

2010

# Welding Project Engineering and Management Final Report

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Team # 9

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**Professor**

FERRIS STATE UNIVERSITY

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## FOREWORD

“One must try by doing the thing; for though you think you know it, you have no certainty until you try.” – Sophocles

This is how team #9 felt about the task at hand. We were tasked to not only build a product, but also to plan it as well. The planning included a design schedule, blue prints as well as a fabricated structure. These were all things that we have all done in our career as students in the Welding Engineering degree. The odd thing about all of these was that we had never done them all at once; the task then was to prove our skill by doing them for one project. We had learned all the components of how to undertake a project likes this, we had all the pieces and now we simply put them together. The only way to then prove that we had the skills that we possessed was to then apply them to one project as well as plan project as well to teach us the one thing we lacked, proper planning. In the end we learned everything we learned by doing. The style of instruction was hands on, theory is nice but in the end it is doing it that really affirms that you have mastered a skill that you have learned about.

## ACKNOWLEDGEMENTS

We would like to acknowledge the contributions of the following groups and individuals to the development of our project:

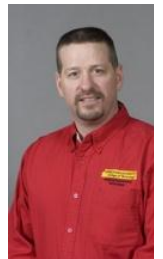
Eng. **Kenneth A. Kuk** “Professor at Ferris State University”

We heartily thank Professor, **Kenneth A. Kuk**, whose encouragement, guidance and support from the initial to the final level enabled us to develop an understanding of the subject.



**Jeffrey N. Carney Associate Professor/Department Chair** at Ferris State University”

We thank **Jeffrey N. Carney** whose instruction and life lessons and advice will always be remembered.



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**David Murray** “Associate Professor at Ferris State University”

We thank **David Murray** whose laboratory sessions have prepared us in many ways for the real world shop work force.



**Blaine Danley “Associate Professor at Ferris State University”**

We thank **Blaine Danley for his metallurgical expertise and interest in the subject matter made learning that much more enjoyable.**



**Sandy Morningstar “Secretary at Ferris State University”**

We thank **Sandy Morningstar whose copy machine expertise was well received during all stages of our project**



Lastly, we offer our regards and blessings to our family and friends who supported us during our education and this project. The truth be told we would have much rather spend some of the hours we spent on this project we would have rather spent with them doing the things that were of the most leisure of activities. In the end it was for a good cause and the benefits cannot only be reaped by us but also by those closest to us.

Above all, utmost appreciation to the Almighty God for the divine intervention this academic endeavor.

## THE PROBLEM

### PRODUCT:

To concept, design, engineer, fabricate, test, and manage the development of a prototype partial uniformly loaded I-beam type span **WELDMENT** in a team environment. The structure will demonstrate the following mechanical capabilities:

- A horizontal top surface
- Will withstand a uniformly distributed “static” vertical load across a center span section
- Will be supported by two reaction shoes (points) in a provided fixture, one reaction point will be allowed to translate in horizontal axis in the fixture
- Will demonstrate high strength and stiffness to the external load

### DESIGN RELATIVE TO COMPETITION:

- High performance operation (Maximum Load)
- High quality manufacture
- High visual appeal

### DESIGN PARAMETERS:

- Overall length 22.000” +/- 0.0625”
- Unsupported span distance will be 14.000” +/- 0.0625” and 3.000” above the shoes
- Overall Height 6.5625” +0.0625”/-0.000”

- Overall width 3.000" +0.0625"/-0.000"
- Two **identical** I-beam and riser subassemblies must be groove welded at the center.  
The load plate is welded to the center of the top flange of the subassemblies.
- Assembly components: One 3" x 4" solid load plate, Four 3" x 11" solid flanges, Two 3" x 11" webs, Four 3" x 4" support risers, Two 3" x 4" support shoes
- Web and Support risers are vertical and can have material removed for weight reduction
- Load plate, Flanges, and Support shoes are horizontal. They must be solid plates.
- Support riser location is team determined but will be parallel to the I-beam length
- Provided material, 3/16" thick 6061 T-6 Aluminum Plate, one 24" x 48" plate per team
- Weld consumable is team selected. Weld joints, sizes, and length are team determined unless specified
- Maximum load span assembly weight 4 pounds
- Assembly must fit the provided fixture and be free move
- 4<sup>th</sup> year students will produce **two identical loaded units only** (No other metal prototypes will be fabricated)
- Loading will be across the top of the load plate at the center of the I-beam span
- Loading ram plate surface is approximately 2.25" x 5.5"
- Each team member is required to perform approximately equal amount of welds

- All fabrication and build work will be in the FSU welding Laboratories
- No Machining is allowed
- Drilling, saw, shear, or manual plasma cutting for weight reduction is allowed
- Exactly five different detail types and thirteen components are required per assembly
- No purchased components are allowed

