TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Science, Department of Biology, Institute for Botany, Chair for Botany

Functional branching morphology of arborescent columnar cacti

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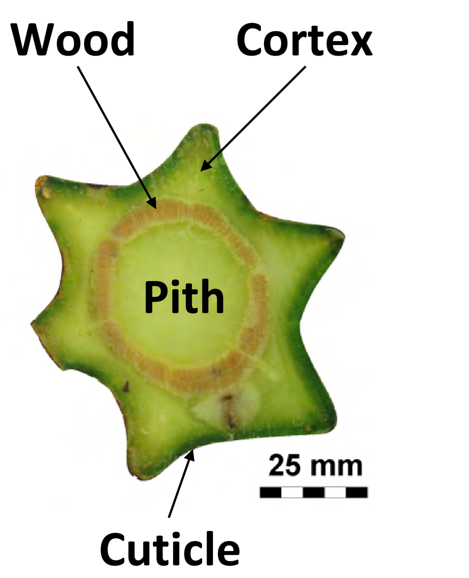
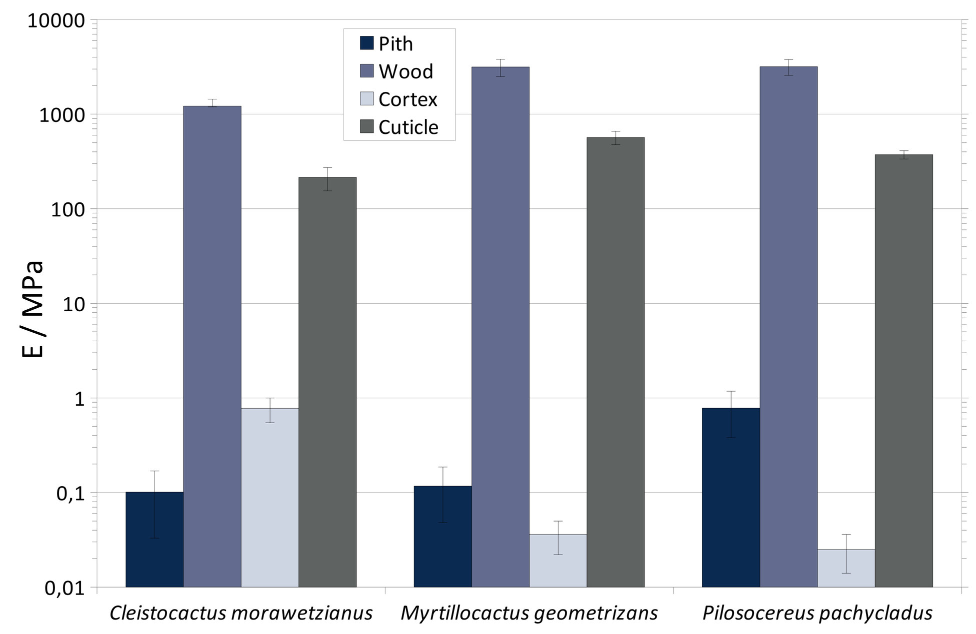
Pilosocereus pachycladus

In contrast to trees, the ramifications of arborescent columnar cacti exhibit distinct constrictions at the junction between branch and stem.
Aim of our investigations is to analyse the integrity and stability of cactus ramifications with state of the art engineering techniques. One approach is to set up detailed Finite Element Models (FEM) with the knowledge from extended morphological and anatomical investigations on cactus ramifications and the mechanical properties of the constituent cactus tissues.
The results might help to develop alternative concepts for fibre-reinforced composites with limited design space.

Material testing:



Stem cross section (*P. pachycladus*)

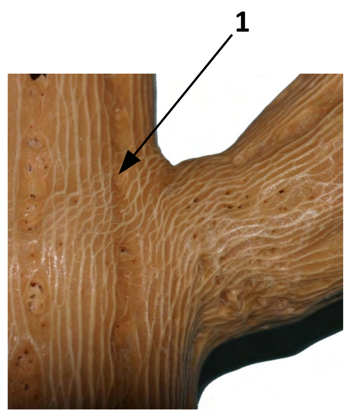


Young's moduli of the main tissues of different cactus species

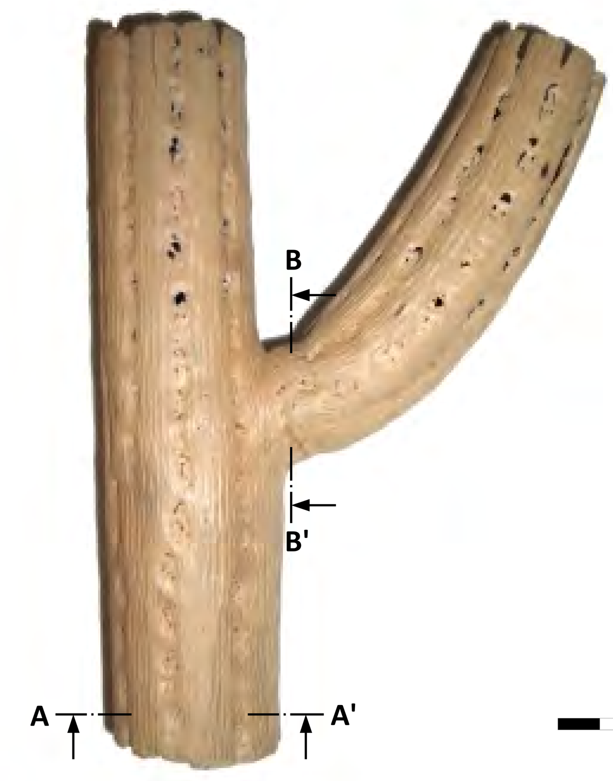
The material tests were performed as quasi-static tension (cuticle), bending (wood) and compression (pith & cortex) tests on a Zwicki-Line material testing machine by Zwick/Roell.

