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ME 4371-02

Mr. Gray

Team Sigma

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Executive Summary

Scope and Objectives:
One of the major concerns in welding is the ability to hold multiple pieces in place to safely join them together with minimal interaction.

The welding fixture that was designed is able to hold a minimum of two components in a position where they can be safely welded together. This welding fixture is able to clamp multiple geometric shapes including flat, rectangular, or round surfaces. The device fits in an 18 x 18 inch footprint and is able to hold at least twenty-five pounds at the end of the clamp without causing the fixture to tip over. All together the welding fixture weights roughly thirty-five pounds so a single person can safely move it. The independent clamps are able to move about four separate axes of rotation, being able to accommodate for typical welding operations. The pieces being clamped do not require solid welds at the seams. The object should be welded at several spots along each seam and then the clamps should be removed so the unit can be welded solid.

Findings and Observations:
Observations and findings include:

- The device must be easily manufactured
- Space constraints must be kept in mind
- Operation of the device must be intuitive
- The device must be able to be adjusted by hand
- The design must be robust and portable
- The device provides personal and commercial application
- The device can accommodate multiple geometric shapes
- Standard welding safety must be met

The expected results of the project include increasing the ability to safely weld multiple pieces together that would ordinarily take at least two people. The entire mechanism will have the ability to fit together without any detailed instruction. All parts will be either standardized or easily manufactured to keep the costs of the design to a minimum.

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Design Problem and Objectives

The purpose of this design project is to create a universal welding fixture that can clamp or hold various objects to be tacked together. The need to reduce complications in welding operations has increased in recent years with advancement in materials and the complexity of assemblies. Faster completion times have driven the design and innovation of welding fixtures. Being easy to operate and have multiple applications is a key component in the design process. In this design, the pieces are tacked and the clamps are then removed to weld the fixture solid. While trying to achieve this goal there are several limitations have to be met. These are not limited to but include:

- Limited space for entire fixture cannot exceed 18" X 18"
- Hold a minimum of 25lb.
- Have at least 3 degrees of freedom
- Commercial and personal applications
- Easily assembled
- Manually adjustable
- No use of tools required
- Materials that can withstand welding operations
- Independent clamping mechanisms
- Be able to accommodate various geometric shapes
- Be able to clamp a minimum of 2 pieces together at a time
- Keep cost within a reasonable range

After the design is finalized, it is manufacturable and be available for anyone wishing to assist themselves in welding at a relatively low cost. The fixture will has the capabilities of holding materials together, moving them in four axis of rotation, and accommodating a variety of geometric shapes in order to weld them in place. The plan is to release a finished product that is portable, robust, useful in many operations, and safe to operate.

Detailed Design Documentation

Base:

In the design of the welding fixture base (Figure 1), it was decided upon that it needed to provide a solid foundation for the clamping mechanism and the added weight of the pieces being welded together. By having a center column that provided a clamping point in which the mechanism could be rotated around and positioned vertically. The wide base is made of ASTM 36 steel that provides the stability to hold the fixture in the upright position and kept the weight manageable. A small plate will be mounted on the side of the base plate in order to provide a safe place for the grounding clamp to be attached to. The center column is a piece of 18” schedule 40 pipe that is welded in the center of the base. This design allowed for the workspace to be focused away from the center, which allows the user to be able to work over a table/bench. Factoring in the entire assembly it was found the base would not tip under the specified amount of weight that the fixture should be able to hold. Also, the base satisfies all the space and weight requirements while still providing adequate strength. The base was made from leftover materials and was made with no cost to the team.

Vertical Bar:

The vertical bar is used in combination with the swing arm in Figure 3 that extends the clamping mechanism away from the base of the welding fixture. This creates a workspace both over the center of the entire fixture and also extends the workspace more over the table/bench that is being worked on. After analyzing the stress and strength of the vertical pipe versus a solid bar we discovered that the pipe was only slightly weaker in terms of yield strength compared to the solid bar, but the pipe provided a significant weight reduction in the overall design. Also, the use of 1 inch pipe throughout the design provided uniformity throughout the design of the rectangular clamp in Figure 4. Cost is set at $14.08 for 1” x 19” schedule 40 pipe.