**ENGINEERING AND MANAGEMENT ACTIVITIES REQUIRED:**

- Design Research
- Design Concept
- Mechanical Analysis: Stress, Distortion, Weld Size
- Complete Detail and Assembly Drawing
- Structural Design Test
- Welding Procedure Specification
- Procedure Qualification
- Welder Performance Qualification
- Prototype Fabrication, Test, Project Management
- Project Report and Oral Presentations

## **Function of the Product**

The function of the product is to hold as much weight as possible while still meeting all the build specifications compiled by the instructor. The challenge is to build an ultimate I-beam and have the highest strength out of nine teams. The most difficult part of this task is to make the product within specifications while maintaining a structurally competitive product. This will be accomplished by using software that has been developed for running prototype testing. This software is known as the Finite Element Analysis (FEA) developed by Solid Edge. The secondary function is that it will provide us with the ability to plan a project from beginning to end and combine all the skills learned during our time here at Ferris.

## **Goals**

Goal 1. From beginning to end, get each component of the project done and completed by the ascribed due date.

On this project we as a team have made it our goal to turn everything in on time and to not have any late work to turn in. During our time at Ferris this is something that everyone in our group has struggled with at times and is the last thing we want to do on our final project.

Goal 2. Build a quality product that meets all design and build specifications.

For this project there were requirements for what we could and couldn't do for building our product as well as the design prints that we would develop and would be required to build to. The build specifications are universal to every group and are the specifications that we have to design and build to. After the build specifications were well realized we were then required to design our parts to meet these specifications. When the part is designed there will be a set of prints for use to build to. The goal then is to build to both specifications as possible, keeping in the build parameters and our own prints as close as we can.

Goal 3. To build a product that ranks in the top 40% of the 18 bridges out of the 9 teams of the class.

As a team one of the easiest ways to measure how good the design of our product is, is to compare it to other designs that have been constructed using the same specifications. What our team desires is to have a product build that does what it was

designed to do successfully or at least as good if not better than some of the other designs that were built.

## Literature Review

The following resources listed are resources that our group believes are valid sources that are believed to have information usable for this project.

- Design of Weldments; Omer W. Blodgett

This book helps to find out weld sizes and stresses on welds as well as the stress on box frames. This comes into play when we need to come up with figures to justify how we are building our product.

- The Procedure Handbook Of Arc Welding 14<sup>th</sup> Edition; The James F. Lincoln Arc Welding Foundation

This book was selected because of the info it provided for the GTAW process in reference to welding on aluminum. There are many basic questions that we may have that can easily be answered by this book.

- Modern Welding Technology 6<sup>th</sup> Edition; Howard B. Cary, Scott C. Helzer

This book was selected because of its wealth of knowledge concerning modern welding processes. To be more specific the book's information about GTAW and electrode information is the main focus of interest.

- Welding, Principles and Practices 3th Edition; Raymond J. Sacks, Edward R. Bohnart

This book was chosen because of the abundance of knowledge of both GTAW process and some shielding gas information. This book will be

a primary source as well as a secondary force to confirm info from other books.

- Welding Handbook 9<sup>th</sup> Edition vol. 2, Welding Processes, part 1; AWS  
This book was selected because of its information about the GTAW process. This book has not just welding information but also technique and joint design specifications as well.
- Metallurgy, Fundamentals; Daniel A. Brandt, J.C. Warner  
This book was selected due to its information about the metal called aluminum. This will be one of the sources we will go too to help determine facts about aluminum.
- Project Management, A Managerial Approach 6<sup>th</sup> Edition; Jack R. Meredith, Samuel J. Mantel Jr.  
This book was selected because of its provided knowledge about project management. For this project we are required to play out our project and then execute it, this will be a good reference during this phase.
- Structural Welding Code – Aluminum, AWS D1.2, AWS  
This is the AWS code for welding on aluminum and how to test it. This is a book that we hope to reference when developing welding procedures for our product.
- Alco tech Website, <http://alcotec.com/>

This website was chosen because Alco Tech is a leading supplier of aluminum. This site is something that our group hopes to take advantage of to help find out properties of the base metal as well as the best filler metal to use.

- ESAB Website, <http://www.esabna.com/us/en/>

This site was chosen because of the wealth of information contained about welding consumables. This site will give us some comparative notes as well as filler metal specifications and recommendations.

- Alro Website, <http://www.alro.com/>

This site was chosen because it is another metals supplier website. The hope is that this site will help confirm things from other sites as well as give more base material information.

- MATweb Website,

<http://www.matweb.com/search/MaterialGroupSearch.aspx>

This site was chosen because of the information contained in the site about 6061-T6 aluminum. This site has some very well compiled information about the material that we will be using for our project and looks to be like a authority in the area of aluminum alloys.

