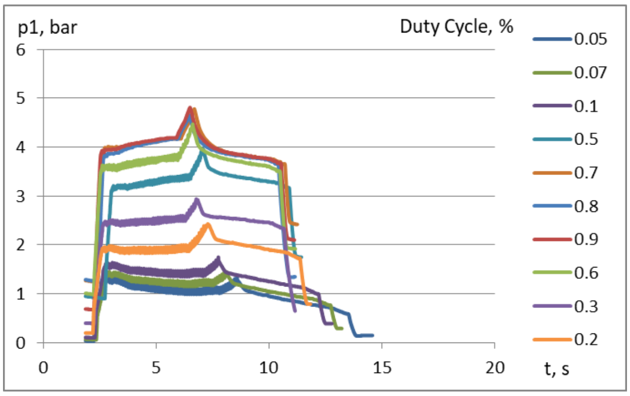


(d) Variation of the piston speed of the pneumatic pistonless cylinder different duty cycle values.

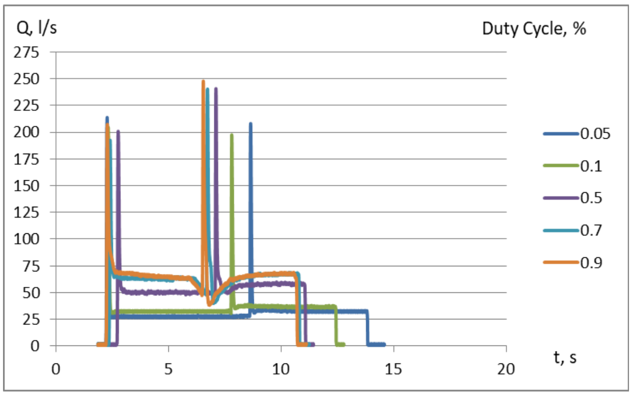
Fig. 3. Experimental transients of pneumatic actuator system with PWM amplitude at 50Hz and

ORDER OF EXPERIMENT:

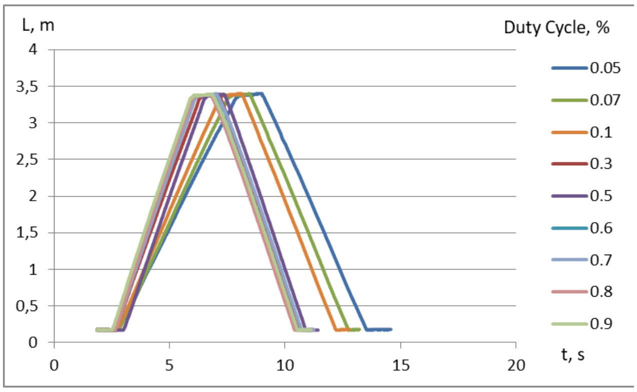
1. Run the virtual instrument to record and process the result in real time with recording 100 times per second. The data from the pressure transducers, flow meter and potentiometric displacement sensor are recorded.
2. The virtual instrument is started to provide the PWM input signal, the desired value is set, the output signal is checked (calibration).
3. Set the working pressure of 6 bar of the pneumatic experimental system.
4. Check the DC 24V supply circuits for the pneumatic quick valves and the set up regulators.
5. The experiments are conducted at different frequencies and different duty cycle values
6. The experimental results are processed and presented in graphical form for convenient presentation and analysis.



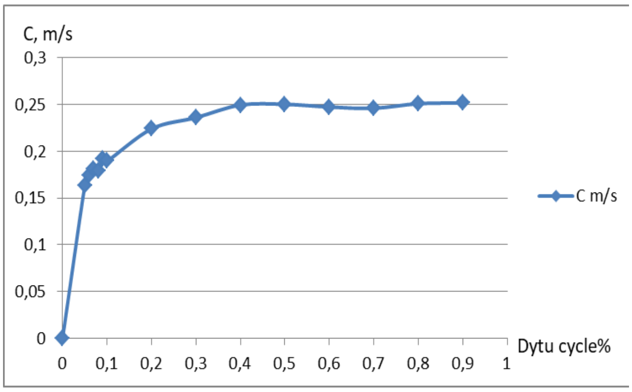
(a) Variation of pressure in the left chamber of the pneumatic ramless cylinder at different values of the duty cycle.



(b) Variation of the flow rate at different values of the duty cycle



(c) Displacement of the piston of the pneumatic pistonless cylinder at different values of the duty cycle.



(d) Variation of the piston speed of the pneumatic pistonless cylinder different duty cycle values.

Fig. 4. Experimental transients of pneumatic actuator system with PWM amplitude at 70Hz and change of duty cycle from 0.02 to 0.9%.

