WELDING FABRICATION

LAKE WASHINGTON INSTITUTE OF TECHNOLOGY WELDING DEPARTMENT

OpenWA
Olympia, WA

CONTENTS

Fabrication is fundamental to our everyday lives. Every object we interact with was fabricated by someone using many different methods and processes. With the help of tools, software, and human ingenuity, anything is possible. This textbook covers a variety of topics surrounding fabrication and provides lab assignments to demonstrate all of the skills learned.

Course Description

This course includes both theory and lab work. It focuses on the principles, procedures, and operation of equipment to properly and safely use layout and fabrication techniques.

Course Outcomes

Upon successful completion of this course students will be able to:

- Communicate with colleagues to determine steps to complete a fabrication project
- Assess and appropriately react to diverse needs of colleagues to complete a fabrication project
- Identify and describe the properties of different metals
- Read and follow blueprints
- Use metallurgy principles to properly select

materials, tools, and equipment, and to perform welding tasks

- Use math to make equipment adjustments/ calibrations and to complete fabrication projects
- Prepare a work area for layout and fabrication projects
- Identify and safely assemble equipment for layout and fabrication projects
- Store, transport, and handle all types of layout and fabrication equipment properly and safely
- Prepare metal for layout and fabrication projects
- Use proper welding tools and equipment to complete layout and fabrication projects
- Identify and use common types of shop equipment and hand tools to safely perform welding and fabrication procedures
- Use technical resources to access information regarding the installation, repair, and maintenance of welding and fabrication equipment
- Use technical resources to access information regarding welding and fabrication processes
- Follow industry standard safe practices, including the using and wearing of all safety equipment needed to weld or be in a welding environment
- Comply with hazardous material laws and processes

- Complete a resume, cover letter, job application, and job search as necessary
- Select the proper metals and consumable materials, including electrodes, wire, filler metal, and/or shielding gases, for various welding tasks by using metallurgy principles
- Prepare metal for welding or cutting procedures using proper equipment and joint preparation techniques for ferrous and non-ferrous metals
- Use welding machines, shop equipment, and hand tools to safely perform welding and/or fabrication procedures
- Select, assemble, and adjust welding machines for various processes to produce welds that meet AWS standards
- Demonstrate the ability to start an arc, run a bead, and assess a weld puddle
- Use proper welding techniques to produce welds on lap joints, corner joints, T-joints, and/or butt joints in a variety of positions, including 1F, 2F, 3F, and 4F and/or 1G, 2G, 3G, and 6G
- Use math to make equipment adjustments and/or calibrations and to complete fabrication projects
- Use visual inspection methods and/or destructive testing to identify defects and/or discontinuities
- Follow ANSI Z49 safety standards, including recommended practices for personal protective

equipment and hazardous material laws/ processes

LICENSES AND PERMISSIONS

For Further Information

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ABOUT THIS BOOK

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PART I

FABRICATING TECHNIQUES AND PRACTICES

1.

WHAT IS FABRICATION?

Fabrication is the action or process of manufacturing or inventing, the assembly of parts to create something more. Assembly of complex parts on large projects takes place one simple piece at a time.

During fabrication of objects, parts may be joined by a combination of methods: welds, bolts, screws, rivets, adhesives, etc. Weldments are components that are joined by welding. Thus, all weldments are fabrications, but not all fabrications are weldments.

The first steps in welding processes are:

- Reading the technical drawing to determine what type of weld is required,
- Clamping to a table or fixture to avoid heat warpage, and
- Tack welding two pieces of metal.

Objectives

After completing this part, you will be able to:

- Explain the various safety issues related to fabrication.
- List the advantages of using preformed parts for fabrication.
- List the advantages of using custom fabrication parts.
- Demonstrate an understanding of the proper placement of tack welds.
- Demonstrate the use of location and alignment points when assembling a project.
- Explain how to adjust parts to meet the tolerance.
- Describe how to control weld distortion.
- Lay out and trace parts.
- Identify common sizes and shapes of metals used in weldments.
- Describe how to assemble and fit up parts for welding.

2.

SAFETY

Safety is always a primary concern when fabricating anything.