## **Analysis of Loading Types and Amounts**

In the analysis of the loading of our part, there were seven items that needed to be factored in and mentioned. These items are Static load, Dynamic load, Impact load, cyclic load, Strength, Deflection, and Factor of safety. A static load will be used to test the part and take it to failure. Dynamic loading will not be as prevalent or as focused on as much as the static load will be. There will be no Impact load or cyclic loading, this is due to the fact that this is a one time use span, the ram does not go fast either. The part will be test on the tensile machine and force will be applied until the force values no long go up. The final item is factor of safety. In this part there is no factor of safety, because the desire for this is maximum strength and it will be taken to failure. The failure of the part will be based on two criteria, catastrophic failure of the welds or that the part plastically deforms so much that the stress value take the part to failure by moving the moment of inertia.

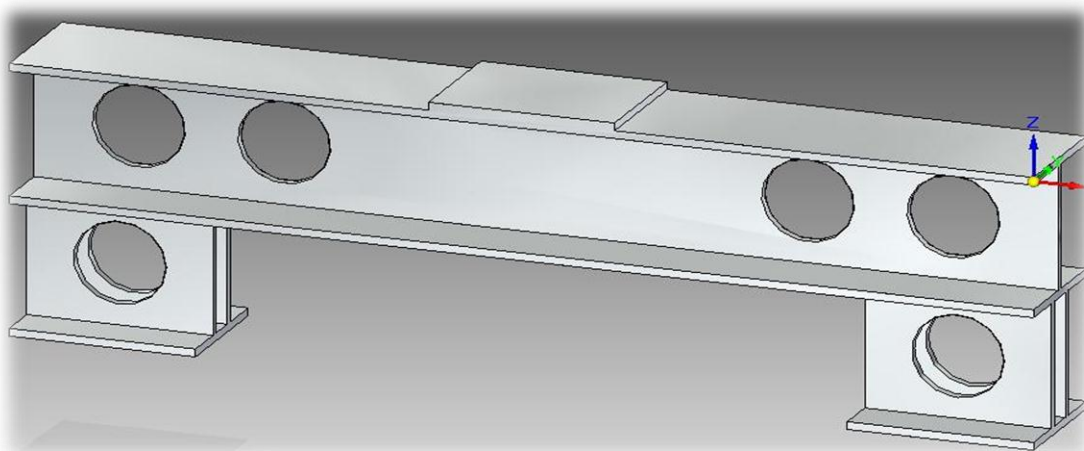
## **Cost**

The cost of this engineering project is going to be measured in the units of engineering and fabrication hours. The estimations of what is the costs in hours is based on the activities that are consider to be engineering activities, and then a conservative amount of hours is put into the place for the length of its duration. The same has been done for fabrication hours. After the conservative estimates were made, then they were added up and tallied. For engineering hours the estimate came out to be 60, while the fabrication hours came out to be 20 hours for a grand total of 80 hours. There is no material or overhead addressed in the estimate. The cost for this item is in currency of the dollar and since the material is being given to us by the school, and we are doing the work ourselves we won't be hiring anyone to do it for us.

## ALTERNATIVE DESIGN

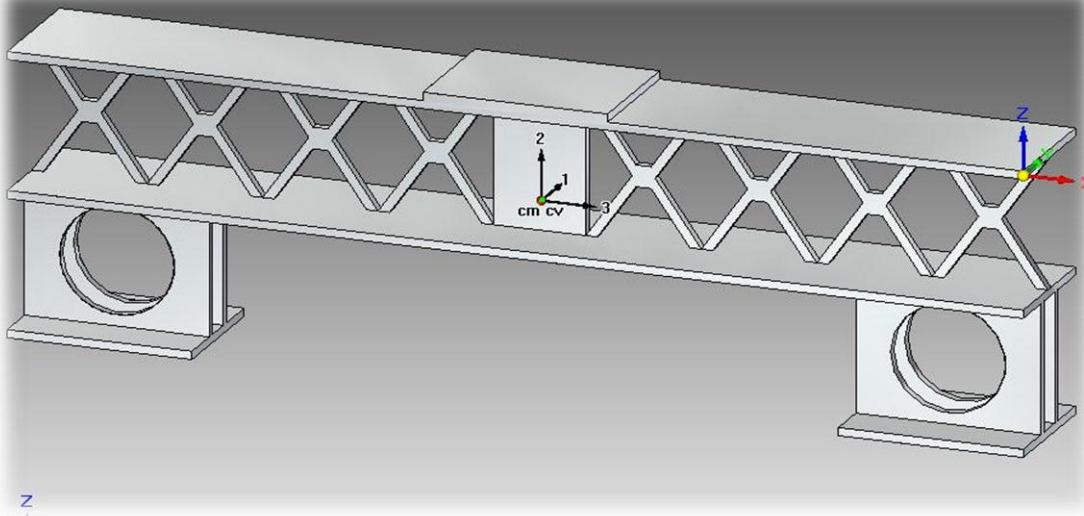
### Option #1

This first design was not chosen because of the weight that would be required to take out of the part would make the circular holes inside the webbing of the I-beam be very close together, so close together that the holes would have to be precision drilled very close together and it was determined that the capabilities were not there for this design to be successfully built. The weight was also a problem with this design. “See picture”



