DETERMINING THE STEP RESPONSE FOR A PNEUMATIC CYLINDER POSITIONING SYSTEM

Radu RADOI[1], Marian BLEJAN[2], Iulian DUTU[3], Gheorghe SOVAIALA[4], Ioan PAVEL[5]

[1] INOE 2000 - IHP, radoi.ihp@fluidas.ro;[2] INOE 2000 - IHP, blejan.ihp@fluidas.ro;[3]
INOE 2000 - IHP, dutu.ihp@fluidas.ro;[4] INOE 2000 – IHP, sovaiala.ihp@fluidas.ro;
INOE 2000 – IHP, pavel.ihp@fluidas.ro [5]

Abstract:

Linear pneumatic actuators are used to provide linear motion for medical, automotive, laboratory and robotics applications or in industrial aplications such as chemical and petrochemical industries, oil refineries, drilling industries, food industries for sorting and packaging lines, paper industries, etc. These actuators must be reliable and accurate to ensure proper and without disruption functioning of the installations they belong to. Applications they belong to sometimes require a high dynamics. In order to determine the performance of an actuator for a specific application or if it is intended to achieve a high dynamics by using new designs or new materials there are necessary experiments.
The paper presents an experimental stand which allows for dynamic testing of pneumatic actuators.

Keywords*: pneumatic, cylinder, step signal, positioning, incremental transducer, converter, controller*

1. Introduction

Linear pneumatic actuators are used to provide linear motion for medical, automotive, laboratory, and robotics applications or in industrial aplications such as chemical and petrochemical industries, oil refineries, drilling industries, food industries for sorting and packaging lines, paper industries, etc. These actuators must be reliable and accurate to ensure proper and without disruption functioning of the installations they belong to. Applications they belong to sometimes require a high dynamics. The paper presents the development of a stand which allows experimentations to determine the performance of an actuator for a specific application or if it is intended to achieve a high dynamics by using new designs or new materials.

2. Description of the testing system

The stand is made of two identical pneumatic cylinders with rods connected oppositely by means of a force transducer. Pneumatic cylinders are mounted in a closed frame, on which the other devices within the stand structure are installed. These other component devices are: the pressure regulator, the pneumatic proportional directional control valve, pressure transducers and the throttle check valve which helps create a load type pneumatic spring using the cylinder located oppositely to the one controlled by the proportional directional control valve.
Pneumatic diagram of the testing system (Fig. 1) includes compressor 1, relief valve 2, limiting the load pressure of the air tank 4, air filter 3, pressure regulator 5, setting the working pressure in the system, manometer 6 allowing visualization of pressure that has been adjusted. The positioning system which is to be tested consists of proportional directional valve 7, controlling pneumatic cylinder 8, equipped with displacement incremental encoder 9. To view the evolution of pressure values in the pneumatic cylinder chambers there wewre provided pressure transducers 10. On the exhaust ports of

the proportional directional control valve there were installed two silencers 11. Cylinder 14, by means of which a load type pneumatic spring is created, has been connected to the actuator cylinder by means of a force transducer 13. At the outlets of the load cylinder there have been installed two throttle check valves 12, allowing to create load only in the opposite direction in regard to the movement of the actuation cylinder. In the diagram can also be found signal converter 15, PID controller 16, USB-6218 data acquisition board 17 and computer 18 equipped with data acquisition software.