During the fabrication of weldments:

- Wear all the PPE required for the operation.
- Stay attentive and alert.
- Keep a clean work area to avoid trips and hazards.

Potential safety issues include:

- Welding outside an enclosed welding booth
- Several welders working on the same structure.
- Ventilation and other work area hazards
- Weight and stability concerns

3.

PARTS AND PIECES

Pre-Made or Custom Made

Welded fabrications are made from pre-cut and pre-formed parts or parts cut and formed by hand.

Advantages of pre-formed parts include lower costs, a higher speed of fabrication, a higher accuracy of measurements, and less waste produced.

Custom-fabricating parts makes certain types of work easier, such as creating originals or prototypes, performing repairs, or other custom jobs. However, most cutting processes remove metal and leave a small gap or space, also known as *kerf space*. Take this into consideration when choosing where to cut.

Materials

Weldments may be constructed from a combination of shapes, sizes, and metals. Common metals include carbon steel, aluminum, stainless steel, and titanium.

Metal stock comes in a variety of shapes including

plates; sheets; flat, square, and round bars; angles; c-channels; i-beams and flange beams; square and round tubing; and pipes.

Laying Out Parts

Parts for fabrication may require lines to be laid out and points to be marked for various operations. Methods of marking include soapstone, metal markers, chalk lines, metal scribes, and a center punch.

Factors affecting the layout process include the materials involved, the shapes of parts, and allowable tolerances.

Layout Tools

Unimaginable amounts of special tools have been developed for laying out parts. There are a few that you will interact with more than others. Tools of note include: tape measures, square, protractors, rulers, calipers, bevel gauges, angle meters, and lazer tools.

Nesting

Nesting shapes is a way of laying out parts so that the least amount of scrap is produced. Odd-shaped and unusual-sized parts often produce the largest amount of scrap. The parts must all fit together in the most optimal way for the sheet or plate. This process may be completed by computer or manually.

Tolerance

The *overall tolerance* is the amount the final assembly can

vary from the layout drawing. Remember that the finished weldment must be within overall tolerance. The engineer has developed the blueprint to allow for margin of error on the smaller parts without jeopardizing the final assembly.

The *part's tolerance* is the amount a part can be bigger or smaller than it should, and still be acceptable. This allows the parts to fit into the larger assembly without having to re-cut or grind them.

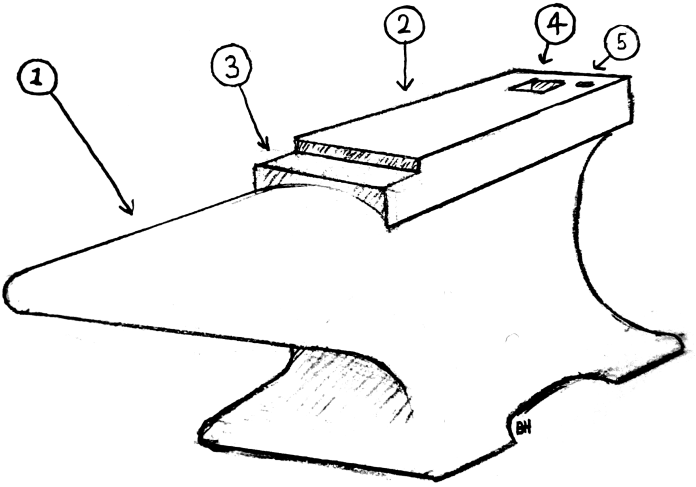
4.

BLACKSMITHING

Blacksmithing is another form of fabrication, used primarily to form steel. For welders, forging is a useful skill set.

There are an infinite number of tools that can be used to form steel. We will only need to worry about a few categories of them.