Anatomic studies:

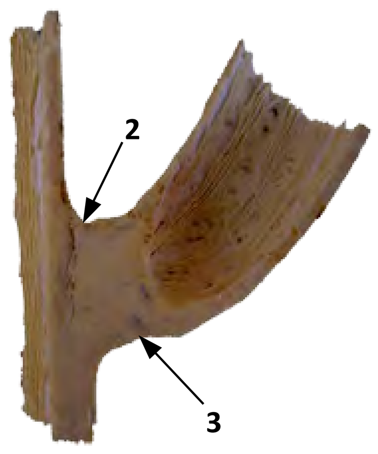
Non-dissceted ramification



Branching region



Wood structure of the ramification



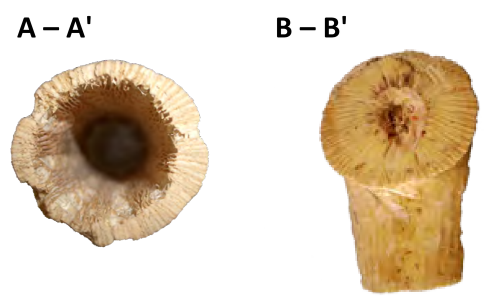
Branch base

50 mm

Microscopic wood sections

Tangential longitudinal section — Transverse section

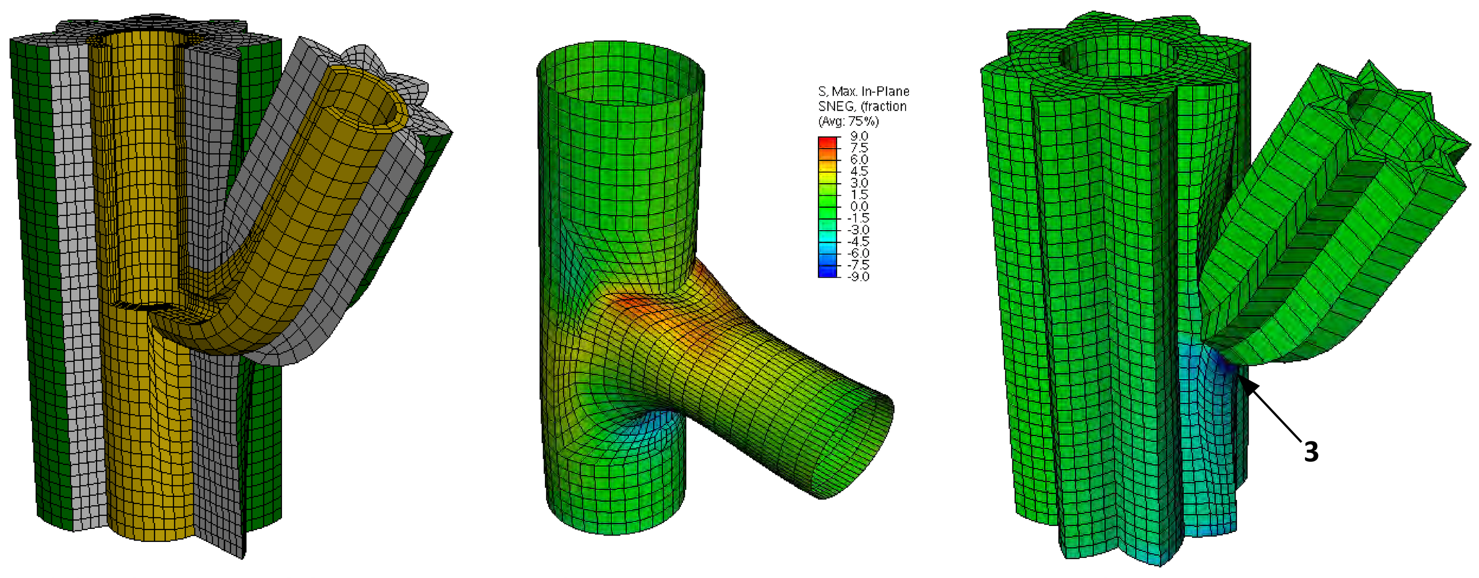
Macroscopic sections



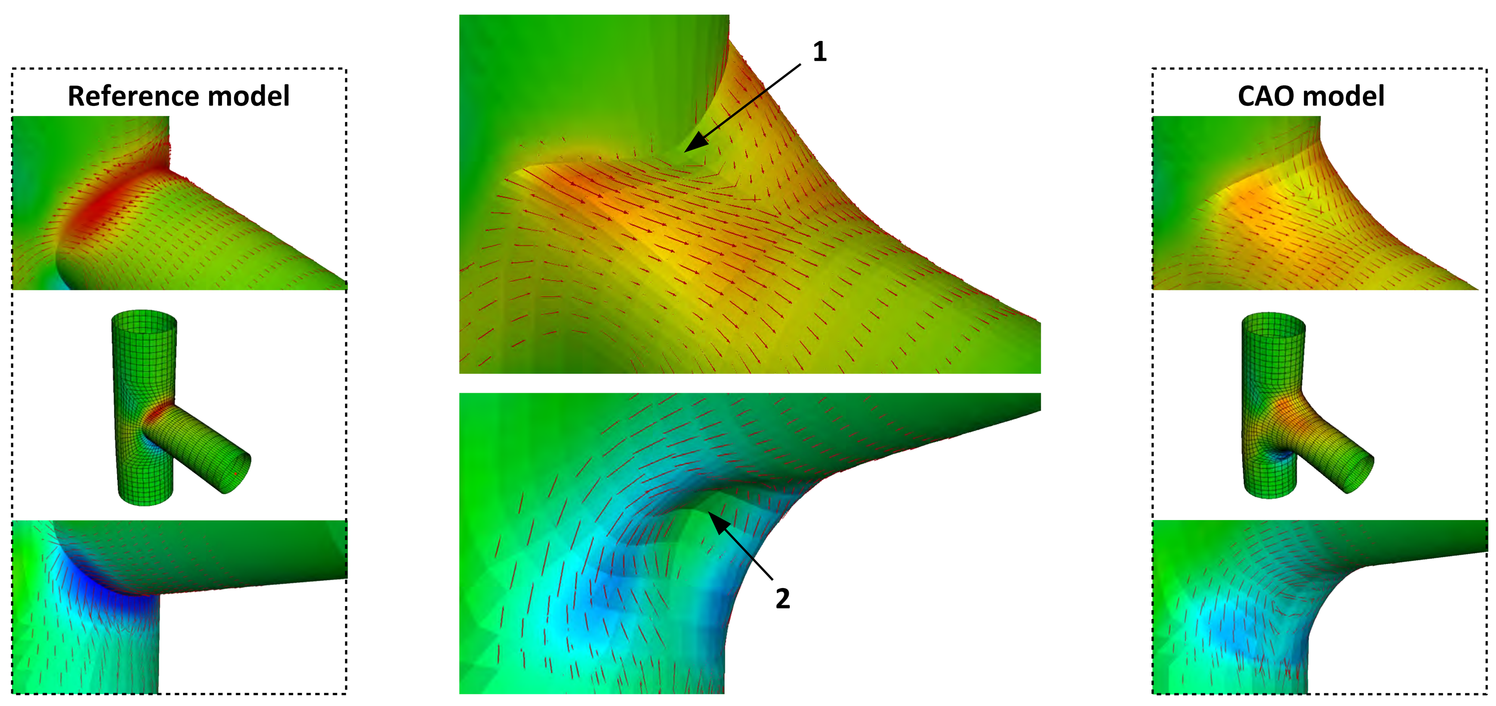
Stem — Branch base

The cactus wood beneath the succulent cortex, normally forming a broad cylinder of wood lamellae (A–A'), is reduced at the branch base to a compact socket (B–B') with distinct indentations on the adaxial (2) and abaxial (3) side. The longitudinal running wood lamellae show a higher degree of interconnection in the branching region (1). On microscopic level the cactus wood resembles diffuse porous hardwood. Its lamellar structure is due to the huge size of the rays.

Finite Element Analysis:



Finite Element Model — Woody support structure — Succulent cortex



Under self-weight conditions, the results show that the load adaptation does not follow the rule of stress homogenisation and minimisation by contour softening as described for hardwood trees (CAO model; Mattheck, 1990). The succulent cortex limits the secondary growth of the wood, hence it is more advantageous to tune the stress state by indentations to already predominant fiber directions (1,2). Another surprising detail is that compression stress on the abaxial side is partly dissipated by the parenchymatous cortex (3).

References

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3. Molina-Freaner F, Tinoco-Ojanguren C and Niklas KJ. 1998. *Stem Biomechanics of three Columnar Cacti from the Sonoran Desert.* AmJBot *85:* 1082-090.
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5. Schwager H, Haushahn T, Neinhuis C, Speck T and Masselter T. 2010. *Principles of Branching Morphology and Anatomy in Arborescent Monocotyledons and Columnar Cacti as Concept Generators for Branched Fiber-Reinforced Composites.* Adv. Eng. Mater. *12: B695-698.*

Collaboration Partners:

Botanischer Garten Plant Biomechanics Group
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