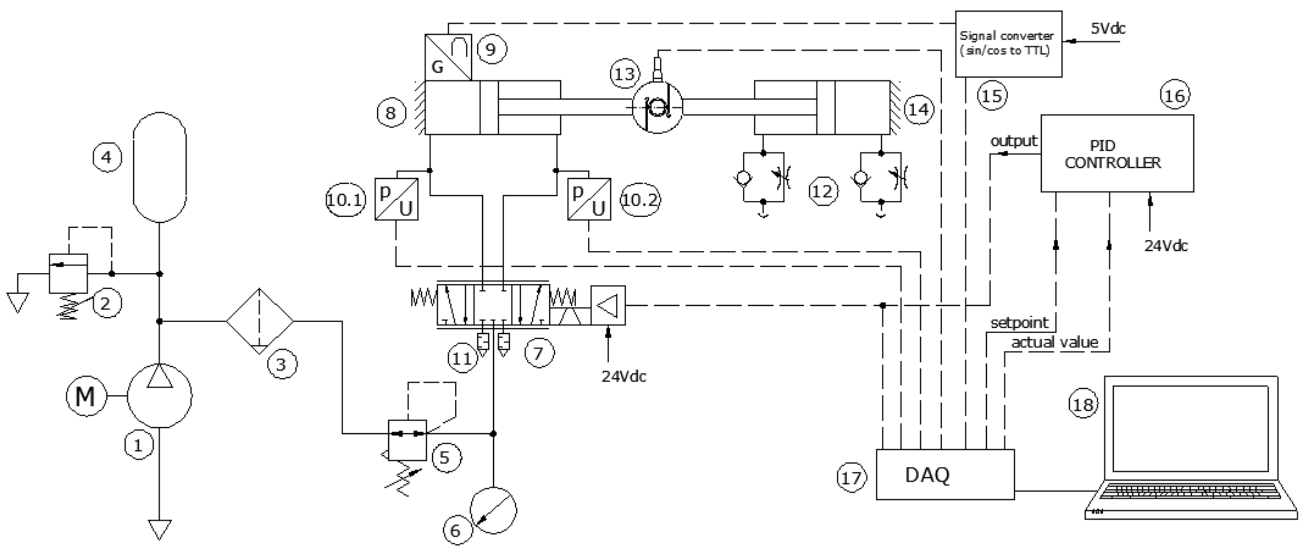


Fig. 1 Pneumatic and data acquisition diagram of the system

3. Data acquisition system

To generate control signals and to acquire signals from the transducers and from the PID regulator there has been used a data acquisition board made by National Instruments. Sine wave incremental encoder (9) incorporated in Festo DNCI-32-200-P-A pneumatic cylinder provides relative values. In order to capture the signal from this encoder with the meters on the acquisition board, there has been developed a module for conversion of sin and cos signals (Fig. 2) supplied by it into TTL signal, a type of signal that can be registered by the meters on the USB – 6218 acquisition board.

