NFPP Lattices to Enhance Formability of Cellulose Nonwovens

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WEAV3D®

VOLKSWAGEN GROUP OF AMERICA

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Outline

- Background
- Project Objectives
- Lab Scale Forming Trials
- Forming and Validation of Full-Scale Demonstrator
- Summary of Results

Why Paper as Composite Reinforcement?

Material emissions to account for 60% of total vehicle life cycle emissions by 2040*

Most industrial natural fibers stem from dedicated plants – grown only in specific regions → high logistics footprint

Large-Scale Recycled Feedstock

- Approx. 40% of all solid waste is paper and cardboard (46 million tons in USA, 2018**)
- Existing supply chains all over the world

Image source: RecyclingInside

Additional Benefits over Other Natural Fibers

- Improved quality control
- Not competing with food crops
- Variety of aesthetics available (natural, bleached, dyed, etc.

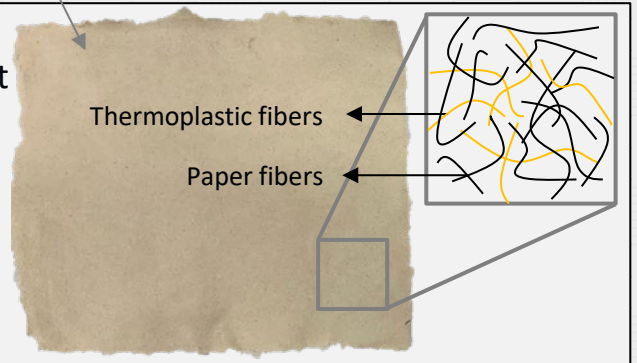
*World Economic Forum - Paving the Way: EU Policy Action for Automotive Circularity
**www.epa.gov

Paper Composites – Benefits and Limitations

Conventional manufacturing technology and equipment

Benefits
- Established molding equipment
- Robust supply chains

Limitations
- Short fiber lengths
- Low melt shear strength
- Low gsm / sheet



Hybrid paper composite sheets

Back injection molded interior panels

Opportunities
- Parts can be back injection molded
- Natural fiber composites are fully recyclable
- Can combine recycled pulp and recycled plastic
- Lattices can improve molding of complex geometries from flat sheets

Paper composites are a cost-efficient alternative to nonwoven NFPP

Image Sources: Molded Pulp Products Manufacturing: Process Development, Characterization and Modeling (2020), Commercial Aircraft Composite Technology (2016)

Why WEAV3D Composite Lattice?

TUNEABLE

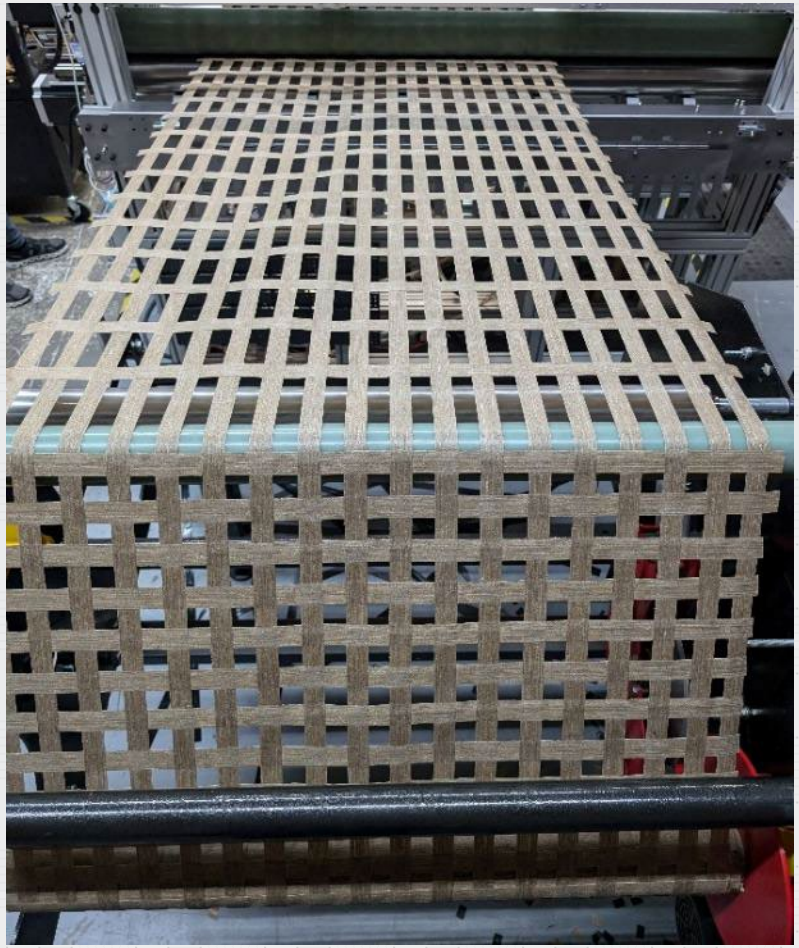
- Locally optimized lattice density
- UD tapes control strain during forming and increase melt strength

