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MASS TIMBER, SMALL FORMAT: OPEN SOURCE FURNITURE PROTOTYPING FROM MASS TIMBER SCRAPS

Cory Olsen[1]**, Linda Zimmer**[2]

ABSTRACT: In assessing current mass timber manufacturing practices, the project team has identified an opportunity to generate well-designed human-scale furniture pieces from commonly occurring small sized offcuts in the factory setting. Typically destined for biomass/cogen or even the landfill relative to local environmental legislation, the possibility of upcycling these scraps by creating furniture instead preserves more embodied energy and sequestered carbon, and may generate additional profit as a value-add offering for mass timber manufacturers.

Through partnerships with the Tallwood Design Institute/Emmerson Lab of Oregon State University as well as DR Johnson Wood Innovations in Riddle, Oregon, the research team has produced both digital as well as built prototypes to test production viability and market interest. With an eye towards open source file sharing, the long term goal is to provide designs to interested mass timber manufacturers in order to reduce unnecessary material inefficiencies in the mass timber production cycle. One of the built prototypes has already gained considerable traction and was showcased at WantedDesign's LaunchPad as part of ICFF (International Contemporary Furniture Fair) NYC in May 2022.

KEYWORDS: Upcycling, Furniture, Offcuts, Value-Add, Open Source

1 INTRODUCTION

By way of a hypothesis from individuals not intricately involved in the mass timber industry, the research team speculates that mass timber manufacturers must inevitably generate an assortment of scraps as panels are sized and architectural fenestration is accommodated [1]. In speaking with industry experts we discovered this to hold true and found that from lack of alternative, current practices relegate this material to indeterminate long term storage, chipping, incineration, or landfill. We propose that an opportunity exists to translate some portion of this remaindered material into useful, well designed furniture pieces and preserve the embodied energy contained in the mass timber product.

2 INDUSTRY INTERVIEWS

To date the research team has interfaced primarily with three entities for interviews on material, production, and life cycle: the Tallwood Design Institute of Oregon State University, Freres Lumber in Lyons, Oregon and DR Johnson Wood Innovations in Riddle, Oregon. These represent two key profiles in the mass timber ecosystem: a research lab and two manufacturers- one of mass plywood and the other of CLT.

2.1 TALLWOOD DESIGN INSTITUTE

TDI hosts a variety of mass timber research projects across various scales in its Emmerson Lab, from small CLT sample chunks for mold and mildew testing to multi-story structural assemblies on a seismic table. The materials used in these mockups and tests have little to no application after they have served their initial research intent. In speaking with then-Technical Manager Jörn Dettmer we found that most material would be relegated to the landfill as local environmental codes limited opportunities for incineration due to the adhesives present across the various materials in the lab (CLT, MPP) [2]. As part of the lab's research posture, they have a suite of fabrication tools available including a small format CLT press, an Italian Biesse CNC panel cutting machine, and a track mounted KUKA industrial robotic arm with a positioning table.

2.2 FRERES ENGINEERED WOOD

Freres is a central Oregon plywood producer that expanded their facilities to become a domestic producer of mass plywood panels in 2017. Speaking with their design and engineering team gave the research team key insights into their (proprietary) target efficiency goals for each architectural project regarding percentages in panel efficiency. Additionally, we were provided an informative disclosure of how they currently address

[1] Cory Olsen, Department of Interior Architecture, University of Oregon, United States, coryo@uoregon.edu
[2] Linda Zimmer, Department of Interior Architecture, University of Oregon, United States, lzimmer@uoregon.edu

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scraps- thin panel clean-ups are collected and periodically taken to their offsite facility for cogen electricity production, while larger scraps are piled and covered in their yard for long term storage, Figures 1,2. The larger pieces are occasionally informally sold to local DIY-minded fabricators but there are no recurring outlets for the large scraps to be repurposed at the moment.

Figure 1: *Thinner and small scale scraps of MPP suitable for chipping and cogen collected at Freres' Cedar Mill facility.*

Figure 2: *MPP saved scraps, of a scale and dimension suitable to furniture reuse but irregular and impractical for building applications.*

Freres utilizes a German made Weinnman 5-axis CNC to size and cut their panels.

2.3 DR JOHNSON WOOD INNOVATIONS

Following an industry presentation of our research hypothesis, Levi Huffman of DR Johnson Wood Innovations reached out to the research team. He confirms that DRJ has been looking for ways to utilize scraps generated in their CLT production line [3]. Equally interesting, we were informed that some panel waste is necessary in their production to maximize press efficiency when transitioning between orders by gluing multiple 3 or 5-ply panels simultaneously even if the additional panel width exceeds project spec. In our eyes, this material is prime grounds for furniture forms that can take advantage of CLT spanning abilities, such as elongated benches for public lobbies and school projects.

DR Johnson utilizes a German Hundegger CNC panel cutter.

