Snap-Fit Joinery System Using Pinewood Material Elasticity Properties

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Highlights:

- The use of wood as joint material in a snap-fit system.
- Optimization and efficiency of the use of material cutting technology.
- A method for applying the snap-fit system to other than commonly used plastic materials.

Abstract. The elasticity of pinewood gives it the potential to be applied in a snap-fit system, a connection system that utilizes the elasticity of a material to connect separate parts to one another. This research was aimed at finding the right shape of the stress-relievers for pinewood snap-fit modules. An experiment was performed using a computer-numerical-control (CNC) router for fabrication with detailed precision.

Keywords: *digital fabrication; joinery; knockdown; snap-fit; wood.*

1 Introduction

Wood joinery is a method to unite several pieces of wood in order to extend, widen and/or change the direction of the arrangement of pieces of wood. The selection of the right connection is partly based on the properties and characteristics of the wood material used. According to Ashby [1] and BASF [2] an important factor for assembly and disassembly is that the snap module can tolerate relatively large elastic deflection of the material.

From the experiment performed by Klahn in [3] the development of manufacturing capabilities can integrate snap-fit connections into other than commonly used plastic materials. Torrosian [4] states that snap-fit joinery can be modified by adding integrated parts to improve the lock mechanism. This can inspire designers to add and develop new functions into the snap-fit design according to their needs and the nature of the material they use. This research aimed to explore snap-fit connections utilizing the elasticity of wood. Wood with a high flexural strength can return to its original form when tapping. The shape of snap-fit components can be explored by using computerized cutting

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technology, with which anchor parts at small sizes can be made easily and precisely [6].

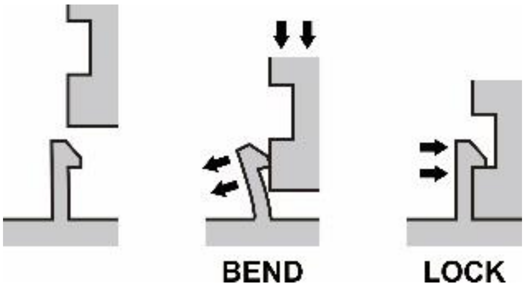

Figure 1 Usage of elasticity to bend the material during assembly in a snap-fit joinery system.

2 Material and Methods

Two types of experiments were conducted: pre-experiments and snap-fit connection shape experiments (Figure 2). The pre-experiments were performed to determine the effect of cutting pinewood by a CNC-router machine. First pinewood was cut following the basic pattern of a snap-fit connection after which the connection flexibility was tested. Then snap-fit connection shape experiments were carried out to find variations in form and/or a system suitable for pinewood. The experimental design included material thickness engineering experiments, shape and size experiments, and stress-reliever experiments. A trial was conducted to test the strength of the resulting connections. The results of this trial can be used as connection criteria and can become the basis for making products that meet these criteria.

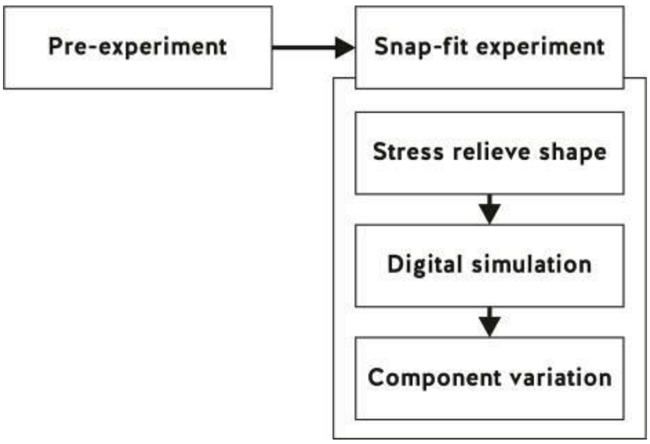

Figure 2 Method and experimental scheme.

2.1 Mechanical Properties of Pinewood

The material used was grade-2 pinewood *(pinus mercusii*) obtained from used shipping pallets, classified as wood with class III durability. According to Siregar [5] pinewood has an average specific gravity of 0.55 g/cm^3 and belongs to strength class III and durable class IV.

Table 1 Physical and mechanical properties of pine wood [6].

Characteristic	**Description**
Color	 Yellowish-red brown *(HW)* Yellowish-white *(SW)*
Natural durability index	3
Silica content	0.2%
Physical Properties	**Description**
Basic density (g/cm^3)	0.58
Air-dry density (g/cm^3)	0.64
Total tangential shrinkage	8.3%
Total radial shrinkage	4.9 %
Mechanical Properties	**Description**
Bending strength (N/mm^2)	52.95
Stiffness (N/mm^2)	10285.7
Compression parallel to fiber (N/mm^2)	25.98
Shear radial strength (N/mm^2)	5.98
Janka hardness (side) (kg)	250
Janka hardness (end grain) (N/mm^2)	27.06

2.2 Material Experimentation With Snap-Fit Joinery

The processes carried out were pre-experiments, material engineering experiments, component flexibility experiments with the help of stress relievers, locking system experiments on the hook components, and module load resistance experiments. The material used in this experiments was limited to used pinewood from shipping pallets.