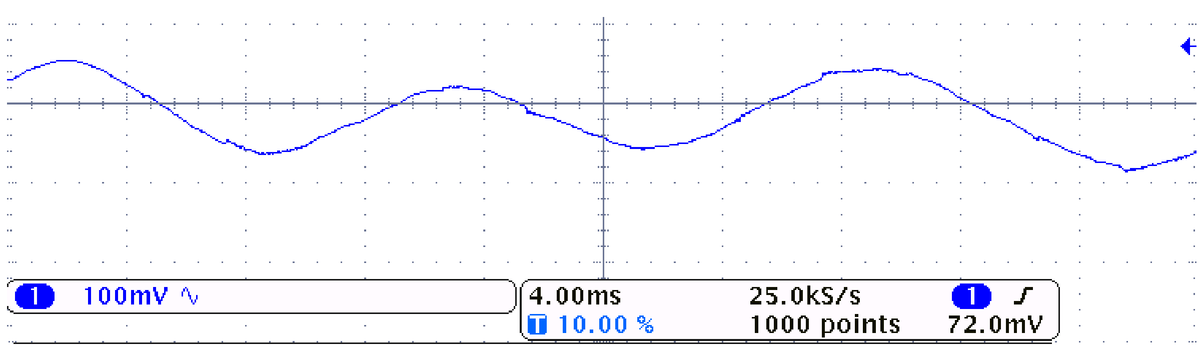


Fig 2 Encoder signal from sin channel of Festo DNCI pneumatic cylinder

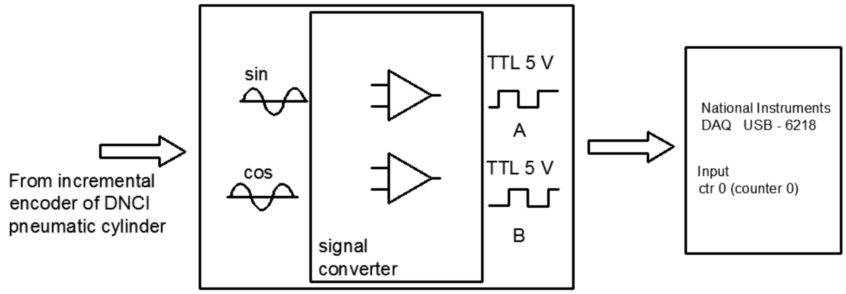
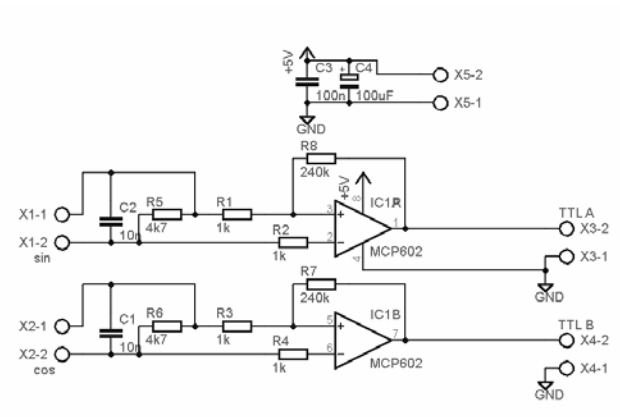
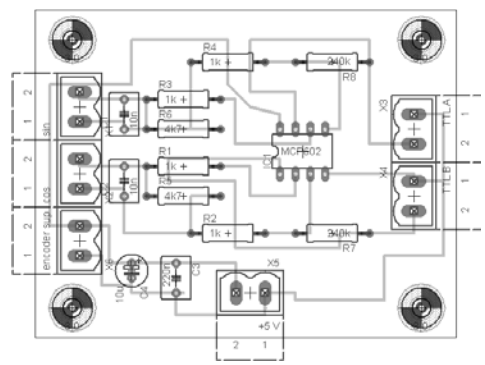


Fig. 3 Block diagram for signal acquisition from incremental encoder

In figure 4 can be seen the diagram developed with two operational amplifiers included in the capsule of an integrated circuit type MCP602. The assembly is powered at 5V DC, and it has terminals located on sides for connecting the cable from the encoder (sin and cos signals, and also the 5V power supply of the encoder), while at the other end it has terminals for connection to the meter of the acquisition board.



a. Diagram of the signal converter



b. The printed circuit board

Fig. 4 Signal converter developed with MCP602 containing 2 CMOS Op Amps

Impulses recorded by the meter of the acquisition board have been processed using the application developed in LabVIEW and converted into a signal of 0 ... 10 V voltage, which was applied to the PID controller as a positioning signal of the pneumatic cylinder – actual value. The setpoint signal has also been generated within the range 0 ... 10 V, manually or as a step signal using a block for simulation of a rectangular signal.

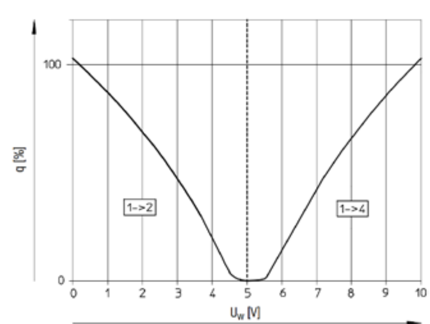


Fig. 5 Control signal of Festo proportional directional control valve type MPYE

According to the theory, the output signal of the PID controller is made of the sum of the terms proportional, integral and derivative.

$$U(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{d}{dt} e(t)$$

The output signal of the PID controller has been scaled from the range -10÷10 V to 5 ±5V, because the control signal of the proportional directional control valve is within the range 0...10 V, the 5 V voltage being the center position of the proportional pneumatic directional control valve, as in Fig. 5.

Signals recorded with the help of the data acquisition application have been the ones from the two pressure transducers (bar), from the force transducer between the cylinder rods (daN), the time elapsed (sec), control signal (%), position achieved by the pneumatic cylinder rod (mm), rod speed (mm/sec) and also the signals that PID controller works with (setpoint, actual value, error, PID output) in volts.

4. Test results

We have carried out several tests during which the parameters Kp and Ki have been varied, aiming that the system to respond quickly and be steady.

Fig. 6 Aspect during tests

The first tests were carried out without load type pneumatic spring, the throttle check valves being fully open. The pressure adjusted at the installation regulator has been of 7 bars. To power the transducers there has been used a 24 V laboratory power source. In figure 7 can be seen graphs of the control signal within the range 30÷70% of the total stroke of the cylinder, PID gains being Kp=7, Ki=5. It can be seen that the answer has a large overshoot and the tendency to get into oscillation.