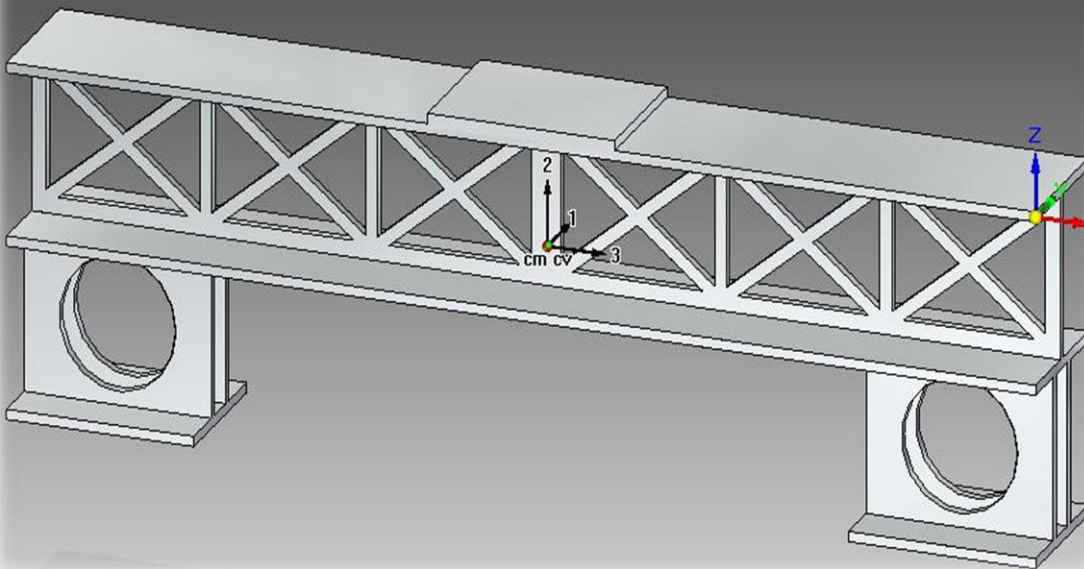
### Option #2

This design met the criteria required for success, but proved to be hard to manufacture. The desired double diagonal was implemented which in FEA made for a very solid structure. In this setup each piece was an individual piece which meant that the pieces would require precision placement and welding to occur. This design was scrapped because the capabilities we possessed were not the capabilities required to build this design. “See picture”



### Option #3

This design was actually a precursor to our final design. This design was not chosen because it was overweight. The part requirements for construction were within the capabilities at our disposal. After the design was modified, it was then expanded on.



## **Filler Metal**

The filler metal that was used in this project was 4043 Aluminum. The reason 4043 Aluminum filler metal was selected because it contains Silicon which will improve the fluidity (wetting action). This alloy is less sensitive to weld cracking and produces almost defective-less welds. Other reason this filler metal was preferred would be because the magnesium in the alloy 6061-T6 migrates into the weld metal to produce magnesium silicide. With the use of this, the weld metal would or will become slightly harder than the original filler metal. Also, this filler metal and base metal combination responds best to heat treatment on Aluminum 6061-T6 that is less than ½ in. thick.

## **Base Metal**

The base metal that was specified to be used for this project was 6061-T6. Reasons for the use of this type of aluminum for this project would be that it is a structural grade aluminum that is used in structural frames both in

automotive and railways. The T-6 for this type of aluminum stands for solution heat treated and stabilized. This applies to products which are not cold worked after solution heat treatment.

<b>Chemical Composition for Filler Metal</b>	
<b>Elements</b>	<b>wt. %</b>
Aluminum, Al	Remainder
Beryllium, Be	0.000800 %
Copper, Cu	<=0.30 %
Iron, Fe	<=0.80 %
Magnesium, Mg	<=0.050 %
Manganese, Mn	<=0.050 %
Silicon, Si	5.20 %
Titanium, Ti	<=0.20 %
Zinc, Zn	<=0.10 %
Other	<=0.15 %

**Table: 1**

<b>Chemical Composition for Base Metal</b>	
<b>Elements</b>	<b>wt. %</b>
Aluminum, Al	Remainder
Copper, Cu	<=0.40 %
Iron, Fe	<=0.7 %
Magnesium, Mg	<=1.2 %
Manganese, Mn	<=0.15 %
Silicon, Si	<=0.8 %
Titanium, Ti	<=0.15 %
Zinc, Zn	<=0.25 %
Other	0.15 %

