GNG 1103 Team 13

Design Project User and Product Manual

Door Slayer hinge jig

Submitted by:

Team Door Slayer, Team 13

Mike Polhamus, 300386686

Omar Nasr, 300365142

Jack Smith, 300379320

Brendon Roy, 300347176

Haolin Li, 300315912

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University of Ottawa

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Table 1. Acronyms

Acronym	Definition
MIG	Metal-inert gas: a type of welding using argon and a consumable metal electrode
CAD	Computer-aided design
FEA	Finite element analysis
“	Inches

Table 2. Glossary

Term	Acronym	Definition
Bushing plate		Plastic piece into which bushings are fitted; interchangeable and friction fit
Bushings		Metal cylinders through which a drill bit is inserted to operate jig
Frame members		Panels of plate steel forming the sides and center of the jig
Drive screw or lead screw		Bolt threaded through side member of jig frame used to clamp machine to a door

Jig frame		The portion of the jig consisting in its three structural members

1 Introduction

This User and Product Manual (UPM) provides the information necessary for door professionals, engineers and engineering students to effectively use the Door Slayer, and provides prototype documentation in addition.

The Door Slayer jig was designed at the request of Ambico to meet their need for a jig that will ensure quick, accurate placement of holes drilled for hinge installation on the side of their doors. Their stated budget was $100 for materials.

The work leading to this jig assumed, as was indicated on documents provided by Ambico, that the company sought a jig that could produce holes for multiple sizes of hinges with varying hole locations, and that could produce such holes perpendicular to the drilling surface, and that could be operated with sufficient ease and efficiency to greatly diminish the time required to drill appropriate holes in their doors.

The team also assumed that any adequate solution must be built to last long periods under daily usage in an industrial environment.

This document is arranged for clarity in the fashion of a typical technical document. An introduction to the device precedes an overview of its use and an explanation of particularities thereof. This will be followed by a detailed set of instructions narrating the means of recreating one of these devices.

The document covers work performed by this team between September, 2023 and the time of the project's completion in early December, 2023, and it is intended for door factory employees, door factory management and consultants, engineers, engineering students, and anyone with an interest in door hinge jigs.

Although there are extensive safety considerations involved in the fabrication of one of these machines, there are no foreseeable safety or privacy harms likely to arise from the use of this User and Product Manual in itself. But as the internet and dangerous power tools are employed extensively throughout the processes preceding and potentially arising from this document, extreme caution should be exercised at all times whenever action is contemplated in relation to this document's contents.

2 Overview

Ambico requested the design of this jig to speed the drilling of holes in their doors. The holes must be precisely located, both with respect to one another, and with respect to the dimensions of the door itself.

The company sought a device that could be used quickly to achieve holes drilled straight into the edge of their doors at exactly the proper location, using existing drills and personnel.

The Door Slayer jig achieves this at a cost of only $115, and would have achieved this for even less were tool steel round stock available in lengths shorter than one meter.

Installation and use of the jig consumes less than three minutes for three hinges. That's a 1000% improvement on the time stated in Ambico's early documents as their current estimate for the equivalent process.

The Door Slayer provides holes that are accurate to tolerances measured in 1/100" increments, in terms of placement, and to within a maximum of 5 degrees off of perfect perpendicularity to the working surface.

This unparalleled accuracy is matched with exceptional durability. The jig's ¼" steel construction means it can be dropped, thrown, hit, and otherwise maltreated at will without risk of losing its incredible precision.

No competing product provides the Door Slayer's unmatched precision or its unbeatable strength.

Key features to the device include drive screws, clamp plates, and interchangeable bushing plates; in fact, there are few other features or components worth mention.

The drive screws are the heart of the device's clamping function. They work like a bench vise: simply turn the handles until the device is firmly attached to a door. The jig fits over the side of the door where the hinge is to be desired, and the clamp plates on the end of each drive screw press the door against the jig's opposing frame member.

In this position, the bushing plate is inserted into an inset routed into the edge of the door, and bushings are positioned just shy of flush with the working surface.

Bushing plates are swapped out by pushing them in or out of the jig frame manually and replacing them with the plate sized for the desired hinge.

Holes are drilled with the jig's aid by positioning a drill's bit through each bushing in turn, and drilling a hole through it.

2.1 Conventions

Within this document, the terms “plate” and “panel” are to be understood as equivalent, and both generally in reference to a piece of steel plate.

2.2 Cautions & Warnings

As previously indicated, tools and techniques discussed below are extremely dangerous. In addition, access to files mentioned in this document could require internet access, which is always likely to sacrifice some measure of privacy and digital security. Proceed with caution before doing anything involved with this document other than simply reading its contents.

3 Getting started

The Door Slayer is designed for ease of use.

To begin, select the appropriate bushing plate (4.5” plate for 4.5” hinges, 5” plate for 5” hinges) and insert it into the large hole in the center of the jig.

Then slide the device over the door to be drilled, until the surface of the bushing plate contacts the edge of the door in need of holes.

Next, turn the handles clockwise until the device is secured to the door.

Finally, take a drill, stick the bit through the bushings, and drill holes.

No special steps are involved in this machine’s use. Operation should proceed exactly as would be imagined according to the description, which is a drilling jig that clamps onto the side of a door.

To remove the jig after operation, turn the handles counterclockwise until the jig is free.

3.1 Configuration Considerations

Successful operation of this jig requires a drill and, optionally, a piece of sacrificial wood to insert between a door’s surface and the metal surface of the jig’s clamping mechanism.

The jig is also configured to fit a pre-routed inset in a given door’s edge, which is shaped to accept a hinge according to dimensions provided by Ambico and indicated in accompanying schematics.

3.2 User Access Considerations

This jig is designed to be used by anyone with the means necessary to turn the handles to the necessary torque and to hold a drill in the correct position once the jig is secured.

Access for users may be limited by a company’s willingness to purchase the device, and a company’s willingness to purchase may be restricted by its finances, but other restrictions upon use are not foreseen.

3.3 Accessing/setting up the System

When employing the "Door-Slayer" jig, begin by familiarizing yourself with its array of features, including the adaptable screw-in bolts, removable bushing plates, and sturdy exterior shell.

