Experimental Methods Aiming to Improve Dynamic Performance of Pneumatic Actuators

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Abstract: *This paper presents the tests carried out on two dimensional types of pneumatic actuators to determine their dynamic characteristics, highlighting the main factors and methods influencing them. The paper presents only three of the tests that have been conducted on actuators. They are:*
- response to step signal in three points of the stroke, at constant pressure - 8 bar;
- response to sine wave signal having initial amplitude, from minimum to maximum value, for three stroke values;
- determining the minimum starting pressure for the pistons of pneumatic actuators for both directions of travel (rod chamber and piston chamber).

Keywords*: pneumatic actuators, dynamic performance, influencing factors*

1. Introduction

In recent years in the Laboratory for Pneumatics of Hydraulics and Pneumatics Research Institute INOE 2000-IHP there have been research concerns about medium pressure pneumatic actuators. There have been developed testing methodologies and test devices for them.
The tests carried out on two dimensional types of medium pressure pneumatic actuators **(DNCKE-100-200-PPV-A**, respectively **DNCKE-40-130-PPV-A)**, highlight the main influencing factors and methods concerning their dynamic behavior, under no load, and they have consisted in [1],[5]:

a. response to step signal in three points of the stroke, at constant pressure - 8 bar;
b. response to sine wave signal having initial amplitude, from minimum to maximum value, for three stroke values;
c. determining the minimum starting pressure for the pistons of pneumatic actuators for both directions of travel (rod chamber and piston chamber).

2. Presentation of the experimental test bench

It consists of (see Fig. 1):

1. Compressed air supply-compressor + air preparation unit GPA
2. Testing device consisting of: Frame; Medium pressure actuator -ALP; Reflex displacement transducer -TDR; Pressure transducers -TP_1 and TP_2; Proportional directional control valve - DP
3. Computerized data acquisition system.

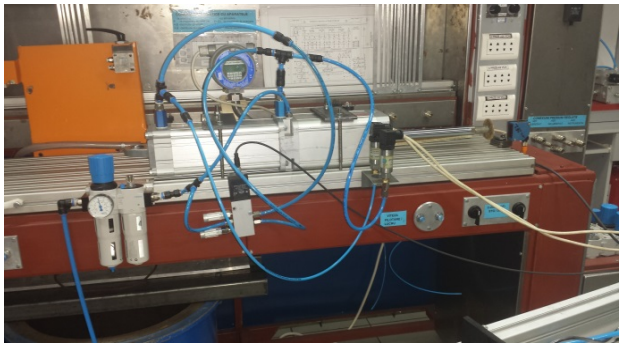


Fig. 1. Bench for testing the DNCKE-100-200-PPV-A medium pressure actuator

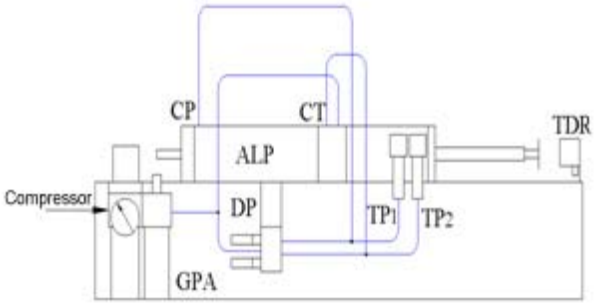


Fig. 2. Pneumatic circuit diagram of the test bench in dynamic regime

The testing software, developed in LabVIEW, consists of block diagrams conducting the test in automatic mode. The results consisting of charts and databases are automatically saved.
On the input of USB-6218 data acquisition board there are inserted voltage-type signals from the pressure transducers (corresponding to the two chambers of the actuator under tests) and the (reflex) displacement transducer [3]. One of the two analog signal outputs of the acquisition board is used to drive the proportional directional control valve in the testing diagram.
Feeding the electromagnets of the proportional equipment, the sensors and data acquisition board is done from a 2-channel power supply, Figure 3.