COST-EFFECTIVE

- Automated continuous process
- Co-formable with paper composite in single step

COMPATIBLE

- Sheet or roll format
- NFPP tape option available for monomaterial solution



Strategic use of UD tapes in lattice provides a cost-effective and adaptable solution

Project Objectives

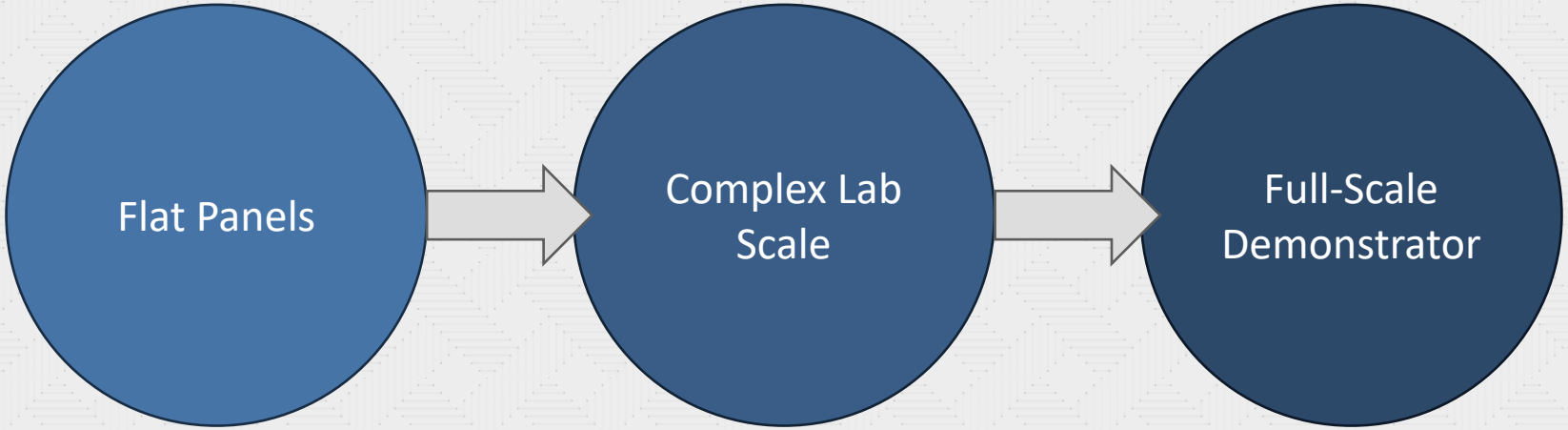
Full Scale Part Forming Goals

1. Eliminate thru-thickness tearing of paper composite in deep draw/complex parts
2. Identify tool and process changes needed to convert from nonwoven NFPP to paper composite

Experimental Goals

1. *Characterize effect of lattice on flexural properties vs. baseline*
2. *Characterize water uptake of lattice reinforced panels vs. baseline*

