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daniel.alejandro@ufsc.br

Soft robot development: Air muscle for rehabilitation robotic application

Hillesheim LF*, Ventura VNS* and Ponce DAS*

**Universidade Federal de Santa Catarina, Blumenau, Brazil.*

Abstract. Physiotherapy is a science which acts in the area of biomechanical and functional disorder, establishing diagnostics and supporting the locomotor system rehabilitation. These procedures require assistance of a physiotherapist, however they are insufficient for the country´s demand. Usually such procedures use devices with the newest technology, in order to enable recovery and avoid possible permanent trauma. In order to face this reality, we have committed to develop an air muscle, based on the McKibben´s model, with the purpose of proposing a new low-cost parallel robot to physiotherapy *(Soft Robot)* for the rehabilitation of patients with ankle injuries. This robot is responsible for moving three degrees of freedom platform, therefore acting directly in the rehabilitation of the patient through the execution of soft and accurate therapeutic movements that stimulate the recovery of operated tissues. First, it is build an air muscle that will be used as actuator in parallel platform. Then is raised a curve of behavior to shift versus pressure on proposed muscle. In conjunction with these data to actuator behavior is modelled and simulated the new parallel robot. This air muscle was build using a latex tube covered by a braided fibred mesh and fuelled by a pneumatic tire valve, therefore obtaining a nonlinear behavior of contraction to each pressure value admitted on muscle. By means of this prototype building purpose, we obtained satisfactory results, such as a contraction of 25% of the nominal length for pressures up to six bars. Considering such a result and the low cost involved building actuator as this one, the advantage in using this model is perceptible.

Keywords. *Physiotherapy, air muscle, parallel robot, ankle injuries, rehabilitation.*

Introduction. The McKibben muscle was invented in the 50s by the American atomic physicist Joseph L. McKibben who was developing an orthopedic device to assist with weakness musculature on forearm. In the 80s, a Japanese pneumatic tyre manufacturer discovered that the muscle model can be used in a new kind of robot for paintings works and for rehabilitation robotics for handicapped people. Therefore, many applications to those pneumatics muscles has been studied and evaluated because of their facilities and cost-benefits.

Nowadays, Brazil has been presenting a shortage on physiotherapy area, where there is less than one professional for every group of a thousand inhabitants, disregarding the fact that professional would be accompanying the treatment for a long time. Those professionals meet in a large majority on private sector using low technology devices, where the conditions are little better than public sector which there is a lack of technology investment.

Looking these applications and studying how the air muscle can be used to build a parallel robot to assist in rehabilitation of ankle injuries. This project has as purpose support physiotherapist on treatment’s patience, seeking faster rehabilitations over time resulting from the accuracy action robot on injuries.

Initially, we studied the best components to build up an air muscle. Next, we have built and started the tests period herewith data collection of muscle behavior. Finally, it was possible to get curve of behavior to shift versus pressure, observing how only one muscle works to build a platform on the future.

Materials and methods. For building this prototype, we chose to use low-cost materials with the purpose of obtain a result that it was accessible and profitable. In this way, we used the components listed below:

- Latex tube;
- Tubular braided fibred mesh;
- Bland clamp;
- Plastic cable tie;
- Tyre valve;

At first we began by using latex tube, which has a malleable performance. We had problems with the irregular diameter of latex tube, and then was necessary find another latex tube, around 8 millimetres of diameter, that is regular to obtain a uniform expansion. This latex tube was enveloped by a tubular braided fibred mesh, thus it was responsible to limit the expansion of latex tube around diameter, being this limit around the lengthwise axis of the muscle.

We have used a tyre valve for taking the input and output control, since a compressor can connect this valve easily. For building this prototype, we need only a tyre valve and would be to use a plastic cable tie or something to obstruct the other muscle side, but due the ways we had to achieve our tests was more useful utilized one valve to input and other to output. This prototype is showed by Fig. 1.

