Woodshop Application Project

Bechtel Innovation Design Center

Purdue University

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The woodshop contains an assortment of machines including the vertical bandsaw, table saw, miter saw, lathe, and CNC gantry, as well as hand tools and other machines that are regularly utilized by members. As a peer mentor, it will be your responsibility to understand the operation of the machines sufficiently to teach members as it pertains to their projects. This document details the use of much of the machinery in the woodshop at the Bechtel Innovation Design Center (BIDC) while guiding you through the construction of a joiner's mallet.

The activities are to be completed in numerical order, beginning with learning about the fundamentals of wood as a material and available resources, and ending with the assembly and finishing of a custom joiner's mallet.

Completion of the application project does not guarantee employment.

Introduction

These activities are designed to be completed individually, but questions are always encouraged. A peer mentor or supervisor should be available during operating hours to assist you if you encounter any obstacles in the process.

This project will require you to design and fabricate a joiner's mallet, such as the one shown below. While there are some requirements (detailed in further sections), exact shapes, sizes, and materials are at your discretion. If you need inspiration, there are centuries of examples to draw from. Have fun!

Activity 1: Material Properties of Wood

Wood Biology & Movement

Fundamental to woodworking is an understanding of wood as a material. Wood is composed of cellulose fibers bound by a substance called lignin. The living portion of the tree's wood is a thin layer only one or two cells thick that lie between the bark and the wood (known as the cambium). Each year, the cambium builds an additional layer of fibers, which constitute the distinctive growth rings. This newly grown layer is part of the section of the wood known as sapwood, which is responsible for the bulk of the water conduction. Eventually, the sapwood undergoes a process that results in stronger, denser wood, darker coloration, and increased decay resistance, which is known as heartwood.

Initially, wood is saturated with moisture, which evaporates during the drying process. As fibers release their moisture, they shrink unevenly, which causes internal stresses and defects such as warpage, checking, and splitting. Even once dried, the fibers of wood are hygroscopic, meaning they absorb moisture from the environment. Over the course of the year, as air humidity levels reach their maximum in the summer and their minimum in the winter, the cellulose fibers swell and shrink. This seasonal movement may also cause warpage, checking, and other issues. These effects can be mitigated through design and by utilizing proper finishing techniques.

Hardwoods & Softwoods

Unintuitively, the terms 'hardwood' and 'softwood' are not designations made to differentiate wood species based on their mechanical properties or hardness. Rather, it is a designation based on the biology of the tree. Hardwoods include wood from species of trees classified as angiosperms, which grow flowers and seeds enclosed in fruit. By contrast, softwoods include wood from gymnosperms such as pine, spruce, and ginkgo. Gymnosperms do not have a fruit that encloses their seeds. Hardwoods are *typically* harder than softwoods, although there are many notable exceptions. Balsa, basswood, and yellow poplar are examples of domestic hardwoods that have significantly lower hardnesses than most softwoods, whereas larch, yew, and certain species of pine are harder than many hardwoods.

Wood Material Properties

Because of the composite structure of wood, it is an anisotropic material, meaning its properties change depending on the direction and nature of the loading. We refer to the arrangement of fibers as wood grain, though grain is also used more broadly to describe wood's figuring, growth rings, and more. Wood is strongest under compressive forces aligned with the grain; however, it is also most vulnerable to shear forces aligned with the grain. This should be considered when designing pieces made of wood. Poor grain orientation selection can result in weakness to mechanical stress or susceptibility to consequences due to wood movement.

Gaging wood strength can be difficult, as certain species may have susceptibilities to certain types of stresses. Density can be a good indicator of general strength and is measured by its specific gravity, or its density relative to water. More specific measures of wood strength include the modulus of rupture, modulus of elasticity, and Janka hardness.

To complete this activity, meet with a supervisor and demonstrate an understanding of the material discussed above and how it will affect this project.

Activity 2: CAD

Integral to the project workflow for many projects is an initial CAD (Computer-Aided Design) model of the design to be constructed. CAD models provide peer mentors with information they can use to assess a design's manufacturability, required machinery, material usage, and more. The primary CAD software used by the center is Autodesk Fusion360. While it is not required for modeling, it is convenient, as it *is* required for generating any necessary toolpaths for the CNC gantry using CAM (Computer-Aided Manufacturing). After downloading, a peer mentor will help you join the Bechtel Center Fusion team, in which your CAD and CAM should be stored.

Even if you are experienced with CAD, please review the BIDC CAD training videos. For insight on designing your mallet, please read this document thoroughly.

In this activity, you will use Autodesk Fusion360 to design a joiner's mallet similar to the one shown below. The mallet should have a head with dimensions approximating the recommendations shown in the diagram, however, the exact design is up to you. The mallet should have a head laminated from three layers engraved with your name, a turned handle, and a wedged through mortise and tenon attaching the handle to the head. Each lamination should be approximately 0.75"-1" thick. The middle laminations of the head must have a tapered mortise to accommodate the expansion of the tenon when the wedges are driven in. This will be further addressed during Activity 4: Milling & Shaping and Activity 6: Turning.