In Fig. 8 is shown the evolution of PID controller signals, also for the test without load, where it can be noticed at the end of the test stationary error of 2.2 %.

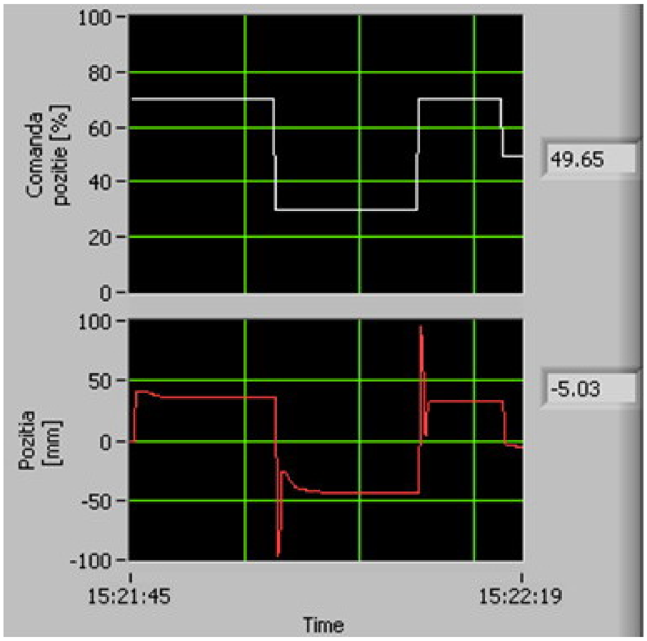


Fig. 7 Test under no load (Kp=7, Ki=5)

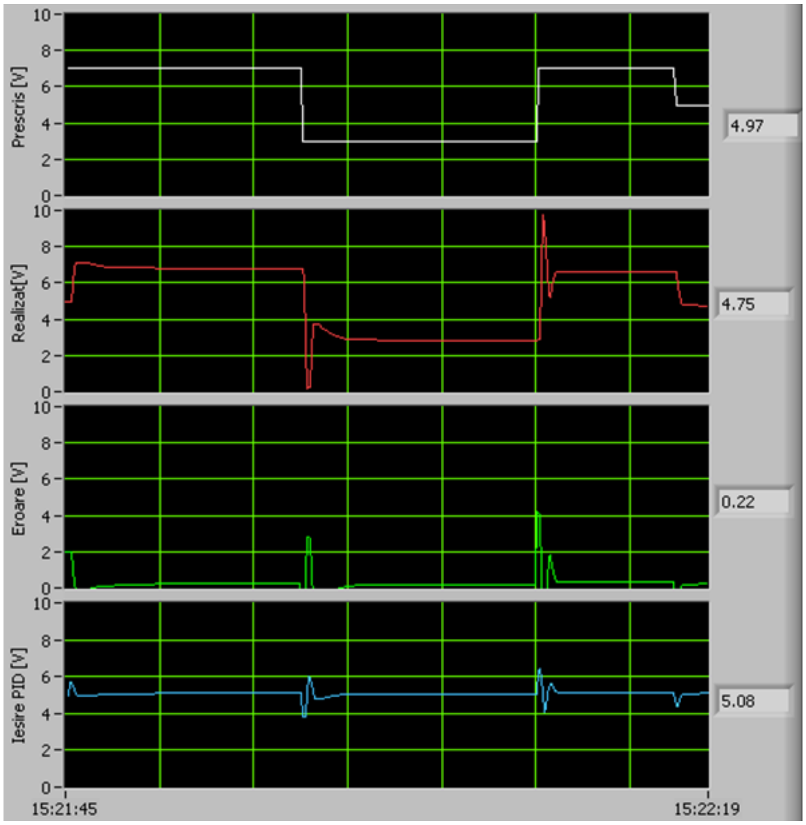


Fig. 8 Signals of the PID controller at testing under no load (Kp=7, Ki=5)

At tests with load type pneumatic spring, the pneumatic throttle check valves at the load cylinder have been completely closed. In figure 9 we present the diagrams of the pressure transducers of the two chambers of the pneumatic cylinder under actuation, and diagrams of the force transducer located between the two rods of the cylinders. For the test presented PID gains have been Kp=6, Ki=5. In figure 9 it can be seen that in a direction the force measured is greater, which is due to the difference in areas between the piston sides.