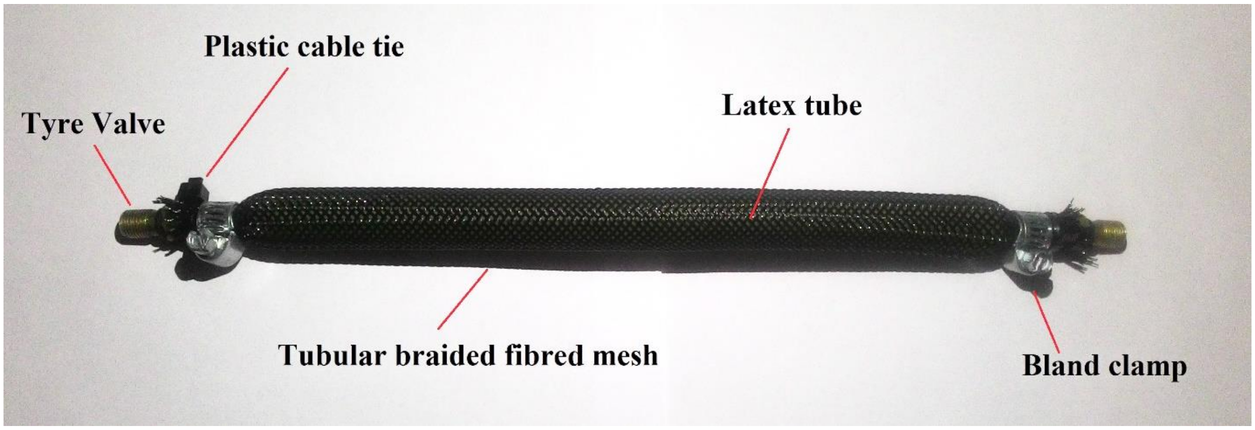

Figure 1. Components used in air muscle.

During the tests, we have checked which this model reaching pressure up to 6 bars, however the lack of attachment in the latex tube with valve was a new problem, it was solved using a band clamp in both extremities of the muscle. In the Fig. 2 is showed a comparison between the muscle depressurized and pressurized.

Figure 2. Comparison between air muscle depressurized (above) and pressurized (below).

Result and discussion. Through the methods wrote previously, we have built a model with 26 centimetres of nominal length. This muscle was pressurized with a compressor of pressures up to 6 bars, resulting in a contraction of 25% of the nominal length. In the Fig. 3 is shown the nominal length of muscle and contraction its.

Figure 3: Measure of shift in air muscle depressurized and pressured.

Through each pressure value admitted on muscle and the difference from contraction behaviour, we observed a non-linear behaviour, as is shown by Fig. 4.

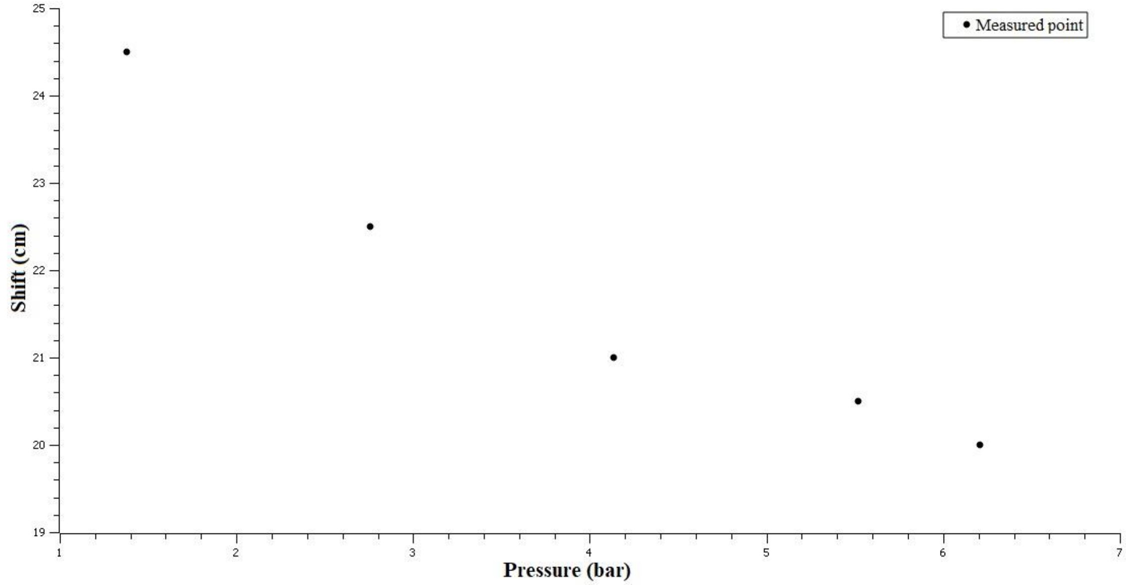

Figure 4. Shift as a function of pressure in air muscle.