**Table: 2**

**Actual Analysis Results:**

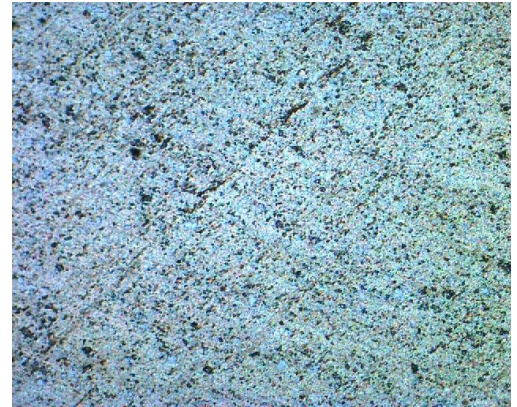
As it shows in figure 1 the base metal microstructure is Alfa aluminum with solution heat treated and stabilized. Figure 2 the Heat Affected Zone shows that the solution heat treated and stabilized a lot less than the base metal that's due to the aging which makes this area weaker than the rest of the metal and less hard. The weld zone which it is 4043 aluminum filler metal which is also not been solutionaized. The actual results shows that the expected results met the actual in most aspect in farther in this report will be discussing the hardness with will be also compared to the expected.

**Hardens:**

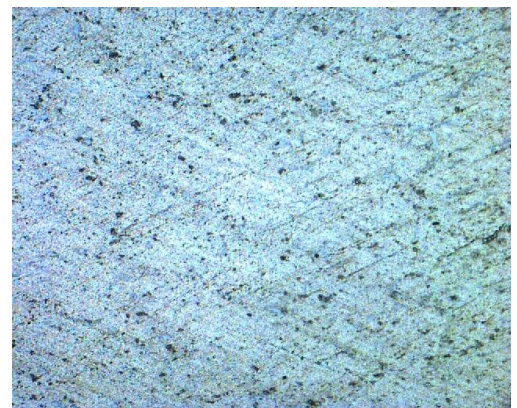
Table 1 shows the hardness and it location in the weldment. It shows that the hardest in the weldment is the base metal and the lowest in hardness is the HAZ. Just like what was expected.

Location	Hardness
Weld	89.8
weld	89.8
HAZ	85.6
HAZ	84.3
Base	86.2
Base	90.7
Base	92.5

