FE Modeling of NiTi Elastomeric Composites for Use as Biomaterials

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Introduction

Over the past few years, textiles made from thin NiTi wires have received increasing attention as they are already used as stents in medical field and further applications are being envisaged. To prevent some apparent drawbacks of NiTi textiles such as friction between NiTi wires and low tensile/shear stiffness, NiTi elastomeric composites are being considered as novel functional structures, to reproduce the mechanical behavior of living tissues for example **[1]**. Moreover, one might tailor the constitutive behavior of those composites through selection of design parameters such as internal textile morphology, macroscopic shape of the reinforcing NiTi textile, shape setting conditions, volume fraction of the matrix etc. However, the high number of design parameter makes it difficult to design a NiTi elastomeric composite for a given application without any numerical modeling tool. A macroscopic approach based on creating a material constitutive behavior reproducing the mechanical behavior of the textile is often used (Duhovic *et al.* **[2]**). A homogenization method is proposed based on textile geometry, using either a low computational time beam based FE analysis, or a general 3D solid model analysis, and the Auricchio behavior model to model NiTi superelastic properties.

Experimental results

On the first part, composites using woven NiTi textile were studied. Considering the mechanical behavior of soft living tissues (*Figure 1* **[1]**) and comparing to the mechanical behavior of straight NiTi wires, one might think about adjusting the properties to fit well the behavior of NiTi wires by using a structural shape and the shape setting possibilities of nickel-titanium alloys. The structural shape chosen was a snake-like shape (*Figure 2*), to allow high recoverable strain up to 40%, like introduced by Chemisky *et al.* **[3]**. To prevent wires to slip within the textile, and to give the low strain mechanical properties to the composite, a silicone matrix is used to coat the textile (Heller *et al.* **[4]**). As the composite is composed of textile reinforcement and a silicone elastomer matrix, both components are first studied alone, and then assembled to form the composite**.** This composite shows a similar behavior as living tissues (*Figure 3*) but only in the direction of winding of the snake-like shape.
Another way to obtain similar mechanical behavior as living tissues is to use a knitted NiTi textile instead of a woven textile. *Figure 4* (Heller *et al.* **[5]**) shows the mechanical behavior in tensile loading in both course-wise and wale-wise direction of a knitted textile made of 0.1mm diameter NiTi wires. The knitted textile offers the advantages of anisotropy, that composites with woven NiTi textile could not achieve. This anisotropic aspect is fundamental in living tissue behavior.

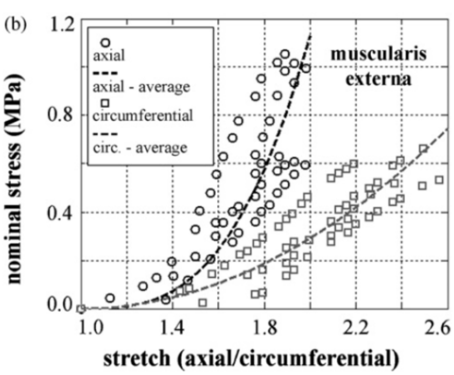

Figure 1: Mechanical behavior of esophageal living tissues in axial and circumferential directions [1]

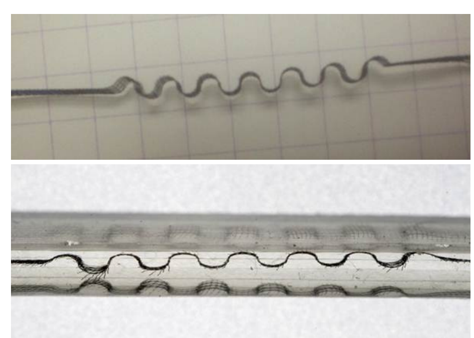

Figure 2: Snake-like shaped NiTi textile, and down: composite with snake-like NiTi textile and silicone matrix

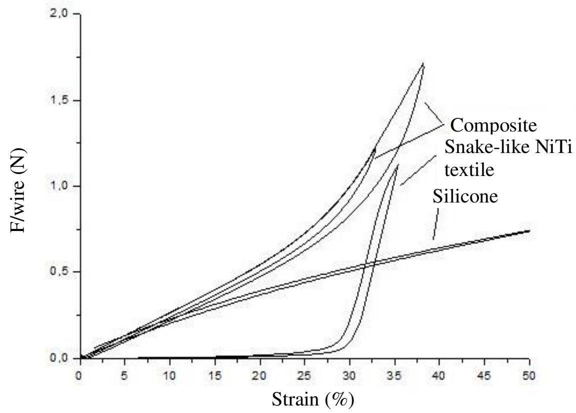

Figure 3: Tensile behavior of snake-like NiTi textile, silicone elastomer, and snake-like NiTi textile molded into silicone matrix

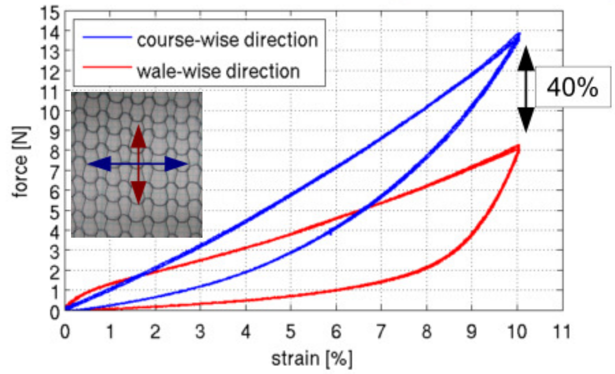

Figure 4: Mechanical behavior in tensile loading of knitted NiTi textile in course and wale direction [5]

Discussion

However, the parameters of design for knitted NiTi textile are numerous, and all play an important role on the final mechanical behavior of the textile. Therefore, it is necessary to be able to predict its behavior, and moreover, to be able to determine those parameters to fit the mechanical behavior of the living tissues which is reproduced.

Conclusion

Leaving tissues show a particular mechanical behavior, composed of stiffening, high elasticity, hysteresis, and anisotropy. To reproduce such mechanical behavior, knitted textile appears to be perfect candidate as they show a similar behavior observed with tensile tests. However, the field of parameters used for knitting is wide, and modeling those textiles and characterizing the influence of each is necessary to determine the textile that will fit the living tissue to reproduce.

References

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