USE OF WOOD-PLASTIC COMPOSITES AS MATERIAL FOR 3D PRINTED BILAYER ACTUATORS

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Authors

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STRUCTURE OF PRESENTATION

- Sustainable view on 3D printing
- Materials, methods and results of our research
- Conclusion

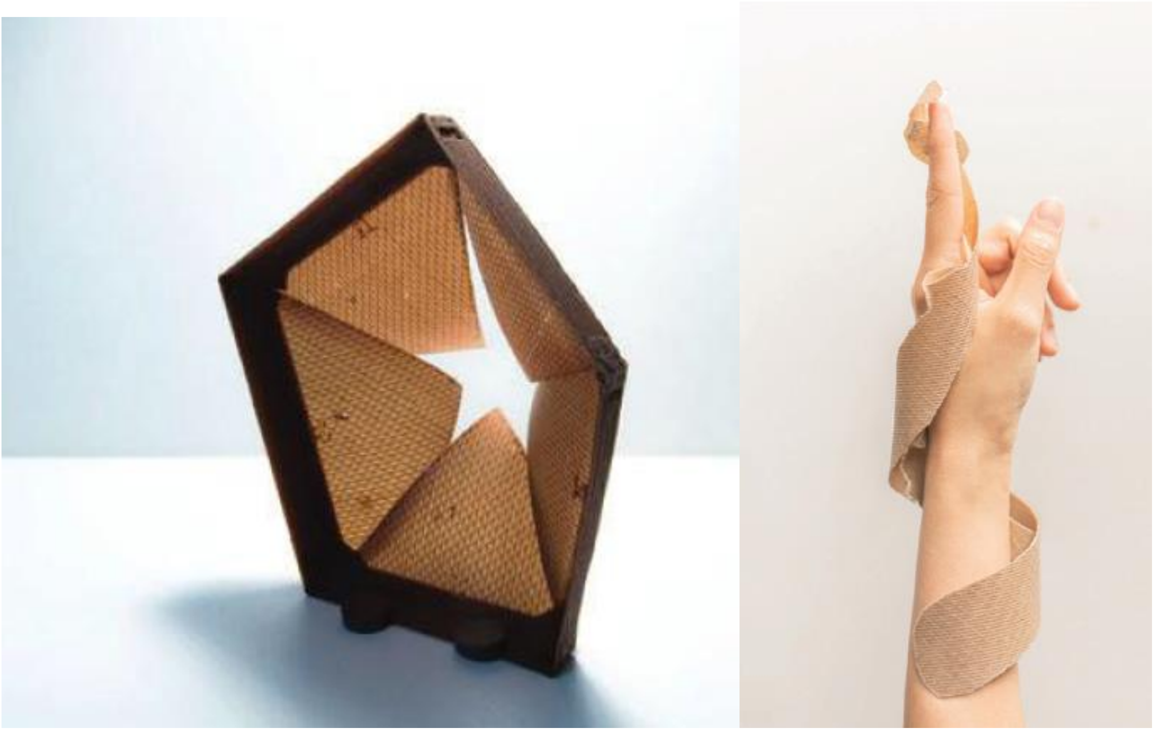

Figure 1. The single-material (left; Correa, 2015) and bi-material 3D-printed elements (right; Cheng et al., 2021)

SUSTAINABLE VIEW ON 3D PRINTING

3D printing methods => better environmental characteristics.

Primary environmental benefits as follows:

- reduction of raw material requirements in the supply chain,
- reduced need for energy-intensive manufacturing processes and wasteful/harmful materials,
- flexibility in designing,
- reduced weight of products,
- parts could be manufactured closer to the point of consumption (Peng, 2016),
- extended product life – easier repair, remanufacture and refurbishment (Ford and Despeisse, 2016).