Anvils:

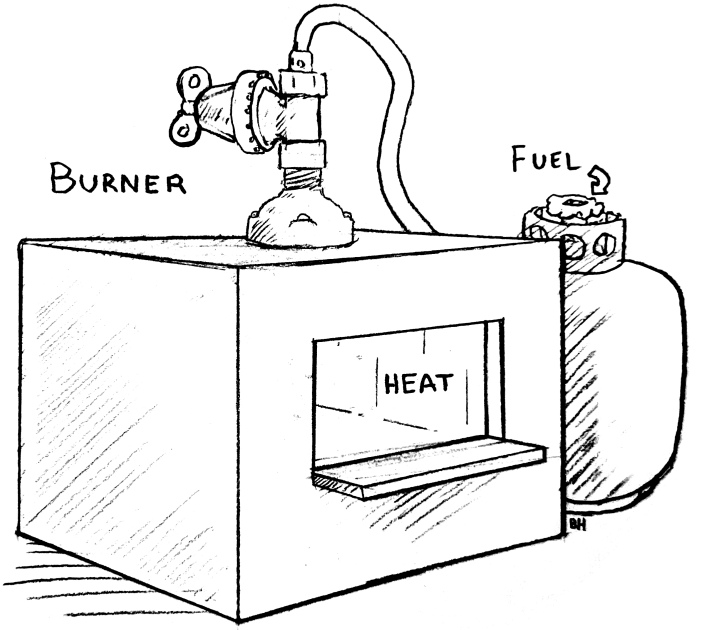


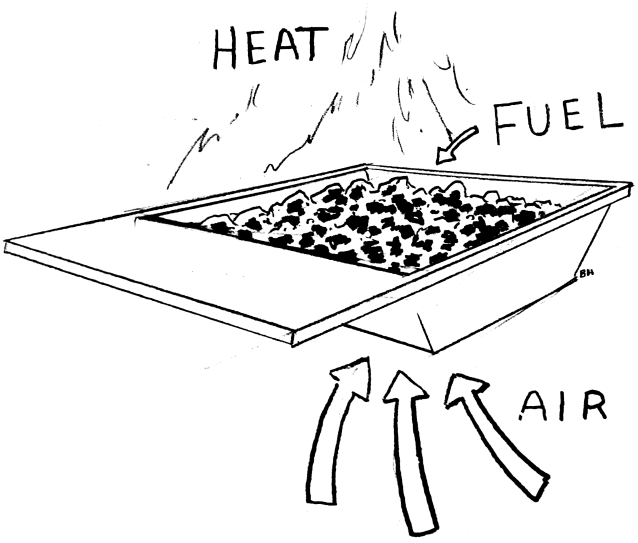
The Anvil is the center of the blacksmith's shop. Anvils have five major components:

1. Horn: used to bend the steel in a round shape as well as "draw out" the material.
2. Face: used to flatten the steel in any direction. One side of the face usually will have a rounded edge that allows you to start a scroll or create a bend without pinching the steel.
3. Step: used to offset the steel or form unusual shapes that a flat surface won't allow.
4. Hardy hole: A place to put hardy tools into. The hardy can be viewed as a custom anvil extension allowing you to place a variety of functional shapes that would normally not be included in the anvil.

5. Pritchel hole: this is a round hole mostly used to punch through the material but can also hold a variety of other tools

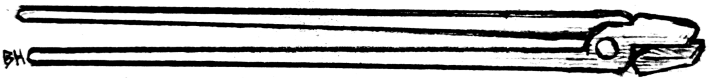
Forges:





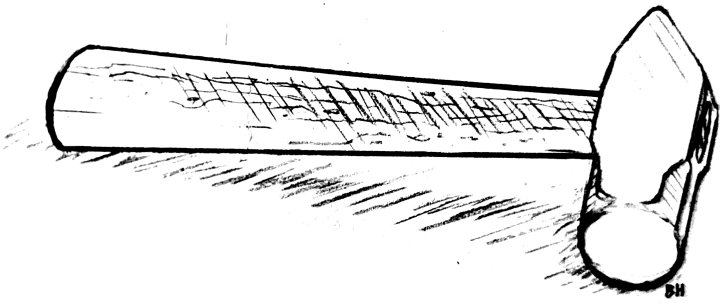
The forge is the most important tool in the blacksmith's shop. Without a forge, the smith must use hand torches to heat the steel which makes it hard to heat the material consistently. There are two types of forges, gas, and coal. Both have their pros and cons.