Swing Arm:

The swing arm was designed with a piece of rectangular tubing with two collars welded on the ends that will house the vertical pipes. The swing arm allows the vertical pipe to be moved away from the central column of the base. Also, it provides the same four axis of rotation when the clamping mechanism is mounted to it. This decreases the chance of the entire fixture tipping because it functions as a counter weight or an extension when the both clamps are oriented in the same direction. The swing arm provides added space between the center column and secondary vertical pipe, which allows for more precise placement of materials the clamps are holding. The collars will be made from cut pieces of 1.5 inch pipe. Cost estimates for 1" x 2" tubing is $4.08. 3"x1.5" schedule 40 pipe is set at $14.08.

Rectangular Clamp:

The rectangular clamp is made from a piece of ASTM A513 11 gauge rectangular tubing with eight holes drilled through it. The holes accommodate both the vertical and horizontal pipes, as well as the thumb screws that will provide compression to keep rotation of the pipes locked in position. The rectangular clamp allows for rotation about the vertical axis and provides rotation to the horizontal bar which holds the bar clamp in place. The rectangular tubing is robust enough to counter-act any stress that may cause premature failure using the given parameters when shear forces are taken into account. The part is designed for ease of manufacturability, and specifications are able to be met inexpensively. Cost estimates for the tubing is 2.5” x 2.5” x 6” is $13.44.

Horizontal Bar:

The horizontal bar is made from standard 1 inch pipe and is capped at both ends in order to hold the bar clamps in place. The caps are made from 1/8 inch thick stock cut from 1.75” bar stock with a hole milled to allow the rail of the bar clamp to be held into position. The horizontal bar is able to rotate in the horizontal plane to allow the bar clamp rotational motion. The pivoting of the bar clamp rail will aid in keeping it from sliding during normal operation when weight is applied at the clamping end. The end caps will be welded and aligned in the same orientation so the bar clamp can fit perfectly. Some filing may be needed in order to get the bar clamp to fit snug.

Bill of Materials

Item #	Part #	Qty	Name	Material	Source
1	1	1	Welding Fixture Base	ASTM 36 Steel	Junk Pile
2	2	2	Rectangular Tubing Mount	ASTM A513 11 gauge 2.5” x 2.5”	Bryce
3	3	1	Vertical Beam	1” Schedule 40 pipe	Bryce
4	4	2	Horizontal Bar	1” Schedule 40 pipe	Bryce
5	5	1	Swing Arm	1.5” Schedule 40 pipe & ASTM 513 16 gauge 1” x 2”	Bryce
6	6	2	V-Pad	Pre-fabricated	Texas Tool & Equipment
7	7	2	Bar Clamp	Pre-fabricated	Stronghand Tools
8	8	2	V-Pad Spacer	Pre-fabricated	Texas Tool & Equipment
9	9	8	5/16 hex nuts	Pre-fabricated (AA grade)	Lowes
10	9	8	5/16” x 18 x 2in thumb screw	Pre-fabricated (AA grade)	Lowes

Safety

Safety is a very important factor to consider for just about everything, but it is extremely important to consider while designing a device that many consumers will be using. We want to avoid as much as we can that could potentially lead to a person getting hurt while using our device, so we created some basic guidelines that we followed while creating our design:

- Operator needs to be free from touching hot surfaces
- Device should be less than 50 lbs. so that a single person can easily move the device
- Pieces of the fixture should not arc together
- Fixture needs to avoid the possibility of tipping over
- Grounding clamp needs to be safely out of the way
- Pinch points on the design

These principles helped guide us to making a welding fixture that will be safe for the consumer to use on a standard basis. Also we have created a list of safety guidelines that the consumer should read before operating our device and should continuously follow while using the welding fixture that we have designed. They are as of follows:

- Beware of pinch points of the device when using the adjustments
- Keep caution for hot material before, during, and after welding has taken place
- Use proper lifting techniques when moving the device

Findings and Observations:
Observations and findings include:

- The device must be easily manufactured
- Space constraints must be kept in mind
- Operation of the device must be intuitive
- The device must be able to be adjusted by hand
- The design must be robust and portable
- The device provides personal and commercial application
- The device can accommodate multiple geometric shapes
- Standard welding safety must be met

Conclusion

Throughout the year, it has been clear that our design has evolved numerous times from one stage to the next. This can be seen by the adaptation of the base from our original table like design, to the current vertical column with heavy base structure. Another adaptation that we made to the design was the clamping mechanisms. These have changed from in the beginning being a universal C-Clamp holder to now a bar clamp with optional attachments. One of the advantages of these optional attachments is that with the V-pad, it will be able to hold any shape of object due to the individual motion of both of the pads. The bar clamp we are using has another advantage in that it can be used both as a clamp and a separator. An improvement that was made to the vertical columns that hold the horizontal beams was to instead of having the column attach to the table we have one attached to the base of the device and the option of adding more with swing arms with vertical bars that go through them. Another improvement that was made to our design was that initially we thought to use a pin and key method of securing the rectangular tubing to the vertical bar but realized that this would limit the amount of adjustment possible to the device. To fix this problem we decided to use friction to our advantage and create a power locking mechanism that goes through the rectangular tubing in order to hold it in place on the vertical bar. The significant result that we have come to is an inexpensive design. This was achieved more so through the change from the C-Clamp holder to the bar clamp because it would have had to been manufactured instead of purchased like all of our other parts. Some of the results of the design that we have made are that it can move on many axes both linearly and rotationally, we believe that the device will be extremely difficult to manufacture, the device will be able to be adjusted and operated intuitively by hand, it will be easily taken apart and put back together, it can be used for both personal and commercial applications, and that it will not intrude on the welding space where you are holding the materials to be welded.

Team Sigma Progress Report

Iterations:

001 – Replacing solid steel bar on the base with 1" Schedule 40 pipe.

- Justification: Replacing the solid 1" steel bar with 1" schedule 40 pipe will benefit the strength to weight ratio of the entire fixture. A 1" pipe has the same bending moment strength as a 1" steel bar but does not weigh close to the same.

002 – Replacing pipe ring mounts on swing arm with collars that can be tightened.

- Justification: By using collars that can be tightened. The swing arm will be able to be more secure and not be prone to tipping or wobbling compared to when the design called for rings made of schedule 40 pipe that were just larger than the outer diameter of the 1" pipe tower.

003 – Increasing height of swing arm from 1 inch to 3 inches, using 1.5 inch pipe as collar ends

- Justification: Using the higher collars allows for more stability of the vertical towers. Hand screws will be used to secure the vertical towers to the swing arm.

004 – Using a 2.5" x 2.5" square tubing instead of 2" x 2.5"

- Justification: 2.5" x 2.5" tubing is more readily available and a more common size then the 2" x 2.5" rectangular tubing. Thus, making it easier to get, and it gives our clamp more material to work with.

005– Drilling 4 holes in the base plate to allow for base to be bolted to a table

- Justification: By having the added holes in the base you can safely secure the fixture with 3/8" bolts. This will help with the stability of the overall fixture to avoid any cases where the fixture could tip over due to weight of the materials being welded.

006 – Using 1.75" steel bar cut to 1/8" thick circles to be used for end caps instead of 1/8" plate

- Justification: Allowed for easier manufacturing of the end caps.

007 – Changing the dimensions of the center hole of the end caps

- Justification: Extending the dimensions from .5" to .625" allowed for the bar clamp to be inserted into the caps and required less manual filing, etc. to get the bar clamps to fit.

008 – Changed location of thumb screw to hold the horizontal/vertical pipe in place

- Justification: The original design did not provide adequate clamping strength. By moving the thumb screw directly above the horizontal pipe and welding a nut on the top to provide more thread area instead of drilling and tapping through the .120" thick material. This design change allowed the thumb screw to be able to hold the horizontal/vertical pipe in place.