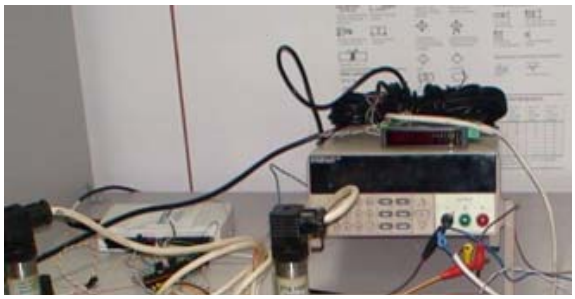


Fig. 3. 2-channel power supply

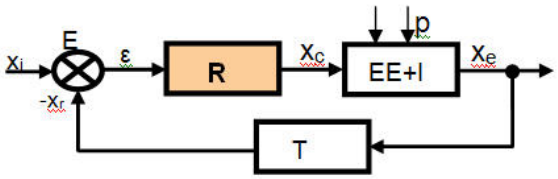


Fig. 4. Block diagram of automatic control system

In the automatic control system used to drive the pneumatic actuators, the automatic regulator (RA) is meant to operationally process the error signal ε (resulted following the linear – additive comparison between input parameter x_i and response parameter x_r in the comparison element) and to generate an output control signal x_c for the execution element. It is located on the direct route between the comparison element and the execution element (the actuator), according to the block diagram of automatic control system shown in Figure 4 [4].
Current information on the automated process is obtained by means of the response transducer TR and it is processed by the automatic regulator RA in compliance with a certain law which defines the algorithm for automatic control (the adjustment law).

3. Presentation of tests conducted and results achieved

a. Response to step signal in three points of the stroke, at constant pressure

The software diagram for determining the response to step signal, developed in LabVIEW, is shown in Figure 5.

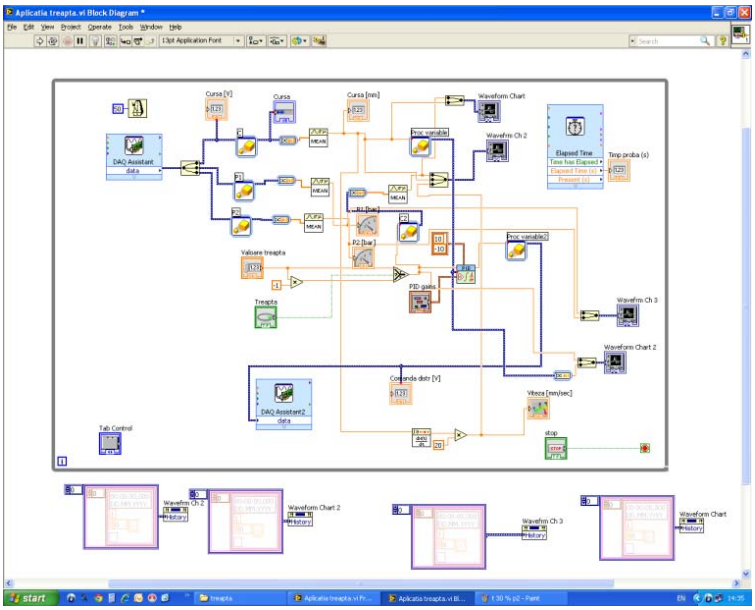


Fig. 5. Software diagram for determining response to step signal, developed in LabVIEW

The tests are conducted at working pressure of 8 bar, in 3 points along the stoke, namely 30%, 60% and 100% of stroke value mentioned by the manufacturer of the actuators, for different values of proportionality factor kc of the PID automatic controller.
In window 1 (screenshot), Figure 6, there are highlighted: prescribed position, achieved position, speed, amplitude variation over time, values of PID parameters of the automatic controller, step value.
In window 2, Figure 7, there are highlighted: pressures in piston chamber -p_1 /rod chamber -p_2, amplitude, values of PID parameters of the automatic controller, step value, time length of the test.

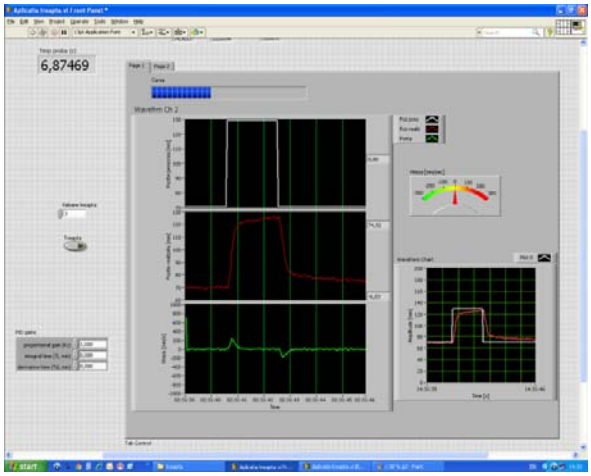


Fig. 6. Window 1 of the application - DNCKE-100-200-PPV-A medium pressure pneumatic actuator

