EXPERIMENTAL DETERMINATION OF PNEUMATIC MUSCLE INFLATION AND DEFLATION TIME

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Abstract. Recent research on pneumatic drive elements has yielded the development of a membrane type drive, known as pneumatic artificial muscle. A pneumatic artificial muscle is a contractile and linear motion engine operated by gas pressure. Its concept is a very simple one: the actuator's core element is a flexible reinforced closed membrane (shell, diaphragm) attached at both ends to fittings (end fittings, closures, clamps) along which mechanical power is transferred to a load. As the membrane is inflated or gas is sucked out of it, it bulges outward or is squeezed, respectively. Together with this radial expansion or contraction, the shell contracts axially and thereby exerts a traction force on its load. The force (tension, load) and resulted motion of this type of actuator are linear and unidirectional. The paper presents some of the results of research carried out in the Fluidtronics Laboratory of Department of Economical Engineering and Manufacturing Systems of the Transilvania University of Brasov. Experiments performed have concerned the determination of muscle inflation and deflation time.

Keywords: pneumatic muscle pressure, force, inflation time, deflation time

1. Introduction

Pneumatic muscles are actuating elements that transform pneumatic energy into mechanical energy. Several concepts of pneumatic artificial muscle have been developed over time, but the best known type is the so called McKibben muscle [2]. This muscle was introduced by McKibben for orthotic applications in the fifties. More and more interest for these actuators is growing and several groups all over the world use McKibben like muscles in various robotic and medical applications. Throughout literature different names are found for pneumatic artificial muscle: Pneumatic Muscle Actuator, Fluid Actuator, Fluid-Driven, Tension Actuator, Axially Contractible Actuator, Tension Actuator [1, 5, 6].

At present pneumatic muscles are produced by a number of manufacturers like the Bridgestone Rubber Company of Japan, the Shadow Robot Company of the U.S.A. and the FESTO Corporation of Germany. However, the utilization of pneumatic muscles in different industrial applications is still in an early stage, due to the relative newness of these components.

The paper presents some experiments concerning pneumatic artificial muscle performances by establishing the determination of muscle inflation and deflation time.

2. Experimental stand for the study of pneumatic muscles

The experimental studies concerning the behaviour of pneumatic muscles were carried out in the Fluidtronics Laboratory of Department of Economical Engineering and Manufacturing Systems of the Transilvania University of Brasov.

Experimental stand built for this purpose is shown in figure 1.The stand contains: a pneumatic muscle; a flow transducer, a pressure transducer and a capacitive force sensor with internal amplifying and an analogical nominal output of ± 10 V. (manufactured by FESTO Co. of Germany). This, according to the catalogue pages, has a field of forces between –1 and 1 kN, as the characteristic force - voltage is approximately linear (maximum error is 0.2% for an electromagnetic disturbance of 3 V/m, and 2% for an electromagnetic disturbance of 10 V/m).

The experimental stand circuit, used for experiments, contains a FESTO application named FluidLab which allows the data input acquisition and their graphical representation. The application offers different types of windows particularised on the chosen pneumatic element.

Also, it is necessary to use FESTO acquisition system that includes communication protocol RS232, which connects the data

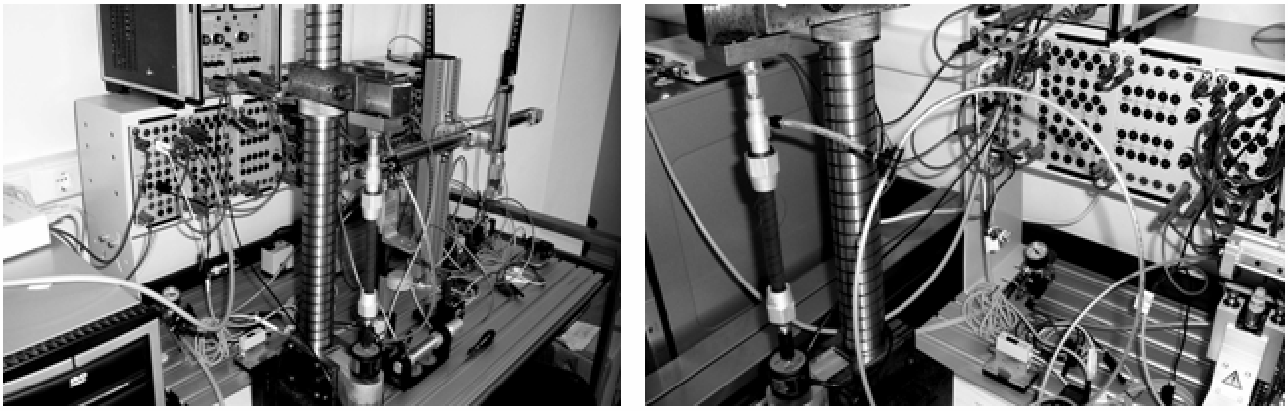

Figure.1. Experimental stand for the study of pneumatic muscles

acquisition board and the FESTO application. Because the FESTO application does not allow viewing negative values it was necessary to utilize an offset compensation circuit

3. Experimental Data Registration

Tests were focused on a pneumatic muscle made by Festo (figure 2). The dimensions of the muscle are: nominal (interior) diameter – 10 mm; muscle length (couplings excluded) – 98 mm.

