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GEOMETRIC MODELLING OF THE BRAIDED SHELL

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ABSTRACT:This paper presents some graphical modalities for constructing the double helical braid and 3D-modelling, which is the basis for the braided artificial pneumatic muscles, by using specialized software aplications. This represents a first stage in achieving the method of finit element analysis of this type of linear pneumatic actuator.

1. INTRODUCTION

The tubular membrane of the muscle is wrapped in a braided shell formed by polyamides fibers that surround the rubber cylinder double-helically. At the two ends the muscle is closed with fittings by means of which: at one end the compressed air is sucked and at the other the pulling force is exerted on its load.

When pressurized inside the rubber membrane, the braided muscle expands against the braided shell. Consequently, tensions occur along the fibers which, being non-extensible act like a pantograph mechanism: the knots of the braid situated longitudinally get closer while those situated radially move off. Thus the muscle shortens axially, generating the pulling force, and the rombs angles, formed by the neighboring fibers longitudinally get larger. The tensions are transmitted to the external load by connectors.

There are two types of braided muscles: one at which both the tube membrane and the braided shell are attached to fittings at both ends and another one at which only the braid is attached to the terminal fittings while the rubber membrane is unattached.

This paper refers only to the first category of pneumatic muscles, also known as McKibben muscles.

2. GEOMETRICAL ELEMENTS OF THE BRAIDED SHELL

The way in which braided muscles behave concerning: the developed forces, the ensured contractions and their shape in expanded condition depends on their geometry in rest position (Figure1) and on the materials that have been used.

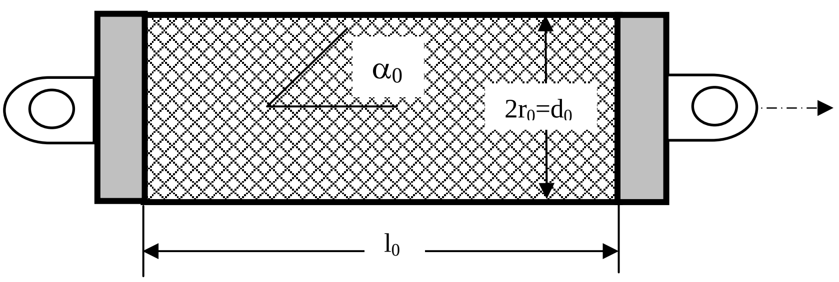


Fig.1 *Braided muscle in resting position*

Natural latex or silicon rubber are used for the tube membrane and aramides, nylon or fiberglass for the fibers.

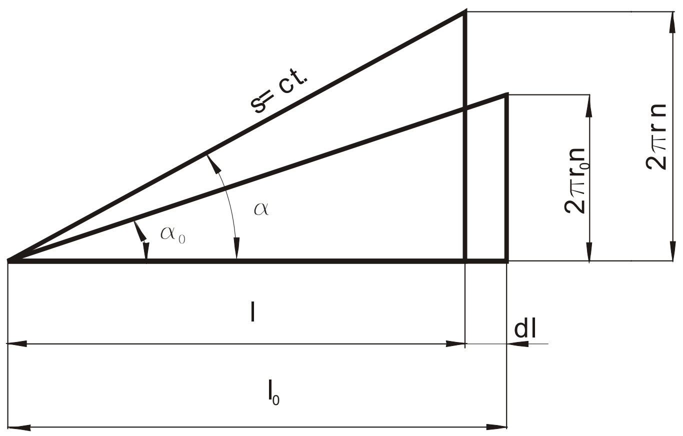


Fig.2 *The helical fiber uncoiled, in rest and in stained position*

In view of geometric modeling of the braided muscle one has started from the geometric elements of the musle at rest: α_0, l_0, r_0 and from the fact that the fibers do not change their length during the swelling, s = ct.

The following relations: (1), (2), (3) are valid between the rest parameters and those from the expanded conditions.

$$\cos\alpha_0 = \frac{l_0}{s} \text{ şi } \cos\alpha = \frac{l}{s} \Rightarrow \frac{l}{l_0} = \frac{\cos\alpha}{\cos\alpha_0} \quad (1)$$

$$\sin\alpha_0 = \frac{2\cdot\pi\cdot r_0\cdot n}{s} \text{ şi } \sin\alpha = \frac{2\cdot\pi\cdot r\cdot n}{s} \Rightarrow \frac{r}{r_0} = \frac{\sin\alpha}{\sin\alpha_0} \quad (2)$$

$$\frac{dr}{dl} = -\frac{r_0}{\sin\alpha_0}\cdot\frac{l\cdot\cos^2\alpha_0}{l_0^2}\cdot\frac{1}{\sqrt{1-\left(\cos\alpha_0\cdot\frac{l}{l_0}\right)^2}} \quad (3)$$

With these, the expression of the tensile force becomes:

$$F = p\cdot(2\cdot\pi\cdot r\cdot l)\frac{dr}{dl} - p(\pi\cdot r^2) \quad (4)$$

$$F = \pi\cdot p\cdot r_0^2\cdot\left(\frac{3}{tg^2\alpha_0}\cdot\frac{l^2}{l_0^2} - \frac{1}{\sin^2\alpha_0}\right) \quad (5)$$

3. MODELLING THE DOUBLE-HELICAL FIBER BRAID

Starting from the parametrical equation of the circular helix:

$$x = R\cdot\cos\theta$$

$$y = R\cdot\sin\theta$$

$$z = R\cdot tg\alpha\cdot\theta = \frac{p}{2\pi}\theta$$

families of helixes pairs have been multiplied several times, which form the muscle network. These graphical plottings have been obtained by using varied software (Mathcad, Matlab) thus obtaining double-helical braid at it can be seen in Figure 3.

