ACM -V

SCIENTIFIC BULLETIN

of

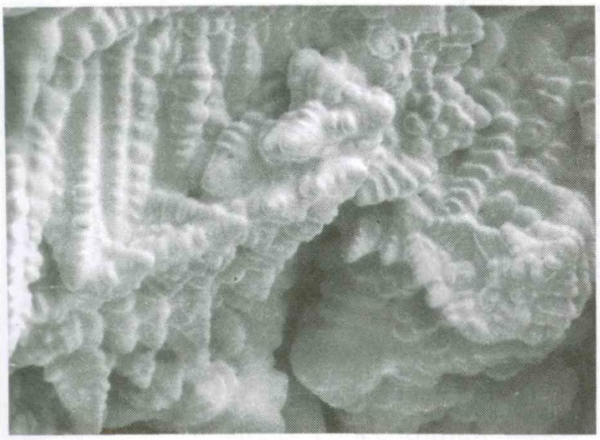
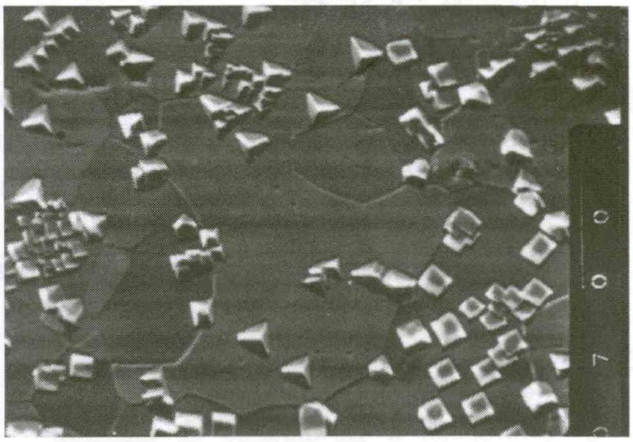
the „POLITEHNICA" University of Timişoara, Romania

Transactions on MECHANICS

XI[th] International Symposium

Young People and Multidisciplinary Research

Organizer: Association for Multidisciplinary Research in the West Zone of Romania

Tom 54(68), Fascicola Special ISSUE S1, 2009

ISSN 1224-6077

EDITURA POLITEHNICA

	CONTENTS	CUPRINS	

SCIENTIFIC BULLETIN OF
THE „POLITEHNICA" UNIVERSITY OF TIMISOARA, ROMANIA
TRANSACTIONS ON MECHANICS
BULETINUL ŞTIINŢIFIC AL
UNIVERSITĂŢII „POLITEHNICA" DIN TIMIŞOARA, ROMÂNIA
SERIA MECANICĂ
Tom 54 (68) ISSN 1224 - 6077 Fasc. S1, 2009

INVESTIGATIONS OF PNEUMATIC ARTIFICIAL MUSCLES

József SÁROSI*, János GYEVIKI*
* Department of Technical and Process Engineering, Faculty of Engineering, University of Szeged
Mars tér 7., Szeged, H-6724, Hungary, e-mail: sarosi@mk.u-szeged.hu, gyeviki@mk.u-szeged.hu

Abstract. The characteristics of pneumatic artificial muscles (PAMs) make them very interesting for the development of robotic and prosthesis applications. The McKibben muscle is the most popular and is made commercially available by different companies.
The aim of this research is to acquire as much information about the pneumatic artificial muscles as we can with our test-bed that was developed by us and to be able to adopt these muscles as a part of prosthesis.
This paper presents the set-up constructed, and then describes some mechanical testing results for the pneumatic artificial muscles.

Keywords: artificial muscles, robotics, pneumatic systems

1. Introduction

PAMs have different names in literature: pneumatic muscle actuator, fluid actuator, fluid-driven actuator, axially actuator, tension actuator, etc. [1,2,3,4].
The pneumatic artificial muscle consists of rubber tubes and fibers. When the rubber tube is inflated with compressed air, the cross-weave sheath experiences lateral expansion, resulting in axial contractive force and the change of the end point position of pneumatic muscle.
The working principle of the pneumatic artificial muscles is well described in literature [1,2,5,6,7]
Pneumatic muscles have many advantages such as high strength, good power-weight ratio, low price, little maintenance needed, great compliance, compactness, inherent safety and usage in rough environments [6,8]. The most significant problem of PAMs is nonlinearity [9,10].
The PAM that was selected as the actuator for our study is the Fluidic Muscle (DMSP-20-200N-RM-RM) manufactured by FESTO. According to its specification, maximum contraction over the nominal length is 25-27 %.