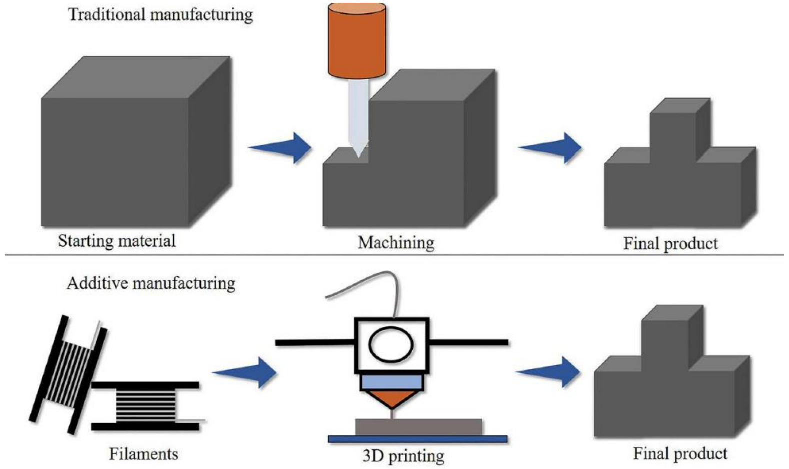

Figure 2. Conceptual comparison of traditional and additive manufacturing (Persons, 2015)

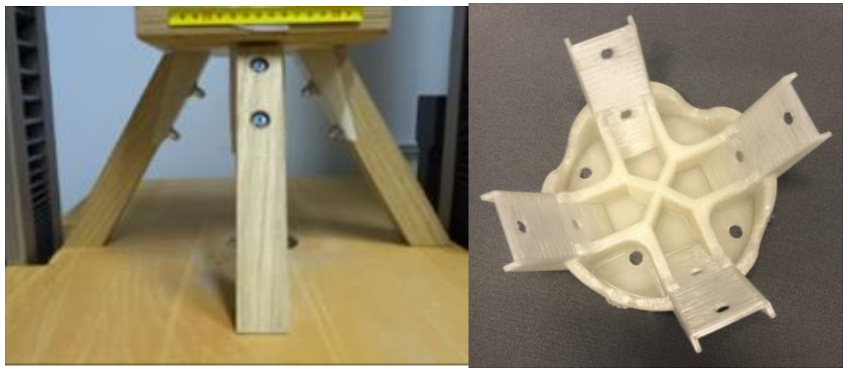

Figure 3. Chair connector made of PLA material (Cvetko M., 2020)

- To overcome resource scarcity => cascading use of biomass and in using by-products more efficiently - filaments made with wood flour.
- The use of AM is increasing => the search for natural-based materials for 3D printing.
- Wood - as a filler or as a reinforcing component. Wood particles - from wood waste from other woodworking industries, adding value to low-cost waste materials or from invasive non-native plants – turning them from harmful into useful products.

Figure 4. Wood residuals (http://www.biofuelmachines.com/Wood-briquettes-treasure.html)

Figure 5. Wood-PLA filament (https://3dprint.me/product/pla-wood-polywood-polymaker-285-mm-s-size/)

- The addition of wood to PLA => hygroscopically active composite, responds to variation in different humidity levels.

- Trend of smart materials – memory shaped materials, adding a new function to 3D-printed elements => 4D printing.

- FDM printing materials with or without wood particles were used to design shape-changing bilayer actuators (an active façade or ventilation valves).

MATERIALS AND METHODS

- Three filaments: PLA (Plastika Trcek, Slovenia; abbreviated as PT) and two Wood-PLA filaments; one with 15 % and other with 25 % of wood share (Kompetenzzentrum Holz GmbH, Linz, Austria; abbreviated as WPL15 and WPL25).
- Creality CR10-V3 (Creality 3D Technology Co., Ltd, Shenzhen, China) with a direct extruder.

Figure 6. 3D printer CREALITY CR-10 V3 (creality3dofficial.com, 2021)