Tongs:



Tongs are the blacksmith's hands; they hold the material at a distance as to not burn themselves. There are a variety of tong types that hold a variety of material shapes. The blacksmith's tongs are usually the first tool made by a blacksmith.

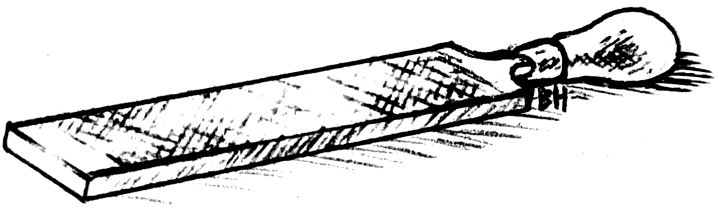
Hammers:



If you thought there were a lot of different types of tongs, wait until you see all the hammers available to the blacksmith. Each hammer has a specific role to play in the metal forming process. If the wrong hammer is used, you run the risk of ruining the piece or even the tools.

The hammer should **never** be swung downwards. All your energy should be spent lifting the hammer and letting it drop. If the hot metal isn't moving the way you want it too, use a bigger hammer, **not** a stronger blow.

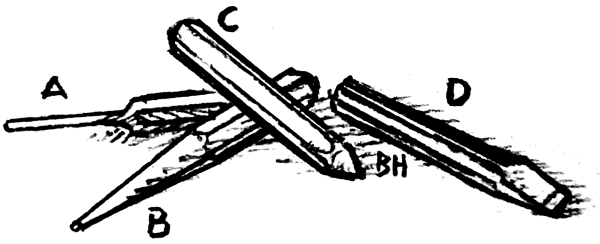
Files:



Files are used to form the final shape of objects created in the forge. Files come in many different sizes, shapes

and coarseness. Rasps are also in the file family and are used to coarsely remove material

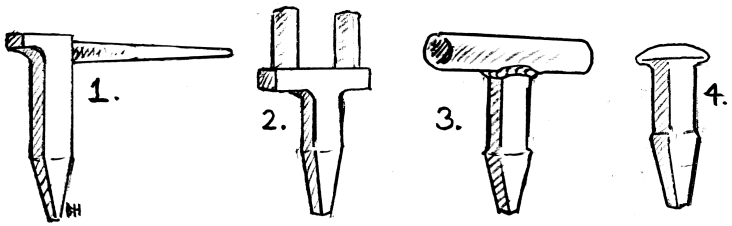
Hole punches and chisels:



Hole punches and chisels are used to create holes and cut material. In order to successfully cut a hole through hot steel, you must allow the punch to move past the steel into the pritchel hole. In the image above are some examples:

- A: Hole Punch
- B: Drift
- C: Center Punch
- D: Chisel

Hardy tools:



A hardy is designed to sit within the anvil to allow for many different types of tools.

1. Mandrels are horn shapes that allow for smaller circles than the anvil horn would allow.
2. Bending forks are used to create ornate scrolls and s-bends.
3. Fullers allow you to "draw out" or extend the steel into a smaller profile.
4. Half rounds or ball posts can be used to shape thin sheet metals.

Numerous other shaping faces with as many variations as possible allow a full range of metal forming.

5.

ASSEMBLY

Bringing together all of the weldment parts to create the final product requires proficiency in several areas, including tack welding, locating and aligning parts, and using various assembly tools.

Tack Welds

Tack welds are made during assembly to hold all weldment parts together before the final welding. Considerations when tacking include: thickness of the metal, the joint length and shape, welding stresses, and overall tolerances and fit-up.

Location and Alignment Points

Locating parts is easier when parts are lined up on an edge starting at a corner. From there, careful checking of alignment points on the welding diagram will help ensure an accurate weld.

Assembly Tools

Many tools are needed to maintain the shape of the product during assembly. Without using tools like clamps or fixtures, welding warps the metal you are working on. This can potentially ruin the part, costing millions.

Clamps temporarily hold parts in place. Types of clamps include: c-clamps, bar clamps, pipe clamps, locking pliers, cam-lock clamps, and other specialty clamps.

Fixtures aid in assembling and fabrication of weldments. They may align, position, or support parts during the fabrication process. This allows for quicker production of the same part multiple times.