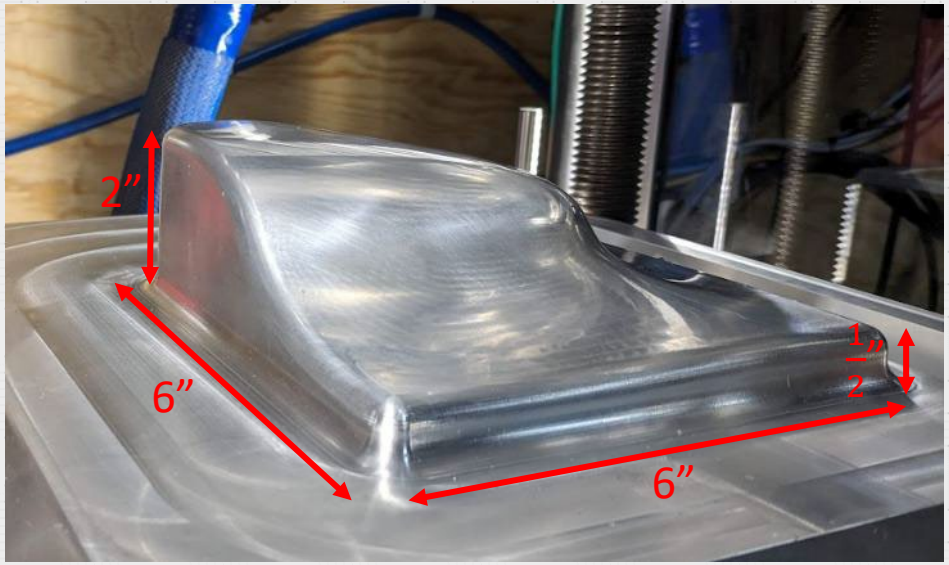
Presented at:



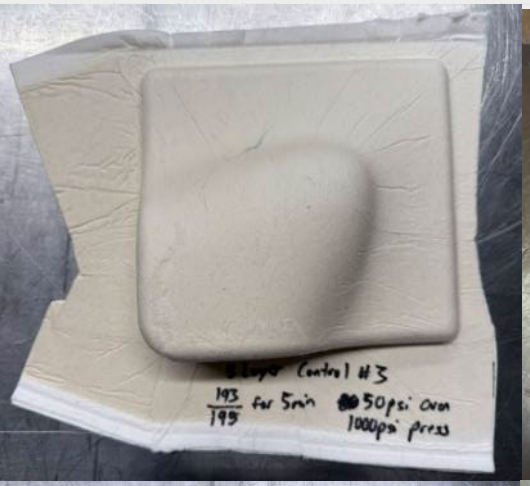
Lab Scale Forming

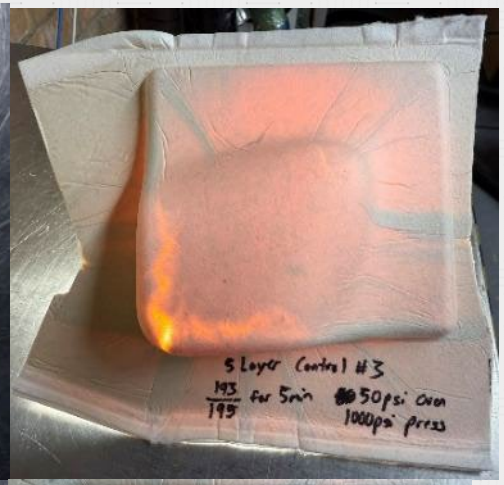
Experimental Approach

1. WEAV3D has a 25-ton thermocompression workcell, with contact oven and manual shuttle
2. Complex geometry tool (~6”x6”x2” cavity) with:
    1. 2” vertical draw corner
    2. Double curvature/bullet nose
    3. ½” step down on 3-sides
3. Control panels (no lattice) molded to establish tearing behavior and layer count limits of tool
4. GFPP and NFPP lattice reinforced panels molded with varying lattice spacing and lattice positioning to understand locality effects of tape position



