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THEORETICAL CONSIDERATIONS CONCERNING THE VARIATION LIMITS OF THE CHARACTERISTIC ANGLE OF THE BRAIDED SHELL

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Abstract: In case of artificial braided pneumatic muscles the essential element is the braided shell. It is made of fibers (polyamide or nylon) which cover double-helically the rubber cylindrical membrane.

When compressed air is introduced in the tube, the rubber presses against the braid in such a way that the inside pressure is counteracted by the stress created in its fibers.

The two constitutive elements of the braided sleeve have different stiffness and therefore it is considered that the strain of the muscle is produced without the modification of the length of the fibers, but only by the variation of the angles of the rhombuses formed by the adjacent fibers of the insertion.

1. INTRODUCTION

The mesh of the net operates like a pantograph mechanism, which means that they knots get closer longitudinally while they space out radially- fig.1. This means in other words that the characteristic angle of the braid increases while the length are modified (shortened) and the diameter of the pneumatic muscle increases. In this way tensions are created which are transmitted to the external load by the fittings from the muscles ends.

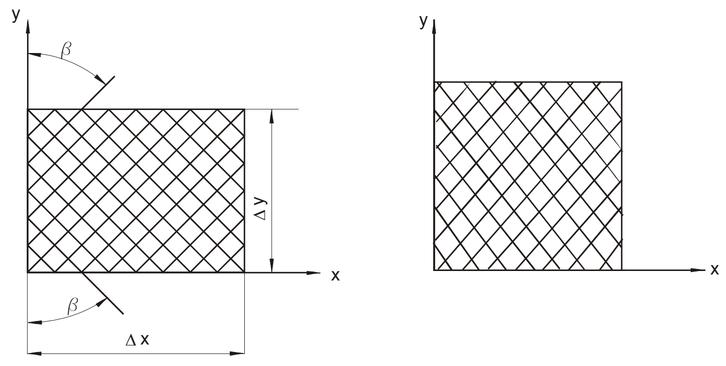

Fig.1 *Fiber grid, before and after the deformation*

The two constitutive elements of the braided sleeve have different stiffness and therefore it is considered that the strain of the muscle is produced without the modification of the length of the fibers, but only by the variation of the angles of the rhombuses formed by the adjacent fibers of the insertion- fig.2.

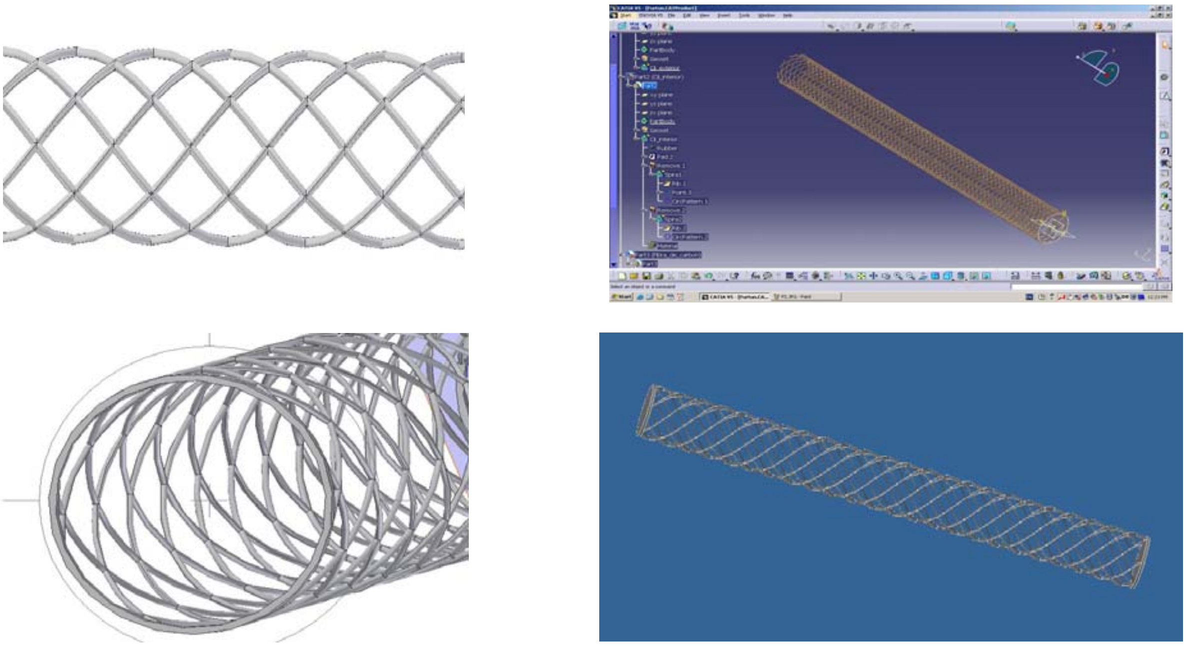

Fig.2 *Braided shell of the pneumatic muscle [3]*

2. SIMPLIFYING HYPOHESES FOR ESTABLISHING THE MAXIMUM THEORETICAL ANGLE OF THE GRID

The following appreciations are made:

- The diagonal of the rhombuses remain perpendicular on one another, after the deformation of the grid, and therefore they represent the directions of the main strains [2];
- The stresses from the rubber are much smaller than those from the fibers, which means that the distortions of the rhombuses are produced without energy consumption;
- As one has previously mentioned as well, the fibers of the insertion are considered inextensible.

