

Measurement of Young's modulus from tensile tests

1. Materials and methods

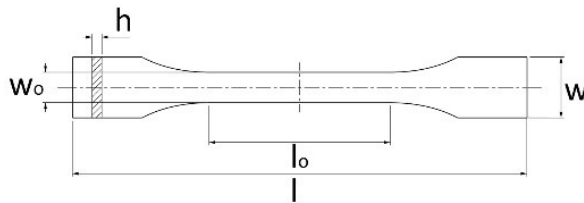


Figure 1: Sample geometry for tensile tests. Samples consisted of single material. Sample geometry corresponds to sample type 1BA of DIN EN 527 with a differing thickness of 1.6 mm.

The tensile moduli of Laywood meta 5 and PLA in all three states were determined according to DIN EN 527-2 (Table 1) on eight printed tensile bars for each material and state (Figure 1) using a universal testing machine (inspect table 5, Hegewald & Peschke Mess- und Prüftechnik GmbH, Nossen, Germany). Humidity was adjusted using a temperature chamber (T56 LN2, mytron Bio- und Solartechnik GmbH, Heilbad Heiligenstadt, Germany) where water vapour or nitrogen were introduced.

Table 1: Parameters for tensile tests. Non-specified parameters were chosen in accordance with DIN EN 527. Tests were performed on a universal testing machine, using a temperature chamber to control environmental conditions.

	Laywood meta 5	PLA
Test speed	0.6 mm/min	0.6 mm/min
Final Displacement	0.87 mm (wet), 0.3 mm (dry, humid)	0.3 mm
Load cell	100 N (wet), 1000 N (dry, humid)	1000 N
Printing direction	transversal	longitudinal

2. Results

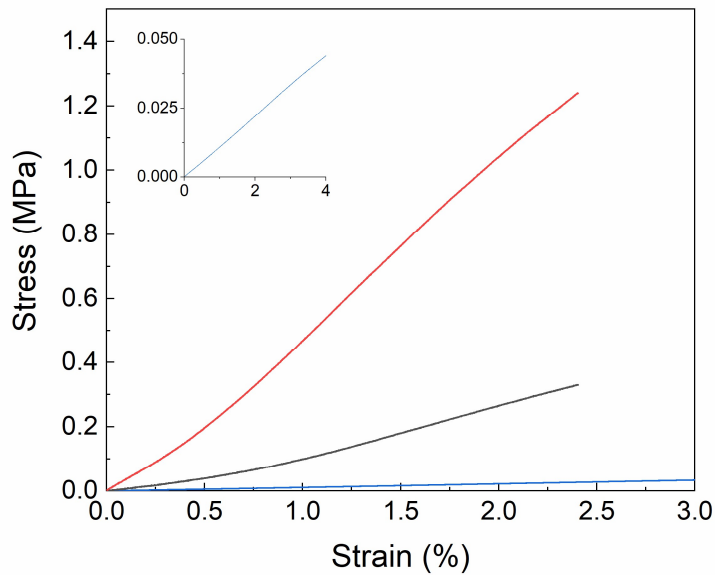


Figure 2: Exemplary curves from tensile tests for Laywood meta 5. Blue: Wet state. Green: Humid state. Red: Dry state. Young's modulus decreases with water uptake. The linear range ends at about 2% strain.

Values for Young's moduli are very different between Laywood and PLA with the ratio of Young's moduli n in the range between 20 and 60 for dry and humid state respectively (Table 2). For tensile moduli, an approximately 60-fold increase from wet to dry state can be seen in Laywood. The tensile moduli for PLA show a small increase from wet to dry state. Due to a more similar stress state, the flexural moduli were used for calculations of bilayer deflections and curvatures.

Table 2: Young's moduli in all states. Measurements given as median (IQR). N = 8

	Tensile modulus in MPa		
	Wet	Humid	Dry
Filament 1	1.2 (0.2)	17.1 (1.1)	56.8 (4.6)
Filament 2	0.8 (0.1)	17.9 (3.2)	63.4 (7.3)
PLA	1008 (19)	1078 (26)	1070 (24)