In the course of your project, commence by selecting the desired bushing size and insert the corresponding plate into the cut-out shell. Observe that the bushing plate effortlessly locks in place without requiring additional force or complex procedures. Subsequently, carefully position the imprinted portion of the bushing plate into the chosen door hinge hole (ensure a proper fit before proceeding).

Prior to securing the bolts, introduce a sacrificial piece of wood (scrap wood) between the door and the bolts. Then, proceed to snugly fit the adjustable screws by turning the top of the user-friendly handles until they are securely tightened, ensuring immovability.

Align your drill with the meticulously crafted bushings and commence drilling! The "Door-Slayer" jig guarantees precision, with holes drilled within a 100th of an inch!. Revel in the confidence of achieving unparalleled accuracy during your drilling endeavors.

3.4 System Organization & Navigation

The Door Slayer is designed for quick deployment and simplicity in operation.

To minimize complexity, the jig's attachment mechanism consists of two drive screws, powered by two handles, terminating in two clamp plates, and an opposing plate of steel on the opposing side of the device.

The drive screws are driven through threads in the steel plate facing the plate that acts as a clamping surface.

The bushing plate consists of four bushings secured by eight snap rings within a single plastic plate. The plate's dimensions match those of the cutout routed at Ambico's factory prior to drilling of the holes intended for hinge installation.

These components are welded together, in the case of the three structural steel plates, or threaded together, in the case of the drive screws and the jig frame, or press-fit, in the case of the bushing plate and the jig frame.

3.5 Exiting the System

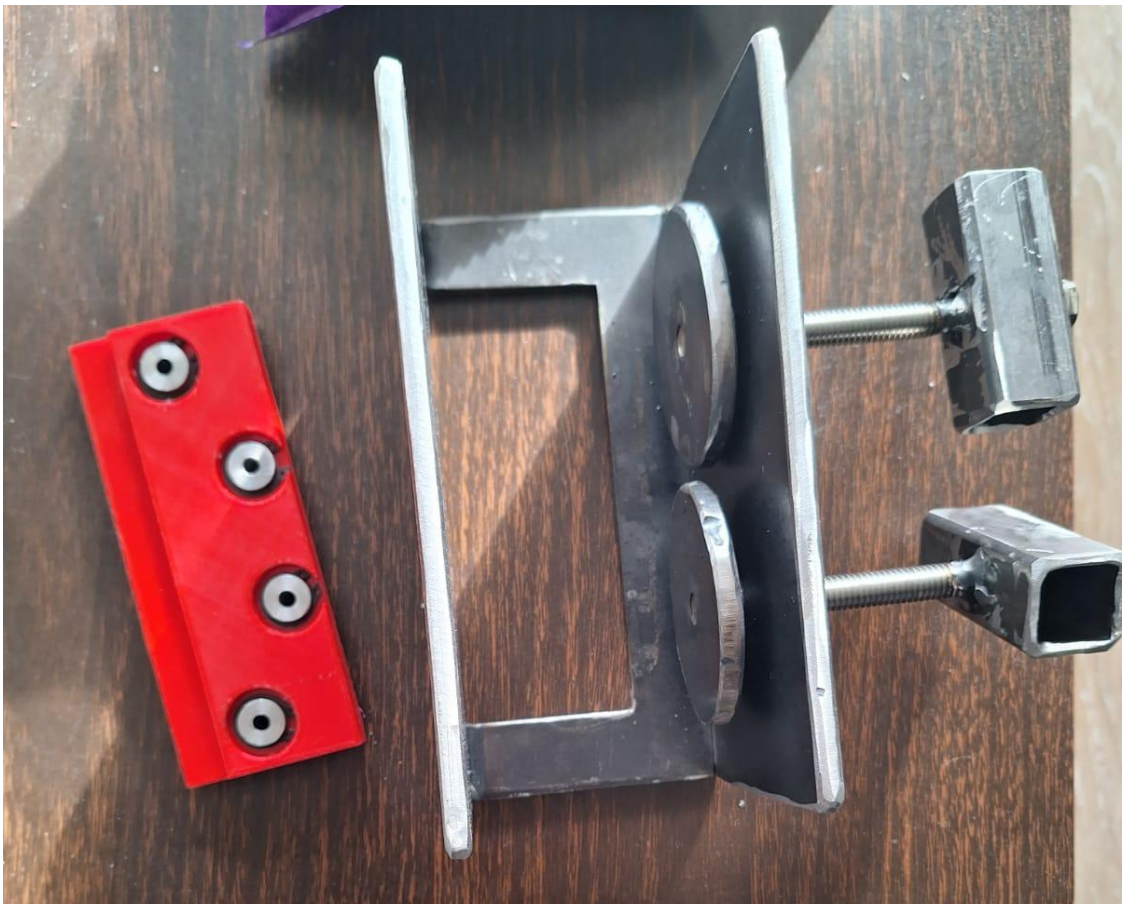
Once satisfactory results have been accomplished with a Door Slayer jig, the system is powered down and exited by way of turning each handle counter clockwise until enough space is provided to remove the jig from the door without impediment.

4 Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the Door Slayer jig.

4.1 Clamp

The clamp is activated by a set of two handles, turned clockwise to fasten the device and counter clockwise to remove it.



The jig's clamp mechanism, pictured right, comprises in large part the jig frame itself, but with the addition of handles, bolts and clamp plates (bushing plate pictured on left)

4.1.1 Drive screw clamp plate

This 2.5” diameter circle of steel plate is attached to the drive screws’ distal ends, and in operation they press against one side of a door. Their operation is actuated by the handles at the drive screws’ other end.

4.1.2 Drive screws

These 3/8” bolts thread through one side panel of the jig frame and rotate within threads tapped therein to provide the mechanical advantage that affixes the jig to a door.

4.1.3 Drive screw handles

These are sections of square stock welded to the headed end of the drive screws to facilitate easy rotation of drive screws and ready utilization of the clamping mechanism by manual means.

4.1.4 Undrilled side frame member

One structural member of the jig frame serves as a portion of the mechanism serving to clamp the jig to a door. The side member of the frame that lacks threaded holes for drive screws is that against which the door is press when the clamp mechanism is in operation.

4.2 Bushing plate

The interchangeable bushing plates are the heart of the system and the device’s only portion not fabricated from steel alone.

