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EXPERIMENTAL RESEARCH REGARDING THE DYNAMIC PERFORMANCE OF PNEUMATIC MUSCLES

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Abstract. Pneumatic muscles continue to generate significant research interest due to their unique advantages. They are low-cost, safe, clean, and possess a high power to weight ratio. The paper presents some of the results of research carried out in the *Fluidtronics* Laboratory of the Transilvania University of Braşov. The experiments aimed at determining inflation and deflation times, the response time and response accuracy in the pressure control.

Keywords: pneumatic muscles, force, pressure

1. Introduction

Recent research on pneumatic drive elements has yielded the development of a membrane type drive, known as pneumatic muscle [1, 5]. They are low-cost, safe, clean, and possess a high power to weight ratio [2, 3].

The experimental studies concerning the behaviour of pneumatic muscles were carried out in the *Fluidtronics* Laboratory of the Transilvania University of Braşov.

Experimental facility, used for these measurements, is shown in figure 1 and contains: a pneumatic muscle MAS-10-N-100-AA-MCFK; a force transducer RDP LOAD CELL MCL/1kN; a flow transducer SFE3-F500-W18-L-2PB-K and a pressure transducer SDE-1-D10.

Figure 1 Experimental stand for the study of pneumatic muscles

It said that for this set of tests, the pressure sensor was connected very close to entry into the muscle. Also, the force sensor used has, according to the catalogue page, a field of forces between –1 kN and +1 kN and the differential output voltage range is from -10 V to +10 V, while the characteristic power – voltage is approximately linear (maximum error page catalogue is 0.2% for an electromagnetic disturbance of 3 V/m, respectively, 2% for electromagnetic interference of 10 V/m).

Under these conditions, measurements performed allowed to obtain characteristics of output voltages measured by the force sensor. In order to determine the force generated by pneumatic muscle it should be considered in the ratio tension - force of the used sensor, which is 1V/100 N.

Experimental data were visualized using the program FluidLab from FESTO company, these data being processed as text files, which were used as the basis to obtain measurements presented in this paper. Experimental research conducted focused on the analysis of muscle response on type level stimulus.

2. Experimental determination of inflation and deflation times

Experimental determination of inflation and deflation times is based on experimental data obtained for a muscle length: L = 98 mm, under a pressure of 3 bar. Using the experimental stand previous presented, there were acquired experimental data and characteristics shown in figure 2.

From the characteristics shown in figure 2 it has been extracted the pressure, the values generated by the acquisition system being placed in a program developed in Matlab simulation environment. This program allows us to obtain the pressure characteristic and determination of inflation and deflation times.

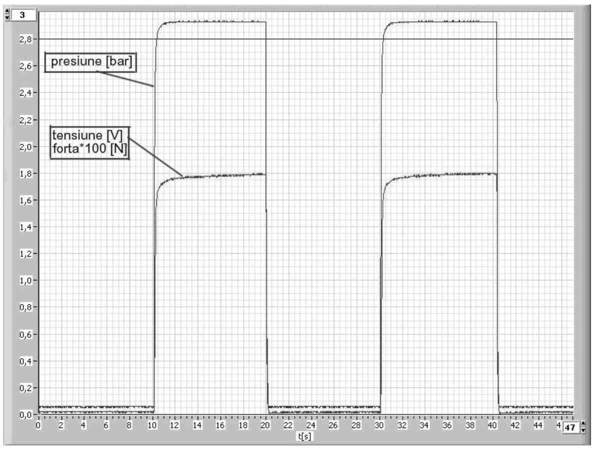

Figure 2. System response

A variation graph of pressure on the inflation zone of pneumatic muscle is shown in figure 3. Zero time, conventional, was elected the moment when pressure was applied to the system.

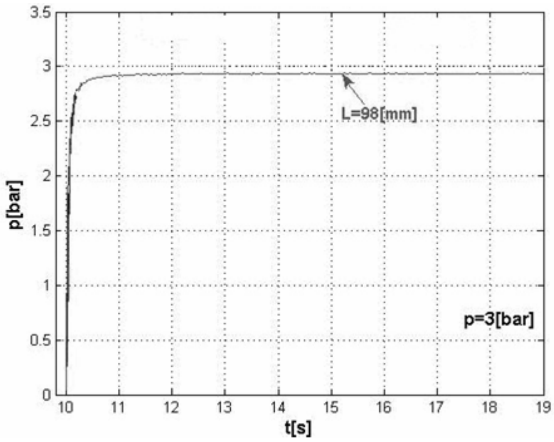

Figure 3. Variation graph of pressure on the inflation area of pneumatic muscle

A variation graph of pressure on the deflation zone of pneumatic muscle is shown in figure 4. The difference between the pressures obtained, 0.059 bar, and zero is caused by the uncompensated offset of the pressure transducer.

