Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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Annals of DAAAM International

THEORETICAL RESEARCHES REGARDING FINITE ELEMENT ANALYSIS OF MAS-20-750N-AA-MC-O-ER-BG PNEUMATIC MUSCLE

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Abstract: *The pneumatic muscle is system based on a contracting membrane, which, under the action of compressed air increases its diameter and decreases its length. The current paper present a finite element analysis of a pneumatic muscle used as actuator for one isokinetic equipment designed for rehabilitation. Traditional rehabilitation devices are usually driven by electric motors, which are typically rigid in nature and may cause discomfort or even pain during continuous passive motion. For offering high levels of safety and flexibility for humans rehabilitation robots should be actuated by pneumatic muscles for their better characteristics.*
Key words: *rehabilitation, isokinetic, membrane, FEA, pneumatic muscle*

1. INTRODUCTION

A Pneumatic Artificial Muscle (PAM) is a pneumatic actuator for converting pneumatic power to pulling force. Recently, pneumatic muscles have found their applicability as actuators of robotized systems. Characteristics as: shock - absorbing, adjustability, simulating capability, storage capable, safeness, lightweight, natural compliance and shock resistance, make the pneumatic muscles being easy to use and with great performances (***Air muscles, 2008).

The paper presents theoretical researches regarding Finite Element Analysis of MAS-20-750N-AA-MC-O-ER-BG Pneumatic Muscle in order to predict its behavior. It has been analyzed the force generated via volume expansion, displacement and inflation pressure released into the membranes. Finite Element Analysis (FEA) provides a reliable numerical technique for analyzing engineering designs. The pneumatic muscle is the actuator for one variant of equipment designed for the recovery of patients with posttraumatic dysfunctions of the bearing joints of the lower limbs (knee and hip), by application of continuous passive rehabilitating motions. A future direction in this research will consider a more in depth analysis and testing of functional muscle performance, as well as the equipment functionality and performances.

2. PNEUMATIC MUSCLE

Pneumatic muscle is an actuator system based on an inflatable and flexible membrane operated by pressurized air. In Fig. 1 is presented the working principle of a pneumatic muscle.

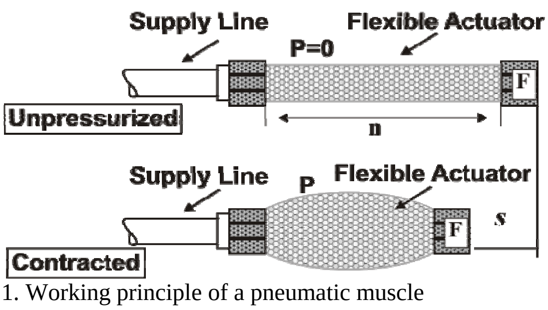

Fig.1. Working principle of a pneumatic muscle

The function principle consists in the fact that, under the action of compressed air, the pneumatic muscle, which is blocked at one end, shortens its lengths and expands its diameter. As the volume of the internal tube increases due to the increase in pressure, the actuator shortens with a certain stroke. The advantages of a PMA include high power/weight ratio, high power/volume ratio, low cost, low maintenance expense, cleanliness, flexibility, and great compliance (Deaconescu, 2008).

3. PNEUMATIC MUSCLE ACTUATED ISOKINETIC EQUIPMENT

All isokinetic equipments required for continuous passive motion currently available on the market place are driven by electric motors with a rigid linkage structure. The prices of such equipment are high, often exceeding the financial possibilities of the potential users (Deaconescu, 2009). Also, the electric drives may cause pain or discomfort to the users. Pneumatic muscle actuator is best suited for application to rehabilitation robots to minimize pain or discomfort incurred on users.

These hypotheses I have considered in conceiving one cheaper but also high quality isokinetic equipment, which offers high levels of safety and flexibility. The rehabilitation equipment is capable of achieving continuous passive motion, by means of a pneumatic muscle actuated system. This is presented in Fig.2. The actuation of the isokinetic equipment is made by an FESTO pneumatic muscle.

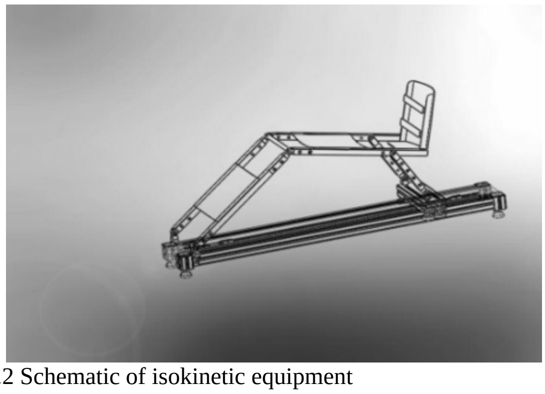

Fig.2 Schematic of isokinetic equipment

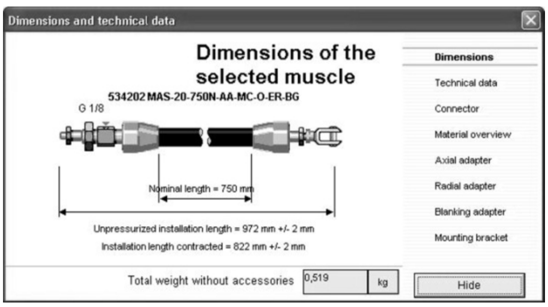

Fig. 3. Dimensions for selected muscle

The type and dimensions of the muscle were selected by using a program given by Festo Company. This program helps us to select the muscle at the dimensions we need: nominal length as supplied, desired length difference, pressure setting and the diameter (one of the three options). The type of muscle resulted is MAS-20-750N-AA-MC-O-ER-BG Pneumatic Muscle.