According to Filson [7] and Edward [8], manufacture using a CNC-router can produce precision and good cutting quality compared to manual cutting methods, especially with detailed design patterns (See Figure 3). The cutting technology in this research used a drill bit integrated with a computer through a CNC-router. The usage of a CNC-router can be developed for mass production easily, as Brando has discussed [9]. In this experiment, the tools used were a CNC 3020 machine and a 3-mm endmill router bit.

Figure 3 Material cutting process using CNC-router manufacture.

Based on the analysis conducted by Klahn [3], snap-fit systems require special tooling and additive manufacturing to prevent undercut and cracking of the material (See Figure 4). In this case, in view of the specific wood type used, a circular stress reliever was added at the end of the gutter to provide extra flexibility and prevent breakage.

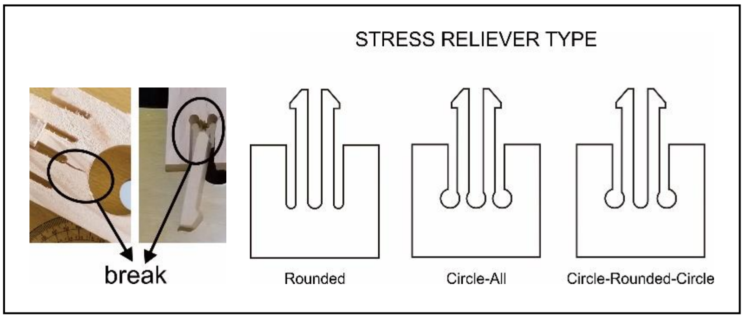

Figure 4 Different shapes of stress relievers to prevent breaking of the material during the snap-fit process.

2.3 Component Shifting and Simulation

Digital simulation was implemented to determine the elasticity threshold of the pinewood so it will not crack during snap-fit assembly. A stress reliever design that was created previously was tested to find out the most appropriate shape to be used for the snap-fit material. The boundary conditions for digital simulation were the material properties, which were simulated to have the same values as original pinewood material. The only thing that was not simulated was the possibility of the wood fibers not being identical, as in fact all wood does not have the exact same wood fiber.

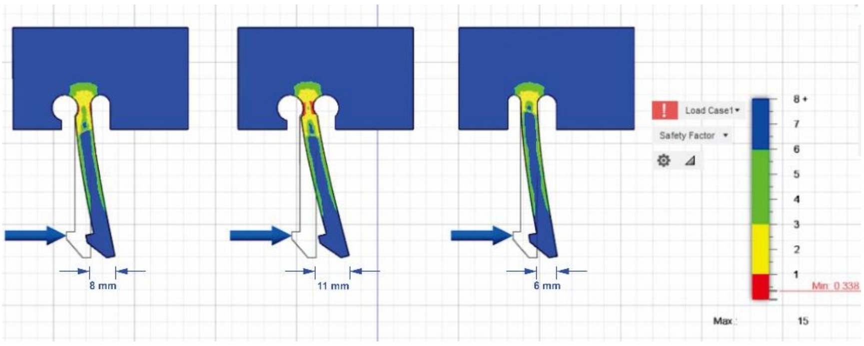

Figure 5 Simulation of stress reliever component design. The force used to deflect each design is the same amount, but the deflection distance is different due to the stress reliever type.

Three types of stress relievers were tested in the digital simulation: circle-round, circle-circle, and round-round. Each specimen had the same compressive strength in the same direction. A striking difference between the shapes was the deflection distance over which the shifting components moved when the hook component received a certain force. It is assumed that the greater the distance, the more elastic the hook shape design (Figure 5). The more elastic the hook component, the more likely the material will not break when the snap-fit is connected.

The hook moves when the joint is connected or disconnected. Figure 6 shows the connection schemes of the different snap-fit system design modules that were tested. Each module completes 3 major steps during assembly as well as disassembly.

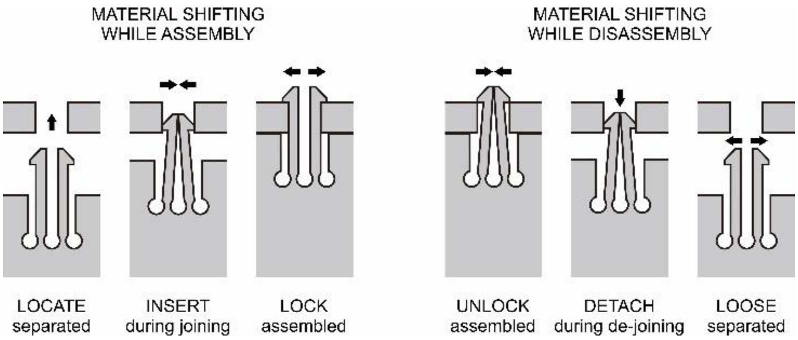

Figure 6 Material shift during assembly of the snap-fit system.