Time of inflation obtained is $t_{u\,L98}$ = 0.209s, and time of deflation obtained is: $t_{du\,L98}$ = 0.062 s.

3. Experimental determination of the response time

Experimental determination of the response time targeted the acquisition of an experimental dataset, for a constant pressure of 3 bar. Dataset consists of force and pressure characteristic for a length of 98 mm of pneumatic muscle.

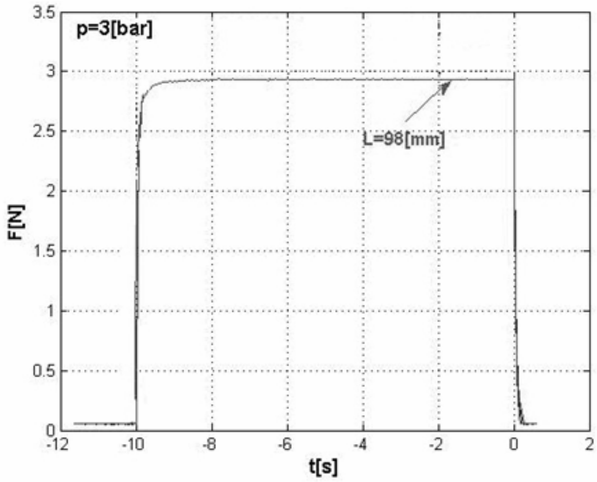

Figure 4. Variation graph of pressure on the deflation area of pneumatic muscle

Because it is necessary to determine the force, all the measurements are focused on these.

Besides, on the characteristics resulted with FluidLab the voltage are represented. It was developed a program, in Matlab, which transforms voltage to force and to analyze these values.

3.1. Determination of the activation and force increased time

Experimental data processing, using the program developed in Matlab simulation environment, allows determining the force characteristics of inflation zone of the muscle, as shown in figure 5.

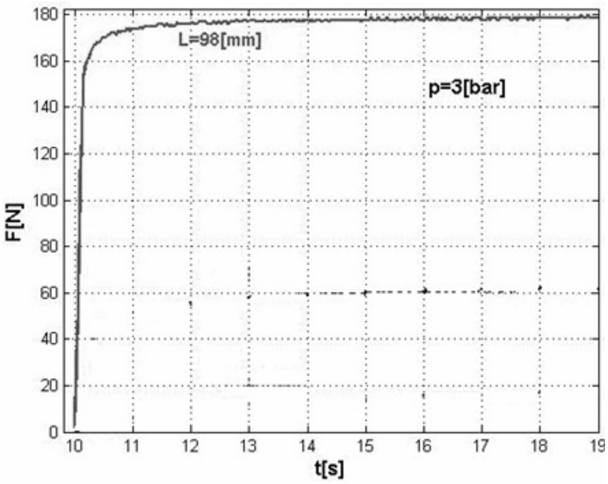

Figure 5. Force characteristic for nominal length and constant pressure

It may be noted that if the length of pneumatic muscle is 98 mm the force appears simultaneously with the pressure. Thus, for a length of 98 mm, the muscle force achieves the maximum value in 0.537s. Based on experimental data presented in figure 5 there were determined also the growth times (time intervals in which the force varies between 10% from stabilized value and 90% of this).

These times can be observed on the graph shown in figure 6 and they are for L = 98 mm, t_c = 0.18 s.

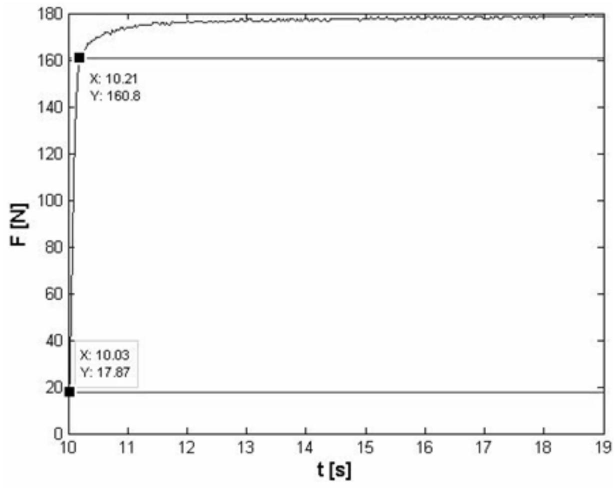

Figure 6. Growth time for the nominal value of muscle length, at constant pressure

3.2. Determination of relaxation time

Determination of relaxation time was based also on the experiments that gave characteristics shown in figure 2. The data acquired were processed and introduced in a Matlab program which allowed the representation and interpretation of the area on which the pneumatic muscle deflates (figure 7).

