Experimental Investigation of the Strength of Solid Wood Under Biaxial Loading Oblique to the Grain Direction

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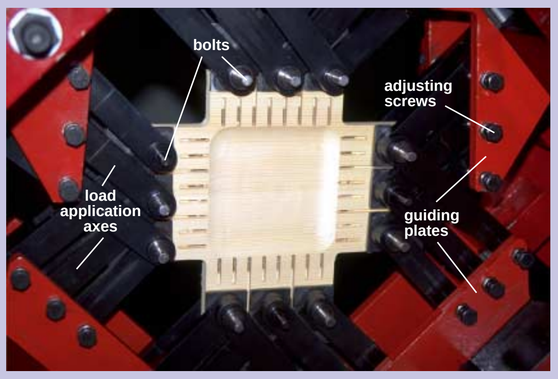
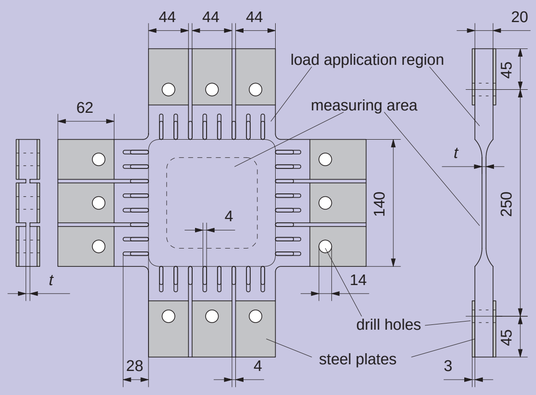
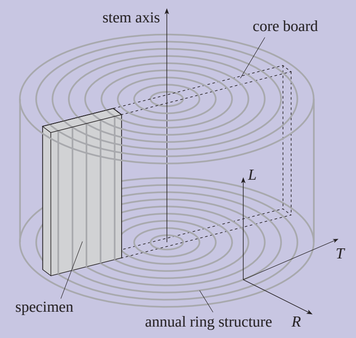
Concept and Equipment

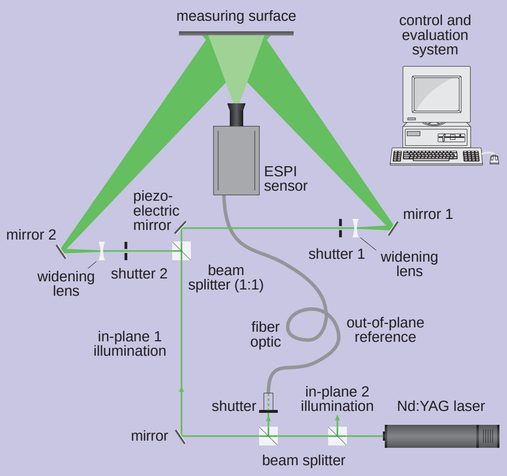




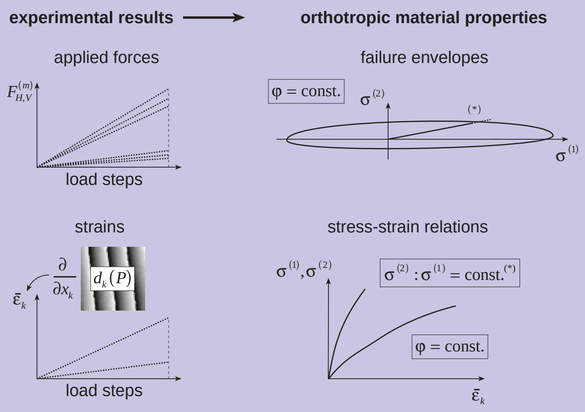


wooden board cut from LR-plane of a stem

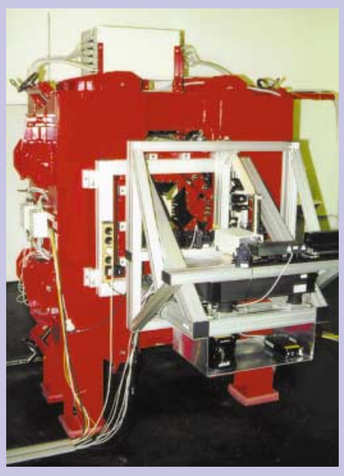
optical setup for in-plane-measurement



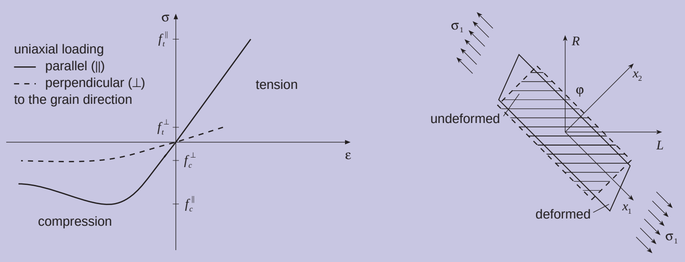
experimental concept



determination of stiffness and strength behavior as a function of grain direction φ and biaxial load ratio η



mechanical behavior of wood – fundamentals



characteristics of the biaxial testing equipment

- hydraulic testing device with 24 loading axes, force limit of ±15 kN, positioning accuracy of 2.4 μm each
- high sensitive (<< 1 μm) interferometric field measuring system for contactless deformation analysis of specimen‘s surface
- numerically optimized specimen (spruce): homogeneous grain structure, 12 % moisture content

Info

Realistic finite element ultimate load analyses of structural details as well as of shell structures made of wood require suitable constitutive equations for the prediction of the deformational behavior of biaxially loaded solid wood. However, there is a lack of adequate biaxial experimental data, particularly if loading situations are considered where the principal load directions do not coincide with the principal material directions.

