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MASS TIMBER FURNITURE DESIGNS FOR OPTIMIZING PANEL YIELD; AN UPCYCLING STRATEGY TO INTERCEPT MASS TIMBER DROP CONCURRENT IN PANEL MANUFACTURING PRODUCTION

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ABSTRACT: In the translation of architectural designs to mass timber panel layouts, invariably each job results in a percentage of remnant panel material. The research team is running a case study analysis of project cut files to identify drop percentages/areas, and explore opportunity to nest small parts for use in modular product designs. Following the case study exercise, an automated nesting script is simulated which can be implemented by panel manufacturers interested in reducing their panel waste while simultaneously offering a collection of design objects and furniture as a value-add byproduct. A range of existing and developing mass timber furniture designs enables an optimization of part catalog options to respond to individual panel conditions.

KEYWORDS: optimization, nesting, furniture design, automation, upcycling

1 – INTRODUCTION

As Mass Timber advocates work to cement the sustainability narrative of the industry, an important factor to consider is the overall efficiency of the mass timber panel-to-building translation. Global construction and demolition waste estimates sit around 60% of cumulative volume [1]. CLT and mass timber presents as an attractive environmental option in embodied energy, carbon sequestration and overall sustainability when compared to traditional mineral-based materials and assemblies [2]. While nesting architectural components is already a common sense practice, there are considerable percentages of panel that remain unprogrammed due to fenestration cutouts, shaft and stair cutouts, unique design geometries, or remnants from nesting inefficiencies in the individual master panels. Some of the waste in panel modification will be chips and sawdust, which is readily repurposed for cogen steam power. The others, such as the cutouts and panel trims can be of significant size. Chipping and incinerating these volumes requires again a considerable amount of energy input while simultaneously sacrificing the existing embodied energy of the engineered product and releasing the sequestered carbon of the wood. In one LCA study assessing the production process of CLT as a whole from raw material to delivered panel, estimates of the waste attributed to CNC operations and panel end cuts are on average approximately 15.25% [3].

Given the relative youth of mass timber architecture, we are not yet to a point where the end of life cycle of the material has become prevalent. As mass timber architecture increases in frequency and implementation, a growing backlog of remnant panel “drop” material from the manufacturing process will continue to amass. And projecting further to the decades to come, mass timber’s compatibility with design-for-deconstruction will also produce considerable quantities of reclaimed, uncertified but functional material. The research team proposes a modular solution to integrate designed parts and furniture components into programmed panel CNC jobs to improve overall panel efficiency reducing waste while simultaneously opening a value-add design furniture line to production operations.

A literature review uncovers similar reuse proposals though a majority of them are pursuing structural architectural reuse. While logical, there are obstacles if structural re-certification of scrap material is necessary. Examples of structural reuse include Dupas and Hudert of Aarhus University designing segmented and hyperbolic paraboloid gridshell structures [4], Robeller and Von Haaren’s novel CLT ‘Recycleshell’ [5], and

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even the reprocessing of CLT scrap into new CLT panels as proposed by Vamza, et al. [6].

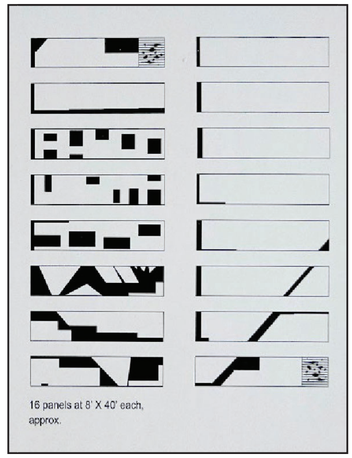
2 – PROJECT GOALS & PROCESS

The research has three primary components 1) a case study analysis of a precedent panel cut layout to make a baseline argument for incorporating small furniture modules, 2) simulating a scripting plug-in operation to identify panel scrap regions and sync to a catalog of mass timber furniture parts that could be nested inside, and 3) building out the furniture catalog with prototype images, developing a modular parts flowchart illustrating suitability for various panel thicknesses, and suggested toolpaths for incorporating into individual panel cut files.

2.1 CASE STUDY

The case study phase of the research documents and illustrates a pre-existing architectural mass timber panel cut job to build out a base logic and approximate typical job efficiency ranges. An example of panel layout logic is well represented by a sample from Susan Jones' designed personal home project "fig. 1" where the black regions are unprogrammed scraps resulting from architectural part geometries and their array into the mass timber master panel dimensions [7]. While the Jones house is a smaller scope than many mass timber projects, it contains multiple conditions this proposal aims to address- fenestration cutouts, panel end trims, unique geometries, and both repetitive and non-repetitive panel arrangements.

