The Adaptation of Traditional Japanese Joinery for (5-axis) CNC Machining

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BSM Factory manufactures solid wood furniture, specializing in 3D Solid woodwork using techniques like steam bending and CNC machining. They produce furniture for other (designer) brands as well as their own line of products. The assignment came to be through a combination of personal interest in woodworking and CNC machining and BSM Factory's desire to look at their manufacturing processes from a different perspective.

This thesis explored the possibilities of using knowledge and techniques from traditional Japanese joinery in a modern production environment using (5-axis CNC machines). Japanese joinery is the tradition of *connecting wooden members of buildings and furniture using joints with complex geometries made using specialist tools by master craftsmen. Japanese joinery distinguishes itself from western joinery by using solely wood, its geometrical complexity, the lack of glue or fasteners, and the use of pins and wedges for locking the joints.*

The reintroduction of these traditional techniques is made possible through advancements in manufacturing technologies. Namely the use of CAD/CAM and (5-axis CNC machining), allowing for accurate repeatable machining of complex geometries like those used in traditional Japanese joinery. Combining this with a shift in consumer behavior, where consumers are demanding more sustainable and transparent products, this leads to the thesis objective: *To create a set of CNC machined, solid wood, wood-on-wood, flat packable, Japanese-inspired wood joints that can be assembled by the consumer with minimal tools.*

The realization of this objective aimed to achieve the following benefits for BSM Factory:

- Diversification of their technical portfolio
- Optimization in the production environment
- Introduction of (more) flat-packable products

First, research was conducted to gain an understanding of (traditional Japanese) joinery, wood as an engineering material, (5-axis) CNC machining, and the furniture market.

This resulted in:

- A characterization of traditional Japanese joinery that gives a framework for designing new joints
- An understanding of wood as an engineering material, such as its tendencies to swell and contract under environmental changes and the challenges in strength testing due to its anisotropic nature
- An understanding of the limitations of CNC machining, such as its inability to create sharp inside corners
- An understanding of the flat packable furniture market and how BSM Factory using these new techniques can take a unique position by combining its small production size with advanced production capabilities

With the research as a foundation, a set of new wood joints was developed through a very hands-on and iterative approach. These joints are partly direct translations of Japanese joints that were adapted for

CNC machining and partly new joint designs that use Japanese principles. Wherever possible prototypes were made to validate and iterate on the designs. While several joints were tested and deemed to have potential, it was not possible to prototype and test every joint to the same extent.

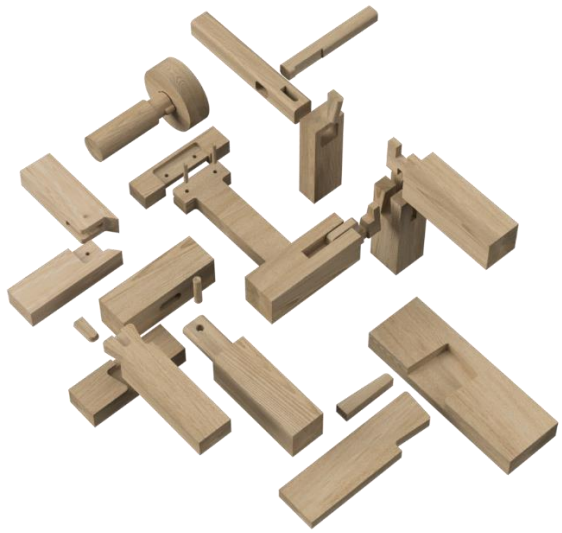

Figure 1. Overview of the developed joints

Figure 2. Examples of prototypes

The development of this set of joints successfully showed some of the possibilities and potential of designing these new types of joints. However, it also confirmed and gave further insight into the limitations. Namely the constraints caused by the nature of wood and the limitations of CNC machining and the associated production processes.
With the set of joints designed and evaluated where possible, several furniture concepts were designed with the goal of showing how the different joints can be integrated into a product. Not just using the joints as isolated features but basing the entire product construction around the joinery techniques.

Figure 3. Furniture concepts

Two of these furniture concepts were chosen for final prototyping. Which resulted in the scale model of a small side table (Figure 7) and a full-size prototype of a coffee table (Figure 6). These prototypes were made as a means of making the results tangible, but also as a final validation step, showing the feasibility of the designs and the achievement of the thesis objective. The choice for these two concepts was based on joint performance and the available time and resources.

Figure 5 and Figure 5 show how joinery can be used as more than just a way to connect two members. In these examples, one joint connects the frame with the legs, while simultaneously clamping the tabletop into place.

Figure 5. Design of a small table

Figure 4. Design of coffee table

Figure 7. Scale model of side table

Figure 6. Coffee table

The objective of this project was to create a set of CNC machined, solid wood, wood-on-wood, flat packable, Japanese-inspired wood joints that can be assembled by the consumer with minimal tools. The set of joints that were designed fulfill this objective and the design and prototyping of the furniture concepts show that the joints can be successfully integrated into designs. However, the development process also showed the difficulty of translating an old tradition into a modern context. It shows how the design and manufacturing process requires a different mindset. And just like in traditional Japanese joinery: A solid understanding of the materials and tools. In production, that means that the entire process needs to be thought through to create well-functioning, reliable joints. To conclude, this project explored the basics of using Japanese-inspired, CNC-made wood joints and proved its potential through prototyping. With a set of designs and prototypes and the methodology used in this project, BSM Factory can continue the development and hopefully reach a point where furniture with CNC machined, solid wood, wood-on-wood, flat packable, Japanese-inspired wood joints will reach the market.