Tensile and fatigue properties of glass fibre / epoxy / nanocellulose composites

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DTU Wind Energy
Department of Wind Energy

VMA-GETZMANN GMBH
Verfahrenstechnik

INCOM

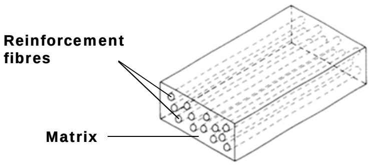
EU 7th Framework Programme, Collaborative Project

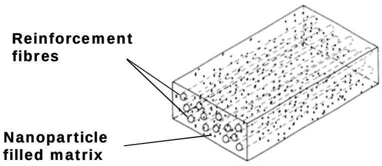
2013 - 2017

"Industrial Production Processes for Nanoreinforced Composite Structures" (INCOM)

The objective of INCOM is to develop economical viable production methods for lightweight composite structures based on sustainable materials

- *The addition of nanoparticles (carbon nanotubes, nanocellulose, halloysite nanotubes etc.) to polymers has for a long time been studied.*
- *Aim is to improve performance of polymers.*
- *Recently, studies have addressed the addition of nanoparticles to conventional fibre composites, to obtain nanoparticle filled matrix composites.*



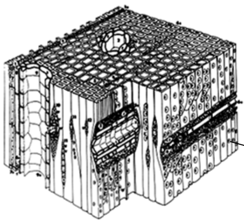


- *Aim is to improve matrix-dominated properties of the composites, such as impact strength, toughness and fatigue life.*
- ***Present study** addresses the potential of adding nanocellulose to conventional glass fibre composites, which are used for wind turbine blades.*

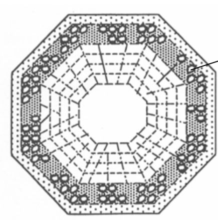
Wood (trees)

Plants (annual crops)

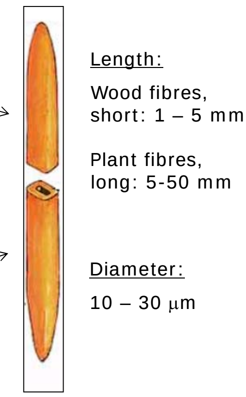
Wood stem structure



Plant stem structure

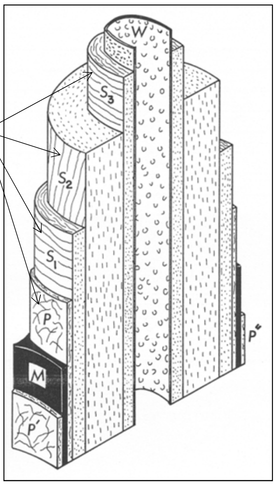


Cellulose fibre

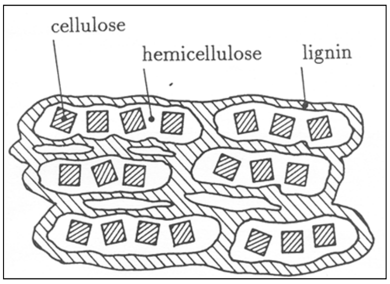


Cellulose fibre

Cell wall layers

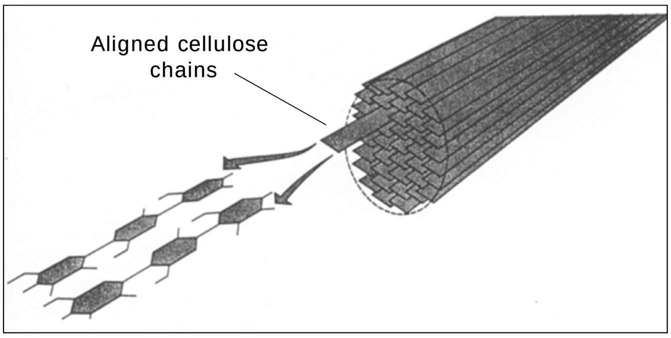


Cell wall cross-section



The cell wall of cellulose fibres is a ***composite material*** *consisting of cellulose microfibrils embedded in a matrix of hemicellulose and lignin*