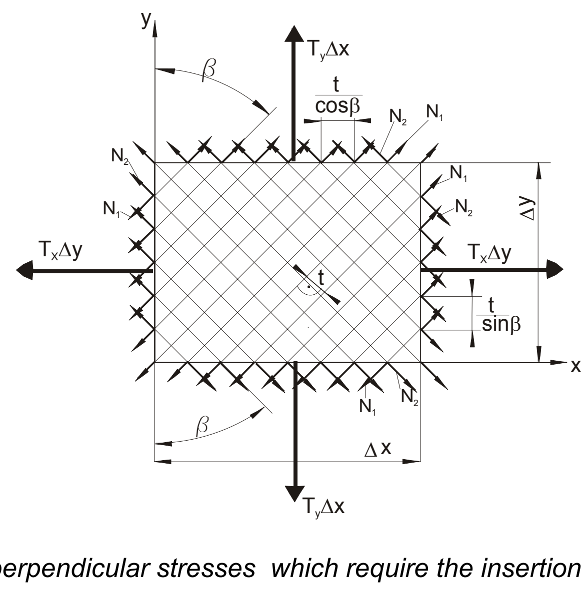

Fig.3 *The perpendicular stresses which require the insertion element*

Based on them and on fig. 3 the following relations can be written:

$$T_x = \frac{2N}{t}\sin^2\beta \quad (1)$$

$$T_y = \frac{2N}{t}\cos^2\beta \quad (2)$$

where: T_x are the meridian stresses; T_y – circumference stresses; $N_1= N_2=N$ – the efforts from the fibers, wherefore one can notice that:

$$tg^2\beta = \frac{1}{2} \Rightarrow \beta_{\max} = 35^\circ 20' \rightarrow \alpha_{\max} = 54^\circ 40 \quad (3)$$

This angle represents the grid balance angle. If the angle of the fibers will be different from it, the tube will be distorted in such a way that the angle wil get closer to the balance value.

The same result is reached if one uses the expression of the volume corresponding to a pitch of the helical fiber. If s_p is the length of the fiber, one can write [3]:

$$V_p = \frac{s_p^3}{4\pi}\sin^2\alpha\cos\alpha \quad (4)$$

and on condition that:

$$\frac{dV}{d\alpha} = 0 \quad (5)$$

the same value will result for the maximum angle.

3. ESTABLISHING THE MINIMUM THEORETICAL ANGLE OF THE GRID

By considering the number of fiber pairs *N,* the thickness of a fiber *g,* the total length of a fiber *s* and the maximum theoretical diameter of the muscle in the maximum expanded state *D*, as one can see in fig.4, a relation of calculus for the minimum theoretical angle can be determined:

$$\alpha_{\min} = \frac{\arcsin\left(\frac{2Ng}{\pi D}\right)}{2} \quad (6)$$

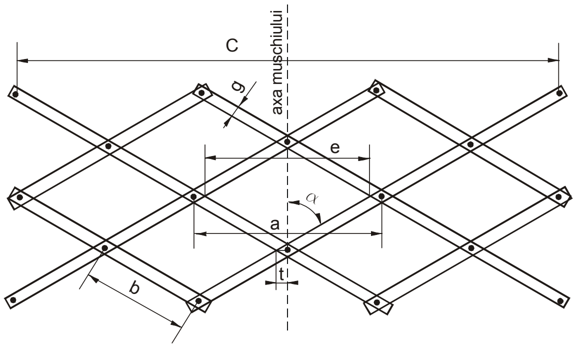

Fig.4 *Geometrical model which is the basis of the calculus for the α angle.*

This relation is useful for the calculus of the maximum length that the muscle can reach [1]:

$$l_{\max} = s \cdot \cos\left(\frac{1}{2}\arcsin\frac{2gN}{\pi D}\right) \quad (7)$$

respectively for the minimum length:

$$l_{\min} = s \cdot \cos\alpha_{\max} = 0{,}5783 \cdot s \quad (8)$$

4. CONCLUSIONS

- The role of the rubber tube is to transmit the pressure from the inside to the fiber rhomboidal grid.
- The fibers are inextensible and therefore their length, *s,* remains constant.
- Both the maximum length and the minimum length of the braid are directly proportional with the length of its fibers.
- The maximum length of the muscle corresponds with the minimum angle α_{min} and the minimum length (maximum contracted) corresponds to the maximum angle α_{max}.
- From the point of view of the braided muscle, the value of α_{max} restricts the value of the operation pressure to a maximum value, above which the muscle does not shorten any more, but begins to stretch.

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