In order to eliminate this deficiency a comprehensive experimental investigation of the stiffness and strength behavior of wood under arbitrary two-dimensional loading was carried out. The mechanical parameter of this experimental study are the ratio between the applied principal stresses and the angle between principal loading direction and grain direction.

The developed test equipment consists of a biaxial servohydraulic testing apparatus for anisotropic materials and of a three-dimensional Electronic Speckle Pattern Interferometer (ESPI) for the spatial deformation analysis of the measuring area of the plane cruziform specimen. The optimization of the shape and the loading of the wooden specimen was performed by finite element analyses.

The displacement-controlled experiments were characterized by a proportional stepwise loading until fracture was reached. The applied displacement steps varied within 4 and 10 μm. The experimental obtained failure envelopes for the investigated grain directions φ = 0°, 7.5°, 15°, 30° and 45° reflect the strong influence of the grain direction on the biaxial strength behavior of solid wood as it is known from uniaxial strength tests. The experimental results are a essential basis for further developments in material modelling.

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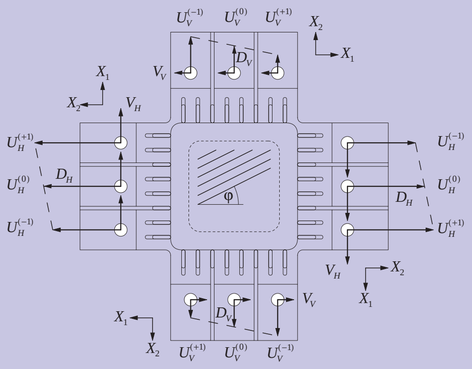
Experimental and Numerical Results

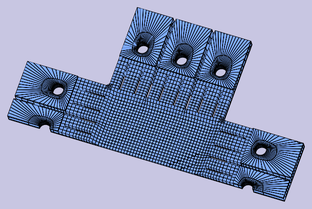
biaxial displacement increments (U, V)



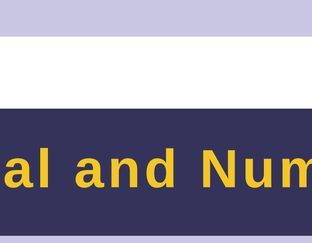
$$U_H^{(m)}(\eta,\varphi) := D_H + mD_H K_H(\varphi) + mD_V K_V(\varphi^*)$$
$$U_V^{(m)}(\eta,\varphi) := U_H^{(-m)}(\eta^*,\varphi^*)$$
$$V_H^{(m)}(\eta,\varphi) := D_H C_H(\varphi) + D_V C_V(\varphi^*)$$
$$V_V^{(m)}(\eta,\varphi) := -V_H^{(m)}(\eta^*,\varphi^*)$$

$\eta := D_V : D_H, \quad \eta^* := \eta^{-1}, \qquad m = -1, 0, 1$
$0° \le \varphi \le 45°, \quad \varphi^* := 90° - \varphi$
η … load ratio, φ … grain direction
$K_H(\varphi), K_V(\varphi), C_H(\varphi), C_V(\varphi)$ … coefficient