2.4 Component Variation Part and Ability

After knowing the design of the snap-fit system with a stress reliever that is capable and resistant to repeated use, two main components of the snap-fit joint were investigated: the fingered male part (hook) and the receiving-hole female part. In this step, component variations were made to exclude the potential of existing connections. By changing the shape of the receiving component (female) from a square to a circle, the connection could be rotated.

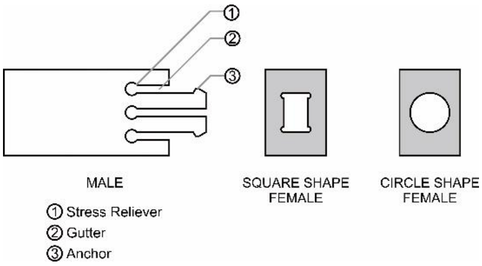

Figure 7 Component part naming.

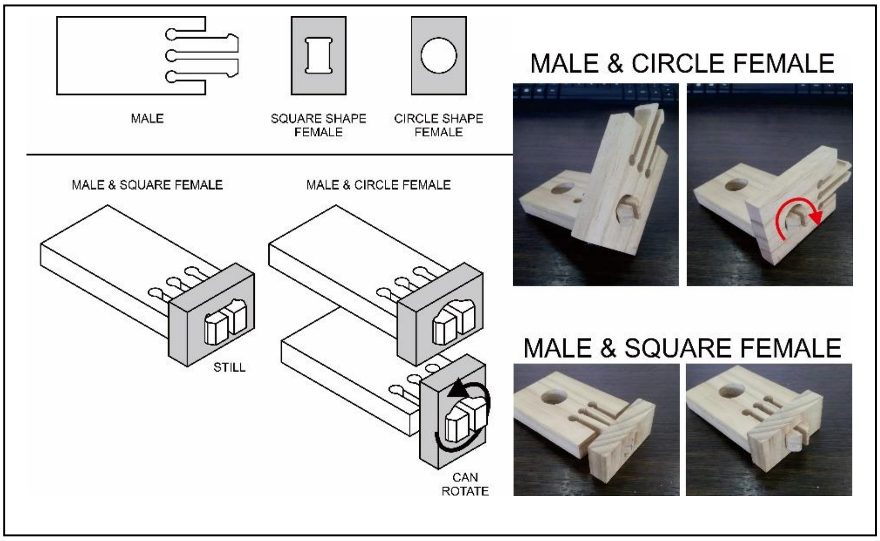

Figure 8 Types of female component shapes. The difference between them is in the way in which they connect with the male component.

3 Conclusion and Potential Product Development

The larger the shape of the stress reliever, the greater the elasticity that occurs in the snap-fit component, however, this will reduce the grip strength of the hook component. This can be a consideration in customizing the grip of snap-fit components by designing the size and shape of the stress relievers.

The superiority of the connection was the main aim in developing this pinewood product. Assembly is based on a snap-fit/knock-down system so that no tools are required and disassembly can be done easily. The female-part components can be used as door hinges or centers of rotation because they can rotate on their axis.

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References

[1] Ahby, M. & Johnson, K., *Materials and Design, The Art, and Science of Material Selection in Product Design*, Ed. 3, Elsevier, 2014.

[2] BASF, *Snap-Fit Design Manual*, BASF Corporation, New Jersey, 2017.

[3] Klahn, C. & Singer, D., *Design Guideliness for Additive Manufactured Snap-Fit Joints*, 26th CIRP Design Conference, pp. 264-269, 2016. (Conference Proceedings)

[4] Torossian, K. & Bourell, D., *Experimental Study of Snap-Fits Using Additive Manufacturing*, 26th Annual International Solid Freeform Fabrication (SFF) Symposium, Austin, TX, pp. 1794-1803, 2015.

[5] Siregar, EBMS, *Mercusii Pine Breeding*, Fakultas Pertanian. Jurusan Kehutanan, Universitas Sumatera Utara, 2015. (Text in Indonesian)

[6] International Tropical Timber Organization, *Pine (Pinus merkusii)*, ITTO http://www.tropicaltimber.info/specie/pine-medium-weight-timber-pinus-merkusii/ (9 September 2019).

[7] Filson, A., Rohrbacher, G. & France, A.K., *Design for CNC*, Maker Media, 2018.

[8] Edward, F., *Getting Started with CNC*, Maker Media, 2016.

[9] Brandao, F., Paio, A. & Antunes, N., *Towards a Digitally Fabricated Disassemble-able Building System, A CNC Fabricated T-Slot Joint*, FABRICATION | Virtual & Physical Prototyping –**2**, pp. 11-20, 2018.

[10] Hirsi, H., *The Joints in Wood Structure*, Aalto University, 2015.

[11] Robeller, C., Mayencourt, P. & Weinand, Y., *Snap-fit Joints – CNC fabricated, Integrated Mechanical Attachment for Structural Wood Panels*, ACADIA 14: Design Agency, Proceedings of the 34th Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA) ISBN 9781926724478, Los Angeles 23-25 October, 2014), pp. 189-198, 2014.