009 – Added Copper Plate to the base of the fixture to serve as mount for grounding clamp

- Justification: Having a flat plate bolted to the base of the fixture allowed for adequate place of the grounding clamp that does not interfere with most welding operations. Using copper allows for good flow of the current through the metal since it is a good conductor.

Team Member Assignments:

- Welding: Kyle, Nick
- Milling: Bryce, David, Jeremy
- Grinding/Cleaning: Everyone
- Drilling: David, Kyle, Bryce
- Material Cutting: Everyone
- CNC: Marco, if necessary

Shop Activities:

- Thursday September 13, 2012: Went with everyone and obtained 6 feet of 1 inch pipe and approximately 1 square foot of 1/8 inch steel plate
    - Bryce, Kyle, Nick, Jeremy, David
- Tuesday October 2, 2012: Cut 1" steel bar off of base and replaced with a 1" pipe that was welded. Cut both 6" horizontal bars and 18" vertical pipe for swing arm tower
    - Kyle, David, Nick
- Thursday October 11, 2012: Drilled 4 holes in the base, faced and cut the 1.75" steel bar for the end caps (Isaac helped).
    - Kyle, Bryce, David
- Tuesday October 16, 2012: Obtained the remainder of the materials (minus fasteners) and cut them all to the proper length (rectangular tubing, square tubing, 1.5" collars). Used a .25" end mill to mill out the center hole of 2 end caps.
    - Bryce, Jeremy, David, Nick
- Tuesday October 23, 2012: Cut new end-cap out of 1.75" steel bar. Completed milling the 4 end caps. Tack welded one end cap to each of the horizontal bars.
    - Bryce, David, Nick, Kyle, Jeremy

- Thursday October 25, 2012: Milled rectangular clamps using a 1 3/8" hole saw. Used 1.5" hole saw to cut curvature into the horizontal arm. Welded horizontal arm to collars.
    - Bryce, Kyle, Jeremy, Nick
- Tuesday November 5, 2012: Milled slots in rectangular tubing, discovered could not be clamped. In the process of re-designing.
    - Bryce, Kyle, Nick, Jeremy, David
- Tuesday November 14, 2012: Acquired fasteners, decided up new rectangular clamp modification in order to provide greater clamping force, drilled out the holes and welded hex nuts to the swing arm, which completed that part. Milled a new rectangular clamp piece using a hole saw.
    - Bryce, Kyle, David, Nick, Jeremy
- Tuesday November 27, 2012: Acquired remaining fasteners, drilled the 3/8" holes for the thumb screws to be inserted into, and welded hex nuts on inside of rectangular clamp in center line with the 3/8" hole instead of tapping the metal to allow the thumb screws to be tightened.
    - Kyle, Jeremy, Nick, Bryce
- Wednesday November 28, 2012: Welded last two end caps on the horizontal bar and completely assembled the welding fixture and did minor preliminary testing of clamp and thumb screw strength. Updated engineering drawings up the rectangular clamp, and horizontal bar.
    - Bryce, Kyle, Nick
- Thursday November 29, 2012: Determined the placement of grounding plate, drilled and tapped a hole to fit a 5/16" bolt. Welded longer cross pieces on the thumb screws to allow for more torque when tightening the set screws to hold the horizontal/vertical bars in place.
    - Bryce, David, Kyle, Jeremy, Nick
- Man Hours: 83 total man hours

Evaluation Criteria:

Safety:

- Overall the fixture follows all safety requirements necessary to complete all welding operations. The placement of the grounding clamp allows for it to be free of interfering with most welding operations unless they are close to the base of the fixture.
- Performance Factor:
    - The fixture satisfied the conditions specified by customer and did what we designed it for. There is a slight tipping problem when the clamps are placed in a certain orientation, but with holes in the base to allow for the fixture to be bolted to a table can solve this problem. However, by bolting the fixture to the table the fixture loses its portability.