6.

POTENTIAL ASSEMBLY ISSUES

While assembling the final weldment out of the various parts, you may encounter several different issues.

Fitting

Unfortunately, not all parts fit exactly as designed. There may be slight imperfections or distortion, but some problems can be solved by grinding or with a small tack weld.

Weld Distortion

Larger welds may cause weld distortion and have larger heat-affected zones. All metals distort by expansion when heated and contraction when cooled.

There are two main factors affecting the degree of distortion: the rate of thermal expansion and the rate of thermal conductivity. There are also factors affecting the

degree at which distortion occurs during welding: heat input, shrinkage of the metal, uniformity of the weld, size of the weld, and whether the parts were offset before welding.

7.

SUMMARY

Completing work on a piece of equipment, building, trailer, or structure is one of the greatest experiences as a welder/fabricator. Layout and fabrication techniques must be learned through time and practice.

PART II

ASSIGNMENTS

8.

BLACKSMITHING ASSIGNMENT

Purpose

- Learn about the various tools required to forge steel.
- Safely and properly use each tool to achieve success
- Understand the effect heat has on steel and the ability to form it.

Task

As a team, use the forge, hammer, and anvil to create two (2) objects made of steel (one for each person in the group). Due to the nature of the forge, there are a few limitations:

- The base material cannot exceed ¾” diameter

steel bar stock

- **No weapons of any kind.**

Depending on the object created, the order in which you form the steel is very important, so work thoughtfully.

Criteria of Success

- The object must have a function. If its only function is aesthetic, then the object must be objectively beautiful.
- The final object must not include sharp edges or burrs.
- The object must be completed with teamwork.

9.

DRILL PRESS ASSIGNMENT

Recommended Drilling Speeds (for High-Speed Steel Drills)

Material	Average Drill Speed (sfm)*
Magnesium	300
Aluminum	250
Brass/Bronze	200
Copper	70
Cast Iron (soft)	120
Cast Iron (hard)	80
Mild Steel	110
Cast Steel	50
Alloy Steels (hard)	60
Tool Steel	60
Stainless Steel	30
Titanium	30
High Manganese Steel	15

**Note: for carbide drills, double the average speeds*

**Surface feet per minute, aka SFM = 0.2618 x (drill diameter in inches) x (rotations per minute, aka RPM)*

Purpose

- Work as a team, dividing up large tasks into smaller ones
- Use technical resources to access information regarding welding and fabrication processes
- Identify and use common types of shop

equipment and hand tools to safely perform welding/fabrication procedures

- Follow industry standard safe practices, including the using and wearing of all safety equipment needed to weld or be in a welding environment
- Use math to make equipment adjustments/ calibrations and to complete fabrication projects
- Prepare a work area to do layout and fabrication
- Select and safely set up layout and fabrication projects
- Prepare metal for layout and fabrication projects
- Use proper welding tools and equipment to complete layout and fabrication projects
- Become familiar with a drill press, drill speed, and drill pressure

Task

In this assignment, you and your team will be making a total of one (1) **six-sized dice** and one (1) **Swiss cube**.

Remember to record all measurements and calculations!

1. Find usable material for this assignment BEFORE you start this assignment.
2. Create an orthographic drawing in AutoCAD of a Swiss cube.
3. Create a print in AutoCAD of a six-sided dice.

4. Calculate drill speed for each size drill press. Note: SFM (surface feet per minute) is the relative speed between the spinning cutting tool and the workpiece. For different materials, the speed has to be faster or slower to prevent the bit from getting too hot and burning up the drill. With harder materials, spin slower. With softer materials, spin faster. Do the math every time you change the SIZE of the drill bit and every time you are drilling into a different MATERIAL. **The math must include the diameter of the drill.**
5. Cut the cubes to size.
6. Measure and mark hole locations.
7. Use a center punch to guide the drill bit.
8. Properly operate the drill press and its features, including using cutting oil.

