Mechanical Characterization of Bacterially Synthesized Nanocellulose Hydrogels

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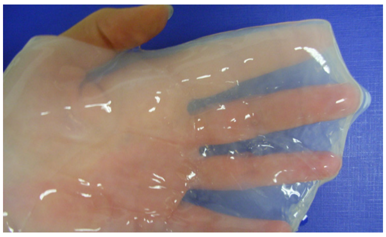
Motivation

Fibrillar structures are building elements often encountered in nature. Cartilage consists of a fibrous, poro-elastic structure, which holds a liquid phase. This biphasic structure leads to its unique mechanical and tribological properties.

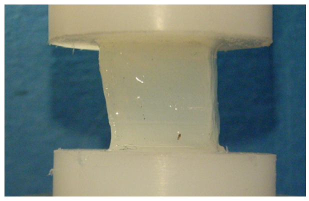


Bacterially synthesized nanocellulose (BNC) is composed of a network of cellulose nanofibers which are able to hold more than 99 wt% of water forming a hydrogel. Due to its structure and biocompatibility it is a potential replacement material for cartilage.

Materials and Methods

BNC sheets were prepared in static culture with the bacteria strain *Gluconacetobacter xylinus*. Mechanical tests were carried out on specimens cut from BNC-sheets which were previously never dried (»pure BNC«). In order to stabilize the BNC, additional specimens were infiltrated with an alginate hydrogel (»alginated BNC«)

$$\varepsilon = \left[\frac{1}{E} + \frac{dt}{\eta} \right] \cdot \sigma + \frac{v}{3},$$
$$E, \eta, v = f(\varepsilon)$$

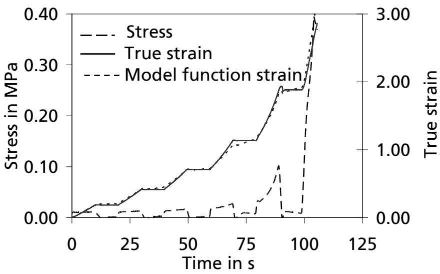


The deformation response was studied experimentally by applying displacement ramps with resting periods.

In order to describe the deformation response under compression and tensile loads of pure and infiltrated BNC, a Maxwell model with an additional swelling component and strain-dependent moduli and volume was used.

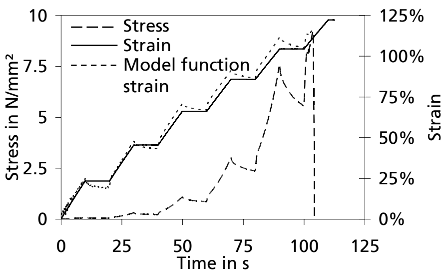
Results

Compression tests: pure BNC



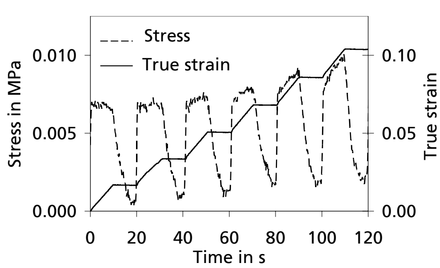
- Force response during compression periods
- No force response during resting periods
- Viscous response at moderate strains
- Volume change and water loss considered when determining true strains

Tensile tests: pure BNC



- Force response during tensile loading
- Visco - elastic response during resting periods
- Deformation response with elastic and viscous components

Compression tests: alginated BNC



- Force response during compression periods
- Visco-elastic response during resting periods
- Deformation response with elastic, visco-elastic and viscous components

Summary

The mechanical response of pure BNC is dominated by

- the viscous response of the water contained in the fiber network
- the elastic response of the fiber network

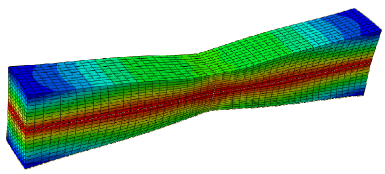
The fiber network can be stabilized with an alginate hydrogel (cross-linked with Ca^{2+} ions). This results in an

- elastic response under compressive loading
- and higher values for the viscosity $\eta(\varepsilon)$ under tensile loading

The infiltration of the BNC with an alginate hydrogel offers the possibility to adjust its mechanical properties.

Outlook

The material model based on the Maxwell model forms the basis for FE-modeling of BNC components.



The insight into the mechanical behavior of BNC will be used to gain an understanding of the tribological contact, friction and wear of BNC.

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