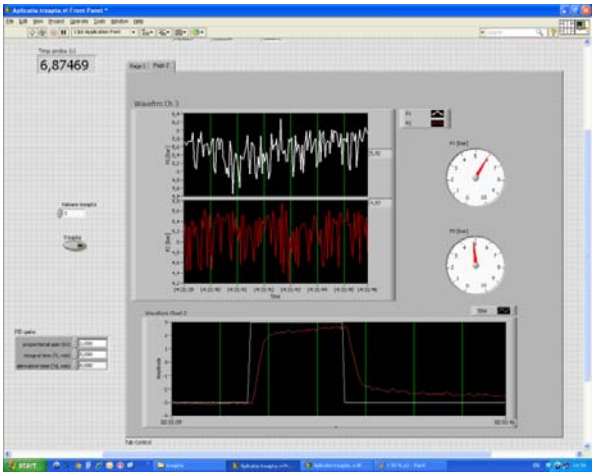


Fig. 7. Window 2 of the application - DNCKE-100-200-PPV-A medium pressure pneumatic actuator

The graphs obtained by running the software, for the two windows of the application, are shown in Figure 8.

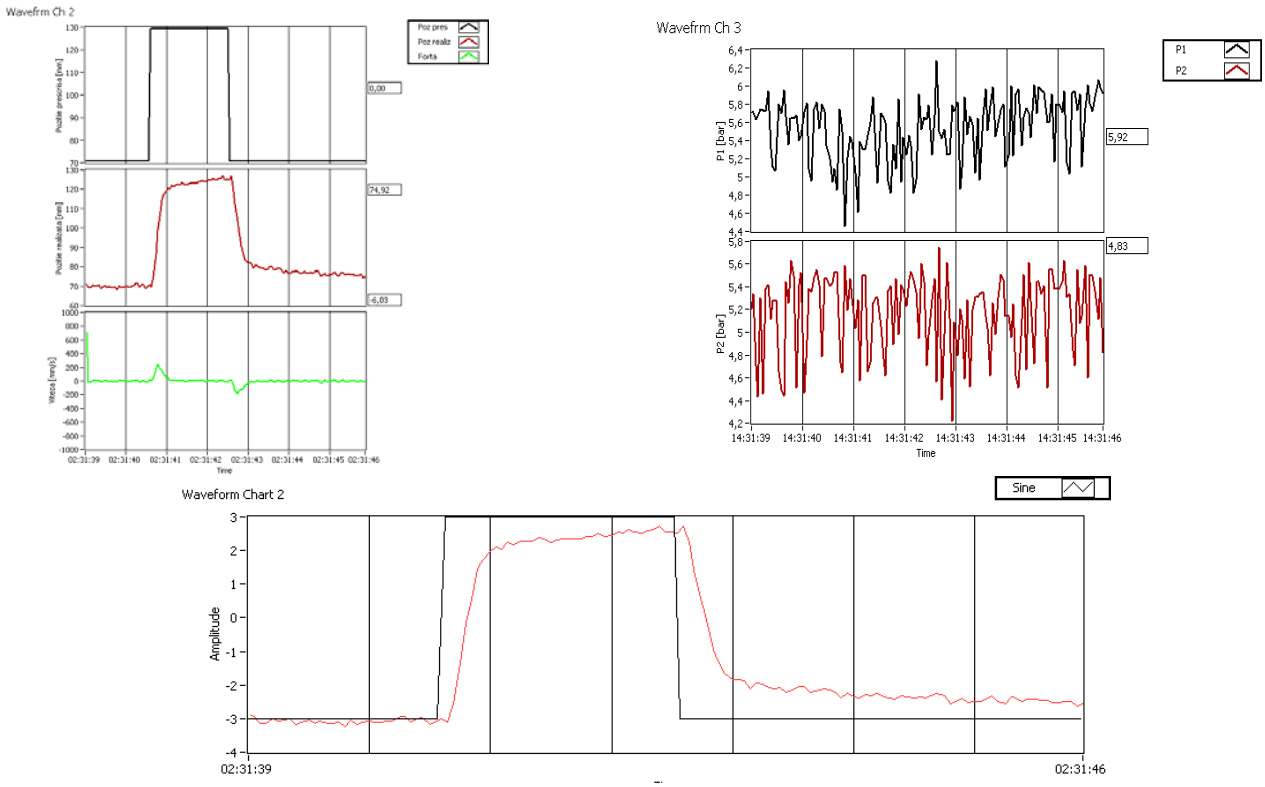


Fig. 8. The shape of graphs obtained during tests concerning the response of the DNCKE-100-200-PPV-A medium pressure pneumatic actuator to step signal

b. Response to sine wave signal having initial amplitude, from minimum to maximum value, for three stroke values