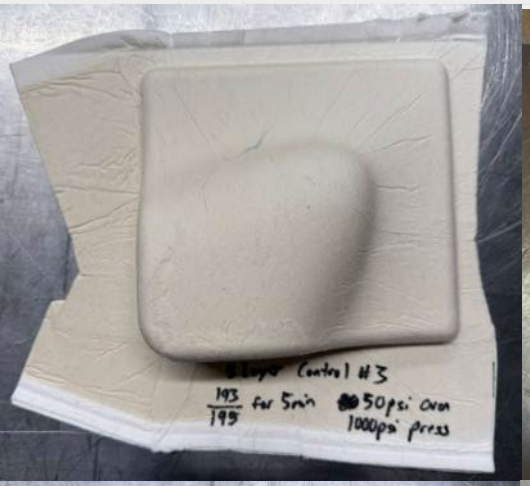
Complex Forming – GFPP 50-50

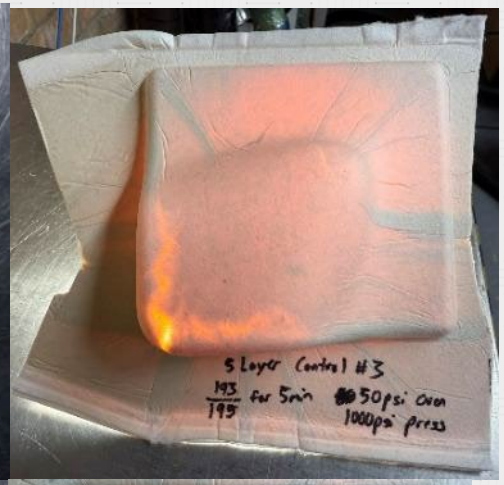




Control 5-Layer

Complex Forming – NFPP 50-50

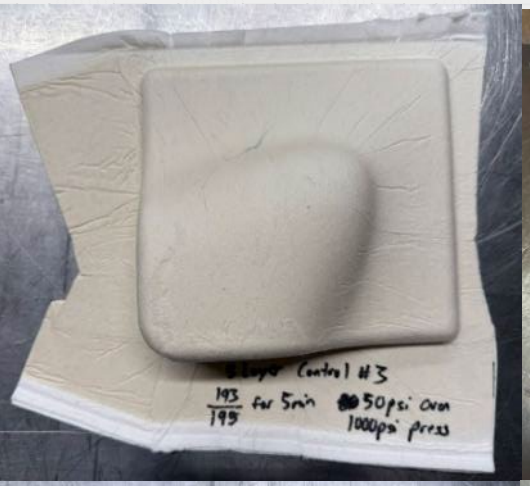


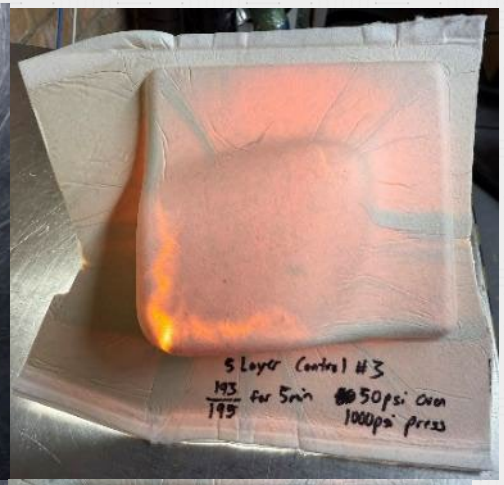


Control 5-Layer

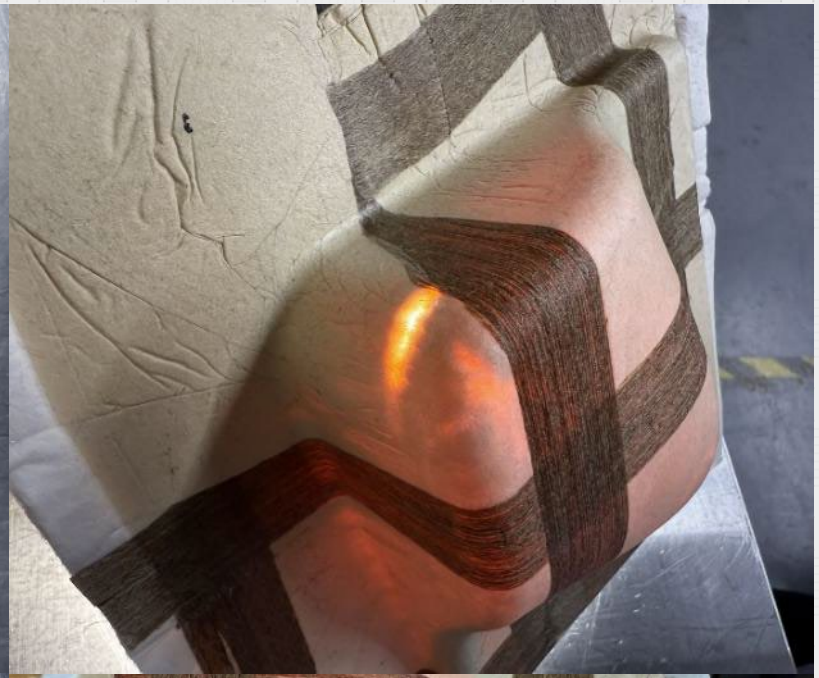
5-Layer