Table 1



**Figure 1: base metal**

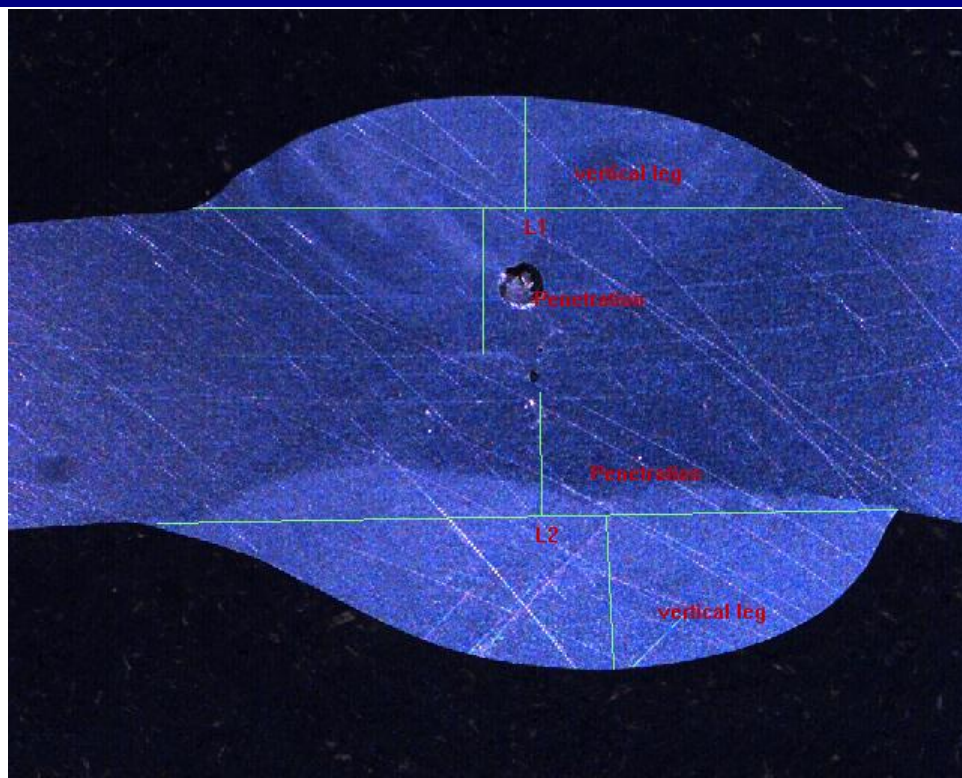


**Figure 2: HAZ**



**Figure 3: weld Zone**

# "butt joint" Measurement Data Report



Measurement Data

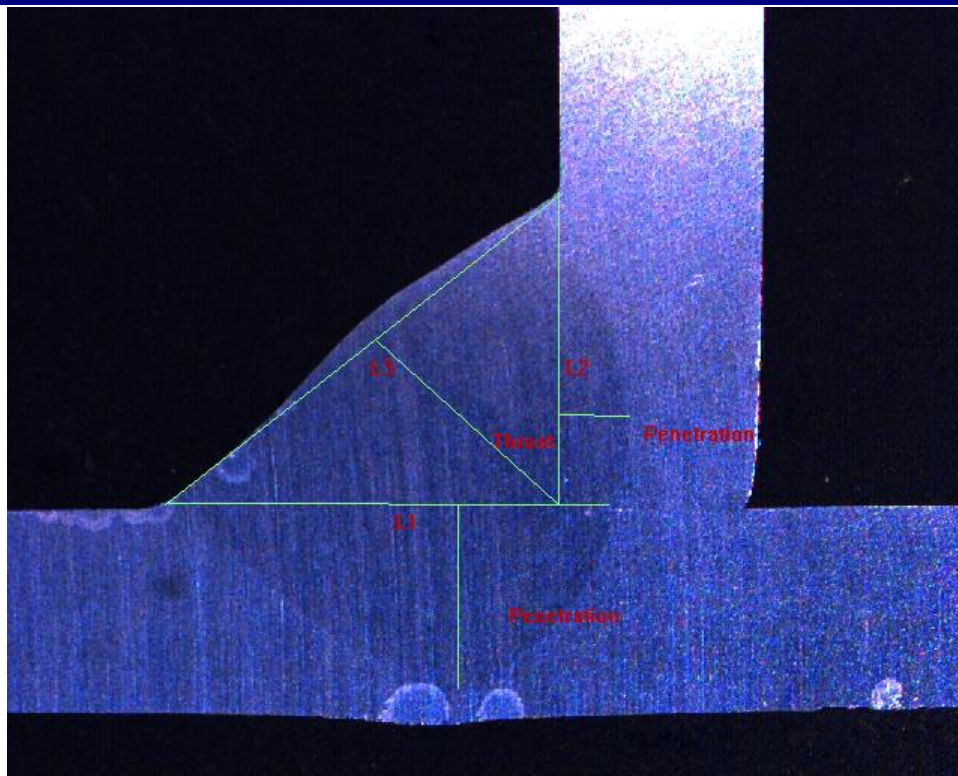
Measurement Totals

Stat	Line	Value
Smallest X	vertical leg	0.000 in
Largest X	L2	0.473 in
Average X	n/a	0.149 in
Mean X	n/a	0.236 in
Smallest Y	L1	0.000 in
Largest Y	vertical leg	0.098 in
Average Y	n/a	0.058 in
Mean Y	n/a	0.049 in
Smallest D	vertical leg	0.073 in
Largest D	L2	0.473 in
Average D	n/a	0.205 in
Mean D	n/a	0.273 in

Line	D value	X value	Y value
L1	0.414 in	0.414 in	0.000 in
vertical leg	0.073 in	0.000 in	0.073 in
Penetration	0.093 in	0.000 in	0.093 in
L2	0.473 in	0.473 in	0.009 in
vertical leg	0.098 in	0.005 in	0.098 in
Penetration	0.078 in	0.001 in	0.078 in



## "fillet" Measurement Data Report



Measurement Data

Measurement Totals

Stat	Line	Value
Smallest X	L2	0.000 in
Largest X	L1	0.282 in
Average X	n/a	0.116 in
Mean X	n/a	0.141 in
Smallest Y	L1	0.001 in
Largest Y	L2	0.199 in
Average Y	n/a	0.104 in
Mean Y	n/a	0.100 in
Smallest D	Penetration	0.046 in
Largest D	L3	0.322 in
Average D	n/a	0.187 in
Mean D	n/a	0.184 in

Line	D value	X value	Y value
L1	0.282 in	0.282 in	0.001 in
L2	0.199 in	0.000 in	0.199 in
Penetration	0.117 in	0.000 in	0.117 in
Penetration	0.046 in	0.046 in	0.001 in
L3	0.322 in	0.254 in	0.199 in
Throat	0.157 in	0.117 in	0.105 in



# Femap Express Analysis Findings

## Final Design

Ferris State University

Team 9

April, 17, 2010

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## 1. Introduction

## 2. Part Properties

Part Name	Final Design.par
Mass	1.749 kg
Volume	645040.044 mm <sup>3</sup>
Weight	17143.616 mN