To complete this activity, meet with a peer mentor or supervisor, and show them your design.

Activity 3: CAM

After CAD is made, computer aided manufacturing (CAM) is used to generate toolpaths used by CNC machines. Reference material is available online, and much of the information is consistent with existing resources for metal shop, such as the Bechtel Center milling playlist and the BIDC Mill Toolpath Guide. Please review the material under the 2D Operations, 3D Operations, and Drilling sections of the guide.

In this activity, you will use Autodesk Fusion to create a CAM program for an engraving operation to carve your name into one face of your mallet head. In Fusion, use the tools in the Bechtel Center team tool library to create your program. The font, placement, size, and depth are at your discretion.

To complete this activity, a peer mentor or supervisor must review your CAM program to check for any errors in tool selection and setup.

Activity 4: Milling & Shaping

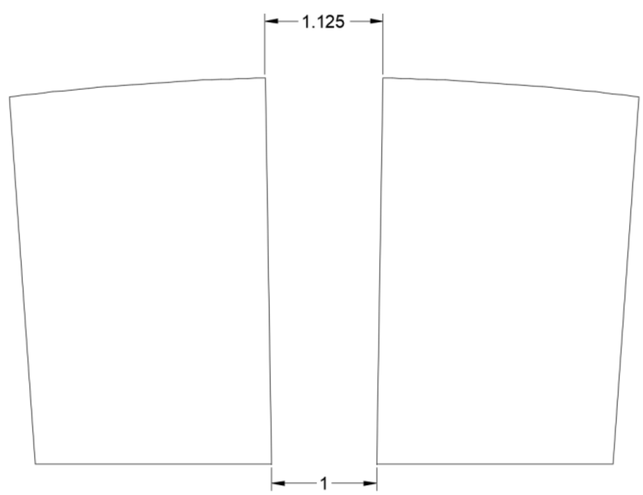
In woodworking, milling encompasses all tasks associated with the process of squaring a board and making it the shape and size desired before continuing to other processes. Typically, wood is bought rough sawn, after which the milling process begins with sawing the board to rough length, jointing two adjacent faces to ensure perpendicularity, planing an opposing face to be parallel, and ripping to width. Shaping encompasses the set of processes involved in forming a piece of wood into more irregular shapes than during the milling process. It may involve the use of saws, sanders, rasps, and other tools. Most projects in the center include these processes, so intimate familiarity with the necessary resources is extremely important.

Schedule time with a peer mentor to learn how to use the necessary machines and to process a rough sawn board into the components of your joiner's mallet design. Before your reservation, review the jointer, planer, table saw, and compound miter saw SOPs on the Bechtel Center website.

Below is a list of all components you must prepare and shape during this activity:

- Outer mallet head laminations (2)
- Inner mallet head laminations (2)
- Mallet handle turning blank (1)
- Wedge(s) for handle (1-2)

Note: Be sure to taper the inner surface of the mortise constructed by laminating your mallet head. Reference the diagram below for a reference of approximately how much to taper this surface.



To complete this activity, you must mill and shape your selected stock under the guidance and supervision of a peer mentor or supervisor.

Activity 5: CNC Gantry Router

One of the most extensively used machines in the woodshop is the ShopSabre CNC gantry router. This activity will allow you to get more accustomed to the fixturing and operation of the machine with a simple 2D machining operation.

Schedule a reservation with a peer mentor to learn how to set up and operate the gantry router. For this part of the activity, you will engrave your name onto one face of your joiner's mallet. Before your reservation, please ensure your CAM has been approved by a peer mentor and review the SOP for the ShopSabre Gantry Router.

To complete this activity, you must engrave your mallet head under the guidance and supervision of a peer mentor or supervisor.