2. Materials and methods

A good background of this research can be found in [11, 12].
The experimental set-up (Figure 1) consists of a slider mechanism. One side of the muscle is fixed to a load cell, while the other side is attached to the movable frame. The load cell (7923 type from MOM) is a 4 bridge element of strain gauges. It is mounted inline to the PAM on the fixed surface. The load cell measures the force exerted by the PAM. The tests are performed by changing the displacement of this slider. The linear displacement of the actuator is measured using a LINIMIK MSA 320 type linear incremental encoder. During each test, frame position, muscle force and applied gauge pressure are recorded.
In the test-bed two fluidic muscles can be mounted. Instead of second PAM a bias spring or an external load can be attached with a flexible steel cable, producing the necessary counter force to pull the actuator back when it is not activated.

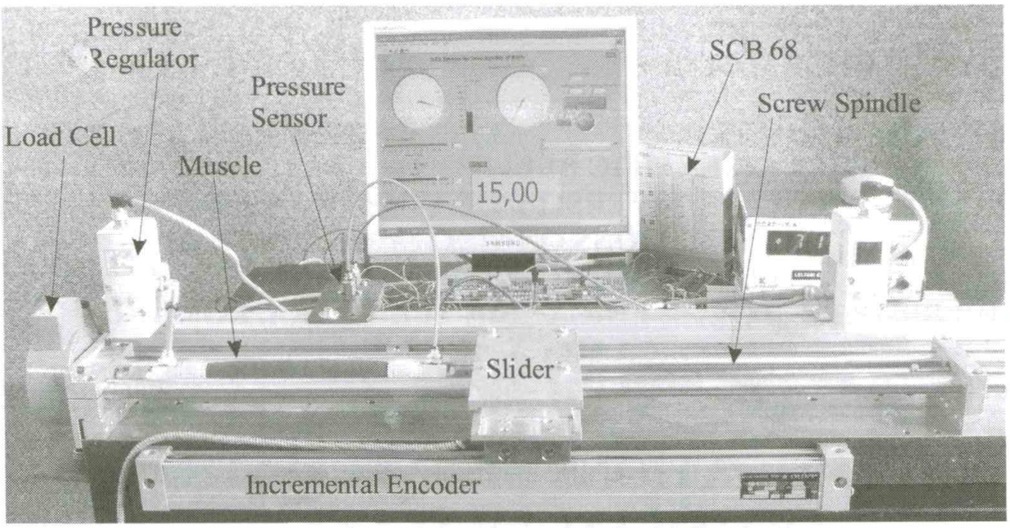


Figure 1. Experimental set-up for analysis of the pneumatic artificial muscle (fixed slider position)

The air pressure applied to the actuators can be regulated with two adjustable regulator type Festo VPPM-6L-L-1-G1/8-0L6H-V1N-S1C1. The proportional pressure regulators (PPRs) are controlled by voltage inputs. The main purpose of the PPR is to regulate the pressure entering the PAM. To measure the air pressure, two Motorola MPX5999D pressure sensors were plumbed into the pneumatic circuit. A National Instruments Multi-I/O card (NI 6251) reads the signal of force, pressure sensors and incremental encoder into the PC.

National Instruments LabVIEW is a typical example for high level software, capable of connecting various kinds of DAQ boards with a PC. We used this program to monitor and collect the data imported through the DAQ card. It will also dispatch the control profiles for the PPRs. Figure 2 shows the environment in LabVIEW.

