SunTrac's Variable Length Braze- Welding Jig

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Mechanical Engineering

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Abstract

The SunTrac Capstone team goal is to design and manufacture a braze-welding jig for a company called SunTrac USA. SunTrac USA is a hybrid climate systems company based in Tempe, AZ that manufactures solar energy capture arrays to be used in AC and HVAC systems. The array focuses sunlight onto a copper manifold heat exchanger which consists of six vertical copper pipes between two horizontal copper pipes. During manufacturing, the manifold must be secured onto the braze-welding jig to weld the pipes together at specific dimensions and tolerances. The team's task is to construct a jig capable of aligning and securing SunTrac's 4', 6', and 8' manifold variations so they can be manufactured. To meet the client's requirements, the team designed a jig that can be collapsed and elongated to fit the requirements for each manifold size. The jig can be raised and lowered to maintain the working height, features an open design for accessibility, rotates 360°, and locks at 14 different positions to accommodate the worker's preference. This project impacts SunTrac by increasing the efficiency of their manufacturing process, decreasing expenses on other jigs, and decreasing idle workspace.

Requirements

The customer requirements below were set by the Director of Engineering at SunTrac USA. Engineering requirements have been implemented corresponding to each of the customer needs.

Table 1. Customer Requirements & Engineering Requirements

Customer Requirements		Engineering Requirements
Safe to Operate	1	Force to Rotate
Cost under $1600	2	Cost under $1600
Fits all product sizes (4',6', and 8')	3	Number of Compatible Products are 3
Machinable parts	4	Standard Parts (90%)
Fits in 5' x 5' square	5	Footprint (5ft x 5ft)
Allows easy access to all copper joints	6	Degree of Rotation (360 degrees)
8+ locking positions	7	Number of Locking Positions
Durable and Robust Design	8	Melting Temperature of Material
	9	Tolerance/ Error (+/- 1/16")
Reliable Design	10	Durability of Product

- Much like any successful product, the jig must be durable, reliable, and safe to operate.
- Suntrac determined a $1600 budget since that was the cost of their previous 6' braze welding jig.
- A jig capable of reconfiguring to the three manifold lengths near solely determines the success of this project
- The footprint of the stand should be as small as permissible, but vertical height does not matter for the warehouse workspace SunTrac operates in.
- An open design with many locking positions creates ease and increases worker effectiveness.
- Material purchasing and manufacturing is more lucrative and time efficacious if the design employs more standardized parts over custom parts and exhibits DFMA principles. SunTrac at the time had projected growth within five years so this is an important requirement to them.

Testing

Table 2. Testing Procedures to Correlating Engineering Requirements

Testing Procedure	ER's Tested
Measure the length of the jig at 4' configuration, then change the jig to an 8' configuration. Spin the jig fastly, then rearrange the jig to the previous configuration and measure the difference of length between trials.	Number of Compatible Products are 3
	Degree of Rotation (360 degrees)
	Tolerance/ Error (+/- 1/16")
Using an Oxy-Propane Torch, the square tubes are heated and the hardness is measured every 30 seconds until 300 seconds are elapsed. The metal temperature is then measured to guarantee its under melting temperature.	Melting Temperature of Material
	Durability of Product
The Bill of Materials has a total cost less than $1600 and the custom parts purchased make less than 10% of the total items.	Cost under $1600
	Standard Parts (90%)
Using a force gauge, the force required to rotate the jig while its in rest is measured and it should be less than 10lbs. Next, the jig is locked and a perpendicular force of 10lb is applied. The jig should remain stationary.	Force to Rotate
	Number of Locking Positions
Measure the area of the triangle that makes up the frame of the jig which is less than 5ft x 5ft.	Footprint (5ft x 5ft)

Design Approach and Results

To construct a successful braze-welding jig, first the clients existing models were analyzed in relation to the customer requirements. The client approved of many features on their existing design and sought that the team would keep these while revising the undesirable features. In example, the skeletal frame of the clients existing 8-foot model [Fig. 1a] is employed with the revision of lessening the number of vertical supports [Fig. 1b].