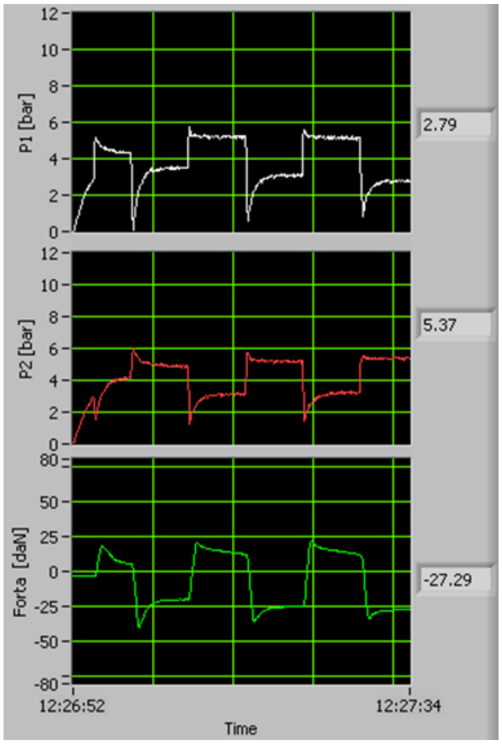


Fig. 9

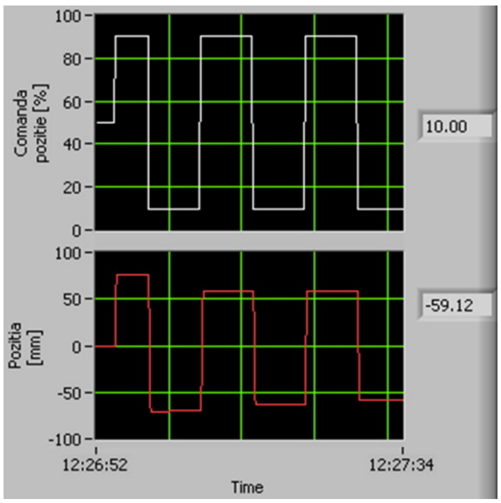


Fig. 10

In figure 10 can be seen the graphs of control signal in the range 10÷90 % and the graph of response of the positioning cylinder rod. Because of the load the system can not accurately track the control signal, there being a stationary error of 10 % that can also be seen in Fig. 11, which shows variation of the signals from the PID controller.

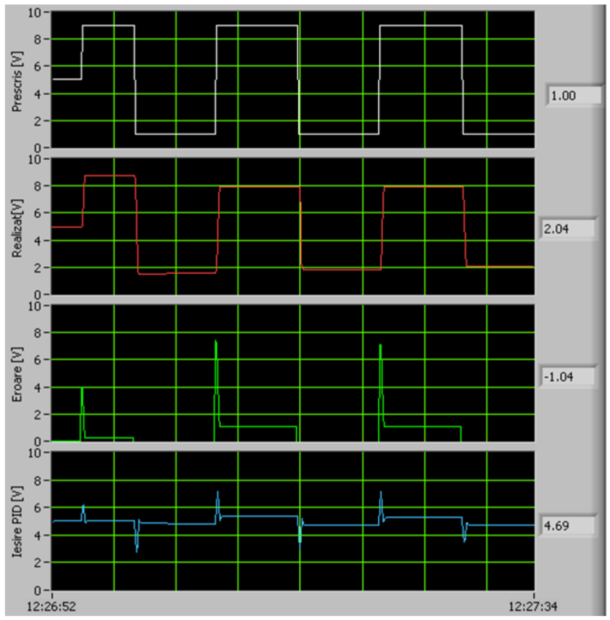


Fig. 11

5. Conclusions

This system enables us to test the response to step signal for a pneumatic cylinder positioning system.

The system enables the tuning of the PID controller in order to obtain an optimal response of the system.

By means of the data acquisition system there can be displayed variation of the signals of interest, and these signals can be registered for further processing.

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