Complex Forming – NFPP 25-25

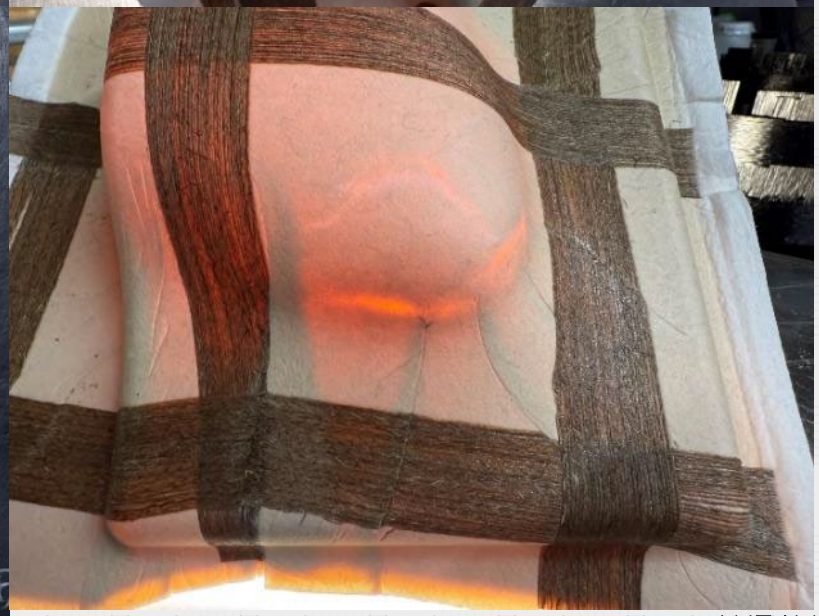




Control 5-Layer

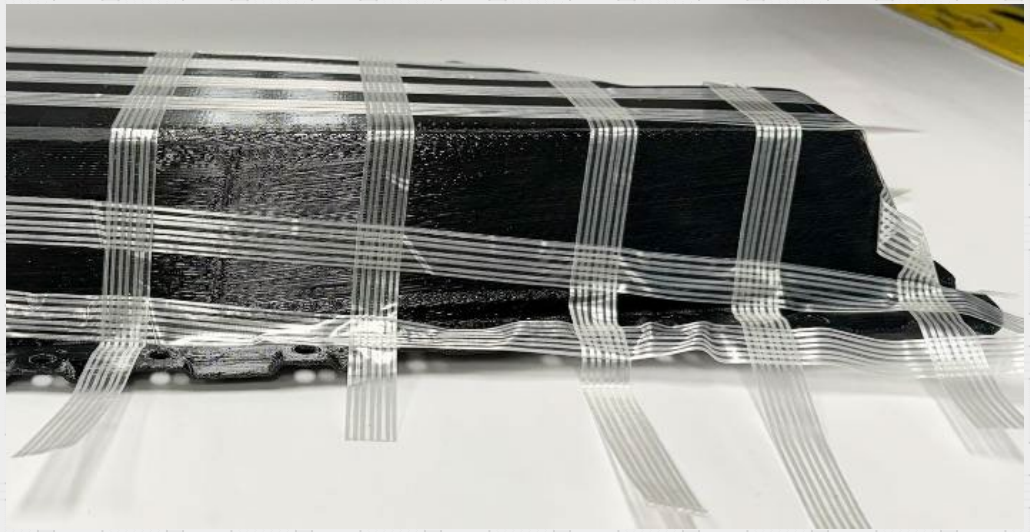


5-Layer

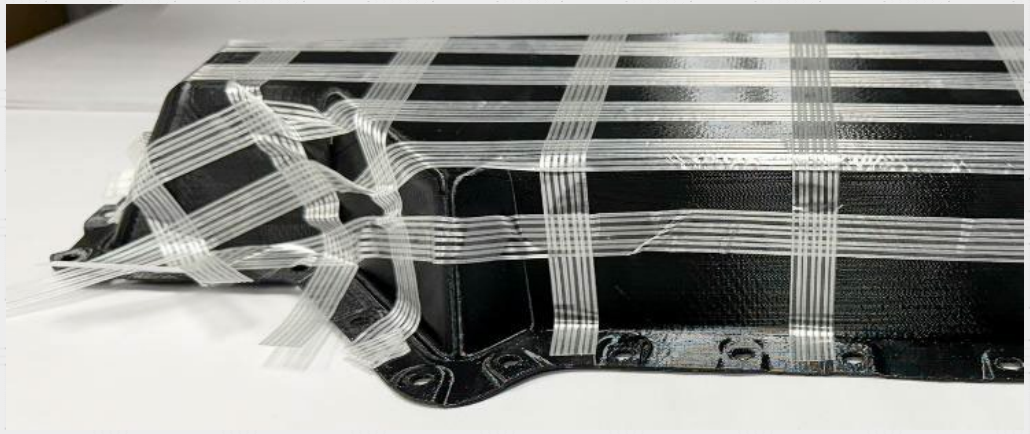


Full-Scale Demonstrator

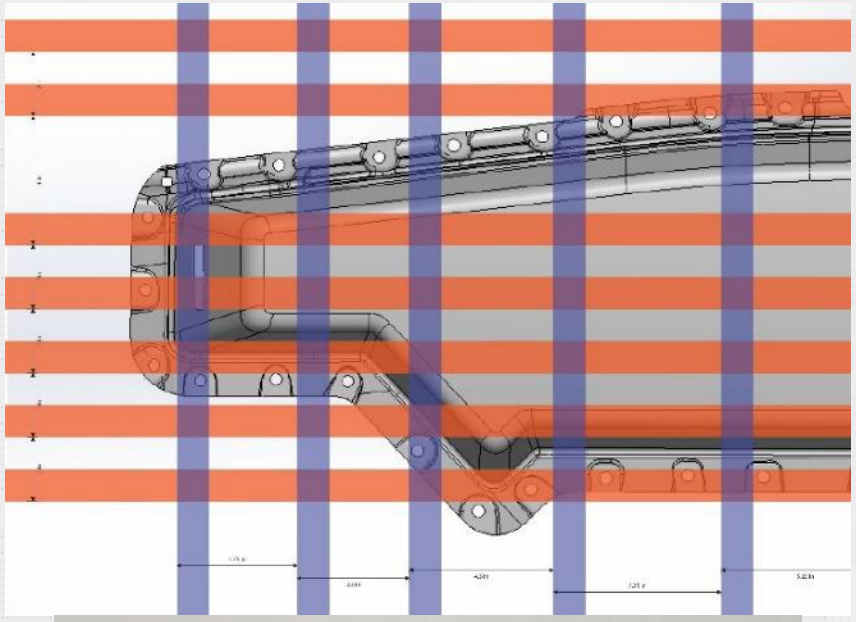
Mock-up of Full-Scale

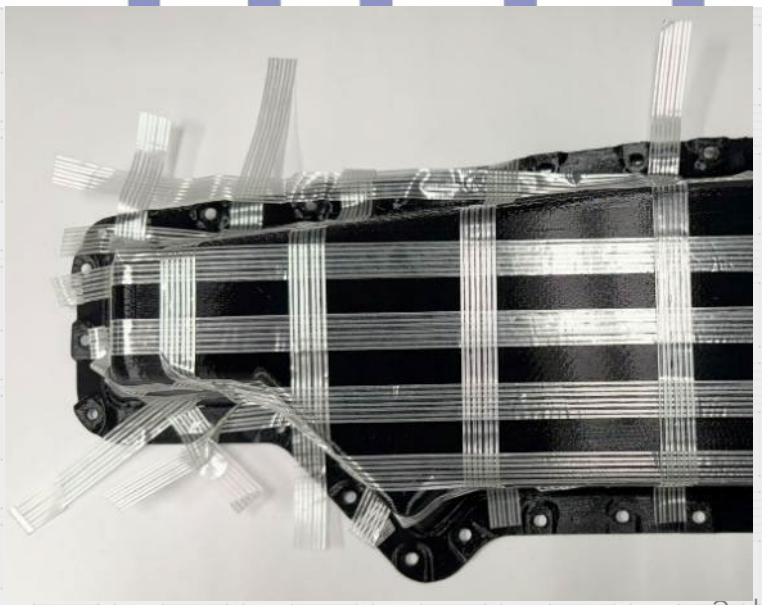


Demonstrator Part, 2:1 Scale



Lattice as Manufactured

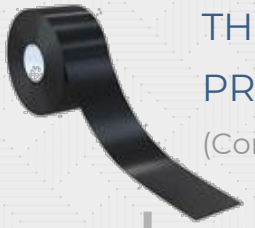




Experimental Approach

1. Molding trials conducted at Tier 1 facility in Spain
2. 16 pieces were produced:
    1. 3 control parts
    2. 10 NFPP lattice-reinforced parts
    3. 3 GFPP lattice-reinforced parts