Figure 1a: Existing Client Model (8 Foot Configuration) without Manifold

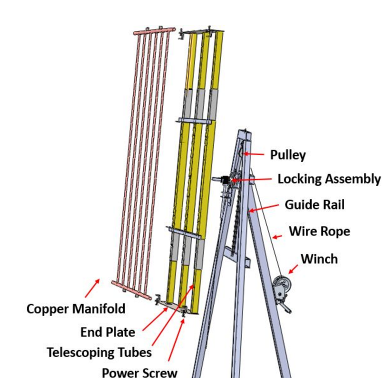

Figure 1b: The Team's Full CAD Model (8 Foot Configuration) with Manifold

As well as revising existing sub assemblies, the team is to design a new feature to allow the Jig Face to adjust vertically between use. A morphological matrix is used to generate design alternatives, which are then filtered through a Pugh chart and decision matrix for the final design. The final design implements a winch, pulley, and guide rail attached to the locking mechanism, allowing the operator to adjust this height. A wire rope connects the winch to the locking mechanism through the pulley as illustrated in [Fig. 2]

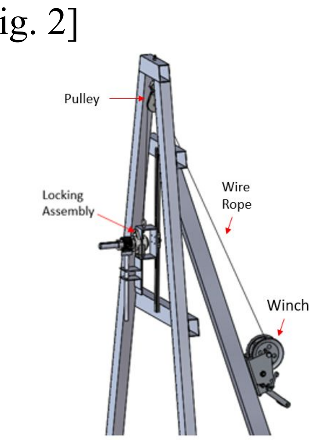

Figure 2: Winch to Locking Mechanism Interaction

Many design revisions for the dynamic Jig Face solution have been made in reaching the finalized apparatus of [Fig. 2]. From considering different manifold lengths through having the operator stand on a platform, to gear rack systems. The final solution for vertical movement is most effective in terms of satisfying the engineering requirements. Specifically, the final design satisfies industry standards as well as having an optimized ratio of mechanical advantage paired with ease of locking versus cost. This is considerable as the cost engineering requirement has a relative technical importance of 1.

To better understand the approach taken in reaching the finalized prototype of [Fig. 1b] consider the intermediate design considerations of [Fig. 3]

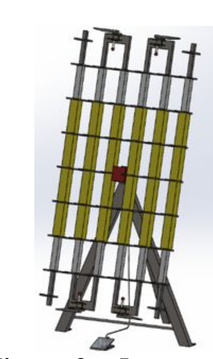

Figure 3a: Intermediate Face Design Iteration

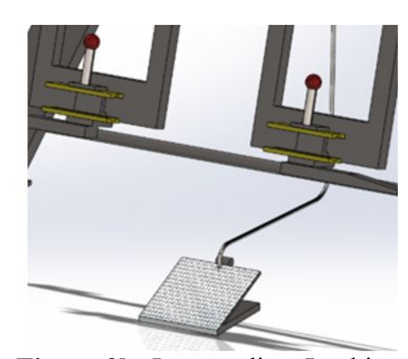

Figure 3b: Intermediate Locking Design Iteration

The open, skeletal design of the Jig Face [Fig. 3a] exhibits a design the client requested. Further meetings unveiled needed revisions

Revisions to the Design

- The end plate and power screw assembly
- Horizontal and vertical manifold standoffs
- The foot pedal subsystem [Fig. 3b] was replaced with a pull handle

The end product satisfies the critical engineering requirements which enables the client to more efficiently produce their multiple product variants. The amount of brazing jigs needed is less in the clients manufacturing facility.