The software diagram for determining the response to sine wave signal, developed in LabVIEW, is shown in Figure 9. [2]

The tests are conducted at working pressure of 8 bar, in 3 points along the stoke, namely 30%, 60% and 100% of stroke value mentioned by the manufacturer of the actuators, for different values of proportionality factor kc of the PID automatic controller.

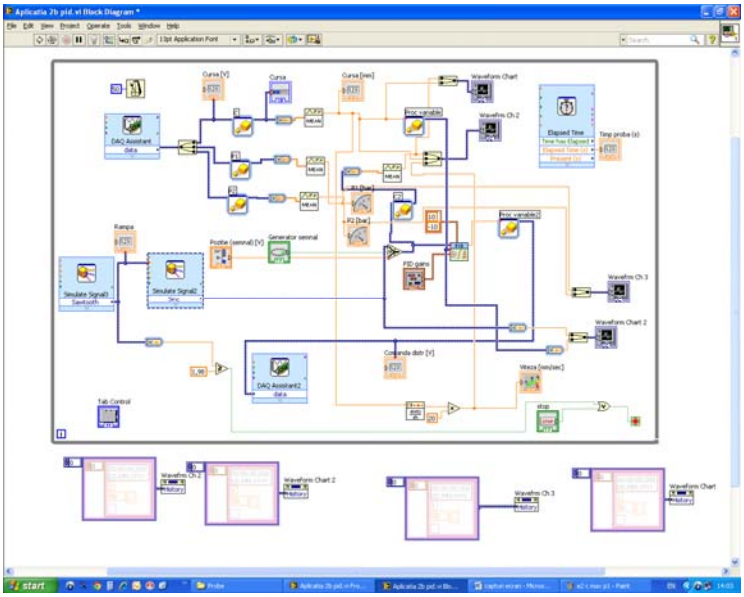


Fig. 9. Software diagram for determining the response to sine wave signal, developed in LabVIEW

In window 1, Figure 10, there are highlighted: prescribed position, achieved position, speed, amplitude variation over time, values of PID parameters of the automatic controller, status of the signal generator.

In window 2, Figure 11, there are highlighted: pressures in piston chamber -p_1 /rod chamber -p_2, amplitude, values of PID parameters of the automatic controller, status of the signal generator, time length of the test.

The graphs obtained by running the software, for the two windows of the application, are shown in Figure 12.

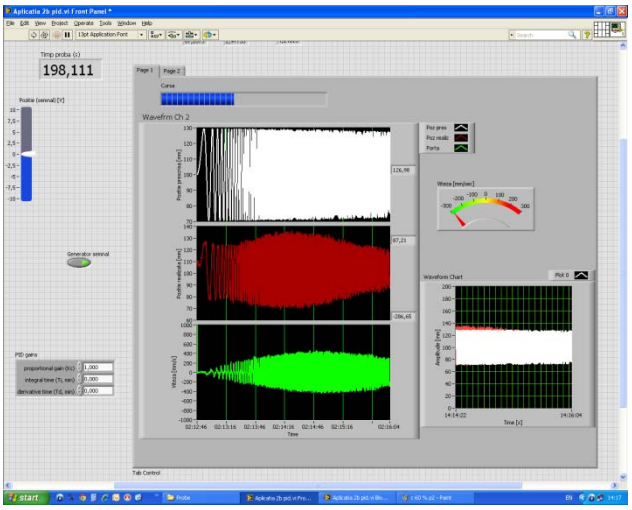


Fig. 10. Window 1 of the application - DNCKE-100-200-PPV-A medium pressure pneumatic actuator