Measurements were made by the successive charging of the tested pneumatic muscle with compressed air at various pressures (3 and 5.3 bar), the values of which were recorded by the pressure transducer. For each pressure it was positioned the point of pneumatic ramification between the pressure source and muscle towards pneumatic transducer, near the muscle.

Figure 2. Tested pneumatic muscles

3.1. Experimental determination of muscle inflation and deflation times

3.1.1. Muscle inflation and deflation time for a pressure of 3 bar

The first experiments were carried out for a 3 bar pressure and the experimental results are shown in figure 3.

From features attained in figure 3 there have been extracted the pressure characteristics, the values generated by the acquisition system being incorporated in a Matlab simulation program. This program allows us to attain the pressure characteristic and to determine the inflation and deflation times of the muscle.

The pressure diagram on muscle inflation area is shown in figure 4. It must be specified that, conventional, zero time was elected, the moment in which pressure was applied in the system.

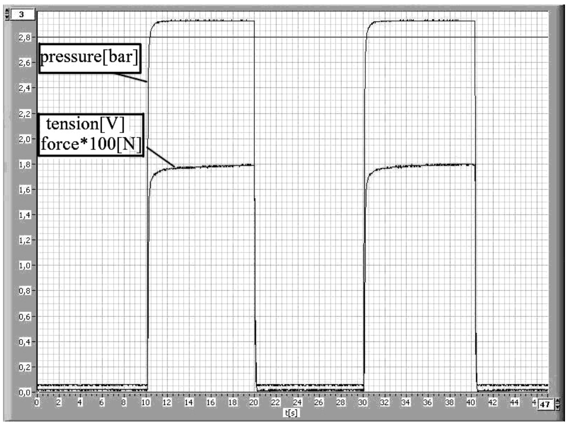

Figure 3. System reaction for a muscle length of 98 mm, p=3 bar

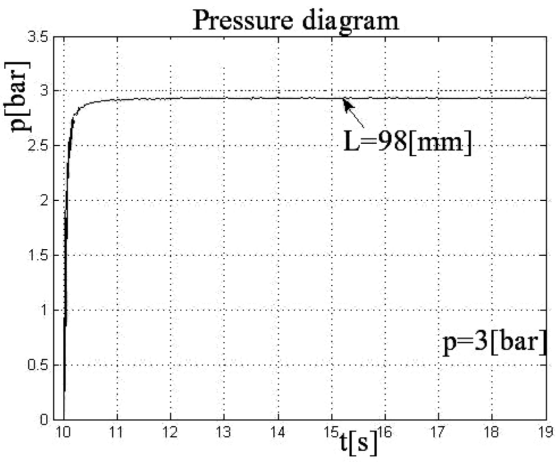

Figure 4. Pressure diagram on muscle inflation area

In figure 5 is presented the pressure diagram on muscle deflation area. The difference between the pressure attained, respectively 0.059 bar, and zero value is generated by the irretrievable offset of pressure transducer.

The analysis of these diagrams allows establishing the time values required for inflation and deflation of the pneumatic muscle, respectively. Thus, the graphs reveal that the time required for muscle inflation is of approximately 0.209 s, while the deflation time is 0.062 s.

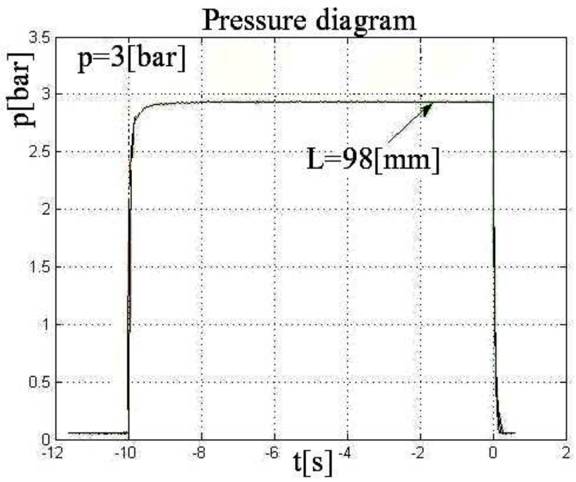

Figure 5.Pressure diagram on muscle deflation area

3.1.2. Muscle inflation and deflation time for a pressure of 5.3 bar

The second set of experiments was done for a supply pressure of 5.3 bar and obtained characteristics are shown in figure 6.