Manufacturing

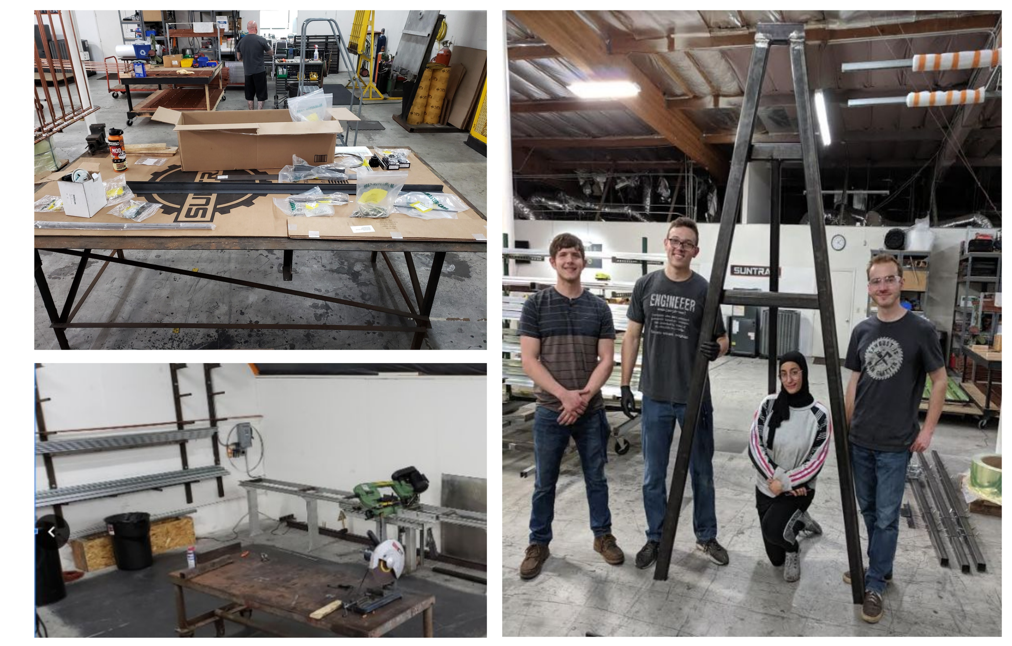

Figure 4: Manufacturing at SunTrac Facility

Manufacturing this Braze Welding Jig took approximately three full weekend trips to Phoenix with an additional two weekends for touch up and finishing work. The first three weeks the entire team participated in cutting the stock pieces of metal to size, drilling holes, MIG welding the frame and face together, and running to ACE hardware to purchase and install all fasteners. The last two weeks consisted of portions of the team conducting various tests as well as instructing the SunTrac executive board on how our product currently functioned.