Criteria of Success

Swiss Cube

- Outer edges must be beveled.
- Edges cannot have sharp edges or burrs.
- Holes cannot overlap or break through to each other.
- The corners need to have 90° angles [5° tolerance].
- All sides of the cube need to be equal in dimension [1/8″ tolerance].

Six-Sided Dice

- Outer edges must be beveled.
- Edges cannot have sharp edges or burrs.
- Holes must be equal depth and cannot overlap.
- The corners need to have 90° angles [5° tolerance].
- All sides of the cube need to be equal in dimension [1/8″ tolerance].

10.

SHEET ROLLER ASSIGNMENT

(“Armillary sphere and greenhouse at the Queen Elizabeth Garden, Dumfries House” by Rosser1954 is licensed under CC BY-SA 4.0.)

Purpose

- Use a roller to create curved sheet metal

Task

In this assignment, you and your partner will be using the roller in E164 to create one **garden ring**.

The object is to make 4 rings that fit inside each other for the purpose of garden art. You may weld or rivet rings together in place.

1. Find usable material for this assignment BEFORE you start this assignment. The plate must **not** be longer than 8′ long or 4″ wide, or thicker than 14g, but can be less than.
2. Use the roller to create concentric circles that fit within each other
3. Rivet or weld all rings together at multiple axes.

Criteria of Success

- The four rings must fit inside each other.

11.

COPING PIPE ASSIGNMENT

Purpose

- Cope, prepare, fit-up, and weld pipes together.

Task

In this assignment you and your partners will be using a manual method, Oxyfuel or Plasma, to cope two pieces of pipe onto the third.

1. Grab a single 2″ pipe that is located in the back cage.
2. Cut it into 3 pieces.
3. Cope two of the pipes at one end to create a 90° angle (I recommend you use a template to trace and cut out the pipe).
4. Fit the pipes together with tack welds.
5. Weld all around the pipe using any process.

Criteria of Success

Your grade will be based on the quality of fit-up and how close to 90° you can get the joint.

12.

CNC PLASMA CUTTING ASSIGNMENT

Purpose

- Apply your newly found knowledge of AutoCAD to use a CNC plasma cutter

Task

1. Create or search the internet for a CNC File (file type DXF or DWG).
    1. The design must be no larger than one foot by one foot, and the image or text must be school appropriate.
2. Convert the file if needed into a readable file for the CNC Controller.
3. Prepare to use the CNC plasma cutter:
    1. Make sure all parameters are set

BEFORE you start cutting.

2. Check the dimensions off of the drawing file: are they close?

4. Use the CNC plasma cutter to cut out your design.

Criteria of Success

- The shape must be cut out with the CNC plasma cutter. If you used the CNC plasma cutter, it is a success.

13.

FIT-UP ASSIGNMENT

Purpose

- Follow industry standard safe practices, including the using and wearing of all safety equipment needed to weld or be in a welding environment
- Prepare a work area to do layout and fabrication
- Select and safely set up layout and fabrication projects
- Prepare metal for layout and fabrication projects
- Use proper welding tools and equipment to complete layout and fabrication projects
- Communicate with colleagues to determine steps to complete a fabrication project
- Assess and appropriately react to the diverse needs of colleagues to complete a fabrication project

Task

In this assignment you and your partner will be making one 12″x 18″ plant holder out of 2″ angle iron. The base plate is 20″x4″x1/2″. The objective of this assignment is to create three different ways to cut angle iron to make 90° and to understand there are always multiple ways to fabricate simple designs.

Criteria of Success

- The final product meets the dimensions listed above.
- Three different ways to cut angle iron to make a 90° angle have been used.
- All corners must have proper fit-up.
- All corners must be 90° (with a 5° tolerance).
- Welds must be quality (no grinding).

Watch out for a bad fit up and distortion!

14.