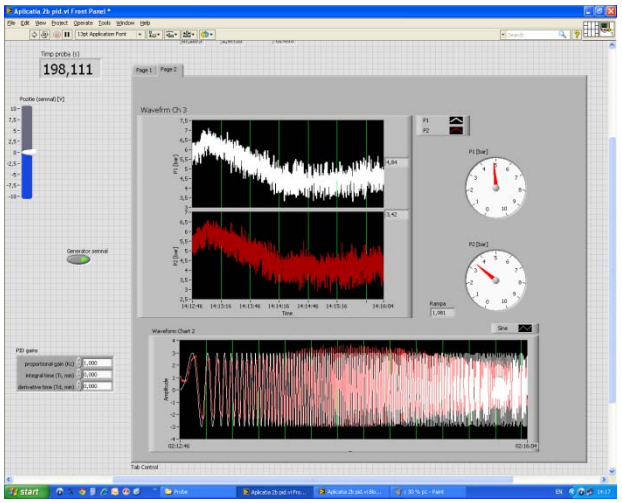


Fig. 11. Window 2 of the application - DNCKE-100-200-PPV-A medium pressure pneumatic actuator

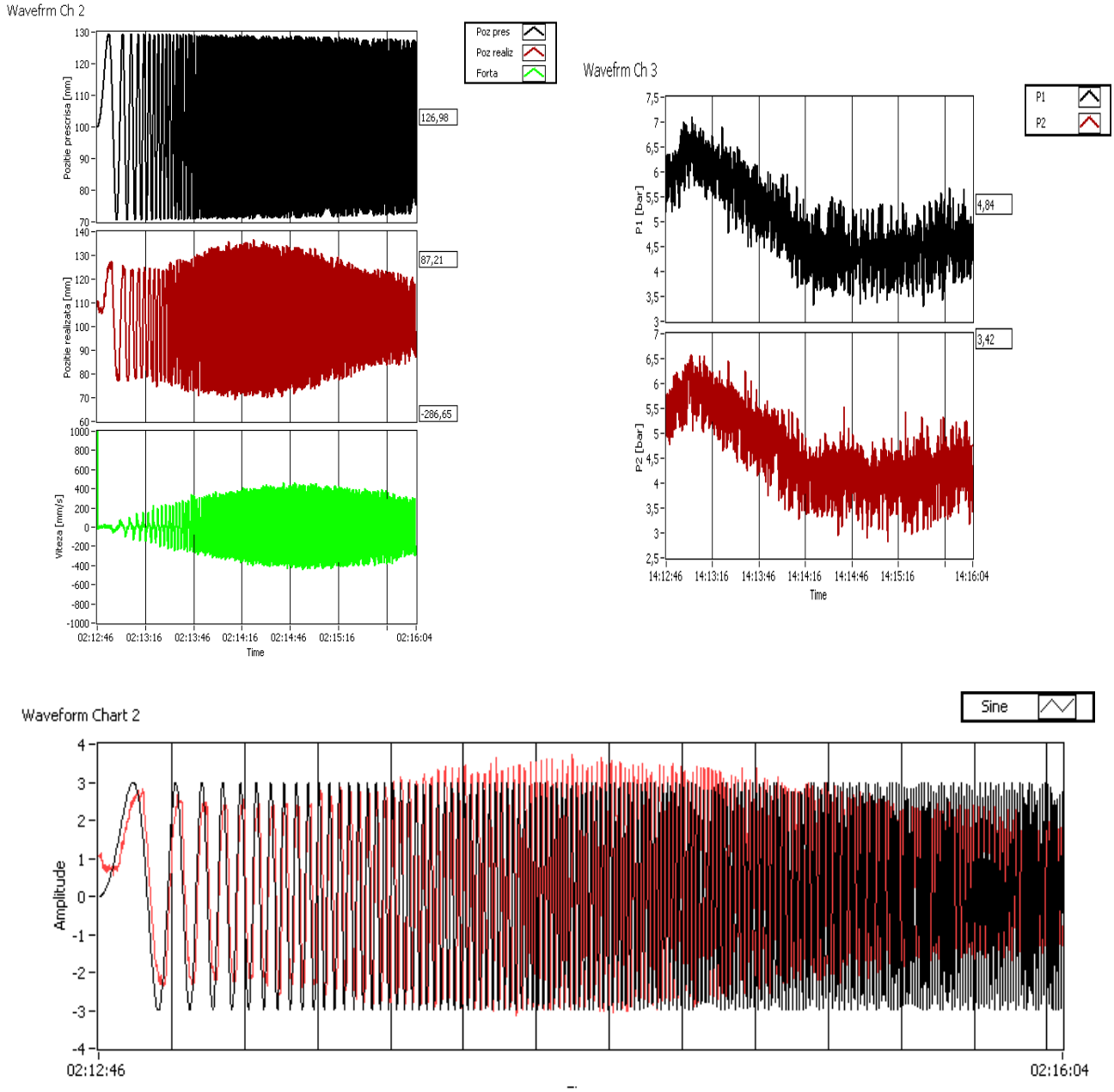


Fig. 12. The shape of graphs obtained during tests concerning the response of the DNCKE-100-200-PPV-A medium pressure pneumatic actuator to sine wave signal