3 DESIGN THINKING

3.1 MATERIAL PROPERTIES

To design viable furniture proposals, the research team first assessed the material properties of CLT and MPP. Key considerations throughout the design process have been material visual scale, volumetric weight, standard thicknesses, and sound joinery detailing. Material consistency, particularly in CLT, is understandably variable and designs have sought flexibility in accommodating surface gaps, voids from wanes, and a minimization of slivered remnants from certain cut angles and depths. As CLT is not edge glued there is a certain risk that some acute cuts may result in unadhered geometries. Mass plywood is available in an array of thicknesses beginning at 2" up to 24" in one inch increments, while CLT is assembled in odd number plys, most commonly in 3-ply which is approximately 4" or 105mm. While mass ply can be considered more-or-less uniform for designing joinery, the scale of the alternating laminations in CLT requires that grain direction and board orientation be thoughtfully considered.

3.2 MANUFACTURERS TOOLING

Our designs operate under a basic assumption that mass timber manufacturers will have tooling on hand to create cuts in panels for overall sizing, craft bevels/miters, and cut out openings (either via plunge saw or router milling heads). The OSU Emmerson lab additionally has a KUKA robotic arm which has been utilized for prototyping but may exceed a baseline manufacturing ability expectation.

Our interviews with mass timber manufacturers regarding their tooling abilities and strategies was very illuminating. While our proposal for utilizing scraps was widely well met, a variety of potential obstacles presented including:

- A CNC bottleneck in current existing production slows jobs and additional machine time for

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furniture components would have to be well justified. Minimizing tool changes and optimizing for fast cutting operations would alleviate- routing a profile takes considerably longer than rip cuts with a circular blade, for example.

- Small scale objects present an operational challenge relative to the CNC panel cutter setups. Panels are supported by spaced bucks with sacrificial cutting layers, but small components could potentially occur between supports. An object cut free could pose an operational risk if it were to bind with a cutter head if unsupported. As a result, machine operators will sometimes prefer to "dust" smaller areas to avoid captured objects and tabbed elements that could bind in the CNC
- For torsional integrity during installation, some panels will ship with openings still tabbed in place, effectively removing the scrap from the factory and placing it at the jobsite where it may be more challenging to recapture.

3.3 PRECEDENT

As mass timber panels are a relatively new building material, there are understandably few direct precedents for mass timber furniture. One notable collection is the Pipedreams set of residential scale pieces by Douglas & Company based in Cape Town [4]. Their pieces utilize reclaim material from an architectural project and manifest as a daybed, bench, and stool.

The mass of our potential pieces led us also to various precedents of other wooden construction, with significant relevance towards laminated plywood constructions and milled solid timber pieces. Similar in form to the Squall is Nadaaa's Bob Sidetable, constructed from a billet of laminated plywood pieces and milled [5]. Bernard Cache and Patrick Beauce's Objectile outputs are another CNC produced form of laminated and formed plywood construction [6]. The studio furniture of the late Wendell Castle reveals a more intuitive approach to a stereotomic carving of wooden mass [7]. And recently the works of Gareth Neal such as his Hack Chair and Of Cuts series emerge from a starting point of mass [8].

4 PROTOTYPING

4.1 DIGITAL MODELS

The research team initially develops digital proposals to explore aesthetic quality, scale, material relationships, and joinery. These models are created as 3D digital forms in Rhino, which allows for volumetric file sharing through a variety of file extension types (OBJ, STL, DXF, SAT, etc). This flexibility allows reasonably easy interface with a variety of CAM software that may be used across the mass timber manufacturing spectrum. Beyond a proof of concept in generating prototypes, our goal is that panel manufacturers can incorporate these component cuts into their active production lines as an open-source design sharing model and fabrication opportunity.

Through the use of rendering software such as VRay, materials are accurately mapped to test the visual character of each piece, Figures 3,4. Renderings also enable a discussion with manufacturers in regards to parts orientation and grain direction, again particularly relevant when considering CLT and joinery, Figure 4,5.

Figure 3: *Mesa Bench visualization*

Figure 4: *Facet Table visualization*

Figure 5: *Facet Parts illustration for visual communication to saw operators*

4.2 TDI EMMERSON LAB : SQUALL STOOL

Capitalizing on the availability of the Emmerson lab KUKA robotic arm, an initial prototype was produced that leveraged the tools spatial flexibility to create a complex undulating surface, Figure 6. Named the Squall Stool, see: Figure 7, the piece consists of a stack lamination of four pieces of 3-ply CLT milled to a compound flowing

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surface. The design is parametric in nature, such that every stool produced can easily incorporate formal variations for each to be unique within a family of serial difference. The Squall was recently shared with an international audience at the 2022 ICFF as part of WantedDesign's LaunchPad prototypes feature.

Figure 6*: KUKA robotic arm milling Squall prototype*

Figure *7: Squall Stool*

The Squall took approximately 7 hours to mill on the KUKA as an initial prototype run. While a considerable amount of time, in the lab setting the machine is rarely occupied and this form is a capitalization of its abilities and components, including the positioning table for milling pieces in the round. With further experience, refinement and optimization the milling time could be reasonably expected to reduce.