3D FE model of the specimen



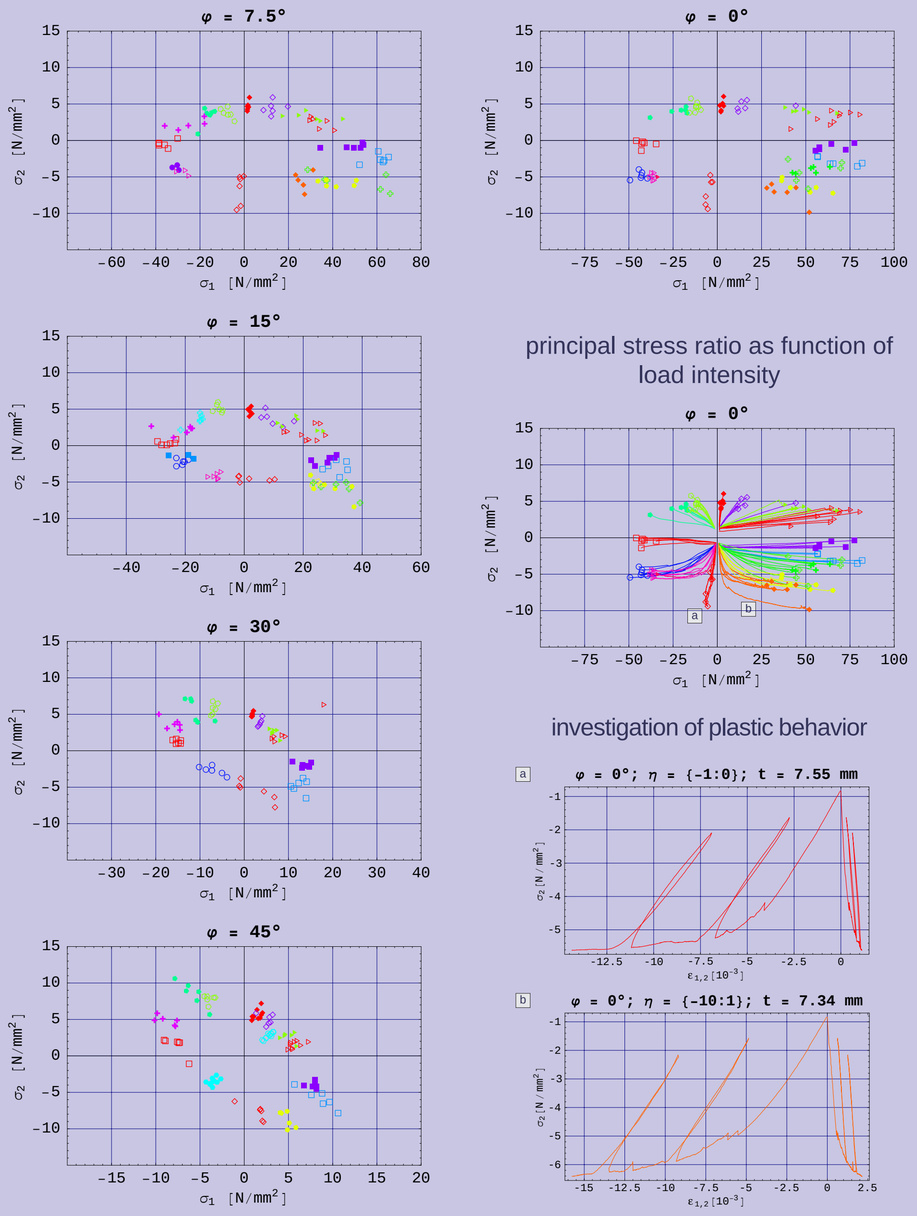
φ = 15°, η = 0:+1



component 1 of principal material stress [N/mm2]

horizontal displacement component [mm]

failure envelopes for investigated grain directions φ



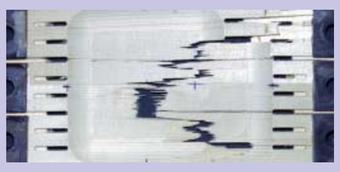
principal stress ratio as function of load intensity

investigation of plastic behavior

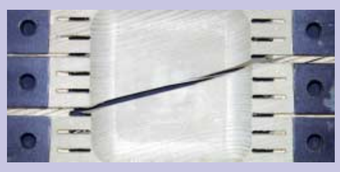
biaxial load ratios η

η =	0 : 1		η =	-5 : -3
η =	2 : 5		η =	-5 : -2
η =	1 : 1		η =	-5 : -1
η =	5 : 2		η =	-10 : -1
η =	1 : 0		η =	-1 : 0
η =	5 : -2		η =	-10 : 1
η =	5 : -4		η =	-50 : 13
η =	1 : -1		η =	-10 : 3
η =	3 : -10		η =	-2 : 1
η =	0 : -1		η =	-5 : 3
η =	-1 : -1		η =	-4 : 5
η =	-5 : -4		η =	-2 : 5

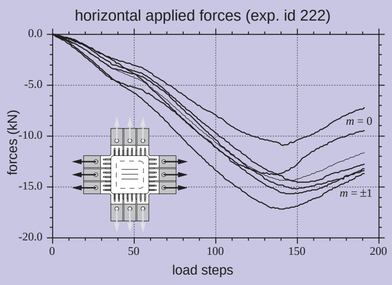
φ = 0°, η = 0:-1



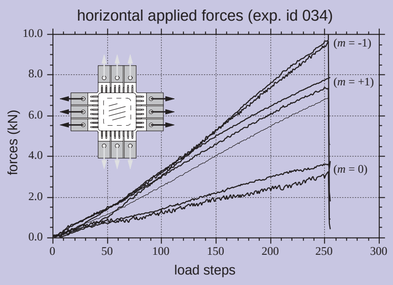
φ = 15°, η = -2:+1



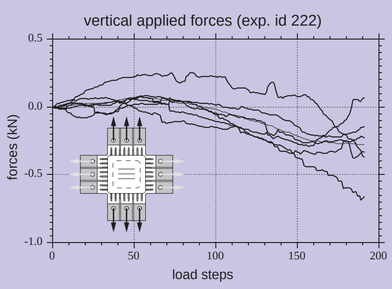
horizontal applied forces (exp. id 222)



horizontal applied forces (exp. id 034)



vertical applied forces (exp. id 222)



vertical applied forces (exp. id 034)