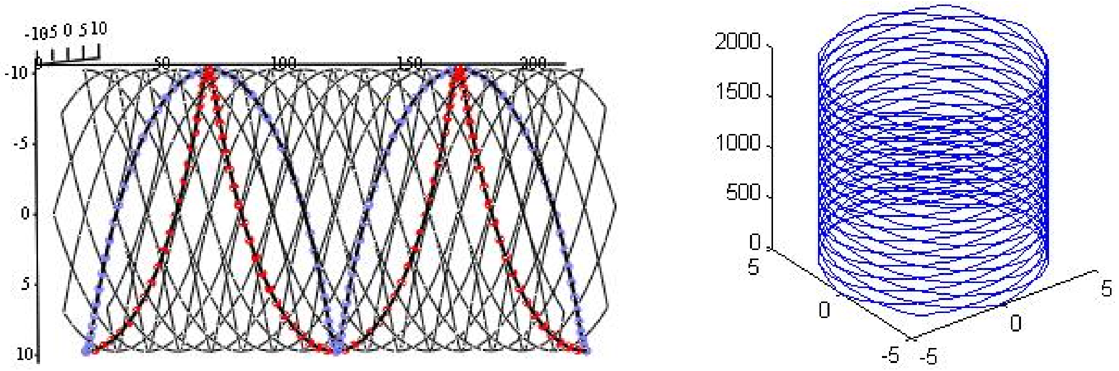
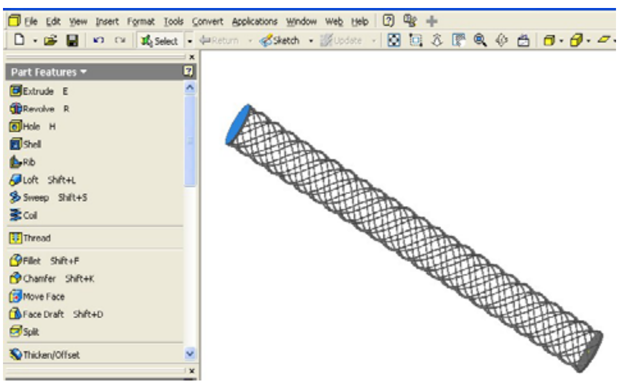


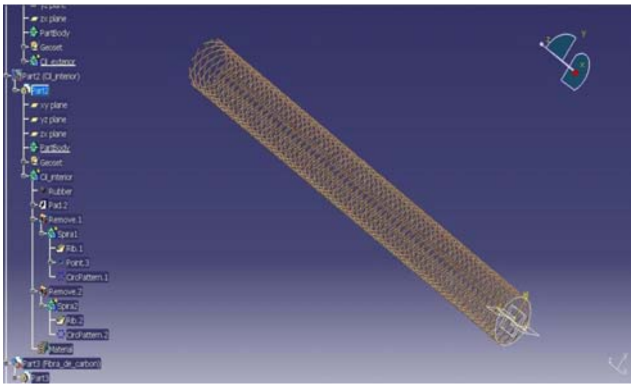
Fig.3 *Modelling the double-helical braid by using graphical application*

Then the 3D-modelling of the braid was achieved, namely the tubular membrane by using specialized programs: Inventor and Catia. For thus a coiling cylinder was consider, having the diameter d_0=20 mm, the length in position of rest l_0=200 mm and a thickness of the braid fibers of 0.5 mm.

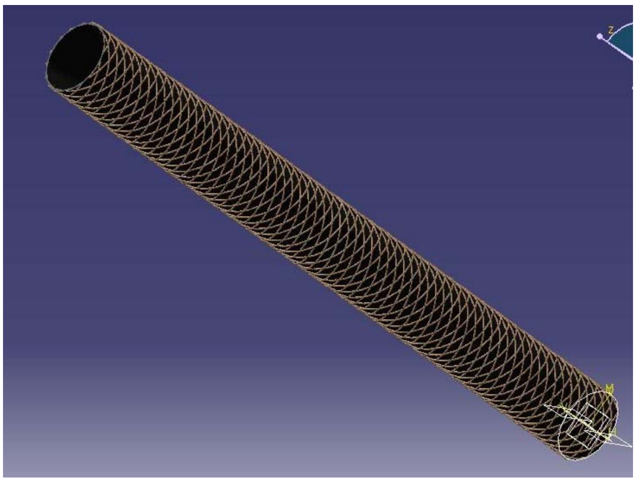
In Figure 4 a, b, c, d are presented some hypostases of the models constructed in this way.



a)



b)



c)

d)

Fig.4 *3D-Modelling of the braided artificial muscles*

CONCLUSION

Due to the reborn interes for the braided artificial pneumatic muscles, in order to use them in different applications such as the human skeleton prostheses and the rehabilitation of the people with locomotor disability, we focused on the research concerning this problem. Therefore we have created study patterns by using specialiyed software and having as a starting point we will develop complex analyses and simulations in order to appreciate the behavior of these muscles, their weak points and to what extent they are useful in the respective domain.

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