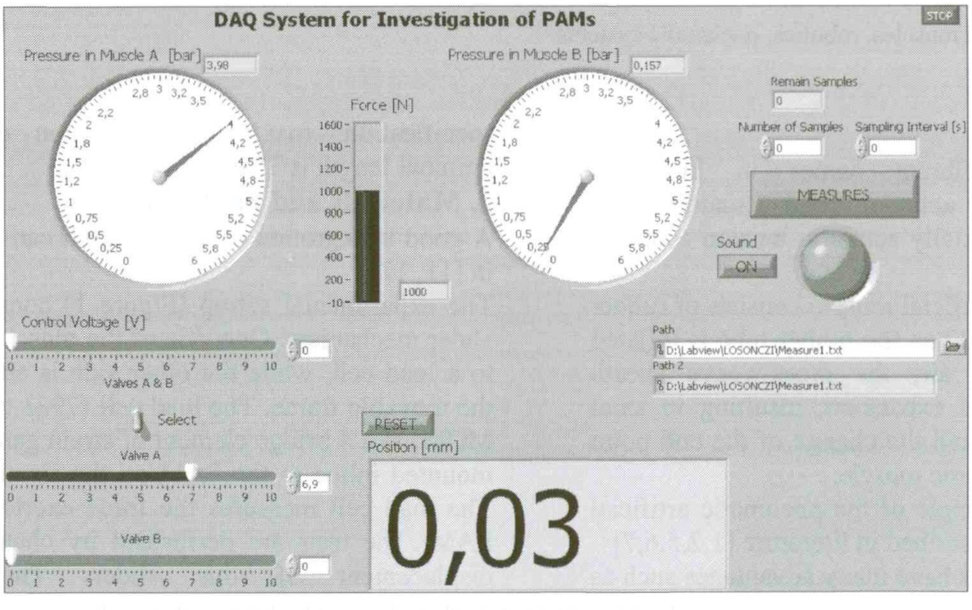


Figure 2. Front panel of the LabVIEW program

With the specially constructed testing machine, we are able to measure the static and dynamic characteristics of several versions of these pneumatic actuators.

3. Experimental results

The first experiment was done under different constant pressures (0-5,5 bar). Figure 3 shows the relation between tensile force [N] and position [mm] of this 20 mm inner diameter and 200 mm length artificial muscle. Tensile force of artificial muscle is under different constant pressures a function of muscle length and of air pressure. The force always drops from its highest value at full muscle length to zero at full inflation and position.

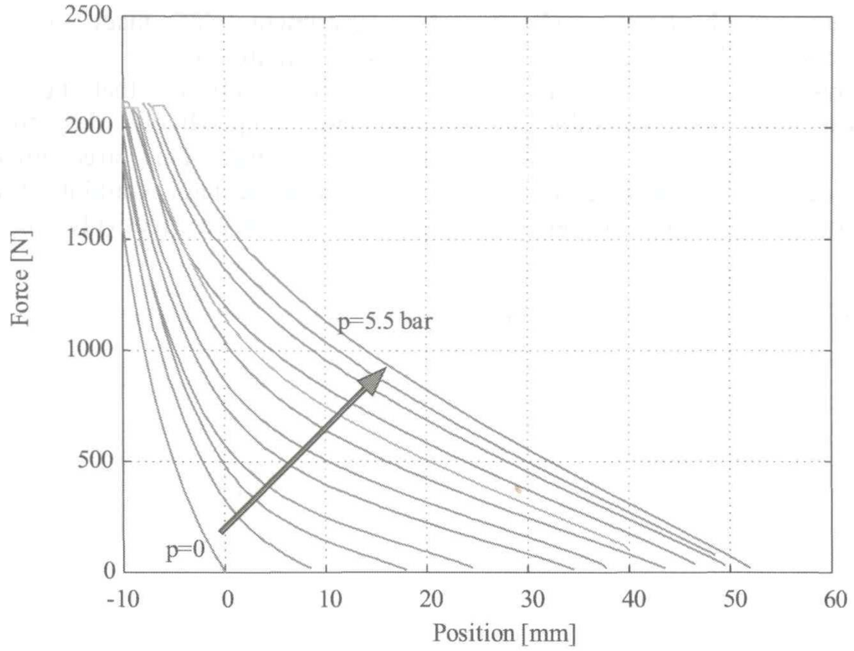


Figure 3. PAM isobaric force-position characteristics

Next, we examined the characteristics of PAMs in antagonistic set-up.

The antagonistic configuration of the actuators causes the active muscle to have to pull against the stiffness of the passive muscle. So, a pair of pneumatic artificial muscle actuators put into antagonistic configuration can imitate a biceps-triceps system and emphasize the analogy between this artificial muscle and human skeletal muscle.

In the antagonistic set-up, in the test-bed two muscles were mounted. The characteristics of pneumatic artificial muscles under different constant pressures with antagonistic configuration of PAMs are shown in Figure 4, where x_{max} means the maximum range of motion (±6-10 mm). In an antagonistic set-up without external load, position is determined by the ratio of pressures in both muscles.

