

Additive Manufacturing with Residues: Binder Jetting Applications in the SAMSax Living Lab

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Background & Motivation

- Climate change and resource scarcity require sustainable production solutions [1-3]
- Additive Manufacturing (AM) enables low-waste, flexible, and material-efficient manufacturing [4-5]
 - Binder Jetting (BJT) is especially suitable for integrating organic and industrial residues into AM processes [6-8]
- Living Labs as real-world platforms for interdisciplinary research and innovation [9-11]
 - simul⁺ model project SAMSax: Living Lab for the circular economy using AM – “Test before invest” for SMEs
 - focuses on regional, organic, and inorganic residues, integrating them into the Binder Jetting process, promotes sustainability and reduce reliance on fossil-based raw materials

Binder Jetting Technology at SAMSax

- ZPrinter 310 and Concr3de Armadillo White adapted for sustainable materials
- Large-scale Binder Jetting system
 - Experimental unit:
 - Lab-scale testing of materials, binders, and parameters, same ink system as production printer → 1:1 scalability
 - Production system:
 - 1 m³ build volume, up to 8 printheads
 - Supports particle sizes from 5-1000 µm & bulk densities of 0.1–4.5 g/cm³
 - Temperature-controlled, degassed, and filtered ink circulation

Methodology

- To assess AM suitability, each residue is tested for: particle size distribution, bulk & tap density, Hausner ratio, and Carr index
- > 50 residual materials have been analyzed and processed:
 - **Agricultural Residues:** (e.g., beech and birch sawdust), grasses like Miscanthus, and shells or kernels (e.g., hazelnut)
 - **Industrial By-products:** glass grinding dust, textile fibers (e.g., recycled cotton and denim fiber dust), and chromate-free sanding residues
 - **Specialized Organic-Inorganic Mixtures:** mineral-wood composites, pyrolysis coke, and cellulose-sand mixtures
- Binder Development:
 - Used: Polyvinyl alcohol (PVA)
 - In development: gelatin, rosin-based binders
 - Objectives: biodegradable, recyclable, bio-based

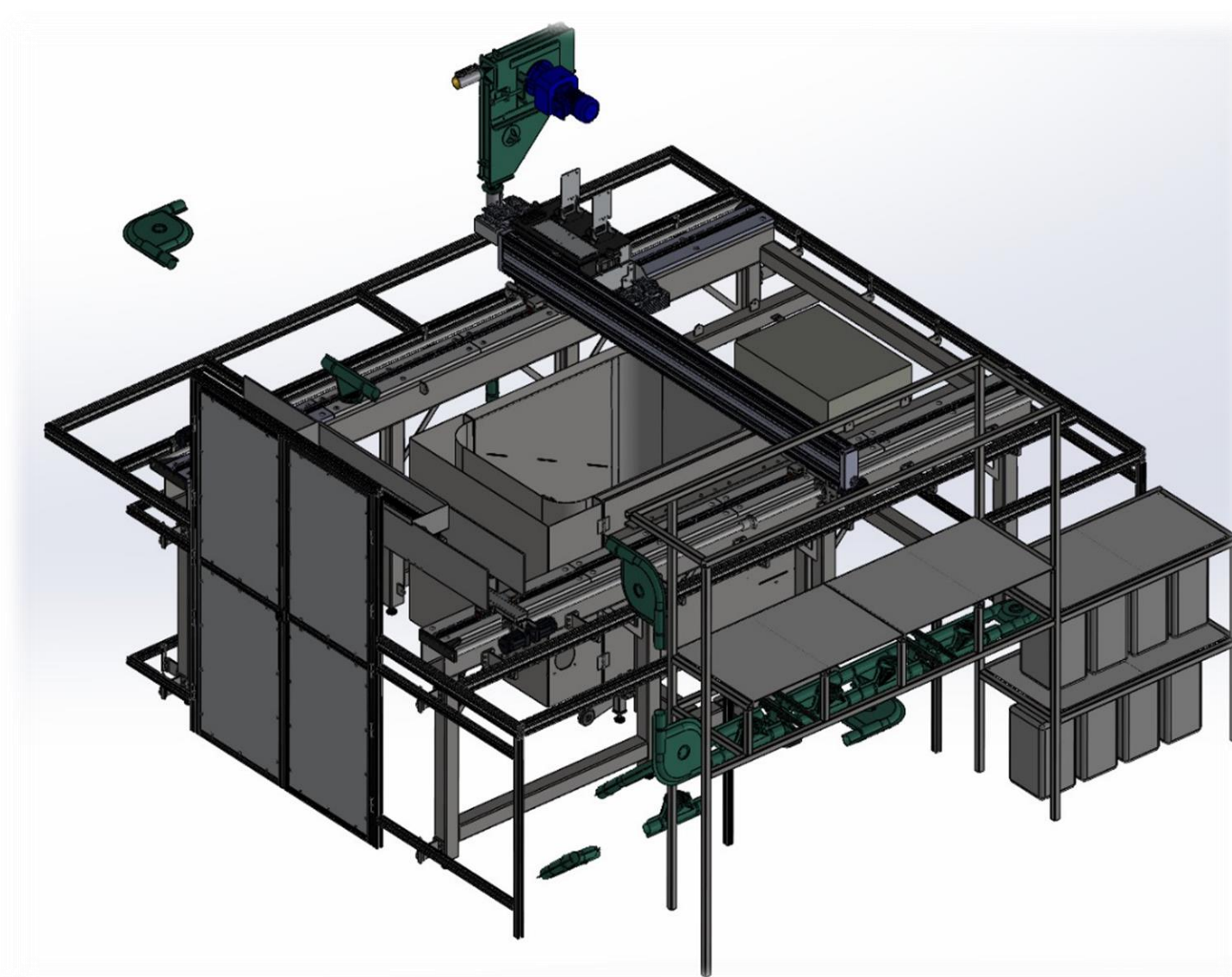


Figure 1: Construction phase of the production system, © C-Marx GmbH



Figure 2: Experimental unit and the production system, © C-Marx GmbH

Production of Stage Elements - Chemnitz Theater	Restoration Elements – Bust & Gargoyle	Shells for minerals - terra mineralia
<ul style="list-style-type: none">• Five identical column capitals produced using BJT• Material: powdered Miscanthus & 15 wt.% PVA binder, Water-based ink• Layer thickness: 250 µm• Printer: Concr3de Armadillo White• Focus on sustainable material use, fine detail resolution	<ul style="list-style-type: none">• Collaboration with INTOPLAN GmbH• Material: adapted mortar suitable for Binder Jetting• Layer thickness: 0.1 mm; saturation level: 120%• Printer: ZPrinter 310• Focus on water resistance, fine details, and restoration-grade precision	<ul style="list-style-type: none">• Custom shells for mineral exhibition drawers• Material: Miscanthus• Printer: Concr3de Armadillo White• Post-processing: resin infiltration + black lacquer• Ensures object stability, aesthetic presentation, and tailored fit



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Conclusion & Outlook

- Binder Jetting (BJT) enables the upcycling of diverse residual materials into functional products
- The dual-system setup supports both material innovation and scalable production
- Expand the material library with new bio-based and industrial residues and refine powder-binder formulations for better printability and consistency
- Investigate industrial-scale applications of sustainable Binder Jetting and Explore complex geometries and multifunctional components
- Reinforce circular economy principles: reduce, reuse, recycle

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