# Mechanics & design of fiber-reinforced vascular prostheses

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# Mechanics & design of fiber-reinforced vascular prostheses

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## Introduction

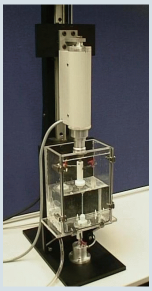
Failure of small diameter ($< 5$ mm) synthetic prostheses is often contributed to a mechanical mismatch with the host artery [1], [2]. Our objectives:

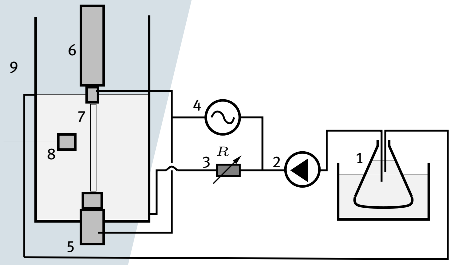
- ☐ development of a small diameter synthetic vascular prosthesis which is mechanically compatible with the host artery
- ☐ design based on an experimentally validated computational model

## Method

### Mechanical characterisation

In an experimental setup the artery is subjected to *internal pressure* being suspended under *axial extension*. Real-time diameter measurement is performed using *Ultrasound*. These experiments provide material properties in longitudinal and axial directions. The applied loading is *dynamic* to investigate viscoelastic properties.



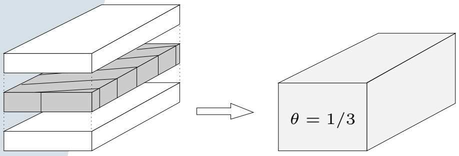


### Computational

**framework** The model is based on a FE implementation of *geometrically and physically nonlinear* material. Incompressibility is incorporated using a *mixed formulation* and the balance equations are solved using an *integrated method*.

**constitutive model** The matrix-fiber structure is modeled using a new *composite model* incorporating fiber density:

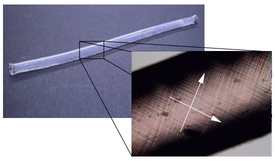
$$\boldsymbol{\sigma} = -p\boldsymbol{I} + \hat{\boldsymbol{\tau}} + \sum_{k=1}^{N} n\left(\tau_{fk} - \vec{e}_k \cdot \hat{\boldsymbol{\tau}} \cdot \vec{e}_k\right)\vec{e}_k\vec{e}_k$$



Initially a simplified *non-FEM numerical model* is used to fit the experimental data.

## Prototype development

The prototype consists of a *viscoelastic matrix* (hydrogel) which is reinforced with *non-linear elastic fibers* (Lycra) to obtain material properties that match those of arteries. Design parameters are derived from the numerical model to give an *optimized fiber layout*.



The fibers are fully embedded in the matrix to give extra strength to the graft and to provide better biocompatibility.

## Results

Several results are presented in figure 1 and 2.

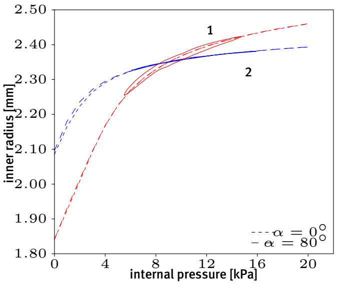


**Figure 1:** *Pressure radius behavior of human artery (solid) and fit with model (dashed)*

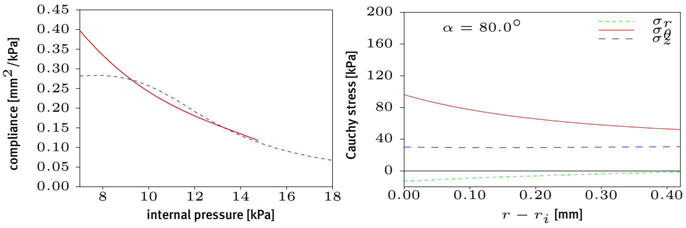


**Figure 2:** *left: Compliance of human artery (solid) and a possible gel graft (dashed). right: Stress distribution along the wall.*

## Discussion

- ☐ tests on natural arteries and hydrogel grafts
- ☐ fiber reinforced hydrogel tubes show better results than existing prostheses with respect to matching mechanical behavior of natural arteries
- ☐ there is still a mechanical mismatch between the artery and the prosthesis but it is likely that this mismatch can be eliminated

### References:

[1] How, T.V. and Guidoin, R. and Young, S.K.: *Journal of Engineering in Medicine* 206, 62-71, 1992

[2] Hofstra, L.: *Intimal hyperplasia in human vascular grafts*, PhD. Thesis, University of Maastricht, 1995

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