A bushing plate (pictured above) with snap rings around bushings visible inside counterbores

4.2.1 Bushings

These tool-steel cylinders, four per plate, are where a drill bit is inserted when the jig is in use. By sticking the bit through this component's central bore, the bit's perpendicularity to the drilling surface is ensured. These are fastened to the bushing plate by snap rings. Bushings are easily removed or inserted with the aid of snap ring pliers, in the unlikely event that replacement should become necessary.

A bushing, shortly after fabrication by Team Machinist Jack Smith

4.2.2 Bushing plate proper

This plastic piece is counterbored to allow bushings to recess within it, averting contact between bushing ends and the surface of a door. These plates are sized to fit exactly within the inset routed into doors prior to drilling. Fit between the plate, the bushings, and the snap rings is so precise that bushings do not rotate within the plate even under working loads.

4.2.3 Snap rings

A set of eight snap rings secure the bushings in place inside the bushing plate. These are easy to remove, provided the proper procedure is followed. Proper procedure requires removal of the snap ring not recessed within the bushing plate's counterbore before removal of the bushing from the plate allows removal of the bushing's second snap ring.

5 Troubleshooting & Support

In the unlikely event of problems arising during use of a Door Slayer jig, it is essential that panic or extreme emotion be avoided, as these conditions are likely only to further increase whatever setback has arisen.

The only possible problem discovered in operation of the Door Slayer thus far has resulted from over tightening of the handles.

If a drive screw is overtightened, and as a result won't easily back off, simply tighten the other drive screw until the stuck drive screw is freed by the decrease in tension. Back off drive screw tensions in successive increments until removal is permitted.

5.1 Error Messages or Behaviors

The above-mentioned error can be known to have occurred when, upon attempting to remove the jig from a door, a given handle won't readily turn.

5.2 Special Considerations

Although a Door Slayer jig is designed to be thrown, dropped, hit, beaten, or otherwise maltreated, the bushing plate is not of so sturdy a construction as the rest. Avoid smashing the bushing plate, as it is a plastic piece and is liable to breakage under extreme circumstances.

5.3 Maintenance

To ensure the longevity of your Door Slayer, users should:

- Keep it away from water
- Avoid beating it with instruments larger than a standard framing hammer
- Avoid areas with high concentrations of airborne particulate matter
- Paint the steel body with anti-rust paint

5.3.1 Bushing plate maintenance

The bushing plate is weaker than the jig frame. If visible deformities appear in the bushing plate, it is advised to reprint the plate (without replacing the bushings, provided no issues with bushings are apparent) to ensure perfect perpendicularity.

For instructions on reprinting a bushing plate, please see detailed sections on fabrication below.

5.3.2 Bushing maintenance

The tool steel bushings have a lifespan of 60,000+ uses. After 60,000 uses, it is recommended that the perpendicularity of holes they produce undergo testing.

If holes appear to be crooked as a result of bushing wear, or if wiggle room develops in the bushings, replacement is recommended, along with new snap rings.

For detailed instructions on bushing reproduction and installation, see the relevant section on fabrication below.

5.3.3 Drive screw maintenance

Drive screw threads should be greased with auto bearing grease or marine grease as desired, to provide smooth operation.

5.4 Support

Emergency assistance is always available from the design team's Chief Officer, Omar Nasr, whose contact information may readily be had by simply requesting it from the University of Ottawa Engineering Faculty.

For all other support inquiries, contact Team Door Slayer's Head Technical Functionary at ilovetoskifast@gmail.com. Please include with inquiry a telephone number, a first name, and a brief description of the issue in question.

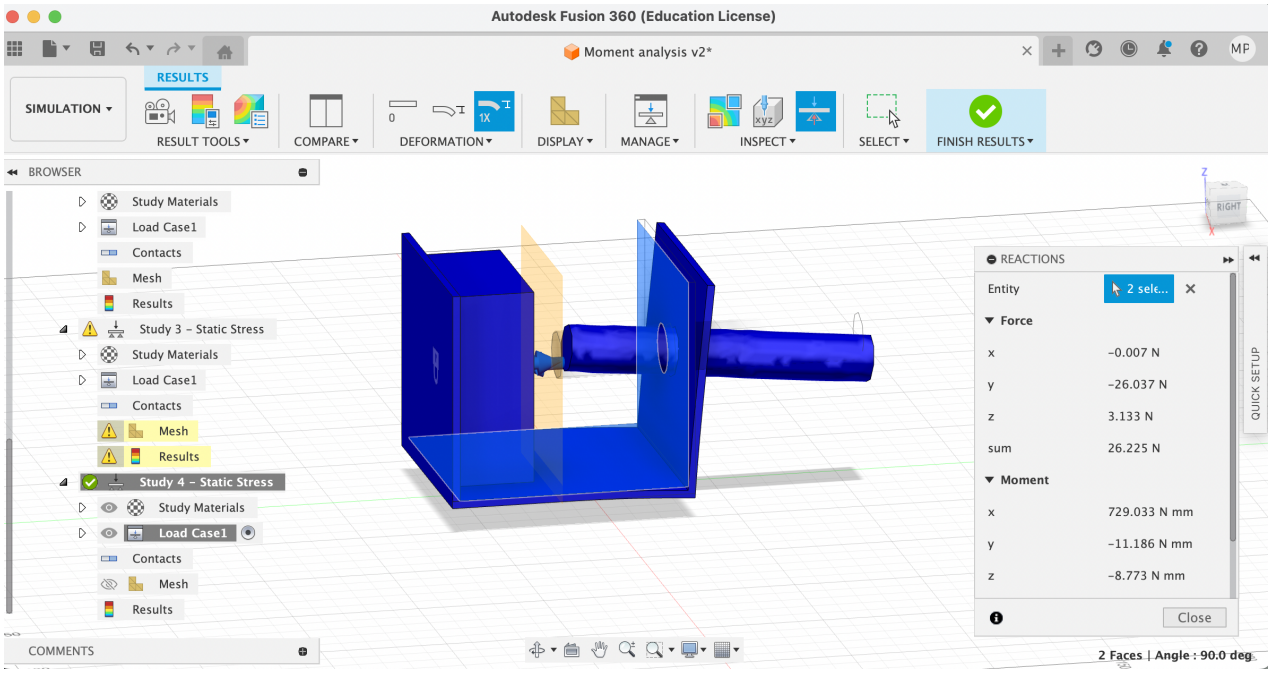
6 Product Documentation

For this device, the choice of steel was an easy one. Steel was the cheapest material that possessed the mechanical properties required by a tool intended to be clamped onto an object and used in a factory setting.