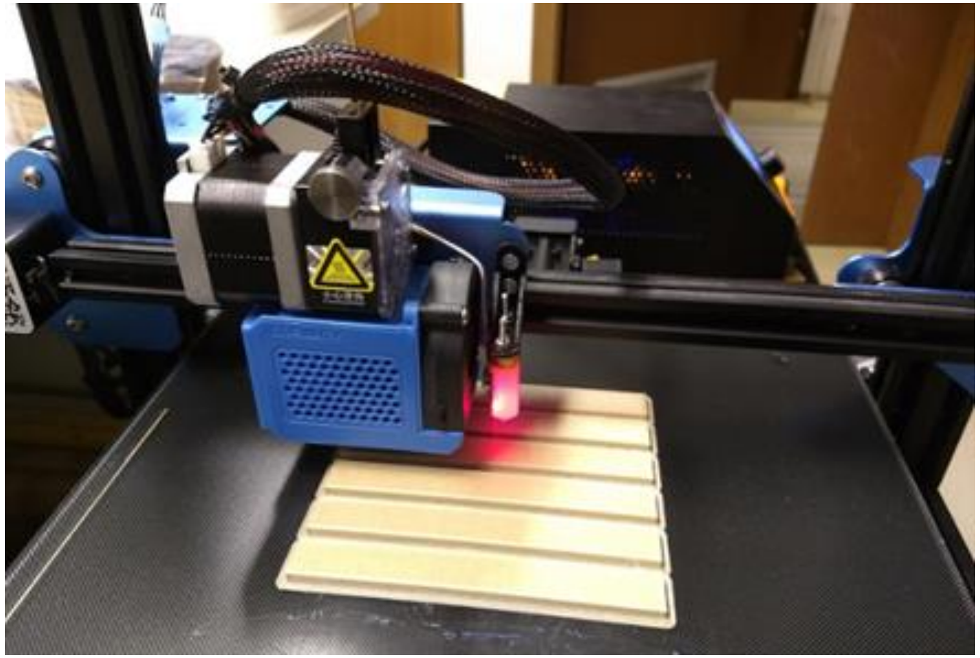

Figure 7. 3D printing of samples (Kokot M., 2021)

2.1DIMENSIONAL STABILITY OF THE MATERIALS

- Samples for first step - dimensional stability - moist/drying tests, dimensions 120 × 15 × 4 mm^3 (length × width × thickness).
- The dimensional stability tests - in the laboratory drying tunnel TLS-01 (Kambič, Semič, Slovenia).
- The moisturizing kinetics of 3D-printed samples - of 80 % or 20 % RH, T 20 ^oC. The moisturizing process: interval weighing and measuring three dimensions of samples.

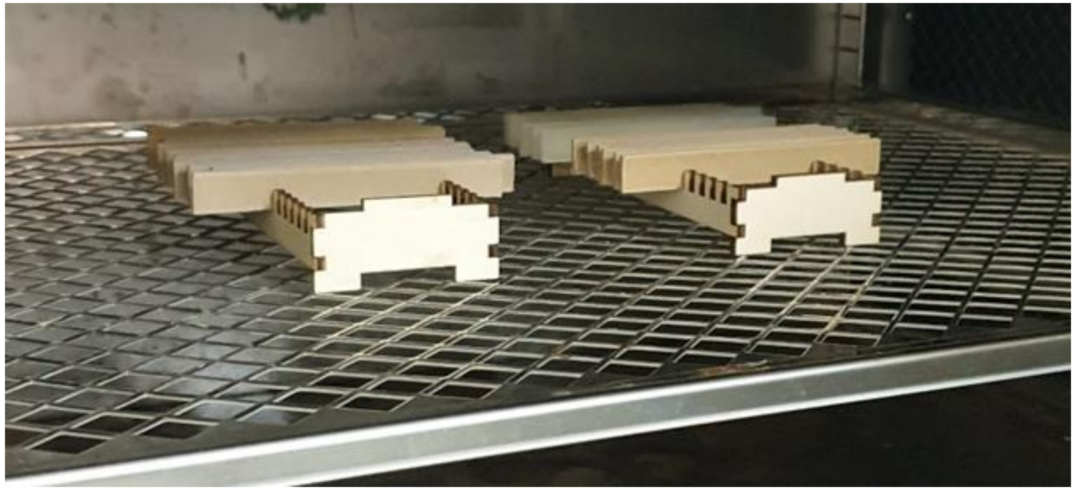

Figure 8. Samples in the laboratory drying tunnel

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- The lowest longitudinal swelling - PLA (0.09 %). Wood-PLA - higher longitudinal expansion (0.3 and 0.47 %). WPL 25 - highest length expansion.
- Moisture adsorption with wood content in composites - free hydroxyl groups (OH) of hemicelluloses and amorphous cellulose within the cell wall of wood fiber (Neagu et al., 2006).
- The relationship between wood content and moisture uptake applies correspondingly to mass change.