Forming Process



THERMOPLASTIC PREPREG TAPE(S)

(Commercially Sourced)

WEAVE

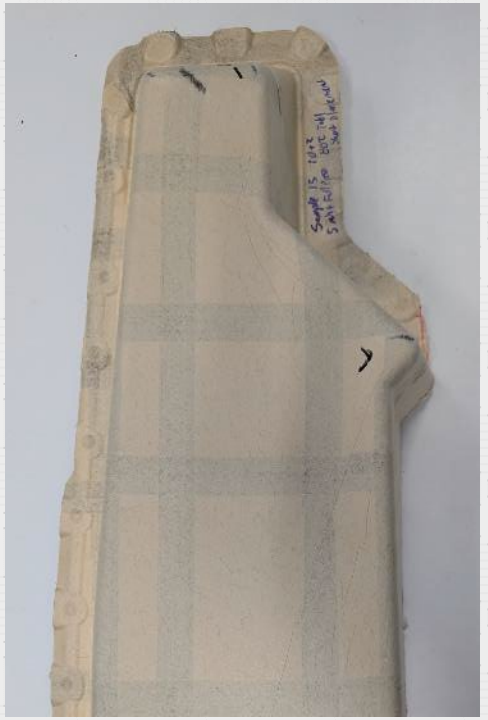
Output lattice in sheet or roll format

TRIM

Tack and Co-Mold

THERMOCOMPRESSION MOLDING

In-Mold Shear Trim



LATTICE REINFORCED PAPER COMPOSITE PART

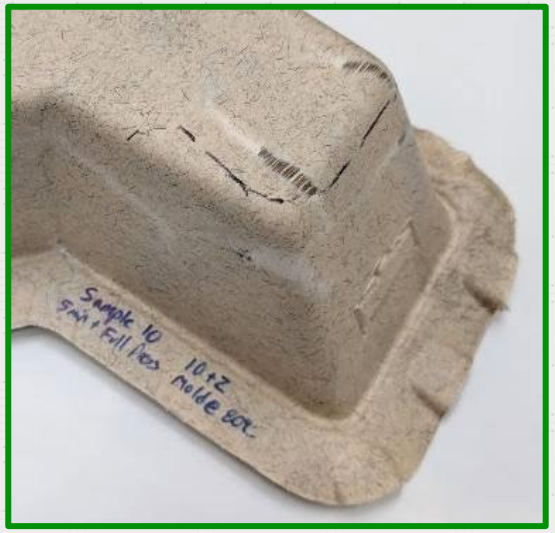
Comparison Against Control

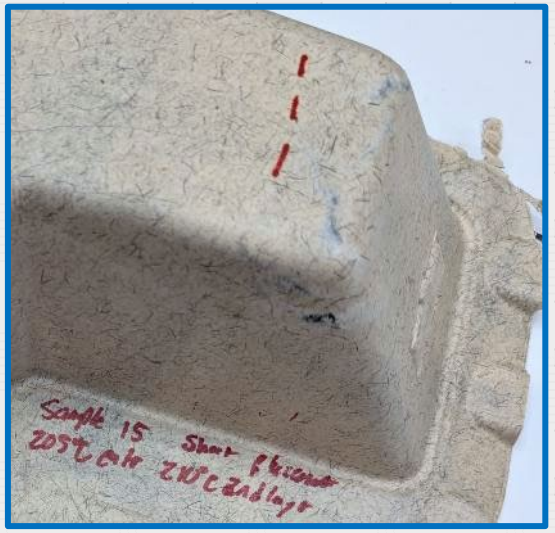
Control – 11 Layers

NFPP Lattice – 10+2 Layers

GFPP Lattice – 10+2 Layers

Comparison Against Control





Control | **NFPP Lattice Outer** | **NFPP Lattice Under** | **GFPP Lattice Under**

Summary of Results

1. Lattice reinforcements successfully eliminated thru-tearing in paper composite

2. Lack of compressibility of paper composite requires tooling changes to accommodate wrinkle thickness along tool edge

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WEAV3D Lattice Enables Increased Draw Depth of Low Melt Strength Materials