The stool sits on 5 rotational casters for ease of movement. The recesses for the casters were machined by hand while the team was iterating through options, though these also offer an opportunity to leverage the KUKA while the piece is being fabricated.

As a furniture piece the Squall provides an ergonomic seating height at 16.5" suitable for table height work and casual use, figure 8. It can easily serve a secondary role as a side table as well. Aesthetically the smooth surface provides a novel visual to the CLT where the 90 degree alternating laminations blend smoothly from edge grain to end grain. Each milled blank will reveal a different grain pattern and coloration adding to the uniqueness of the serial family.

Figure 8*: Squall in use*

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4.3 TDI EMMERSON LAB : THE "SUITCASE"

Following the success of the Squall, an additional prototype the "Suitcase" has been produced with the assistance of the TDI labs, Figures 9, 10, 11. Recognizing that the utilization of the KUKA may exceed industry capabilities, the design team shifted our focus to the panel CNC. The "Suitcase" as it is currently codenamed represents a culmination of our learning since embarking on our mass timber furniture research. The design consists of four bevelled CLT strips that are assembled together into a single mass. The component widths are sized to take advantage of linear narrow scraps, such as those common in the DRJ production when they are pressing multiple panel specs in job transitions. The components are cut with a vertical or bevel rip cut, utilizing the circular blade of TDI's Biesse CNC machine. The length of the suitcase can be anything from a single seat to the full length of a mass timber panel. From an efficiency standpoint, longer lengths negate concerns about pieces being unsupported by the saw bucks. Each rip cut takes from seconds to minutes, adding a minimal amount of machining time to any job. The small single seat Suitcase was assembled using Domino XL joinery and adhesive, while a larger prototype has been assembled using CLT wood screws. On reflection, using wood screws has benefits of allowing lighter individual parts to be transported and assembled on site quickly with tools that will already be in use. Parts could be delivered pre-sanded and prefinished or completed on location.

After lamination, a simple bent steel backrest is bolted on along with a linear dimensional lumber lumbar support, maintaining the SPF materiality of the CLT itself. Similar to the Squall, the individual Suitcase rests on four recessed casters to allow an ease of movement despite the overall weight of the piece. For longer runs of the Suitcase a fixed foot strategy would be utilized to make it into a stationary monumental installation.

Figure 9*: Suitcase parts at TDI fresh from the Biesse Saw*

Figure 10*: Suitcase Seating prototype in a single width*

Figure 11*: Suitcase in use. Bevel angle allows for natural footrest and backrest placement.*

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4.4 DR JOHNSON

In partnership with DRJ, files have been shared so that they may pursue factory produced prototypes. These are generated in between panel production runs at the discretion and availability of the saw operators. One design has been produced in multiple, the Torii Bench as shown in Figure 12. Additional pieces are available in their queue and will be produced as their fabrication schedules allow. This includes designs from a family of related forms named the Capsule Collection, see Figure 13.

Figure 12: *Torii Bench cut and assembled by employees at DR Johnson's Riddle, OR location.*

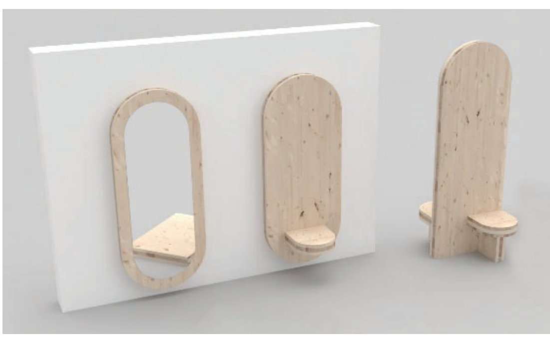

Figure 13: *Capsule Collection showing wall mounted mirror, seat, and freestanding 'Tete a Tete' chair sharing a common pill shape feature geometry.*

5 FUTURE-CASTING

5.1 DESIGN FOR DECONSTRUCTION/DISASSEMBLY

One of the leading arguments for the environmental benefit and sustainability of mass timber architecture is its ability to sequester carbon [9]. While most mass timber structures are too recent to be facing replacement those days will inevitably come. The tectonic nature of mass timber assembly can lend to an organized disassembly enabling building elements to be recaptured and reused [10]. Ideally architectural panels could be recycled into new architecture but this would require a considerable amount of planning, anticipation and execution. The research team proposes that a highly flexible secondary application for recaptured mass timber would be furniture scale objects. Oddly shaped, unique, or damaged panels could be reasonably easy to optimize through parts nesting, with the majority of the sequestration volume left intact.

6 CONCLUSIONS

Scraps and offcuts are known to occur in mass timber production though current means of utilizing these are limited. Furniture design prototypes have been produced as a means to upcycle and preserve the embodied energy of these materials, and the research team hopes to involve more interested manufacturers to reduce waste stream volumes while providing functional, aesthetically pleasing furnishings to projects. Further, as mass timber constructions reach their end of life, the potential for reuse increases with avenues such as furniture and products.

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