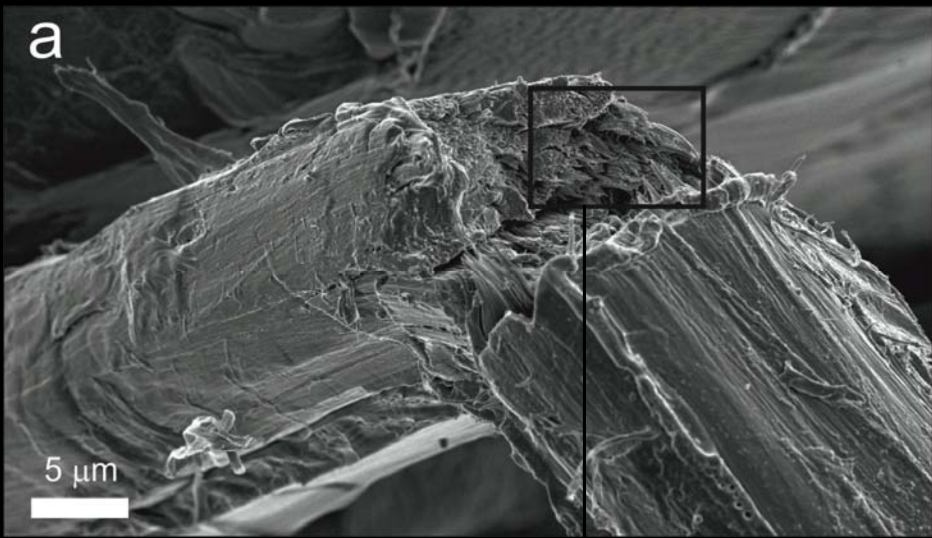
Cellulose microfibrils



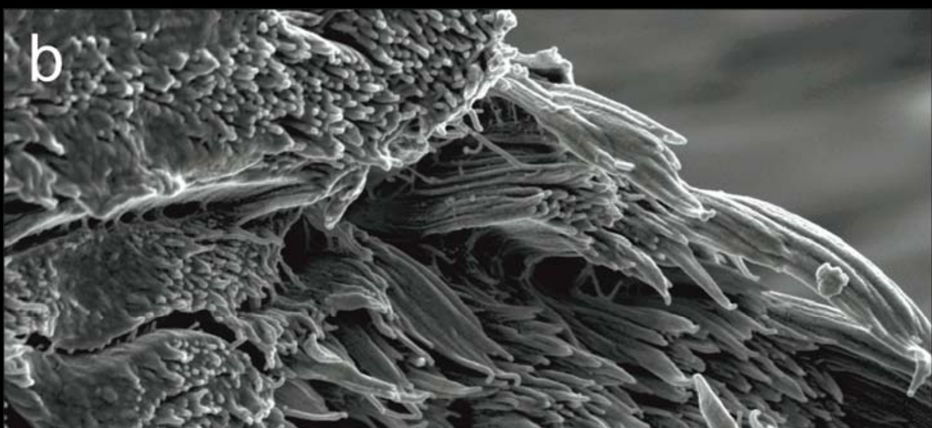
Properties of cellulose microfibrils

Density: 1.64 g/cm^3; Stiffness: 120 GPa; Strength: 15,000 MPa

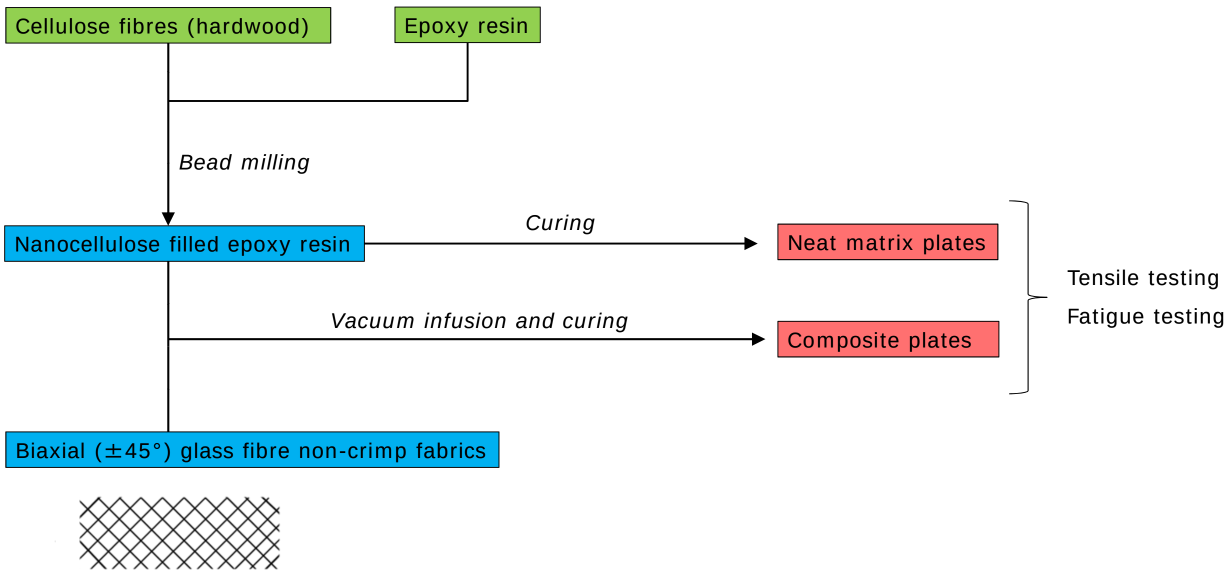
Partly broken cellulose fibre



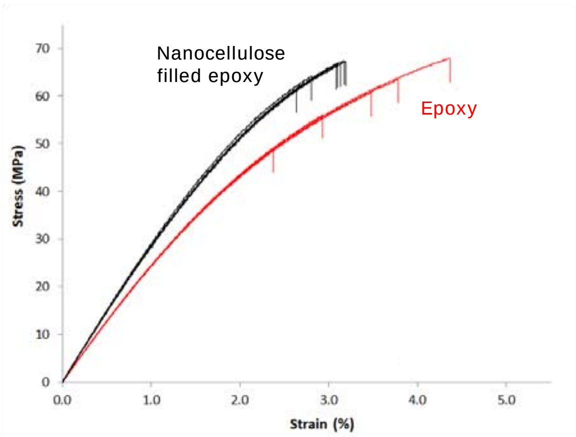
Cell wall with cellulose microfibrils



Experimental outline of study



Tensile stress-strain curves of neat matrix plates



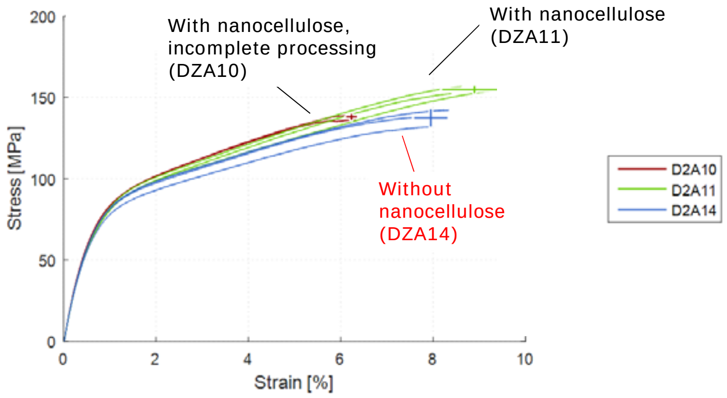
- *Stiffness of nanocellulose filled epoxy is slightly increased (3.5 vs. 2.5 GPa).*
- *Strength is unchanged, however, failure strain is decreased.*
- *The addition of nanocellulose to epoxy is making the polymer more brittle.*

Biaxial glass fibre / epoxy / nanocellulose composites

Plate code	Fabric type	No of fabric layers	Nanocellulose content in resin [wt %]
DZA14	Glass, ±45°	6	0.0
DZA10	Glass, ±45°	6	1.0
DZA11	Glass, ±45°	6	1.0

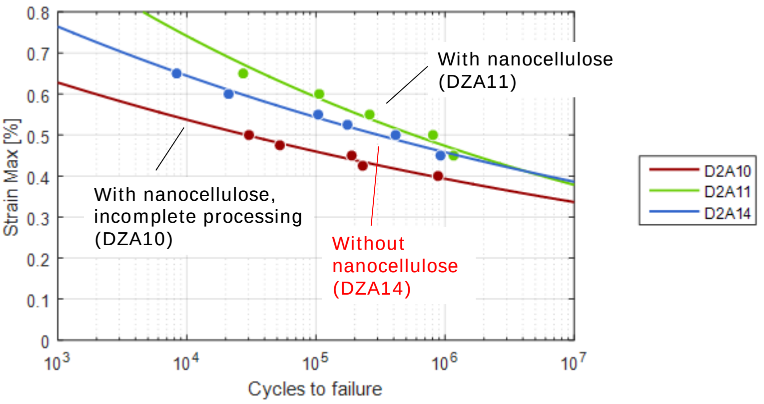
- *The fibre content was measured to be in the range 56-58 vol% for all three composite plates.*
- *A low porosity content of about 1 % was measured for all three composite plates.*
- *DZA10 was manufactured by an insufficient/incomplete vacuum infusion process.*

Tensile stress-strain curves of composites



- *Stiffness is the same for all three composites plates (in the range 13.5 - 14.8 GPa).*
- *DZA10 and DZA11 are following the same "curve", but DZA10 is failing prematurely.*
- *DZA11 is showing larger toughness and strength than DZA14, which is indicating a positive reinforcement effect of nanocellulose.*

Fatigue S-N curves of composites



- *The curve for DZA11 is above the curve for DZA14, which indicates that there is a positive effect of adding nanocellulose to the resin for the fatigue performance.*
- *Thus, at any given maximum strain value used in the cyclic loading, the composites can sustain a larger number of cycles before failure when nanocellulose is added to the resin.*

Conclusions

- The potential of adding nanocellulose to the matrix of conventional fibre composites has been studied.
- Focus has been on extending the fatigue life of composites.
- Case materials are biaxial glass fibre/epoxy/nanocellulose composites, manufactured by vacuum infusion.
- The addition of nanocellulose to the matrix of the composites leads to a slight increase in tensile strength and toughness.
- The fatigue life of the composites is increased.
- Altogether, it is demonstrated that nanocellulose offers a promising route for the improvement of matrix dominated properties of conventional fibre composites.