This particular alloy, 44W steel, is a Canadian alloy that is cheaper than other mild steel varieties available in the country.

Metal was in general an obvious choice of frame material, as it provides torsional stiffness necessary for solid clamping along with the strength and durability needed to ensure precise operation of the device.

Testing done through FEA (see sample below) showed a significant moment was generated at the joint between two frame members. The attachment of those members would need to be rigid and durable for the jig to operate as intended. Again, metal seemed to offer the ease of joining these panels that our team required, and the durability of construction that Ambico demanded.



FEA analysis performed by Team Modeler Mike Polhamus

Tool steel was chosen for the bushings because no other alloy offered the toughness that seemed appropriate in a component through which a drill bit is operated at high speeds, constantly and for long periods.

The bushing plate came to be made of 3D printed plastic after it became apparent that milling it from acetal, PVC or Delrin would cost more than was budgeted. The 3D printed plastic provides acceptable performance at a low price, but a production model of this jig would likely require a more durable variety of polycarbonate.

Snap rings were chosen to secure bushings within the bushing plate as adhesives didn't offer the durability this team considered essential to a successful design.

The drive screws are fashioned from 3/8" bolts because imperial hardware is the standard found in Canada, and because that particular size offered the strength this application seemed to require.

Coarse threads on the drive screws were chosen for the property that type of thread possesses to lock a setting in place somewhat better than fine threads under loads such as are achieved by manually applied torques. An Acme nut and corresponding drive screw might have provided better thread-locking capabilities (due to the isosceles trapezoidal thread profile's characteristics in the Acme nut thread standard as opposed to the isosceles triangle thread profile found in standard bolt threads), but their cost was prohibitive.

Once the choice of materials was made, the only means of fashioning and attaching the pieces involved became clear as well. Welding was the only suitable choice for construction; plasma cutters, bandsaws and a mill the only suitable means of shaping. The only feasible alternative to welding – bolts – would have compromised much in terms of reliability and simplicity while adding cost and potential points of failure.

6.1 Materials, equipment and fabrication

6.1.1 BOM (Bill of Materials)

- 1' square ¼" 44W steel plate
- 6" length of 1" square stock, 1/8" wall thickness
- 2 3/8" hex head coarse-threaded steel bolts
- 1' section of ½" diameter tool steel round stock
- Plastic for bushing plate printing or alternative material if plate is to be milled with CNC instead (Acetal, PVC or Delrin recommended as suitable material for CNC machined bushing plates)
- 8 ½" snap rings per bushing plate (each bushing plate is configured for a single hinge dimension)

6.1.2 Equipment list

- MIG welder
- Plasma cutter
- Mill
- Magnetic right-angles for aligning corner welds

- C-clamps of all shapes and sizes
- Angle grinder
- Flapper wheel
- Mill capable of top- and side-milling
- CAD file of bushing plate converted to G-code file
- 3D printer with .4 mm nozzle
- 3D printer software
- Horizontal bandsaw
- Drill press
- 3/8” coarse-threaded tap
- Snap ring pliers (fine tip)
- Square
- Paint pen
- Bench vise
- Steel center punch
- Metal scribing compass
- Micrometers
- Welding pliers
- Bench grinder
- Metal scribe

6.1.3 Trainings required to use necessary tools at Brunsfield Centre

- Lathe
- Mill
- MIG
- Welding safety
- Basic safety
- Plasma cutter

6.1.4 Instructions

If you have been tasked with recreating a Door Slayer door hinge jig, glad tidings are upon you, for a Door Slayer jig is a pleasure to own and a delight to construct.

First, obtain the necessary training.

Next, obtain the materials this project requires.

Then, gather the necessary tools in a convenient spot.

Finally, once sufficient preparations have been made, commence fabrication.

Steps to fabrication are as follows:

1) 3D print the bushing plate, or, better, mill it from a superior material on a CNC machine.
    a. Get dimensions from included schematic
    b. Printer settings very important
        i. Fill should be set to at least 80 percent with gyroid pattern for strength and for density in case sanding is necessary
        ii. Use .4 mm print nozzle to ensure clean bushing pass-through holes
        iii. -.1 horizontal expansion will ensure pass-through hole definition
        iv. Wall line count of at least 4 needed for clean wall prints
        v. Top and bottom layers should be at least 6
        vi. Print speed of 50 mm/s and wall speed of 40 mm/s provide adequate printing time for good definition on pass-through holes for bushings
        vii. Walls and top and bottom settings should be at least 1.2 mm thick
        viii. Print cooling should be enabled
        ix. Fan speed: 100%
        x. Layer height of .1 mm for best results
2) Fashion bushings
    a. Cut bushing blanks to length using angle grinder
        i. Tool steel is too hard to cut readily using other tools and methods
    b. Cut circlip grooves into exterior of bushings using lathe and carbide tools
    c. Cut central bore using end-stock drilling method on lathe using carbide bit
3) Scribe measurements on steel plate
    a. For side member, central member, and bushing plate retainer tab dimensions:
        i. Perform several test cuts on scrap material to find distance from cutting guide to relevant edge of plasma cut
        ii. Add or subtract that measurement as needed from final dimensions to locate cutting guides such that plasma cut kerf does not intrude upon intended final dimensions of jig members
        iii. Measure twice, scribe once
    b. For circular clamp plates:
        i. Using metal punch, place dent into steel plate marking center of the circle describing clamp plates' perimeters
        ii. Trace circle using metal scribing compass
        iii. Trace compass scribe marks with paint pen for visibility when cutting from behind welding hood
4) Plasma cut the frame members from a plate of ¼" 44W steel
    a. Cutting is done most easily, for flat sections anyway, with a section of 1" square stock serving as a guide c-clamped to the surface of the steel plate at a distance measured to produce the correct cut location.
    b. Alternatively, just cut the sections oversize and fit to dimensions on bandsaw or mill
    c. Circular clamp plates affixed to drive screws must be cut freehand