With these points was possible calculate a contraction of muscle and then, use it to compare with other models of market that was developed in the huge companies.

Conclusion. By means of results we produced and because of the low-cost components used, the large usability of such air muscle to build a parallel robot it is visible.

That actuator model has been showing a difference in relation to linear actuators, even being harder to mathematically model it, those non-linear models provide a non-constant force variation along the muscle shift. This difference could be beneficial around the parallel robot actuation, enabling force changes along the route.

Observing the contraction percentage, we got and comparing it to similar models present in the market, as *FESTO* for example, we can conclude as satisfactory the results here showed.

In the future, there is the possibility to apply a mathematical model to control three air muscles, fixed on a platform, which constitute a parallel robot to rehabilitation procedures in operated tissues.

Future work. Future work ideas include the development of this work to others of its kind platform and apply it to different rehabilitation model.

References.

[1] Tavares. LRC. Costa JLR, Oishi J and Driusso P. Territorial distribution of physical therapists in Brazil – National Register of Health Service Providers (Cadastro Nacional de Estabelecimentos de Saúde, CNES) / 2010". ConScientiae Saúde, 2016;15: 53-61.
[2] Tavares LRC, Costa JLR, Oishi J and Driusso P. "Distribution of physical therapists working on public and private establishments in different levels of complexity of health care in Brazil". Rev Bras Fsioter, 2012; 16(5): 422-30.
[3] K. Zang, Y. Wang, X. Fu and X. Hu, "Study on Modeling of Mckibben Pneumatic Artificial Muscle," *2008 International Conference on Intelligent Computation Technology and Automation (ICICTA)*, Hunan, 2008, pp. 721-725.
[4] Datasus.gov [Internet]. "Brazil: Cadernos de informação de saúde". 2010. Available from: http://tabnet.datasus.gov.br/tabdata/cadernos/cadernosmap.htm.
[5] Tondu, B. Lopez, P. "The McKibben muscle and its use in actuating robot-arms showing similarities with human arm behavior". Industrial Robot, Vol. 24 No. 6. 1997; 432-439.
[6] T. Nuchkrua, T. Leephakpreeda and T. Mekarporn, "Development of robot hand with Pneumatic Artificial Muscle for rehabilitation application," *The 7th IEEE International Conference on Nano/Molecular Medicine and Engineering*, Phuket, 2013, pp. 55-58.
[7] Sárosi, J. Szépe. T and Gyeviki. J. "New mathematical model for pneumatic artificial muscles". Journal of Hungarian Agricultural Engineering, Vol. 22 No. 13. Dec, 2014; 49-52.
[8] E. J. Koeneman, R. S. Schultz, S. L. Wolf, D. E. Herring and J. B. Koeneman, "A pneumatic muscle hand therapy device," *The 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, San Francisco, CA, 2004, pp. 2711-2713.
[9] T. Choi, S. Jin and J. Lee, "Implementation of a Robot Actuated by Artificial Pneumatic Muscles," *2006 SICE-ICASE International Joint Conference*, Busan, 2006, pp. 4733-4737.
[10] W. Lepiarz, "The vision analysis of a McKibben pneumatic artificial muscle," *Proceedings of the 2014 15th International Carpathian Control Conference (ICCC)*, Velke Karlovice, 2014, pp. 306-309.
[11] K. Moon, D. Ryu, C. Chun, Y. Lee, S. Kang and M. Park, "Development of a Slim Haptic Glove Using McKibben Artificial Muscles," *2006 SICE-ICASE International Joint Conference*, Busan, 2006, pp. 204-208.