Specimens	Mass change during moisturizing in %	Mass change during drying in %	Length expansion in %
PT	0.61	- 0.45	0.09
WPL 15	1.91	-1.50	0.30
WPL 25	2.82	-2.15	0.47

Table 1. ***Mass*** *change* ***and length expansion*** *during* ***moisturizing and drying*** *- according to the material*

2.2 BENDING PROPERTIES OF SELECTED MATERIALS

- Samples conditioned in standard climate (20 °C, 65 % RH) and tested in a 3-point bending test on Zwick Z005 universal testing machine (ZwickRoell GmbH, Ulm, Germany).

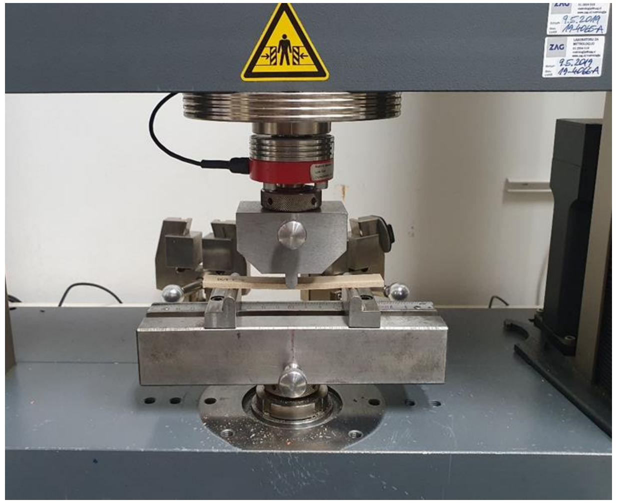

Figure 9. 3-point bending test

Specimens	Average MOE in [N/mm^2] at 65 % RH	St. dev.
PT	3107	222
WPL 15	2168	139
WPL 25	2238	237

Table 2. MOE for samples conditioned at 65 % RH

- Values of material with 25 % wood content were higher than those of material with 15 % wood share. At low wood additions - reinforcement, at higher loads the polymer cannot fully encapsulate the particles => poor bonding and limited load transfer.

2.3 SHAPE CHANGE OF BIMATERIAL ACTUATORS

Bi-material samples, 200 × 12 × 1.8 mm^3 (length × width × thickness); 0.3 mm (1 layer) pure PLA, 5 x 0.3 mm (5 layers) Wood-PLA