c. Determining the starting pressure

The software diagram for determining the starting pressure, developed in LabVIEW, is shown in Figure 13.

Starting pressure was determined by gradually increasing the supply pressure of the actuator under tests from a ZERO value, while runing the software which tests the response to step signal.[5]

Upon reaching the starting pressure, on the graph of the application there occurs a leap in the step signal.

In the application window, Figure 14, there are highlighted: stroke value, pressures in piston and rod chambers, status of the signal generator, time length of the test.

The graphs highlighting the starting pressure for the piston chamber / rod chamber of the DNCKE-40-130-PPV-A actuator are shown in Figure 15.

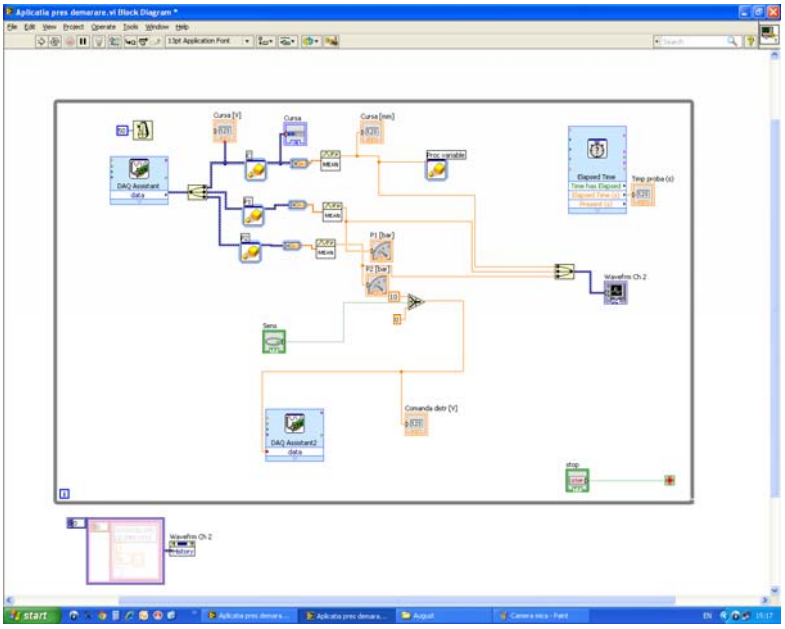


Fig. 13. Software diagram (graphics) for determining the starting pressure

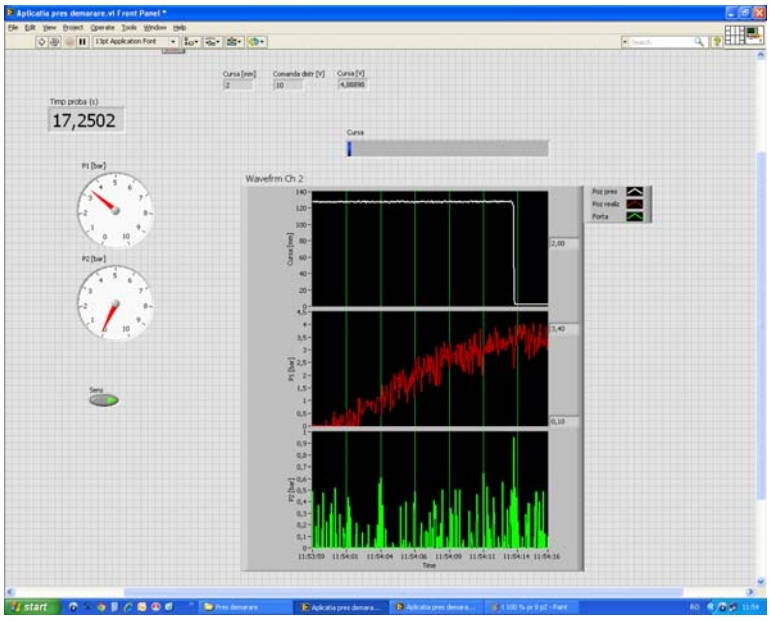
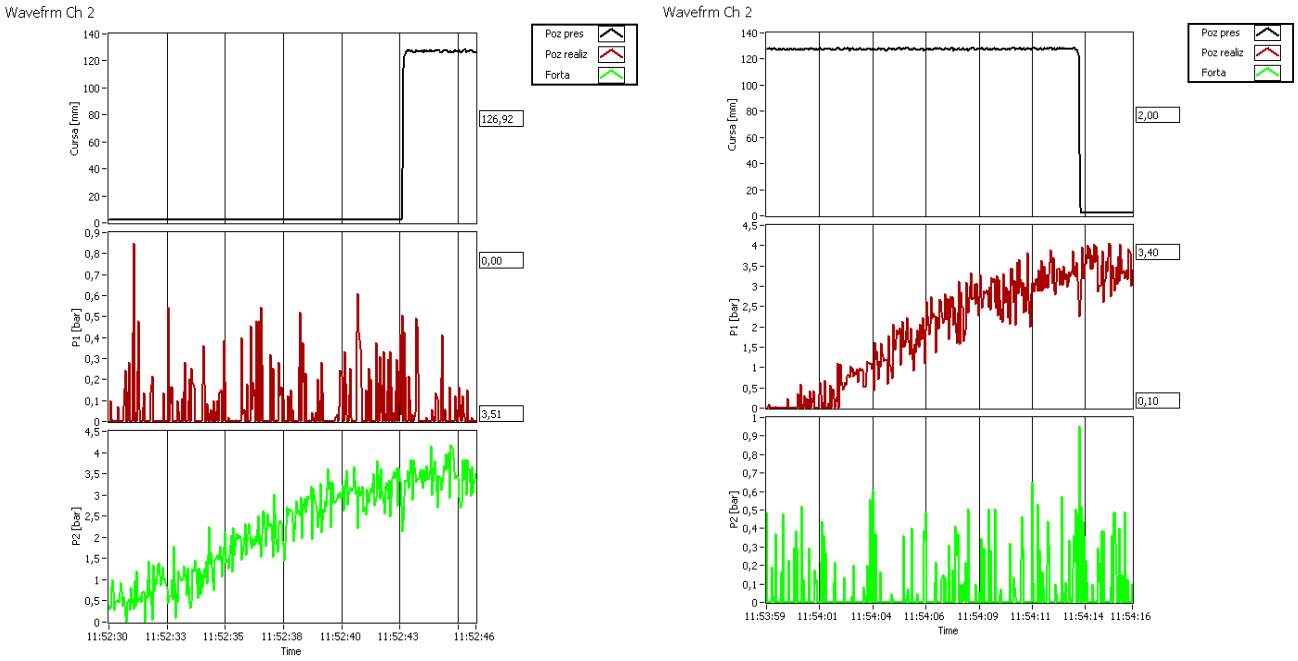


Fig. 14. Window of the application for determining the starting pressure
- DNCKE-40-130-PPV-A actuator

4. Conclusions

1. Experimental research on main factors and methods influencing the dynamic behavior of medium and high pressure pneumatic actuators has been carried out on two dimensional types of medium pressure pneumatic actuators **(DNCKE-100-200-PPV-A**, respectively **DNCKE-40-130-PPV-A)**.
2. Tests concerning the response to step and sine wave signal, determination of starting pressure, influence of parameters of the automatic regulator within the automatic control system (PID) have been run in the LabVIEW environment.



Piston chamber starting pressure Rod chamber starting pressure

Fig. 15. Graphs of starting pressure for the DNCKE-40-130-PPV-A actuator

3. Influence of sizes, type of seals and the materials they are made of, the level of processing (surface quality of cylinder liners and their rods), quality of working fluid on dynamic performance of actuators has been analyzed on the basis of research performed in the field and presented in scientific literature.
4. Temperature of the working fluid has been maintained rigorously at the standard value of 25 ^{0}C.
5. Working pressure (at the input of actuators' chambers), controlled by the pressure regulator within the air preparation group, has been 8 bar.
6. The automatic controller used has been P (proportional) type, the only variable factor of the automatic control system being the proportionality (amplification) factor k_c.

References

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