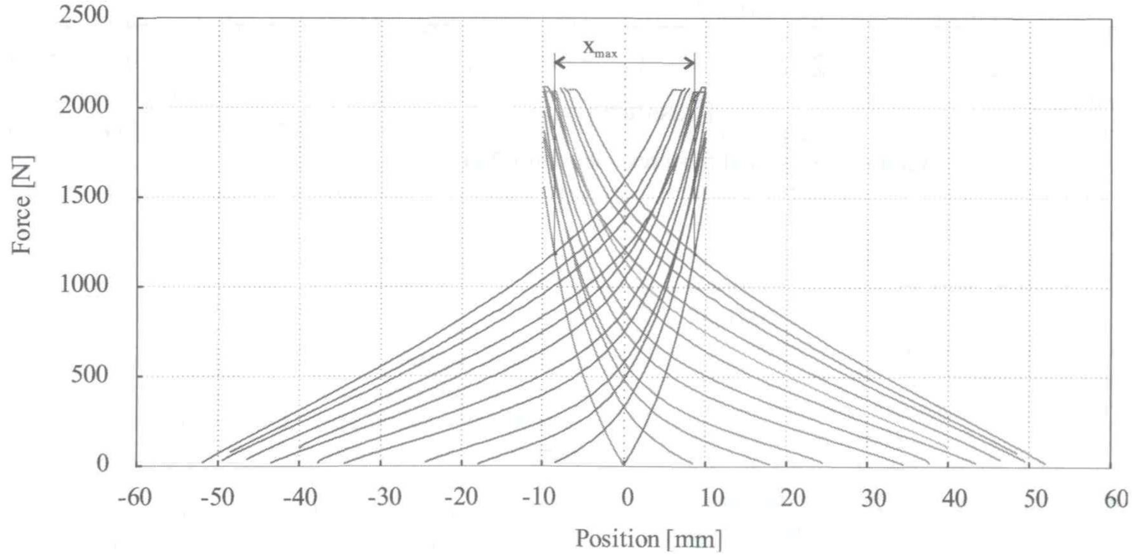


Figure 4. PAMs isobaric force-position characteristics in antagonistic configuration

Many researchers have investigated the precise position control of pneumatic muscles during the past several years. Most of them dealt with the control of single or antagonistic pneumatic muscles. The positioning of PAMs requires accurate determination of the dynamic model of pneumatic actuators. We can accurately predict with our test-bed the nonlinear hysteresis and creep effects that were measured. The viscoelastic behaviors contribute to hysteresis and creep in an actuator, and will also limit the allowable frequencies of operation.

[8] reports that the main cause for hysteresis in the McKibben muscle is Coulomb friction between the braided mesh shell and the internal bladder. An experiment was made to illustrate the hysteresis (Figure 5).

The Figure 6 indicates that the PAM displays significant creep, likely due to it's highly viscoelastic nature. This large amount of creep means that the actuator would need to be warmed up before it could be effectively used.