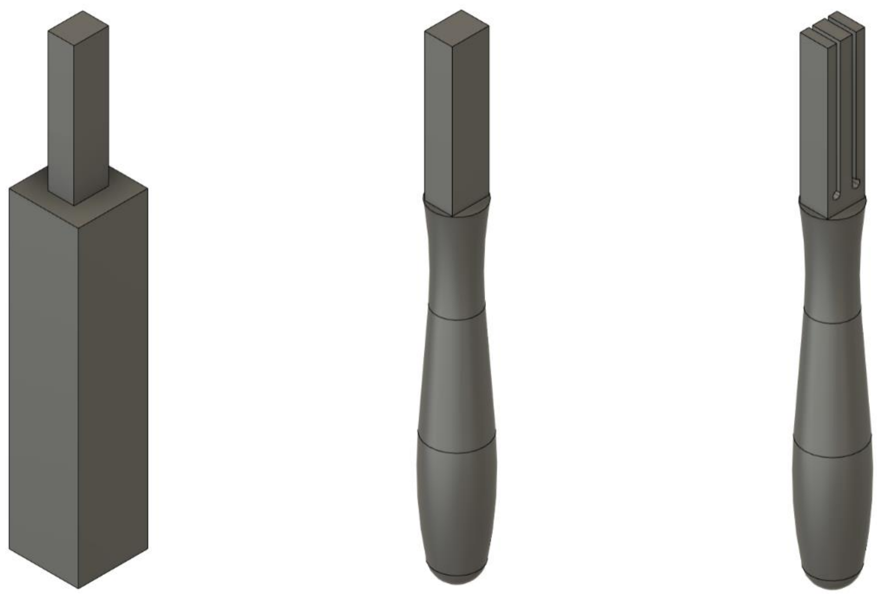
Activity 6: Turning

Another commonly used machine in the woodshop is the wood lathe. This activity will give you hands-on experience using the lathe and will allow you to learn about the various cutting tools and techniques involved in spindle turning, where the grain is oriented parallel to the axis of the spindle (in contrast to bowl turning, where the grain is oriented perpendicular to the axis of the spindle).

Schedule a reservation with a peer mentor to learn how to operate the lathe. For this part of the activity, you will turn the handle of your joiner's mallet using the blank prepared during **Activity 4: Milling & Shaping**. Prior to your reservation, please review the SOP for the wood lathe on the BIDC website. A guide for approximate initial dimensions is shown in the diagram below.

The images below illustrate the blank before turning, after turning, and after cutting relief cuts for wedges which will be inserted during the assembly (**Activity 7: Assembly & Gluing**).

Notes:
DO NOT cut reliefs prior to turning as this weakens the area engaged by the spur drive.
Please use a hand saw for making the relief cuts.



To complete this activity, you must turn your mallet handle under the guidance and supervision of a peer mentor or supervisor.

Activity 7: Assembly & Gluing

Assembly is perhaps the most consequential step in many projects. This activity will give you hands-on experience using wood glue while learning about the various types of wood glue available. It also gives you an opportunity to learn how to clamp irregularly shaped parts. While this step is fairly straightforward, the risk associated with a poor glue-up can be high, so be sure to listen to the input of the peer mentor or supervisor you work with at all stages of the process.

To complete this activity, assemble your mallet under the guidance and supervision of a peer mentor or supervisor.

Activity 8: Surface Preparation & Finishing

The final step in any woodworking project is the application of a finish. Finishes protect the wood from moisture and some mechanical stresses, in addition to enhancing its beauty. Prior to the application of a finish, the surface must be prepared. This can be done by sanding, scraping, and planing, depending on the surface requirements and the properties of the wood. Sanding is the most versatile and can give more consistent results, though scraping can highlight wood figure more.

When sanding, it is important to work through grits as needed. If prominent tooling marks are left from the milling and shaping process, a more aggressive grit should be used. Sandpaper grits are denoted by the average number of abrasive particles per square inch. Lower numbers indicate fewer particles, though each particle is larger. The large particle sizes of low grit sandpapers cause deep gouges in the workpiece which need to be removed by higher grits. As a result, best practice is typically to follow a progression of grits, incrementally increasing until the surface is as smooth as needed for the finish. It is important to sand parallel to the grain when hand sanding. Sanding across the grain can leave deep scratches that can be difficult to remove and should be avoided.

Prior to the final sanding, many woodworkers recommend applying a small amount of water to the surface (by wiping with a damp cloth or spraying with a spray bottle). This swells the fibers at the surface, leaving a fuzzy texture to be removed in the final sanding pass. When the finish is applied, the fibers will not swell further, leaving a smoother feeling surface.

Finishes can be sorted broadly into two categories: evaporative and reactive finishes.

Evaporative finishes, including shellac and lacquer, are composed of a resin dissolved in a solvent such as alcohol or lacquer thinner. As the solvent flashes off, the resin is left on the surface where it hardens, forming a protective film. No chemical reaction takes place and the resin remains soluble, so additional applications of finish partially redissolve existing layers, forming a single layer.

Reactive finishes, including polyurethane, varnish, and drying oils (boiled linseed oil, tung oil, etc.), form an insoluble compound once cured. After any solvents (if any are included) evaporate, the resin reacts with a catalyst such as the oxygen in the environment to form an insoluble barrier. Unlike some other reactive finishes, drying oils seep into the fibers, leaving only a very thin film on the surface and offering little protection against scratches or impacts.

Other considerations should be made for toxicity, ease of reapplication/alteration, and expected wear in use. If you are interested in more information, this Fine Woodworking article goes into more depth on the nuance of evaporative and reactive finishes.

Be sure to follow all PPE requirements in accordance with the Safety Data Sheet of the finish you are using. A peer mentor should be able to guide you to the necessary PPE, such as gloves, splash goggles, respirators, etc.

To complete this activity, finish your mallet with the available finish of your choice under the guidance and supervision of a peer mentor or supervisor.

Please keep your completed mallet in the center until a supervisor has had a chance to look it over.