    d. Beware of warped metal. If metal warps, defects that arise will require straightening before the final weld. Warping may be avoided with careful plasma cutting, done in short sections to prevent overheating
    e. Warping is especially to be avoided on central member, but warping is unfortunately most likely to occur here, as this section requires much plasma cutting on a section left with relatively little material to dissipate the heat
5) Chop rough edges off frame members with horizontal bandsaw, or mill them if not cuttable
    a. Plasma cutter tends to heat-treat this alloy steel and harden it to a point that vertical bandsaw will not cut the material, meaning any defects not curable with a horizontal bandsaw will need to be overcome by a mill and a six-bladed tool.
    b. Take care to ensure square cuts as jig relies upon perfect squares achieved throughout in order to ensure holes are perpendicular to working surface once assembled
    c. If only small adjustments are required, milling will again be the preferred tool, as the steel is likely too hard to engage a horizontal bandsaw's blade for trimming and squaring of edges where insufficient material remains for blade to fully engage material
6) Grind edges of cut steel plate on bench grinder
    a. This is both for safety's sake and for functional purposes
    b. When welding the critical half-open outside corner seams, the ground edges offer space for material to penetrate more fully into the weld, allowing welding to take place with members flush against one another to ensure squareness and precise dimensions while still permitting weld to infiltrate interface between plates
    c. Grinder is needed to achieve circularity on drive screw clamp plates, as this is very difficult to attain using freehand tracing of compass scribe marks with plasma cutter
7) Mill central member cut-out where bushing plate fits
    a. 1/1000" tolerance achieved, and for the sake of the friction fit it should be sought out.
    b. First clear side edges of plasma cut using side-mill technique, then size side edges to within ¼"
    c. Top-mill middle portion, leaving ¼" margin at the corners to avoid catching side of tool on whole inner surface of frame member
    d. Side-mill side surfaces to within 1/1000" of desired dimensions
    e. Side-mill corners, taking care to avoid engaging entirety of tool against inside edge of plate, until cut-out dimensions all sit within 1/1000" of bushing plate dimensions; once dimensions are near, frequently attempt to insert plate, to ensure not more steel is milled than absolutely required to permit the bushing plate
    f. Six-bladed cutting tool recommended, because steel is likely heat-treated by plasma cutter
8) Cut handles from sections of 1" square stock using angle grinder or bandsaw
9) Drill pass-through holes through the middle of handle sections, using drill press
10) Drill holes in one side member for drive screws at placements indicated in attached schematic
11) Drill holes for drive screw clamp plates through plates' center, indicated by center-punch used to locate scribing compass
12) Tap drive screw clamp plates central holes and side member drive screw holes
13) Weld first corner (half-open outside corner)

a. This corner will be between the uncut side of the central member and bottom of the inward face of the drilled and threaded side member
b. Half-open outside corner necessary to keep dimensions identical to opposite side, where half-open outside corner is required to:
    i. Ensure welds do not interfere with fit between jig corner and door corner; inner corner weld would put material inside the corner where the door must fit flush with the jig's inside faces
    ii. Allow other side member to fit with the cut-out on the central member such that friction fit with bushing plate remains possible; if full open corner weld is used instead, cut-out dimensions will be either shortened by ¼" or else a ¼" space will open up beneath its bottom edge, allowing the bushing plate to slip beneath
    iii. Permit ready penetration of weld, which a fully closed outside corner weld doesn't offer
c. Corner should be made with member plates held square, either on magnets intended for the purpose or else by holding the plate firmly against large-cross-section piece of square stock
d. Check squareness of plates with a square and cold-set using bench vise after tack-welding the joint together before placing the seam
e. Take care to avoid overheating plates, especially the critical central plate, which lacks sufficient material to effectively dissipate heat
    i. Good idea to weld only a couple inches at a time here and allow jig to cool between welds
    ii. Material may lose warping if permitted to cool completely; do not panic if warping occurs

14) Weld the second side plate to central member
a. Half-open outside corner weld necessary here or else bushing plate won't fit correctly
b. Ensure that side member's broad face presses against outward thin edge of central member, rather than the reverse, or else bushing plate will cease to fit within cut-out
c. Tack edges together held square upon spare section of large-cross-section square stock
d. Using a bench vise and a firm grip, cold-set members to square joint after tack-welding the joint
e. Finish the weld once members are perfectly square

15) Tack 1" square stock sections to bolts to serve as handles
a. Slip distal end of drive screw bolt through drilled square stock's pass-through holes
b. Just a few tacks around the circumference of the bolt, at the interface between the bolt head and the outer face of the square stock, and at the interface between the bolt's threaded portion and the inner face of the square stock, offer adequate strength to withstand manual torques to which drive screws are subjected during use

16) Thread drive screw through side plate's drive-screw threaded holes

17) Tack circular clamp plates to threaded end of drive screws
a. Thread bolt's distal end completely through circular drive screw clamp plates once threaded through side member

b. Back off drive screw from clamp pads one full turn to withdraw distal end of bolt within clamp plates' threaded holes, to prevent end of bolt from contacting working surfaces
c. Tack around circumference of outward face of clamp pad where it meets drive screw threads. Just a few quick tacks is sufficient to hold assembly firmly in place
d. Take care not to overheat drive screw and potentially warp material