4. FINITE ELEMENT ANALYSIS OF MAS-20-750N-AA-MC-O-ER-BG PNEUMATIC MUSCLE

Finite Element Analysis (FEA) provides a reliable numerical technique for analyzing engineering designs. We analyzed the force generated via volume expansion, displacement and inflation pressure released into the membranes. The Finite Element Analysis of MAS-20-750N-AA-MC-O-ER-BG pneumatic muscle was made with COSMOSXpress program. The input data for the FEA refers to material and load and restraint information.

The muscle was modeled as a rubber cylinder endowed with two Alloy fittings. The rubber mass is 0.614967 kg and volume 0.000614967 m^3. For inferior fitting, the mass is 0.186611 kg and volume 6.9115e-005 m^3 and for superior fitting the mass is 0.19153 kg and volume 7.09372e-005 m^3. Both the ends of the cylinder are restrained from any translational and rotational degrees-of-freedom, except the translational freedom to move along its longitudinal axis on one end, to represent the side which will be acting as actuating free-end. (Ramasamy et al, 2005). The stroke is 150 mm. As load we considered a pressure of 5 bars. The limits of the stress, displacement and strain resulted are shown in Table1.

Name	Type	Min	Max
Stress	VON: von Mises stress	671.097 N/m^2 Node: 1004	2.31876e+007 N/m^2 Node: 3108
Displacement	URES: Resultant displacement	0 m Node: 128	0.162289 m Node: 17580
Strain	ESTRN: Equivalent strain	1.30977e-008 Element: 693	1.19807 Element: 17472

Tab.1. FEA results of pneumatic muscle

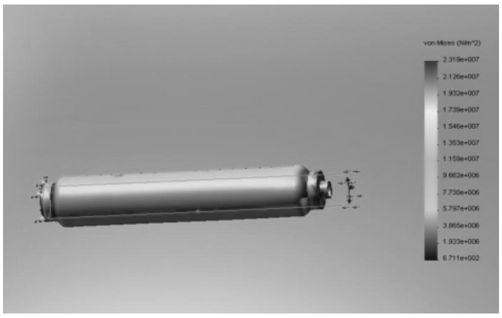

Fig. 4. Stress representation of the muscle

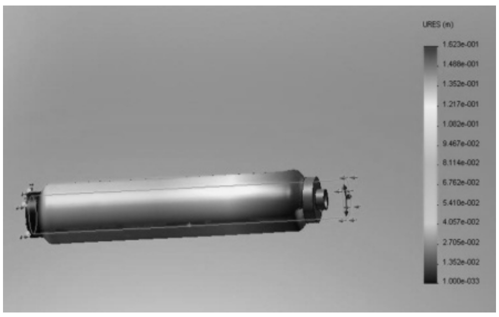

Fig. 5. Displacement representation of the muscle

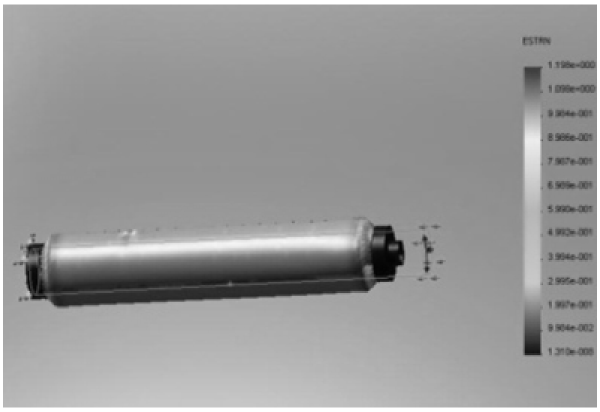

Fig. 6. Muscle deformation

In the presented figures it can be see the behavior of the muscle – the volume expansion (Fig.4), the stroke that is capable to realize (Fig.5) and the inflation pressure released into membrane (Fig.6).

5. CONCLUSION

Since their conceiving pneumatic muscles have evolved into realistic tool which offer a wide range of possibilities. Their low assembly weight and high power-to-weight ratio make the pneumatic muscles to be considered for use in mobile robotics (Verrelst et all, 2006).

The research described in this paper lead to the idea that MAS-20-750N-AA-MC-O-ER-BG pneumatic muscle is suitable as actuator for the isokinetic equipment considered, the next step being the analysis of this equipment performances in rehabilitation.

This research will be continued with a more in depth analysis and testing of functional muscle performance, as well as the equipment functionality and performances.

6. ACKNOWLEDGEMENTS

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/88/1.5/S/59321.

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