## 3. Material Properties

Material Name	Aluminum, 6061-T6
---------------	-------------------

Mass Density	2712.000 kg/m <sup>3</sup>
Young's Modulus	68947570.000 kPa
Poisson's Ratio	0.330
Thermal Expansion Coefficient	0.0000 /C
Thermal Conductivity	0.180 kW/m-C
Yield Strength	275790.280 kPa
Ultimate Strength	310264.065 kPa

#### 4. Load and Constraint Information

##### Load Set

Load Set Name	Load 1
Load Type	Pressure
Number of Load Elements	1
Load value	165474.175 kPa

##### Constraints

Number of Constrained Faces	2
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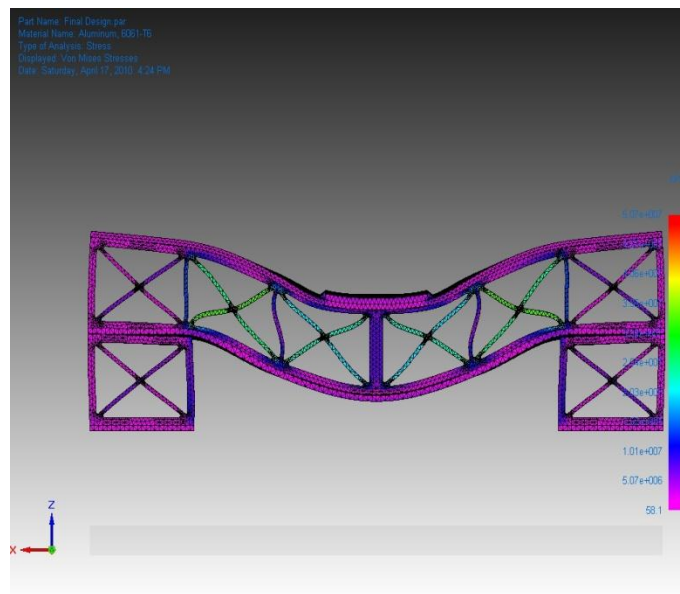
#### 5. Study Properties

Mesh Type	Tetrahedral Mesh
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Number of elements	58,169
Number of nodes	120,494
Solver Type	Nastran

## 6. Stress Results

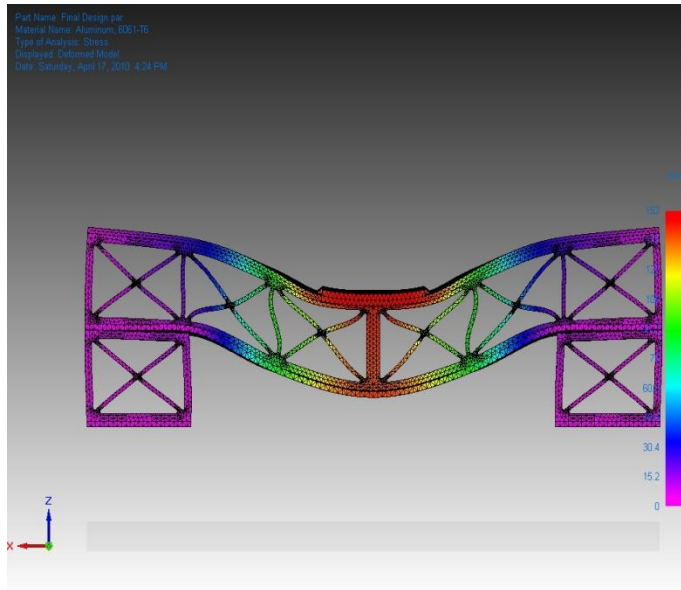
Type	Extent	Value	X	Y	Z
Von Mises Stress	Minimum	5.809e+001 kPa	-59.27 mm	-0.04 mm	-159.50 mm
	Maximum	5.073e+007 kPa	-419.24 mm	40.44 mm	-40.06 mm



## 7. Displacement Results

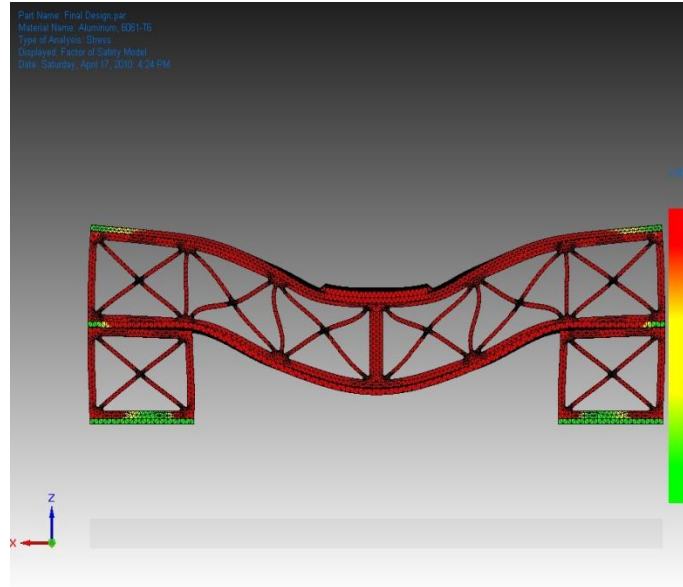
Type	Extent	Value	X	Y	Z
Resultant Displacement	Minimum	0.00e+000 mm	-80.43 mm	21.12 mm	-164.26 mm