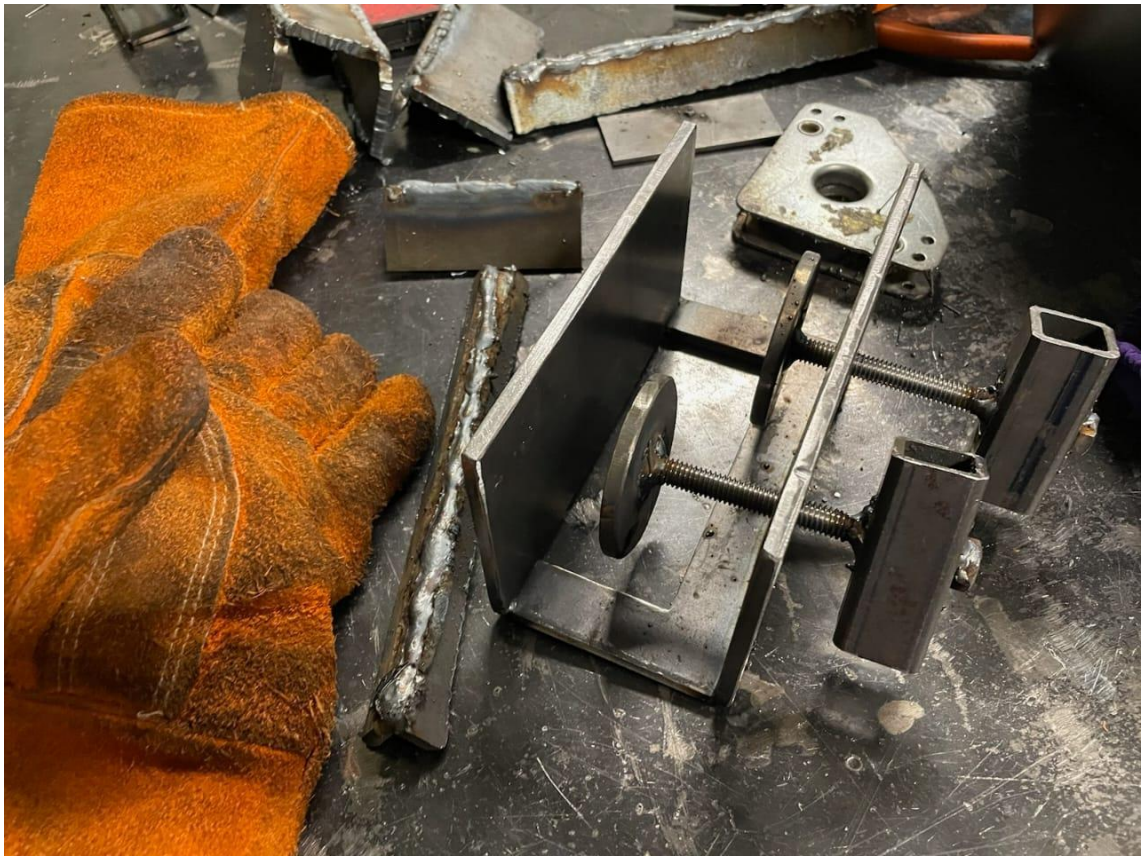
18) Weld 1" square tabs of ¼" plate to outside of bushing plate inset hole, against outside face of jig's central member, to prevent bushing plate from backing out of the opening
19) Using angle grinder with flapper attachment, sand welds and jig surface to remove imperfections
    a. Dremel inaccessible spots as needed
    b. Pneumatic grinder also useful for removing rough edges from inside of handles and hard-to-reach tacks on drive screws
20) Test bushing plate fit
    a. Sand plate perimeter by hand as necessary to achieve perfect fit
21) Insert bushings into bushing plate
    a. Attach snap ring to inwardly-located groove of bushing
    b. Slip bushing into pass-through hole on plate from side with counterbores
    c. Seat bushings so that bushings' inner surface is withdrawn beneath plane of bushing plate's inward surface, preventing contact between bushing ends and working surface
    d. Attach second snap ring to bushing to secure it place within bushing plate
22) Insert bushing plate into jig
23) Attach jig to door
    a. Seat bushing plate dimensions to fit within routed inset on door edge
24) Drill holes for hinges with ease, elegance, and efficiency

Drive screw side plate and central plate with bushing plate prior to assembly (drive screw bolts seen in bottom center of photo)

Tricky things to watch out for:

- Welding takes time to learn, but the flapper wheel corrects a lot of bad technique.

- Fabricating the bushing plate could be difficult without a 3D printer
- Milling the central cut-out takes a lot of time and care; milling the edges of remaining rectangular pieces could also require a great deal of time depending on quality of plasma cut
- Plasma cutter seems to harden 44W steel, so beware when cutting small pieces to leave plenty for the horizontal bandsaw to seat on or else rough edges may need to be milled smooth.
- Perfect perpendicular alignment of frame members is challenging, especially after welding the first corner. A method that worked for me was to tack the remaining ends of the central member onto the remaining upright, and then cold-set the entire assembly to achieve proper angles throughout, before completing the welds to give structure and lock everything in place.
- Precision is very important when milling the friction-fit central cut-out for the bushing plate
- A couple of tabs should be welded beneath the bushing plate, which is designed around the dimensions the tabs create for the plate relative to the inner surface of the central structural member of the jig. The tabs prevent the plate from slipping out of the back, and they translate the flat surface on the bottom of the jig into the bottom surface of the bushing plate, ensuring a flat base for the plate.
- All circular edges on bushings except for circlip grooves should probably get a chamfer; ours was straight-bore and my suspicion is that the edge this created around the inner circumferences' opposing faces was responsible for chewing up my drill bit when we ran practice runs through the fully-functional comprehensive prototype.
- When tapping threaded holes for drive screws in circular clamp plates and in lateral frame member, ensure threads are cut perfectly perpendicular to face of steel plate or else resulting clamp pad misalignment could mar working surface
- Industrial felt is recommended for all inward-facing surfaces of Door Slayer to prevent direct contact between steel and doors' wood



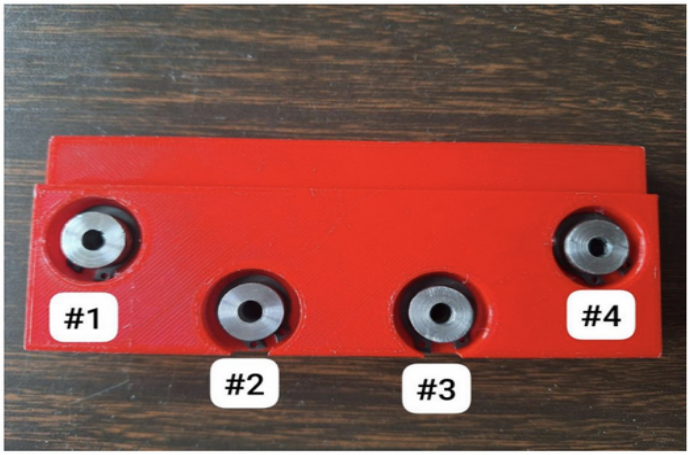
Door Slayer seen here immediately following assembly by Team Welder Mike Polhamus

6.2 Testing & Validation

Too many tests to list in this limited space informed the process of designing this device. However, the most important tests – those showing its capabilities once assembled – occurred the day following its assembly.