The Jones house consists of sixteen 8' x 40' individual 3-ply CLT panels as illustrated above in figure 1; graphic sourced from *Mass Timber : Design and Research* [7]. Translating the panel positives and negatives, the project as drawn has an overall panel utilization efficiency of approximately 81.5 %. On a single panel basis, the most efficient panel is 97% utilized (top right in fig. 1), while the least efficient panel utilizes only 44% of its area (6th down in first column of fig. 1). This least efficient panel additionally illustrates a scenario where the panel drop is most conveniently processed while the master panel is being cut; once removed from the CNC the resulting drop geometry will be cumbersome to both relocate and store. Industry estimates average panel efficiency ranges from approximately 5-20% depending on project size, typology and structural strategy. The calculated Jones project efficiency of 18.5% falls within this range and the small single family residence is a typology that frequently exhibits lower overall efficiency due to pursuit of novel form and minimal architectural repetitions.



CLT Panel nesting array from Atelier Jones.

Figure 1.

2.2 AUTOMATED NESTING SCRIPT

From the case study, a CAD based nesting script identifies available scrap regions through true/false area selections (fig. 2). These regions can then be cross-referenced to an existing and evolving designed furniture parts catalog to determine suitable parts nesting within the available scrap dimensions in each panel. The furniture catalog is indexed to account for different panel thicknesses based on common CLT ply construction and MPP one inch increments. A proof-of-concept is developed through Rhino and parametric plug-in Grasshopper, but implementation in factory settings will require collaboration with CAM suppliers specific to each enterprise. Given that different CNC machines have varied toolsets (circular blade, plunge saws, rotary milling heads) the base library forms can be assigned an adjustable buffer perimeter offset to allow for blade kerfs (fig. 3).

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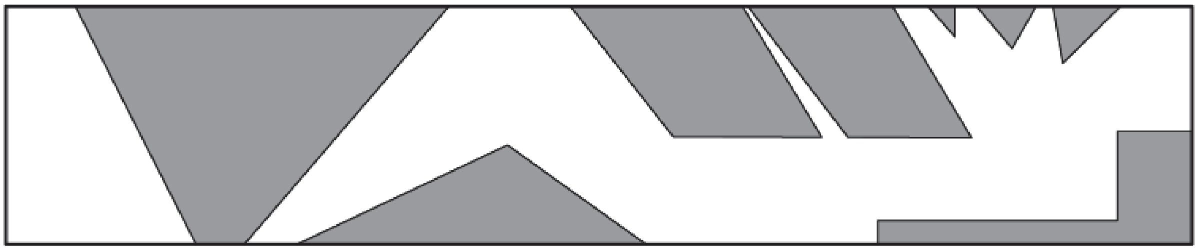
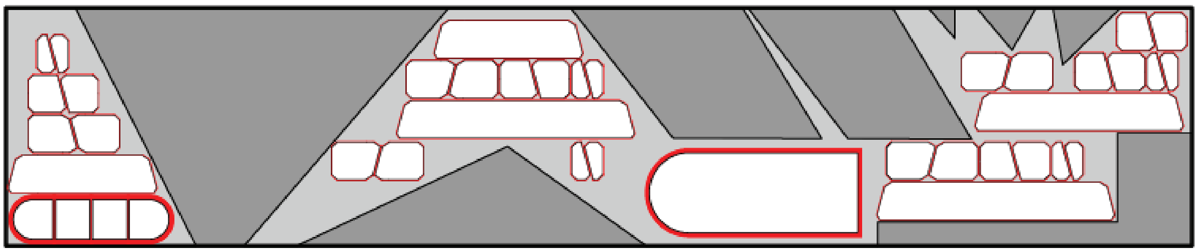


True/False selection of master panel to identify scrap regions for nesting analysis.

Figure 2.



Furniture parts nested in drop. Red outlines coordinate to programmable tool kerf offset.

Figure 3.

Once a part module is selected, the region is added to the panel layout for the CNC programmer to assign toolpaths . With partner interest, these could also be pre-programmed to the part file for individual CAM setups to enable an automated drop-in to an existing panel cut file- a degree of industry overlap is anticipated in general G-Code scripting so this step may be largely automated. Understanding that CNC programming can lead to more significant operational overhead, the ability to pre-populate individual parts with toolpath settings and clearances is an aspirational goal of the proposal to reduce barriers towards implementation and integration into existing manufacturing sequences. Machining time will increase, but the opportunity to reduce panel waste, prevent large component storage, and providing the resultant fabricated furniture pieces are seen as value tradeoffs that exceed the machine operation cost.