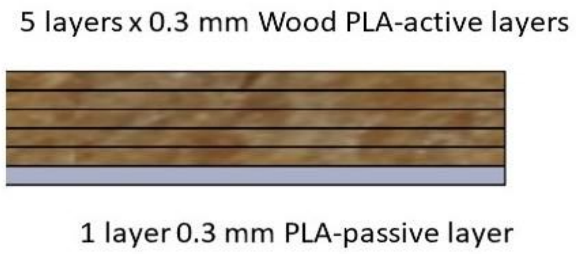

Figure 10. The composition of the bilayer actuator

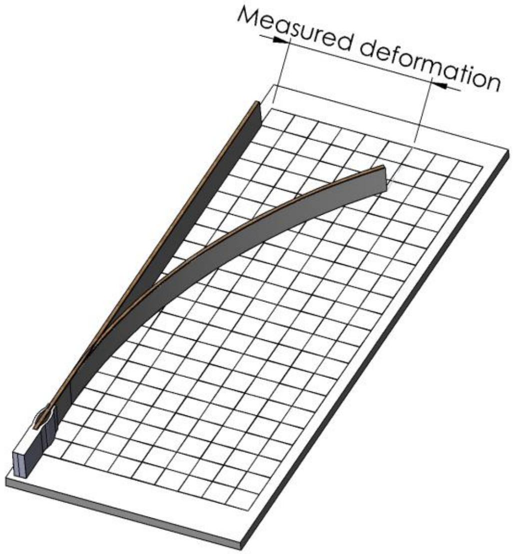

Figure 11. Bilayer clamped on one end on a template with millimetre grid

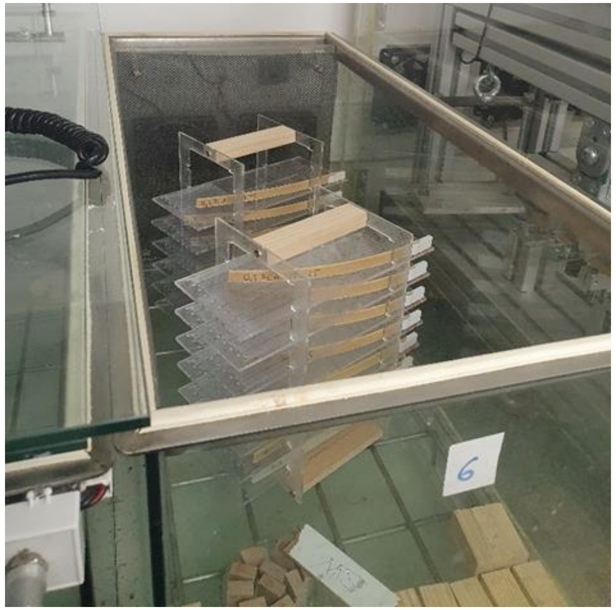

Figure 12. Samples in a climatic chamber

Humid thermostatic climatic chamber with 80 % RH and 20 °C. Measured deformation and weighing of samples. After one week => dry thermostatic climatic chamber (20 % RH and 20 °C).

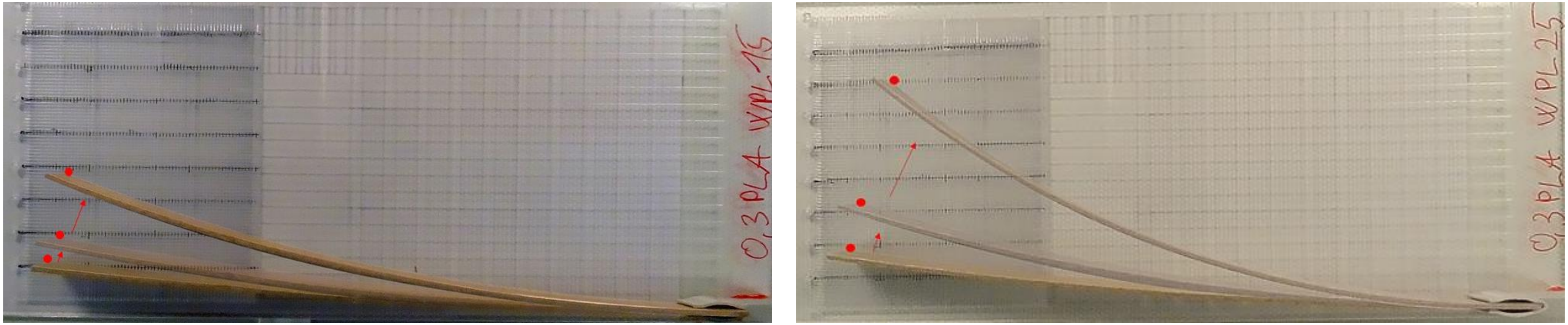

Figure 13. Curvature of samples 0,3PLA WPL15 and 0,3PLA WPL25 at initial position, after 6 hours and after 168 hours in 80 % RH and 20 °C

- Natural fibres act as an actuator in swelling => hygromorphic biocomposites should be developed with as high a volume fraction as possible. A high natural fibre content => faster and stronger swelling, improving reactivity and response of the actuator.

CONCLUSION

- Wood-PLA composites with different wood content could be used as materials for shape-changing actuators/products.
- Strains and mass change are bigger for material with higher wood content (WPL 25).
- PLA and Wood-PLA materials can be used for 3D-printed shape changing actuators, that change in alternating climate conditions. Further research is needed to evaluate their long-term behaviour and potential application in products.

THANK YOU

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