DFM:

- Design of the rectangular clamp piece needed to re-evaluated after discovering it would not squeeze around the horizontal bar.
- Many drawings were not up to par as far as manufacturing of the pieces was concerned. They were good engineering drawings but did not specify specific process needed to produce the need parts, how things were orientated or aligned. After going through the design process and doing the manufacturing ourselves we realized how many elements go into the process of producing a legitimate proposal to take to a machine shop.l

Ease of Operation:

- The design of this fixture was especially geared towards intuition and ease of operation and exceeds those qualities. Utilizing standard thumb screws allows for adjustment and torque without the use of tools.
- No noise or vibration should be present while using the fixture.

Costs:

- By using standard, store bought parts, and scrap metals we were able to completely cut the costs of the overall project, and still have room to make replacement parts if needed.

Size:

- Designing a fixture to fit inside and 18” by 18” is obtainable, but with the design we have it could exceed those boundaries if the clamps and swing arms are positioned a certain way. In conclusion we do not feel that this minor detail is sufficient enough to require a complete over haul.
- The weight of the object could be an issue since we are using all steel parts for this design. However, OSHA standards say an average person can handle 50lbs single handedly. The fixture is hard to maneuver if fully assembled, but with the ease of the addition/removal of clamps and swing arms you can disassemble the fixture quickly to allow for easier portability.

Materials:

- We have succeeded in using as many already made available parts/materials. By using store bought clamps and fasteners, and using standard steel materials found in everyday scrap yards. The cost was lowered, parts are easier to replace, and less manufacturing of parts is required.

Lessons Learned

When designing and building a project, no matter how few the parts may be, keeping tolerances in mind plays a major role. When building our welding fixture, we had simply specified that many parts could be plus or minus a few thousandths of an inch but this would not suffice when the design called for interference fit. One must take into account that not all parts will be made exactly 1" in diameter and that interference fit must have the hole always err on the larger side of things should the pipe be larger than anticipated. Also, when one part is not made exactly to specifications it can cause havoc on the design since many parts depend on each other.

Store bought parts are always easier to implement in a design than a fabricated part and should be chosen over manufactured when given the opportunity. This helps save time and keeps the design from becoming overly-complicated.

While a semester may seem like ample time to complete a design, it is important to have a schedule and timeline and stick to it. If the schedule is not followed and updated accordingly, it is very easy to push back dates when parts should have been completed. Given the limited amount of time that the shop was open was limited and the problems of getting everyone together in the shop at one time proved to be tough. The schedule is what kept the entire project on-track and ensured that all team members knew what had to be done.

Drawings done in design 1 lacked depth and detail that is required in a professional setting. Understanding that someone may be making this design without any prior instruction and having only the drawings for reference shows that more description was necessary. This can be seen when a certain type of welding or machining is necessary for specific portions of a part. Also knowing when holes had to be on the same axis and level in order for parts to be successful is needed, such as the bar clamp to fit through the end caps.

Sometimes in order to finish on time, last minute on-the-spot decisions must be made. This was apparent when we found that the clamping mechanism did not have ample force to hold the pipes in place. In order to overcome this with limited time, brainstorming was performed and a compromise was found by welding a nut to the inside of the clamping mechanism. This simple iteration provided ample force for both the horizontal and vertical components of the system and ensured that all apparatuses remained static.

Acknowledgements

- Mr. Gray
  - Assisted in the brainstorming of ideas
  - Provided us with fixture/welding information
- Bluco Modular Welding Fixtures
  - Highly advanced welding fixtures that proposed some ideas
- De-Sta-Co
  - Presented different clamps that could potentially be used in our design
- Ryerson Steel
  - Provided stock materials sizes, shapes, weight, etc. to assist in choosing certain materials for the overall design
- Texas Tool & Equipment, Lubbock, TX
  - Gave us more ideas of what we could use for clamping mechanisms
- Strong Hand Tools
  - Provided clamping mechanism used in final design

References

- ASTM Handbook
- Engineering Design Graphics with Autodesk Inventor 2010