STUDIES REGARDING THE PERFORMANCE OF PNEUMATIC MUSCLES

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Abstract. While compressed air is one of the most important energy sources in industrial drives, pneumatic drives tend to hold an increasing weight in the conception of modern industrial systems. Currently, the development of new pneumatic components and systems allows the achievement of high complexity assemblies, many of which with applicability in robotics. Such a component is the pneumatic muscle, its utilisation in the construction of pneumatic drives undergoing continuous development, particularly in the field of industrial robots.
The paper presents some of the results of research carried out in the Fluidtronics Laboratory of the Regional Festo Training Centre established at the Transilvania University of Braşov. The experiments aimed at determining the variation diagrams of the feed pressure and the flow of consumed air for a complete cycle of the analysed pneumatic muscle. Further, the response times of the muscle could be determined for various values of the feed pressure, and the influence of adding a quick exhaust valve to the circuit on the response time for muscle deflation could be studied.

Keywords: pneumatic muscles

Compressed air is one of the most efficient means for driving and automation of manufacturing systems. It has already been mentioned as a means for drives 2300 years ago, in the case of pneumatic catapults built by the ancient Greeks.

Over the years the continued development of pneumatic drives has moved from the utilisation of individual components to the implementation of complex automation systems. New systems were developed adding mechanical and electronic elements, as well as sensors to the classical pneumatic constructions. The figure below presents the evolution in time of constructive solutions for pneumatic automation:

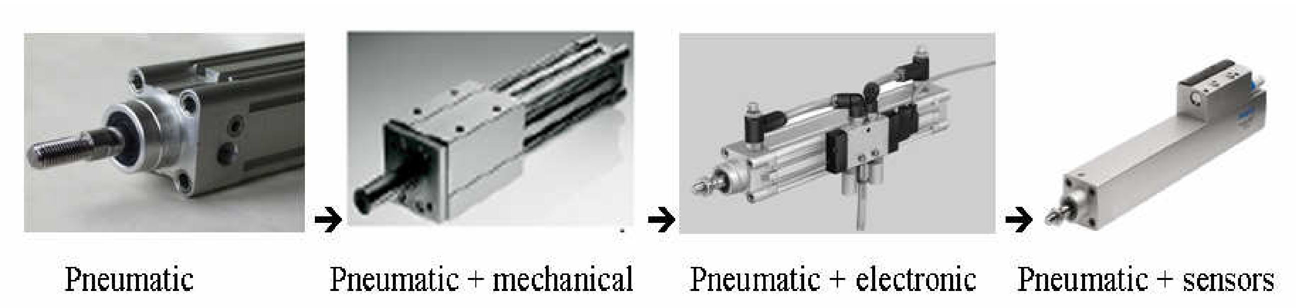


Figure 1. Constructive variants of pneumatic drives

The constantly increasing use of compressed air in industrial applications is due to its advantages like easy generation and stocking, non-inflammability, minimum risk of explosion and low maintenance of pneumatic systems, etc. Another important advantage of compressed air is it being a clean, ecological working medium, thus lending itself for utilisation in environmentally friendly processes, like applications in food, electronics or pharmaceutical industry.

Currently, the development of new pneumatic components and systems has allowed the achievement of high complexity assemblies, many of which with applicability in robotics. The figures below feature several such examples:

Figure 2. Utilisation of pneumatic drives in robot construction

Recent research on pneumatic drive elements has yielded the development of a membrane type drive, known as *pneumatic muscle*. The utilisation of muscles in the construction of pneumatic drives has known continuous development, particularly related to industrial robots. In this respect worth mentioning are: the pneumatically actuated arm developed by the American McKibben, the stepping robot built by the Japanese company AMS of Osaka, or the humanoid robot made by Festo Ltd. in cooperation with the Technical University of Berlin:

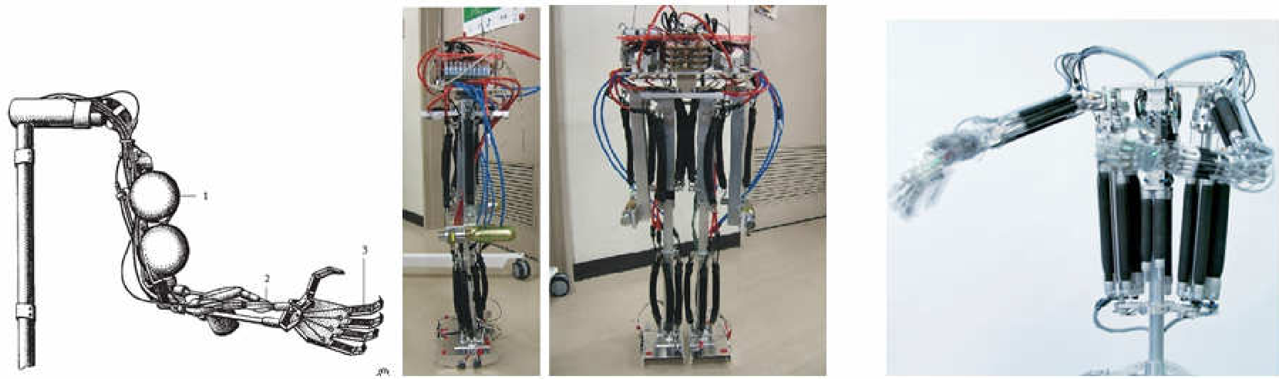


Figure 3. Applications of pneumatic muscles

To date the several manufacturers of pneumatic muscles have produced a number of constructive forms of pneumatic muscles, as shown below:

Figure 4. Constructive variants of constructive muscles

Pneumatic muscles have been used for a number of years as actuators in robotic systems, usually for those that mimic human actions. They are most commonly used in systems designed to aid physically handicapped people. Air muscles consist of an inflatable tube, usually neoprene rubber that is constrained by a nylon mesh. When compressed air is passed into the muscle, which is blocked at one end, the tube inflates, but the action of the enclosing mesh forces the tube to shorten. The resultant force is sued as a linear actuator.

The Fluidtronics Laboratory of the Regional Festo Training Centre established at the "Transilvania" University of Braşov is engaged in the study of the operational behaviour of pneumatic muscles. Some of the achieved experimental results are presented in this paper.

The tests focused on a pneumatic muscle made by Festo, used for a pneumatic mini-press (figure 5.). The dimensions of the muscle driving the press are: nominal (interior) diameter – 10 mm; muscle length (couplings excluded) – 145 mm.

