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Three-dimensional elasticity of yew (*Taxus baccata* L.) and spruce (*Picea abies* [L.] Karst.)

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ABSTRACT

With respect to its elasto-mechanical behaviour, the adult heartwood of Common Yew (*Taxus baccata* L.) stands out from the remaining European conifers: In spite of its high raw density, the longitudinal Young's modulus is astonishingly low and the elastic strain is high. This makes yew an interesting case study. The radial and tangential elasticity, however, is largely unknown.

Thus our aim was a comprehensive characterisation of the spatial macroscopic elasticity of yew at standard climatic conditions (20°C, 65% relative humidity). To achieve this, we first had to ascertain the elastic engineering parameters experimentally. By performing tensile tests on "dog-bone" shaped yew specimens, we determined the three Young's moduli and the six Poisson's ratios ν_{ij} with the aid of a Zwick Z100 universal testing machine and a digital image correlation technique (VIC 2D, Correlated Solutions). By measuring the ultrasound velocity of transversal waves (1 MHz) on small cubic specimens, we estimated the three shear moduli. All of the tests were also applied to spruce wood so as to serve as a reference species.

Table 1: Elastic engineering parameters and compliance parameters of yew and spruce.

	Moisture content	Elastic engineering parameters				Compliance parameters			
	ω	E_T	G_{LR}	ν_{LR}	ν_{RL}	s_{11}	s_{44}	$-s_{23}$	$-s_{32}$
		E_L	G_{TR}	ν_{TR}	ν_{RT}	s_{22}	s_{55}	$-s_{13}$	$-s_{31}$
		E_R	G_{TL}	ν_{TL}	ν_{LT}	s_{33}	s_{66}	$-s_{12}$	$-s_{21}$
	(%)	(MPa)	(MPa)	(-)	(-)	(Pa^{-1})	(Pa^{-1})	(Pa^{-1})	(Pa^{-1})
Yew	11	627	1740	0.041	0.46	1594	575	44	44
		10526	368	0.50	0.20	95	2717	535	324
		927	1650	0.48	0.029	1078	606	46	46
Spruce	12	397	617	0.018	0.36	2520	1621	28	28
		12799	53	0.48	0.21	78	18868	768	528
		625	587	0.45	0.014	1601	1704	35	35

The full set of elastic engineering parameters (Table 1) allowed the calculation of the 12 compliance coefficient s_{ij} and thus the description of the stress-strain relations of yew and spruce regarded as a rhombic crystalline system. Based on the compliance coefficients, the 3-dimensional elastic behaviour was describable, even when the load axis did not coincide with one of the three orthotropic axes L, R and T. For wood, the principle of the latter was shown for the first time by Hörig [1] and illustrated in 2-dimensional polar diagrams. Grimsel [2] transferred these interrelations to 3-dimensional illustrations (so-called "bodies of deformation"). They have to be interpreted as follows: To any arbitrary chosen axis in the 3-dimensional coordinate system representing the L, R and T directions of a wood species, an identical tensile load is applied. The bodies illustrate the degree of deformation depending on the load direction.

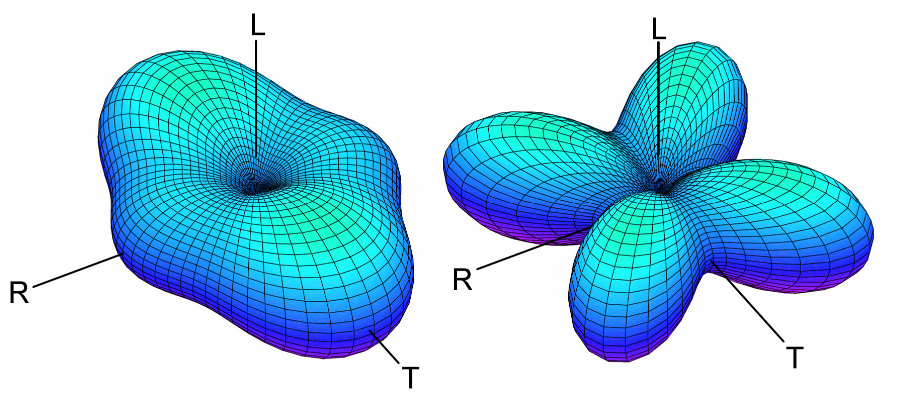

Fig. 1: Deformation bodies for yew (left hand side) and spruce (right hand side) under uniaxial tensile load

Deformation bodies of that kind based on the compliance coefficient listed in Table 1 are shown in Fig. 1. Evaluating these illustrations revealed that yew had a lower stiffness only in the longitudinal direction. In all other 3-dimensional directions, spruce was clearly more compliant than yew. As became apparent, both species varied largely in their degree of anisotropic elasticity particularly in the radial-tangential plane. All mentioned differences between yew and spruce originate at the microstructural level. When used for construction purposes, such results might help choosing the best-suited wood species under the given mechanical demands.

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