Analyses

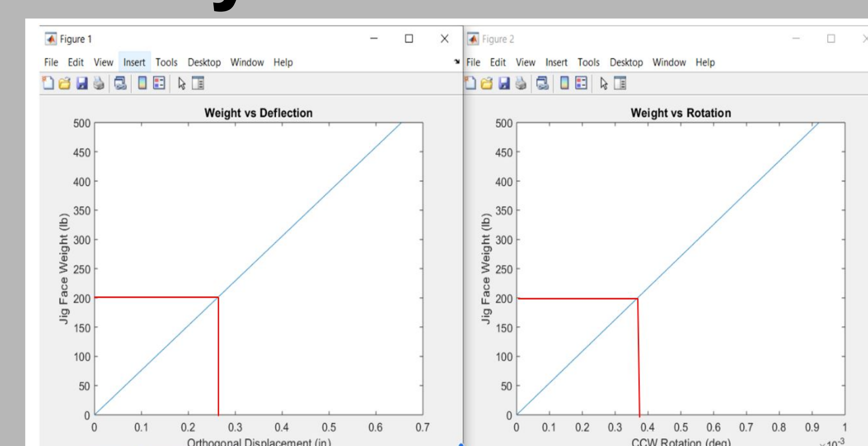

Figure 5: Guide Rail Structural Analysis

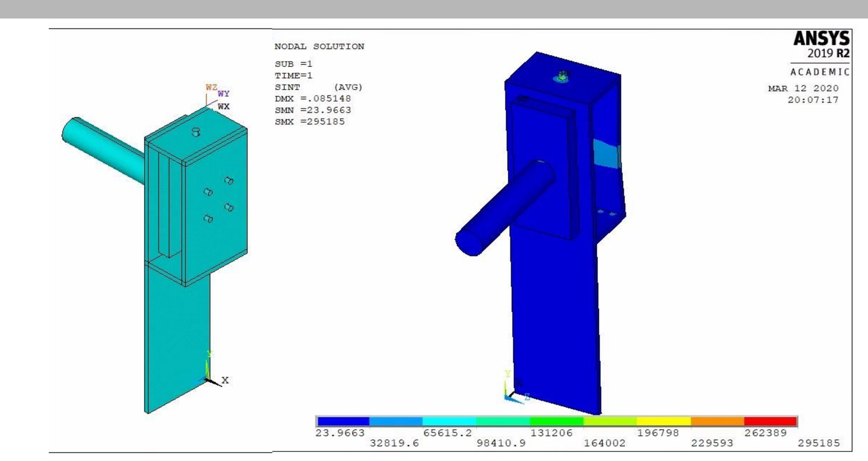

Figure 6: Locking Mechanism FEM in ANSYS

The guide rail assembly outlined in [Fig. 2] is a critical component with a high risk priority number. An FEA analysis has been conducted, then performed in MATLAB to determine the deflection and rotation at the center of the guide rail (beam) given two fixed end supports. The expected results occur at a Jig Face weight of 200 lb and are shown on [Fig. 5] with a red line. The resulting displacement of 0.3 inches has been used to justify adding an extra support.

The Locking Mechanism bears a significant load as it supports the Jig Face. The Guide Rail and this must combat the induced moment created from the load. A 3D Solid FEA Analysis was conducted with ANSYS to determine the locations and magnitudes of high stress propagating through the Locking Mechanism. The analysis results show the edge of the carriage contact point and bolt tear out stresses are the highest but do not violate the factor of safety.

Conclusion

The current state of the prototype shows that all components/sub-assemblies are assembled and functional except for one sub-assembly that needs two joints to be welded. SunTrac has asked us to suspend finishing the project until the summer of 2020 in hopes that the dangers involved with COVID-19 might be over. SunTrac has been provided with a detailed document showing how the team manufactured the product up until this point as well as our plans for how to finish the last few welds. After multiple analyses using SolidWorks, MATLAB, and ANSYS the team is confident that the design will increase the efficiency of the clients manufacturing processes, as well as cut down idle workspace in SunTrac's manufacturing facility. Under the circumstances, the team and SunTrac have deemed this project a success and will greatly benefit SunTrac as they continue to grow.

Acknowledgements

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References

[1] "Renewable Energy Manufacturer: SunTrac USA: United States," *SunTrac USA*. [Online]. Available: https://www.suntracusa.com/. [Accessed: 13-Mar-2020].

[2] S. Siebens, Interviewee, *Ideal Characteristics for Revised Braze Welding Jig.* [Interview]. 30September 2019

[3] M. P. Groover, *Fundamentals of modern manufacturing: materials, processes, and systems*. Hoboken, NJ: John Wiley & Sons, Inc., 2013.

[4] Engineering ToolBox, (2003). *Young's Modulus - Tensile and Yield Strength for common Materials*. [online] Available at: https://www.engineeringtoolbox.com/young-modulus-d_417.html [Accessed 17 Oct. 2019]

[5] R. G. Budynas, J. K. Nisbett, and J. E. Shigley, *Shigley's Mechanical Engineering Design*, Ch 13. 9th ed. New York, NY: McGraw-Hill Education, 2011.

[6] R. G. Budynas and N. Keith, Mechanical Engineering Design, New York: McGraw-Hill, 2008.

[7] R. C. Hibbeler, *Statics and Mechanics of Materials*, Ch 2,4. 9th ed. Singapore: Pearson, 2014.