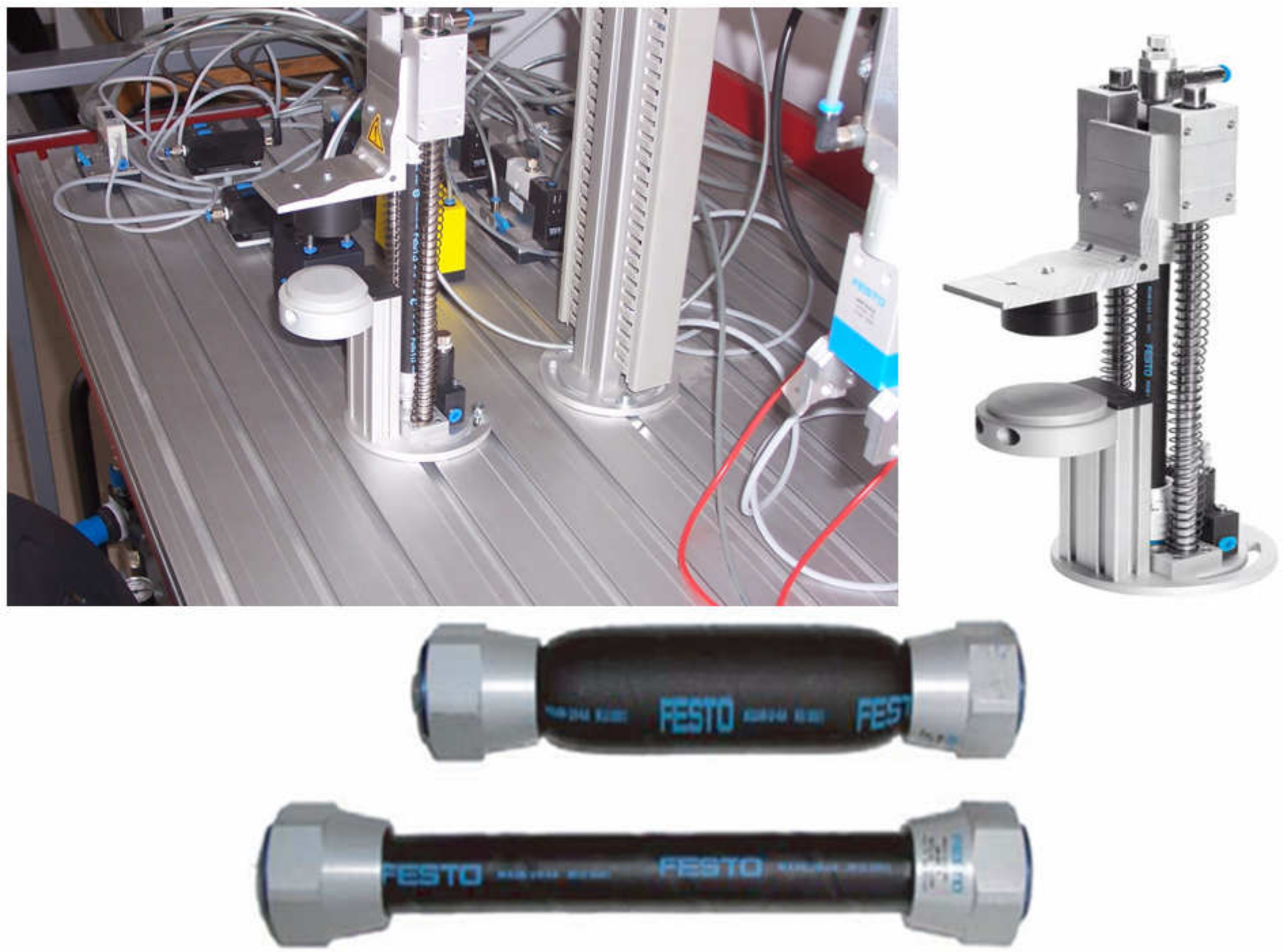


Figure 5. Tested equipment

Figure 6 presents the pneumatic actuation diagram of the mini-press and also the diagrams of the links between the pressure and flow transducers and the computer, achieved via the EasyPort interface. A flow and a pressure transducer were mounted on the feed circuit, the experiments aiming at plotting the variation diagrams for the feed pressure and of the consumed air flow for a complete cycle executed by the analysed pneumatic muscle. Further, the response times of the muscle could be determined for various values of the feed pressure. A quick exhaust valve was also added to the pneumatic circuit, in order to ensure the rapid evacuation of the air from the muscle, that is to achieve a high withdrawing velocity of press punch.