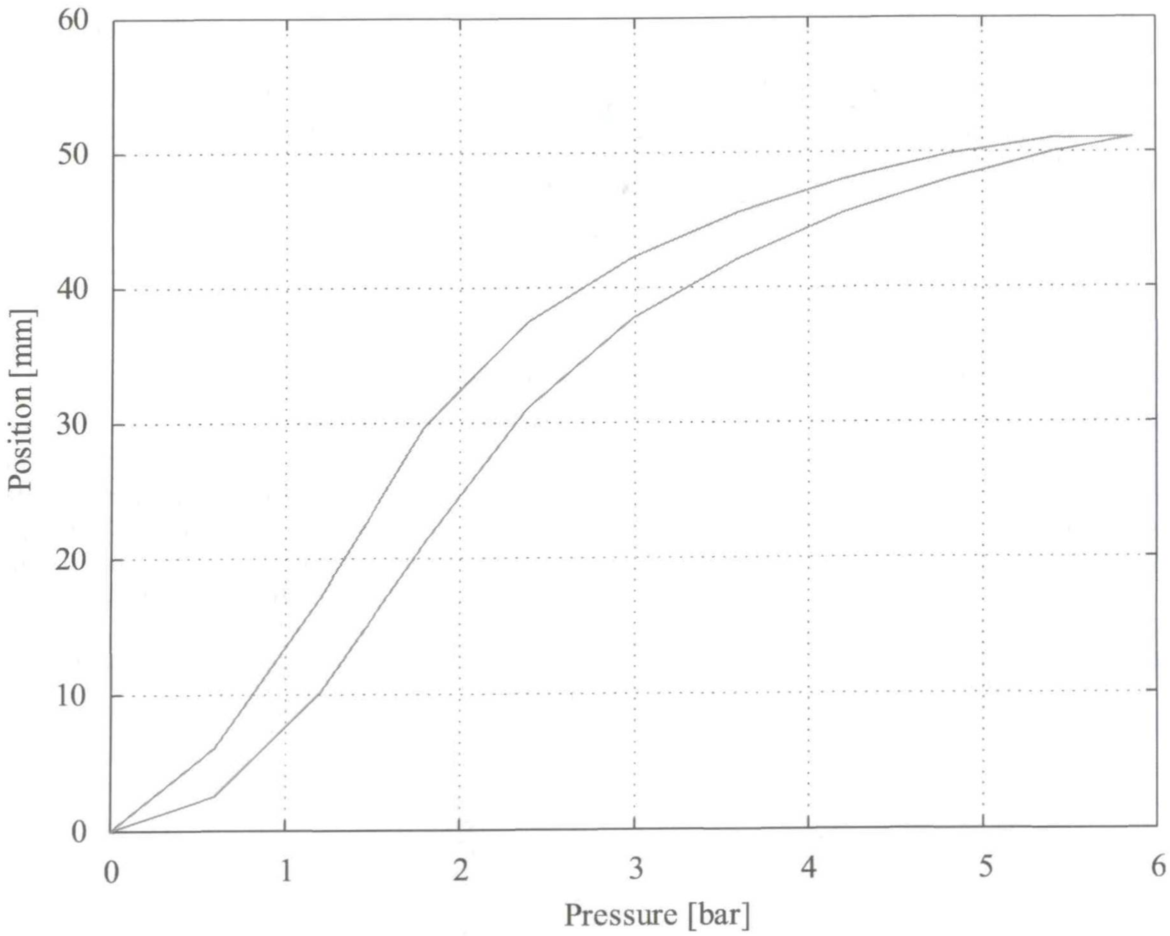


Figure 5. Measured hysteresis loop of PAM

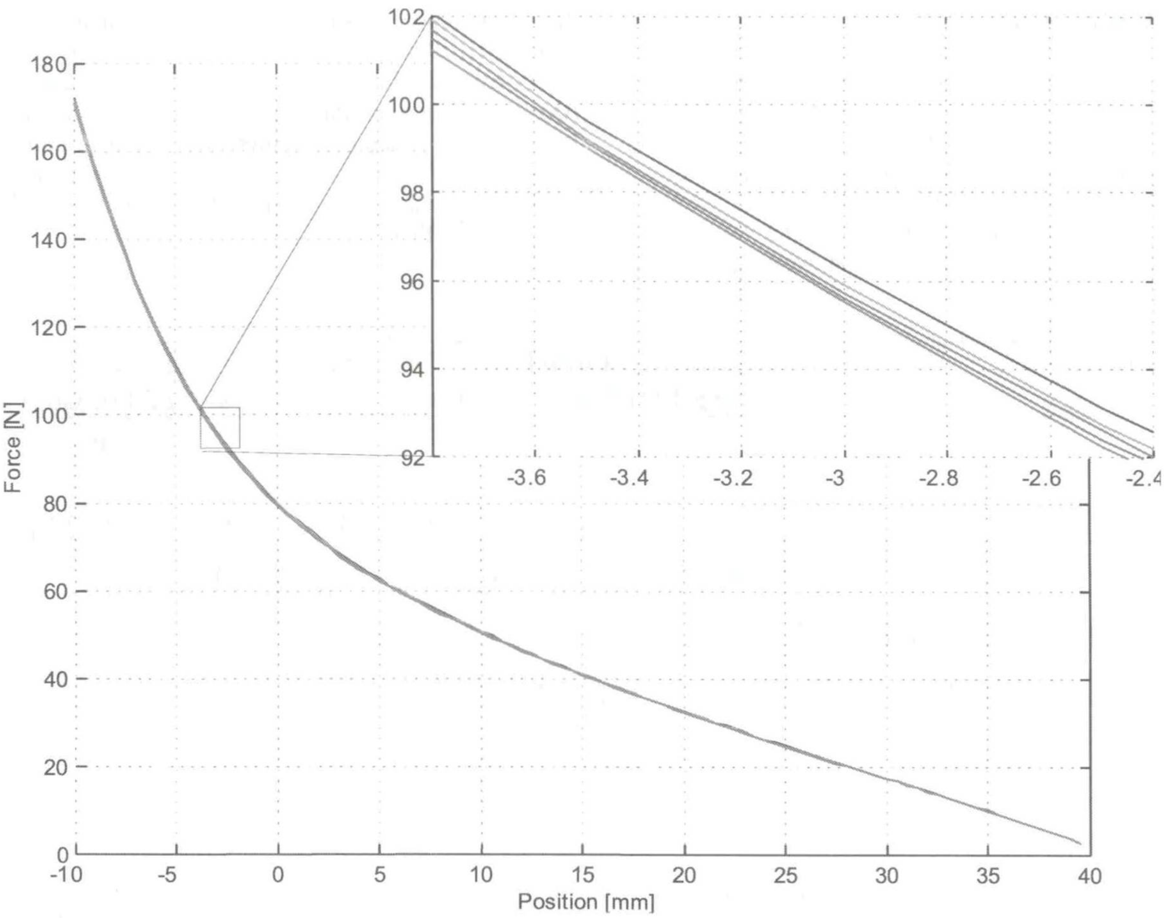


Figure 6. Measured creep effect of PAM

4. Conclusions and future work

This paper presented the mechanical structure of our test-bed that is capable of carrying out several static and dynamic investigations of PAMs. The results are a study on PAMs that have the potential for use in robotic and prosthesis applications. The future work for this project is to show that the fluidic muscle can be used as a good approximation of the biological muscle. These muscles seem a better choice than present day electric or other drives.

References

1 F. Daerden, *Conception and realization of pleated artificial muscles and their use as compliant actuation elements*, PhD Dissertation, Vrije Universiteit Brussel, Faculteit Toegepaste Wetenschappen Vakgroep Werktuigkunde, 1999, pp. 5-33.

2 F. Daerden, and D. Lefeber, *Pneumatic artificial muscles: actuator for robotics and automation*, European Journal of Mechanical and Environmental Engineering, 2002,Volume 47, pp. 10-21, ISSN: 1371-6980

3 Plettenburg, D. H. (2005), Pneumatic actuators: comparison of energy-to-mass ratio's, Proceedings of the 2005 IEEE, 9th International Conference on Rehabilitation Robotics, Chicago, Illinois, USA, 28 June-1 July, 2005, pp. 545-549, ISBN: 0-7803-9003-2

4 M. R. Juhari, M. Mamat, R. Ramasamy, N. F Mohd Nasir, M. Sugisaka, R. Yaacob, *An application of finite element modeling to pneumatic artificial muscle*, American Journal of Applied Sciences, Volume 2 (11), 2005, pp. 1504-1508, ISSN: 1546-9239

5 D. G. Caldwell, M. J Goodwin, A. Razak, *Braided pneumatic muscle actuators*, Proceedings of the IFAC Conference on Intelligent Autonomous Vehicles, Southampton, United Kingdom, 18-21 April, 1993, pp. 507-512, ISSN 0278-3649