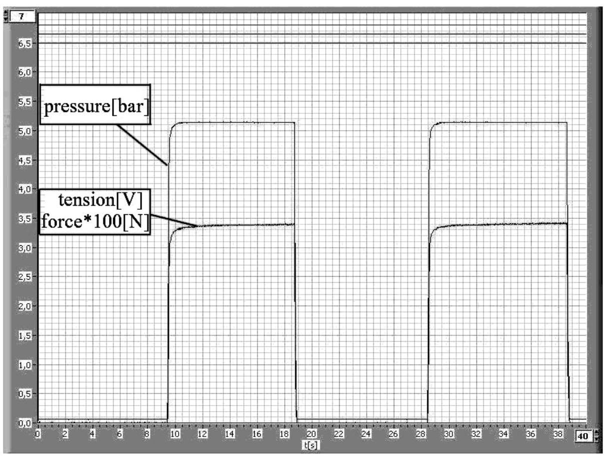

Figure 6.System reaction for a muscle length of 98 mm, p = 5.3 bar

Similar to the case of 3 bar supply pressure, in order to do a comparative analysis of the system reaction, the sets of experimental data previously obtained have been incorporated in a Matlab simulation program.

Thus, in figure 7 is shown the pressure diagram on muscle inflation area and in figure 8 for the deflation area.

The analysis of these diagrams allows establishing the time values required for inflation and deflation of the pneumatic muscle, respectively. In this case, the graphs reveal that the time required for muscle inflation is of approximately 0.236 s, while the deflation time is 0.090 s.

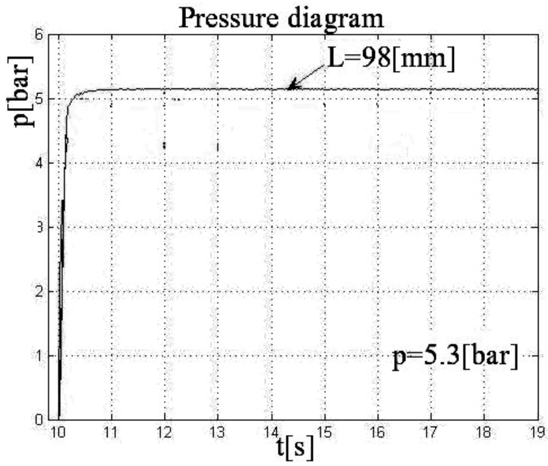

Figure 7.Pressure diagram on muscle inflation area

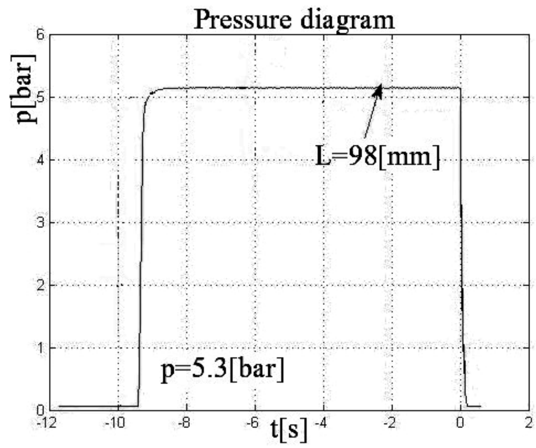

Figure 8. Pressure diagram on muscle deflation area

Table 1 centralises the measured data of the response times of the pneumatic muscle while inflating and deflating

Table 1. Values of the inflation/deflation times for the tested muscle

Working pressure [bar]	Inflation time [s]	Deflation time [s]
3	0.209	0.062
5.3	0.236	0.090

4. Conclusions

A pneumatic muscle is a system employing a contracting membrane that, under the action of air pressure increases its diameter while decreasing its length. Thus the pneumatic muscle carries out a certain stroke, depending on the level of the feed pressure [3, 4, 7].

This paper presents some behavioural study of a pneumatic artificial muscle. Experiments performed have concerned the determination of muscle inflation and deflation time. Thus, they were experimentally attained the force and pressure characteristics for a muscle with a length of 98 mm at 3bar and 5.3 bar pressure and for a positions of the pressure transducer connection of 5 mm from the muscle.

Theoretical and experimental research have proved that pneumatic muscles, by their functional characteristics (a light structure able to generate high forces, up to 3000N with gauge pressures of only 300kPa and a weight of 100g; can directly be coupled and easily implemented; has an adaptable passive behaviour suited for energy storage; precise position control is possible due to the absence of hysteresis) are suited for diverse industrial applications for soft gripping and clamping operations of parts, in mobile robotics requiring light actuating systems, in braking systems requiring small increase times and large forces.

Acknowledgement: this research project has been supported by a CNCSIS Contracts No. PN-II-ID-PCE-2007-1, ID_184 and PN-II-ID-PCE-2008-2, ID_746.

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