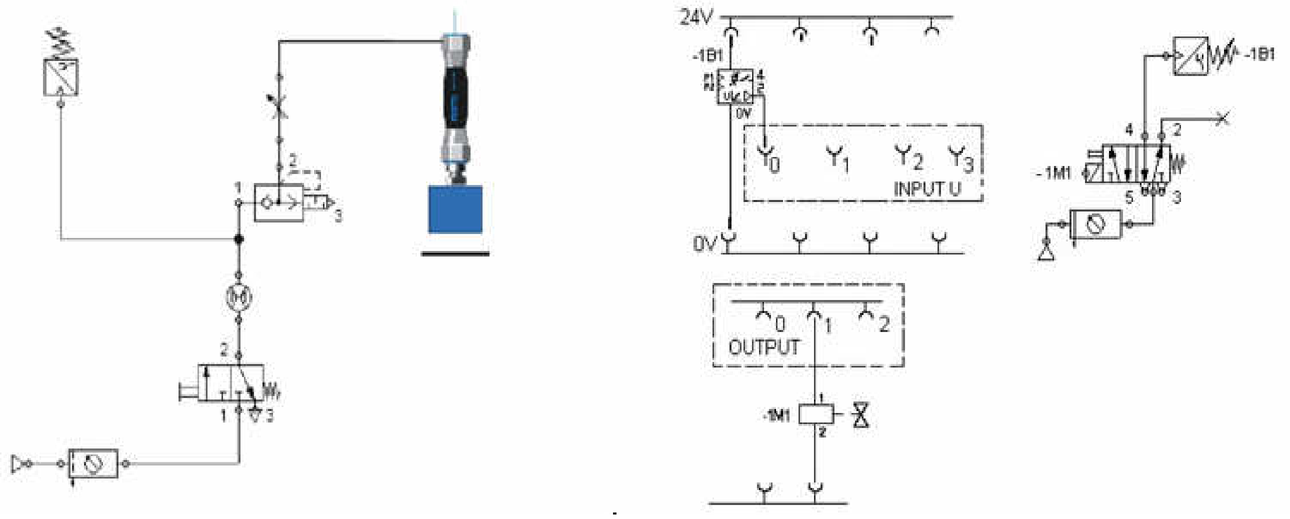


Figure 6. Diagram of the tested equipment

The tested pneumatic muscle was charged successively with 1.4, 1.9, 2.7 and 4.9 bars. Figure 7 shows the diagrams of feed pressure and consumed air flow variation. Figures 8 and 9 feature the response times of the pneumatic muscle during inflating and deflating, respectively:

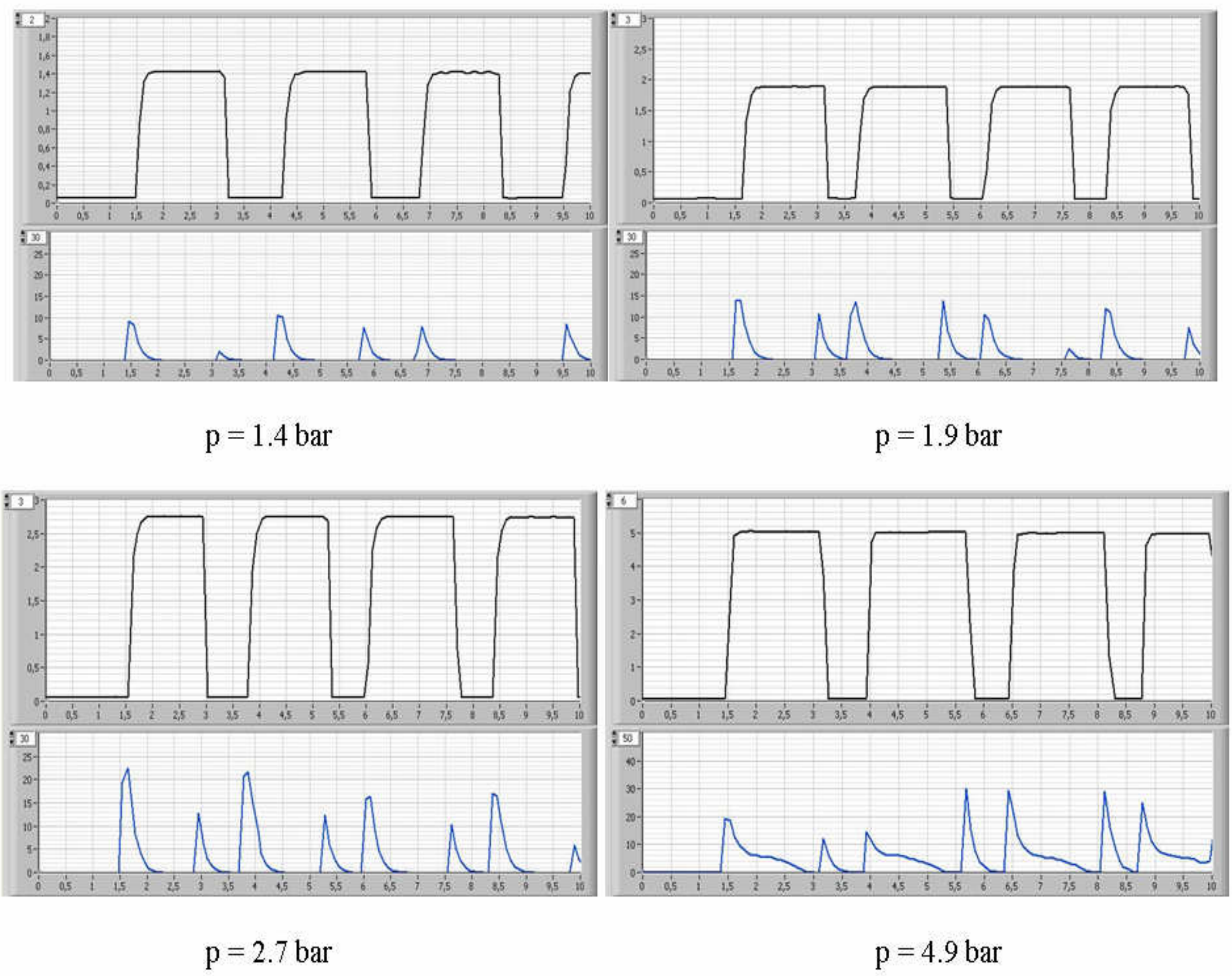
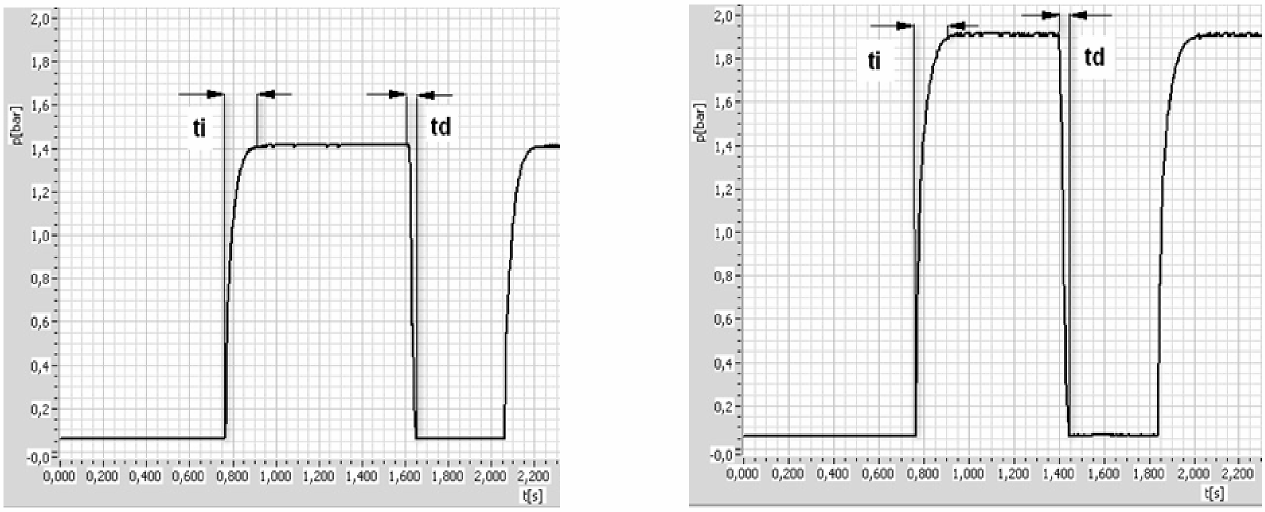
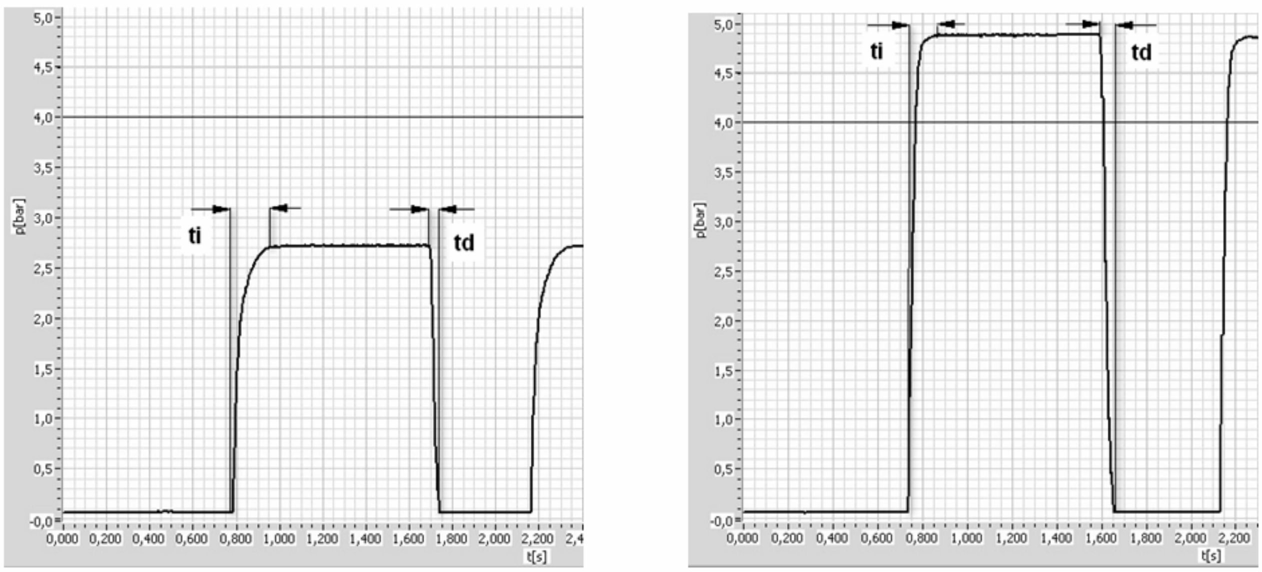