6 P. Lopez, B. Tondu, *Modeling and control of McKibben artificial muscle robot actuator*, IEEE Control System Magazine, Volume 20, 2000, pp. 15-38, ISSN 0888-0611

7 M. Balara, A. Petík, *The properties of the actuators with pneumatic artificial muscles*, Journal of Cybernetics and Informatics, Volume 4, 2004, pp. 1-15, ISSN 1943-7978

8 C. P. Chou, B. Hannaford, 1996, *Measurement and modeling of McKibben pneumatic artificial muscles*, IEEE Transactions on Robotics and Automation, Volume 12 (1), pp. 90-102, ISSN: 1042-296X

9 D. G. Caldwell, M. Goodwin, G. A. Medrano-Cerda, *Control of pneumatic muscle actuators*, IEEE Control System Magazine, Volume 15 (1), 1995, pp. 40-48, ISSN 0888-0611

10 G. A.Medrano-Cerda, C. J. Bowler, D. G. Caldwell, *Adaptive position control of antagonistic pneumatic muscle actuators*, International Conference on Intelligent Robots and Systems, Pittsburgh, PA, USA, 5-9 August, 1995, pp. 378-383.
11 T. Endrődy, J. Gyeviki, J. Sárosi, P. Tomán, A. Véha, (2008), *Design and fabrication of a test-bed aimed for experiment with pneumatic artificial muscle*, International Conference on Science and Technique in the Agri-food Business, Szeged, Hungary, 5-6 November, 2008, pp. 361-367, ISBN 963 482 676 8
12 T. Endrődy J. Gyeviki, J. Sárosi, , G. Szabó, P. Szendő,: *Characteristics of the pneumatic artificial muscles,* International Conferences in Agricultural Engineering "Synergy and Technical Development", Gödöllő, Hungary, 30 August - 03 September, 2009, Conference CD, p. 6.

Scientific reviewers:	**Ion Mitelea, "Politehnica" University of Timişoara** **Mihaela POPESCU, "Politehnica" University of Timişoara**