Those tests showed that the holes this jig produces are not only within hundredths of an inch of their desired location, but also within 5 degrees or less of perfect perpendicularity to the working surface, even when in the hands of a perfectly unskilled operator.

Hole #	Angle Deviation
1	5°
2	1° - 2°
3	1° - 2°
4	0° - 1°



Test results indicating degrees of deviation from perfect perpendicularity, per bushing

Beyond these tests, the prototype has withstood extensive durability testing with no signs of wear, and several rounds of feedback testing brought overwhelmingly positive results in favor of the design's simplicity, precision, and durability.

Its ease of use was demonstrated in feedback testing performed on November 28, 2023, when members of the public used the device without training, numerous times, producing perfectly spaced, perpendicular holes each time.
Extensive feasibility testing has established, as results demonstrate, that the machine may be built with relatively little skill using the techniques and tools described above.

7 Conclusions and Recommendations for Future Work

To conclude, it deserves mention that at many points during the process of fabrication, services were discovered that could have allowed the project's development by slightly different means with fewer technical abilities. The team preferred, however, in many instances to take the somewhat more technically demanding route, as the results seemed to warrant the time invested. But, to give just a single instance, it would be not just possible but far easier and potentially less costly in terms of time, to simply hand the steel plate over to a welding shop and ask for a clamp-shaped object meeting the design characteristics in return.

The choice to cut, shape, and weld every component of this jig was made out of a commitment to quality, but these represent corners that may be cut should enterprising future individuals wish to reproduce the machine with less effort.

It was found as a result of this work that a perfectly serviceable device answering to the client's needs was not only possible, but also within the sphere of abilities in the possession of a small group of first-year engineering students, to design and construct. This was a wholly unexpected finding.

Future iterations of the device might benefit from a bushing plate machined, as said earlier, from a stronger polycarbonate, aided by use of a CNC machine.

8 Bibliography

Engineering Design, GNG1103, taught by Prof. Muslim Majeed, provided most if not all of the documentation required in the process of designing and building this device.