In the sample of Figure 3 above from the least optimized Jones panel, utilization went from 43.75% to 75% and results in the necessary parts for one complete "Tete-a-Tete Chair" and five complete "Mesa benches" in varying lengths. The panel could be even further optimized by making spare additional parts for partial furniture modules, which if looking at an architectural job as consisting of multiple CLT master panels would add up to many completed furniture wholes. These furniture pieces could be provided to the purchaser of the panels with an added labor surcharge for machine time and assembly, or retailed independently with a larger markup to a variety of clients ranging from private residential to institutional. Some pieces such as the Mesa have been designed to array into various arrangements and configurations to suit project contexts and function- these are anticipated to work well in lobbies, libraries, atriums and other spaces for gathering.

2.3 FURNITURE CATALOG

An existing array of furniture designs "fig. 4" exist as part of prior efforts by PI Cory Olsen and partner Linda Zimmer [8]. This catalog will be continually expanded by the current research team to address a range of scales, furniture types, and materials. Existing designs are broken down into modular components for the nesting exercise described above.

Excerpt of samples of existing furniture catalog. The Mesa Bench, Suitcase Seat, Torii Bench, and Tete-a-Tete Chair, respectively.

Figure 4.

In the development of the furniture catalog, individual pieces are graphically represented in assembled isometric line drawings, dimensioned orthographic parts plans, and correlated to suitable material logics for CLT and MPP options as examples shown in figure 5. Where applicable, components that are suited to variable lengths are noted to allow for designs to be made to custom specifications or to be produced at maximum panel optimization (a variable benchtop length, for example).

The furniture designs can be assembled with basic shop tools and equipment. Depending on the base material, some components will be produced in multiple to be laminated into thicker singular components. The assembly could be carried out in-house by the mass timber manufacturer or outsourced to local craftspeople, either of which would support labor positions and reduce downtime between mass timber architectural projects.

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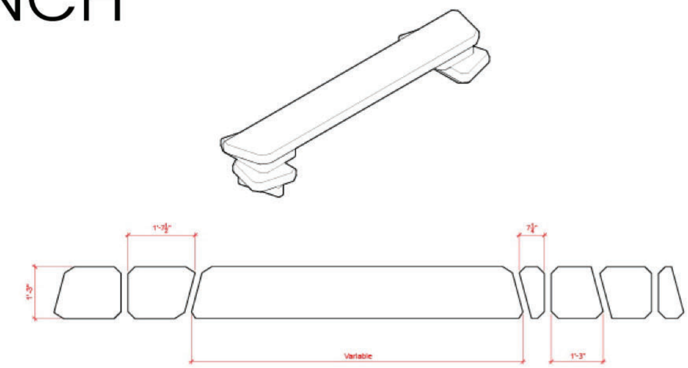
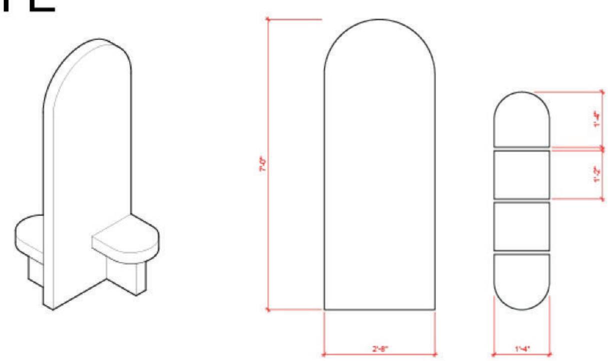
MESA BENCH

CLT	
3-ply	Ideal
MPP	
2″	Suitable
3″	Ideal
4″	Ideal



TETE-A-TETE

CLT	
3-ply	Ideal
5-ply	Suitable
MPP	
4″	Ideal
5″	Suitable



Example of catalog design pages, with quick reference tables for material suitability.

Figure 5.

3 – OUTCOMES AND CONCLUSIONS

The work presented introduces a logical avenue to increase panel utilization in mass timber manufacturing by nesting smaller furniture scaled parts that will be accommodated in a range of scrap dimensions. Implementation of a product based output will reduce waste, preserve embodied energy and carbon stores, and provide useful furnishings in the built environment. A goal of the research is to share this work with mass timber producers and allied advocates to illustrate the potential for implementation and identify interested potential partners. The focus on discreet objects provides an output strategy for mass timber scraps that will not require any structural recertification which is a current obstacle faced by any reuse applications in the architectural realm. In the years to come as design-for-disassembly becomes an active practice, product designs such as these will also provide an immediate use option for salvaged mass timber building materials without necessitating bespoke custom solutions which may or may not match available stock.

4 – ACKNOWLEDGEMENT

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