Figure 7. Variation curves of pressures and air flows for different charges



p = 1.4 bar   p = 1.9 bar

Figure 8. Determining the response times of the pneumatic muscle



p = 2.7 bar   p = 4.9 bar

Figure. 9 Determining the response times of the pneumatic muscle

Table 1 centralises the measured data related to the response times of the pneumatic muscle during inflating and deflating, respectively. Figure 10 shows the graph describing the variation of these two times versus the feed pressure:

Table 1. Inflating-deflating times of the pneumatic muscle

Working pressure [bar]	Inflating time t_i [s]	Deflating time t_d [s]
4,9	0,134	0,068
2,7	0,173	0,050
1,9	0,176	0,047
1,4	0,176	0,042

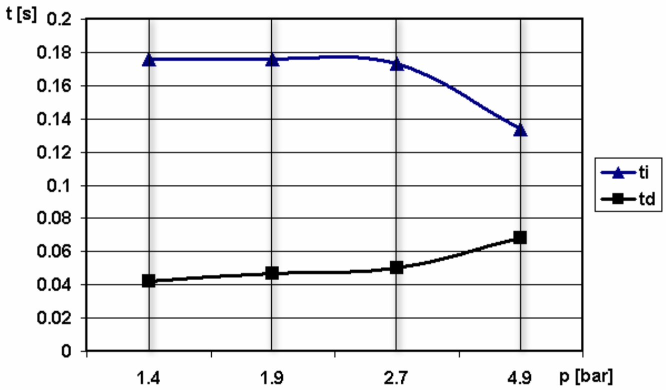
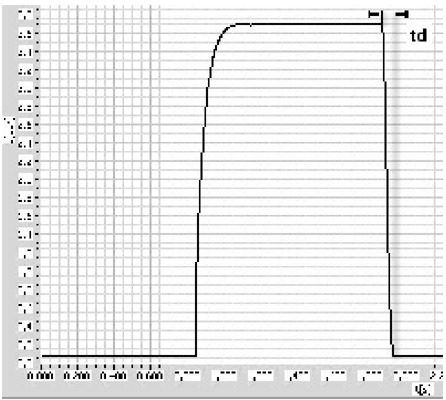
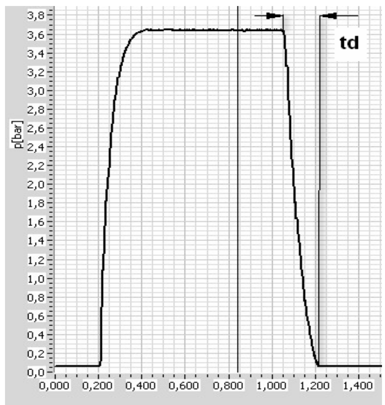


Figure 10. Variation of inflating-deflating times versus feed pressure of a pneumatic muscle

Another research objective is studying the influence of the quick exhaust valve placed in the circuit on the deflating time of the muscle. The figure below shows two graphs, one for the case of a quick exhaust valve included, and one for a circuit without this valve:



With quick exhaust valve t_d = 0,063 s



Without quick exhaust valve t_d = 0,174 s

Figure 11. Influence of the quick exhaust valve on the deflating time of the pneumatic muscle

The research confirmed the behaviour of pneumatic muscles related to inflating-deflating times as being similar to that of simple actuation pneumatic cylinders. The advantage of replacing these cylinders by pneumatic muscles consists in the cost effectiveness of the solution, its lower weight and required maintenance.

Acknowledgement

This research project has been supported by a Marie Curie Transfer of Knowledge Fellowship of the European Community's Sixth Framework Programme under contract number MTKD -CT-2004-014249 and by CNCSIS Contract No. 1054/2007.

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