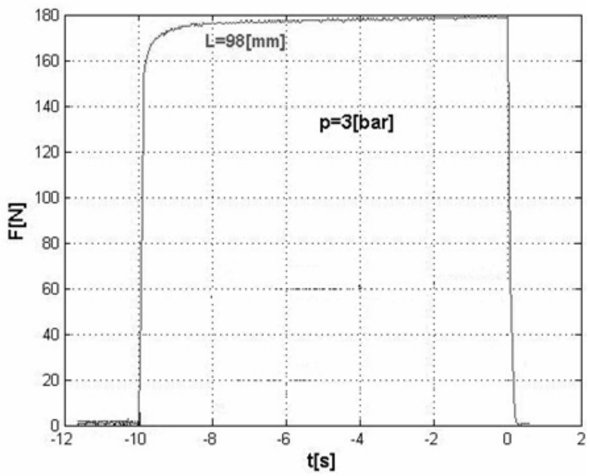

Figure 7. Force characteristic on deflation time area

It should be noted, that in figure 7, zero moment corresponds to the moment when the pressure begins to decrease, and therefore, the force characteristic is drawn from a negative time interval. From the diagram it can be noted that the relaxation time is much shorter than the force activation time. Thus, for a length of 98 mm of muscle, which decreases the pressure of 3 bars requires 0.062 s to completely relax.

4. Experimental determination of response accuracy to pressure command

Each experiment conducted and presented so far has been done once. This can be regarded as insufficient or even inconclusive. To validate the experiments and the data obtained it was repeated for 10 times the same experiment: the force reaction at 3 bars pressure, muscle length being 98 mm, i.e. the nominal length. Data obtained were entered into a program developed in Matlab simulation environment, which allowed the processing and interpretation of data and the determination of force characteristics (figure 8).

Experimental data have been processed so that the pressure in all ten cases to leave from the same point.

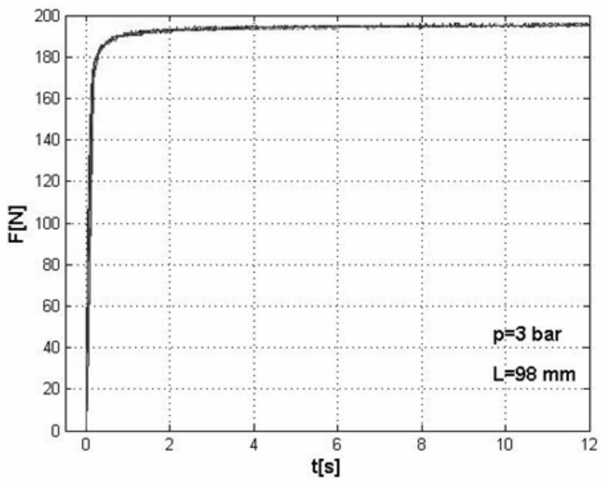

Figure 8. Repeatability precision of force characteristic

After processing the experimental data using the same program, was obtained for each experiment the same maximum force: 196.3 N.

The activation time of force is not the same, but the variations are quite small. Thus, the ten activation times of force are: 0.659 s, 0.708 s, 0.646 s, 0.644 s, 0.620 s, 0.617 s, 0.684 s, 0.633 s, 0.512 s, and 0.599 s. The time difference is 0.196 s.

Also, there were determined the growth times (10 values) of pneumatic muscle (figure 9): 0.174 s, 0.18 s, 0.189 s, 0.192 s, 0.195 s, 0.204 s, 0.196 s, 0.181 s, 0.2 s, and 0.206 s. The time difference is 0.032 s.

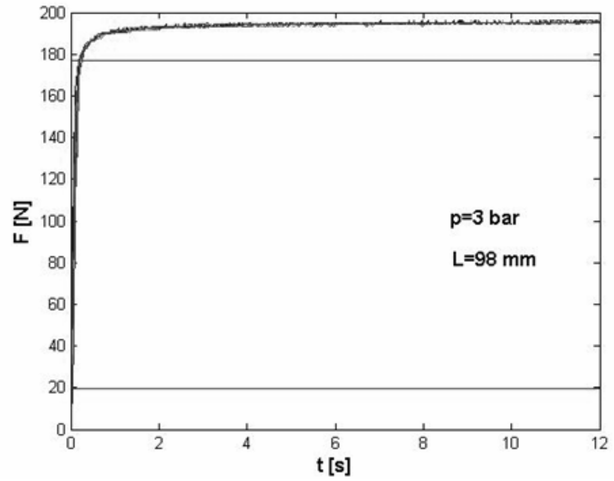

Figure 9. Growth time determination

5. Conclusions

The paper presents several research approaches concerning pneumatic muscle dynamic performances by experimentally establishing the variations of inflation and deflation times, the response time and response accuracy in the pressure control.

Following the experiments presented in this paper it can be concluded that the entire system used to obtain experimental data has a very good repeatability precision, so the system does not introduce, from this point of view, errors in the measurements made.

The utilisation of pneumatic muscles for the actuation of mechanical systems knows an increasingly larger development in industry. In this context in-depth research concerning the performances and behaviour of pneumatic muscle is called for.

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