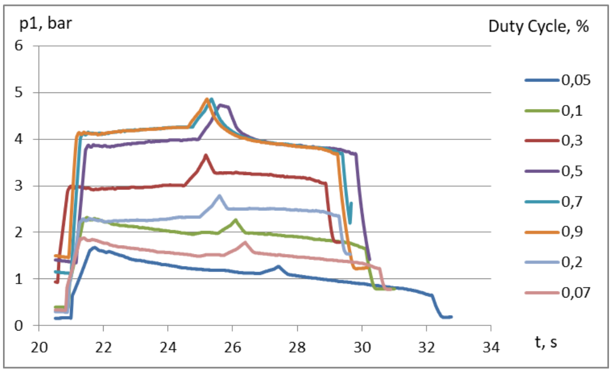
CONCLUSION

From the experimental investigations made on a pneumatic system with Camozzi model: 52M2P32A1000 throttleless cylinder, 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:

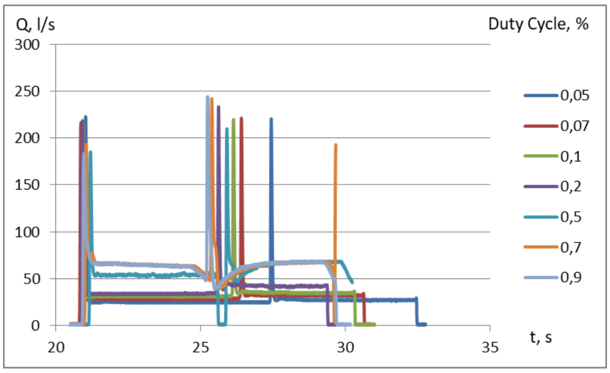
At a frequency of 20 Hz /fig. 2/, a supply pressure of 6 bar, and a change in the duty cycle coefficient ranging from 0.02 to 0.9%, a pressure variation from 0.67 bar at 0.02% fill to 4.71 bar at 0.9% fill was observed, and the flow rate variation under the same conditions was from 7.07 l/s to 69.8 l/s, The maximum achieved piston speed of the pneumatic cylinder was 0.29 m/s.

At a frequency of 50 Hz /fig.3/, a supply pressure of 6 bar and a change in duty cycle ranging from 0.05 to 0.9%, there is a pressure variation from 0.67 bar at 0.05% duty cycle to 4.71 bar at 0.9% duty cycle, the flow rate variation under the same conditions is from 7.07 l/s to 69.8 l/s, the maximum velocity is 0.28 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.

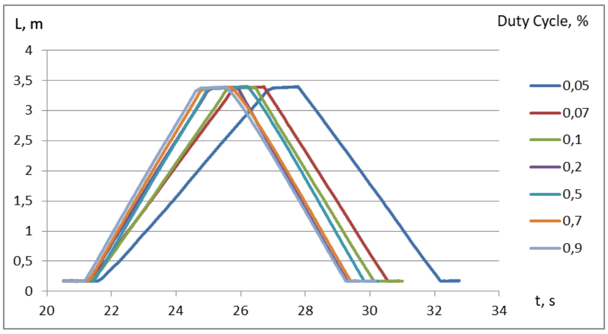
At a frequency of 70 Hz /fig. 4/, a supply pressure of 6 bar and a change in duty cycle ranging from 0.02 to 0.9%, a pressure variation from 1.42 bar at a duty cycle of 0.02% to 4.70 bar at a duty cycle of 0.9% is observed, the flow variation under the same conditions is from 31.85 l/s to 68.77 l/s, the maximum velocity reached is 0.25 m/s. The piston velocity of the cylinder does not change with an increase in duty cycle above 0.4%, but the pressure and flow rate increase.



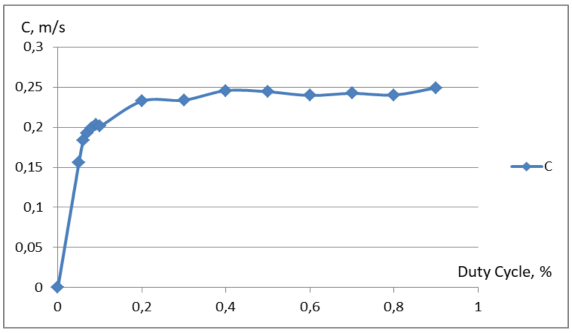
(a) Variation of pressure in the left chamber of the pneumatic ramless cylinder at different values of the duty cycle.



(b) Variation of the flow rate at different values of the duty cycle



(c) Displacement of the piston of the pneumatic pistonless cylinder at different values of the duty cycle.



(d) Variation of the piston speed of the pneumatic pistonless cylinder different duty cycle values

Fig. 5. Experimental transients of pneumatic actuator system with PWM amplitude at 100 Hz and change of duty cycle from 0.02 to 0.9%.

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