RIVET ASSIGNMENT

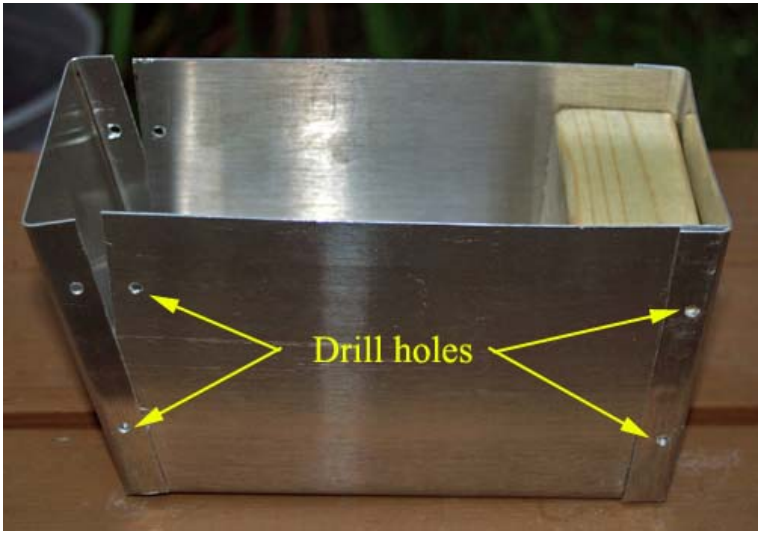
Purpose

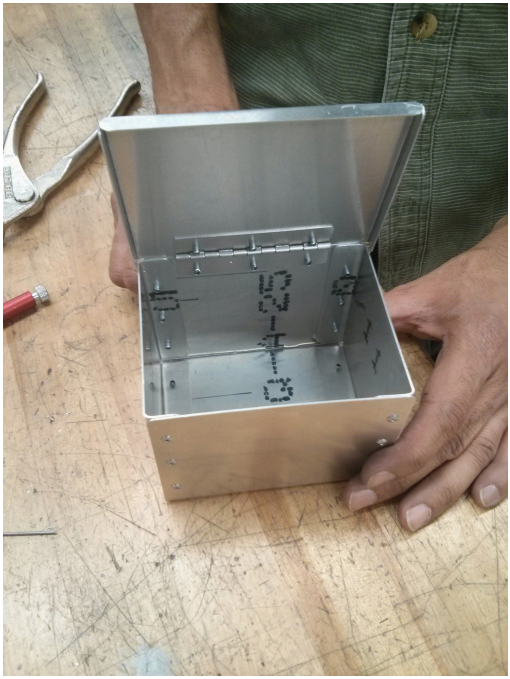
- Use technical resources to access information regarding welding and fabrication processes
- Identify and use common types of shop equipment and hand tools to safely perform welding/fabrication procedures
- Follow industry standard safe practices, including the using and wearing of all safety equipment needed to weld or be in a welding environment
- Use math to make equipment adjustments/ calibrations and to complete fabrication projects
- Prepare a work area to do layout and fabrication
- Select and safely set up layout and fabrication projects
- Prepare metal for layout and fabrication projects

- Use proper tools and equipment to complete layout and fabrication projects

Task

In this assignment, you and your partner will be making a simple riveted box out of aluminum.


Drill holes



1. Find usable material (sheet metal) for this assignment BEFORE you start this assignment.
2. Make a template out of cardboard, including rivet holes.
3. Match the template to your chosen material.
4. Calculate drill speed for each size drill press.
5. Bend ends and edges after drilling holes in parts.
6. Fit up box and rivet together (DO NOT WELD).

Criteria of Success

- Box must have at least five (5) sides to it.
- Rivets must be used evenly throughout the box.
- The material must be bent to a 90° angle (with a 3° tolerance).
- All sides must be parallel to each other.
- The final assembly must not have sharp edges.

How to Submit

- Take two pictures of the riveted box and two pictures of the cardboard template.
- Bring the box to the instructor for inspection. Once approved, submit a picture online.

15.

BLUEPRINT FOR FINAL PROJECT

Purpose

- Create a blueprint for your final project

Task:

1. Using AutoCAD or other CAD programs, draw out your project! This is part of your group project so include as many details as you can.
2. Make sure the lab already has the materials you need to build your design. If we do not have it, you can't use it.

Criteria of success:

- Three (3) 2D orthographic views of your final project

- Title block including:
    - Project name
    - Group name/member's names
    - Scale
    - LWTech Logo
    - Class name/number
- Bill of Materials/parts
- Dimensioning lines