Wood as a Bio-Inspiring Material

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Wood – an Optimized Material

Structure

Mechanical, Fracture Properties

Wood Inspires Development of Fracture Tolerant Materials
Wood – Complex hierarchical structure
Layered and cellular composite

Layers: Annual rings, cell walls

Annual ring layers
Cells: hollow tubes
Cell wall layers: cellulose - lignin

Al-alloy –
Epoxi layers –
Aramid / Glass reinforcing fibres

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Cellular composites

Wood – cells: Hollow tubes
Low density AND High stiffness

Metallic foams – open and closed cells - low weight...

Beech microstructure   Differing cell sizes
  Wood rays perpendicular to longitudinal tracheids
  Fatigue fracture: $\varepsilon = 2.5 \times 10^{-3}$, $N_f = 1.24 \times 10^7$
Orientation and angle of fibres

**Flexibility:** Elementary fibril angle

**Strength:** Spiralic bundles of fibrils

**Nature:** wood

**Man-made rope**
Fracture tolerance – high fracture resistance
Non-LEFM

In situ splitting
ESEM
Spruce LR (R-)

WHY no brittle fracture?
• Crack branching
• Fiber reinforcement by thicker walled late wood cells
• Fiber bridging

Frühmann et al., CD-Labor 2003
Brittle fracture in TR (R-) orientation but final fibre bridging of crack

ESEM *in-situ* fracturing Spruce

Perlega et al 2007
Further Improvement  Compression Wood

In-situ Fracturing of Yew TR

Perlega et al, 2007
Change of Fracture Mode - Yew Compression Wood

Lower load:
• Intercellular (S2 – CML)

High load:
• Ray fracture - brittle

Keunecke et al 2007
Fibre Bridging in Yew Compression Wood

Keunecke et al. 2007
Elongated fibres reinforcing braching, bridging
Layers
Cells and holes crack stoppers

Summary: Fracture Tolerance by Shapes and Dimensions of Structure
Several Mechanisms of Crack Arrest

Several mechanisms → fracture tolerant

Gibson J. and Ashby M., 1988