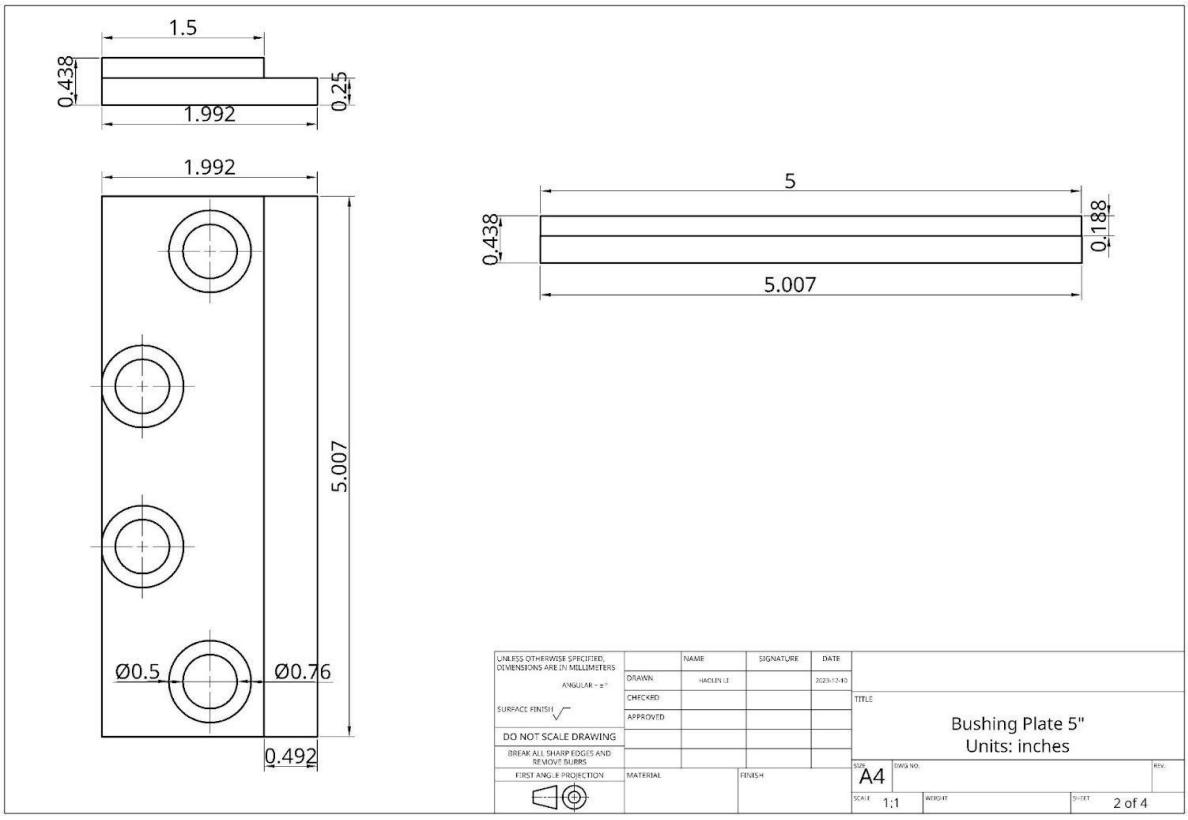
9 APPENDIX: Design Files

Table 3. Referenced Documents

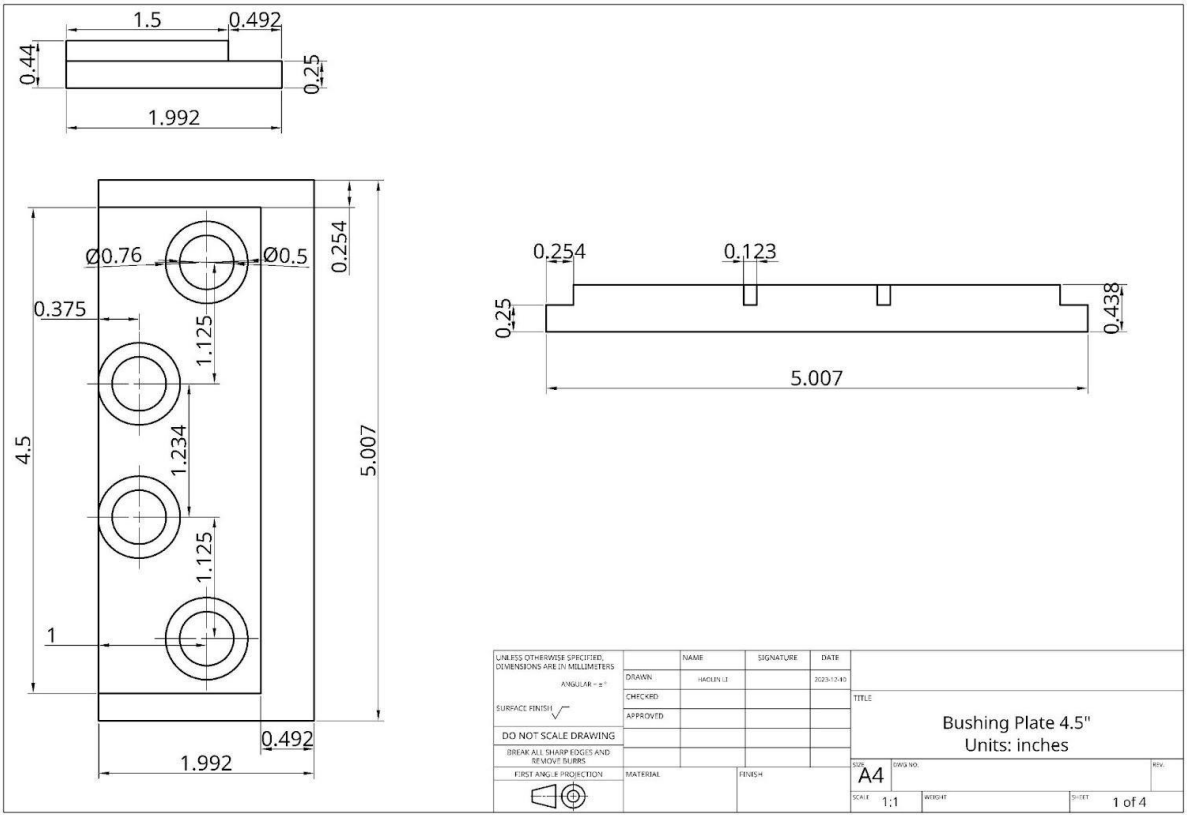
Document Name	Document Location and/or URL	Issuance Date
Ambico design request	https://www.makerepo.com/project_proposals/375	August 16, 2023
CAD files of prototypes and bushing plate	Onshape group folder, enabled for view by faculty of University of Ottawa Engineering Faculty	September, 2023
FEA analysis	See above	October 14, 2023
Schematics and dimensions	See below	December 10, 2023

10 Design dimensions and schematics

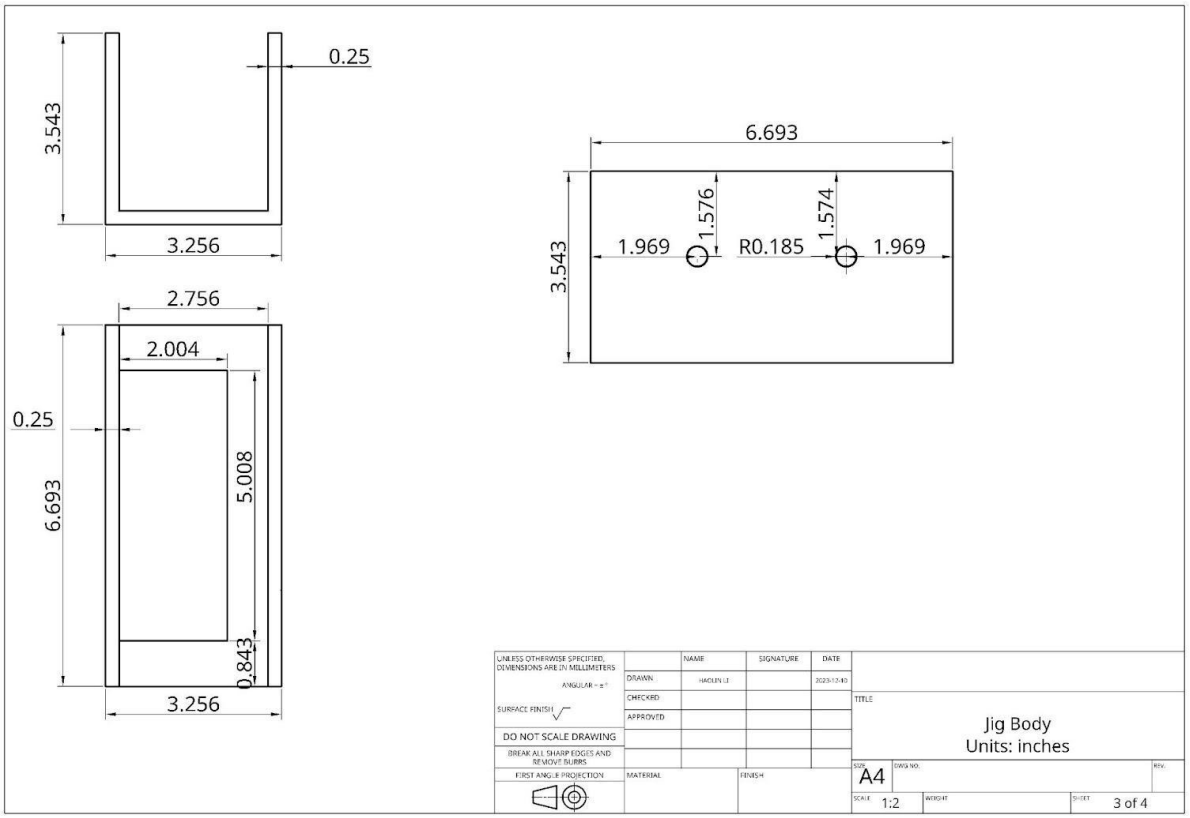
Bushing plate dimensions (5” plate)



Bushing plate dimensions (4.5” plate)



Frame dimensions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2.756
2.004
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6.693
1.576
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1.969
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ANGULAR: ± °
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DATE
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WEIGHT
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3 of 4