					mm
	Maximum	1.52e+002	-279.40	76.16	-2.33
		mm	mm	mm	mm



## 8. Factor of Safety

Factor of Safety Value	0.005
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## 9. Conclusion

## 10. Disclaimer

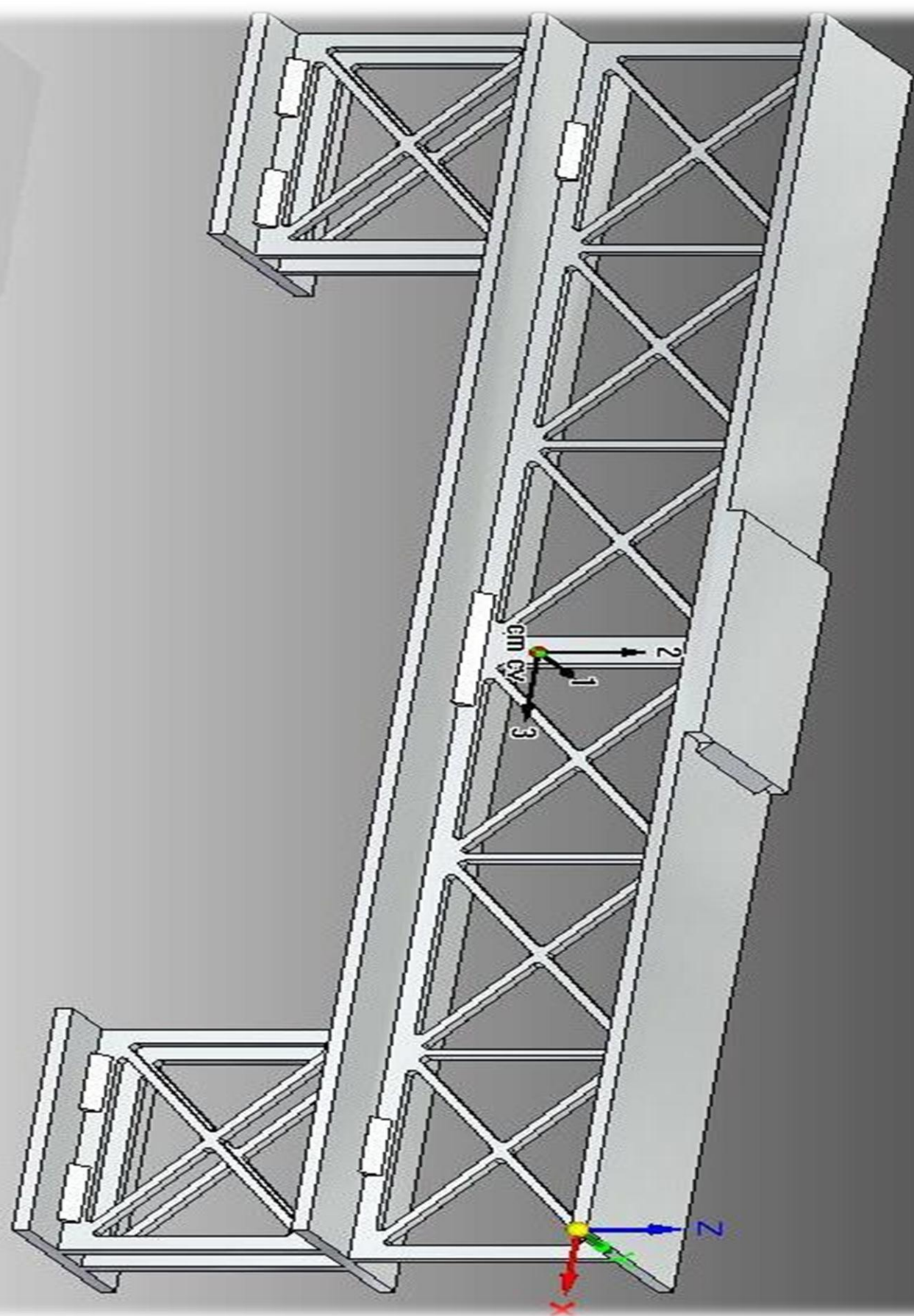
### Important Information

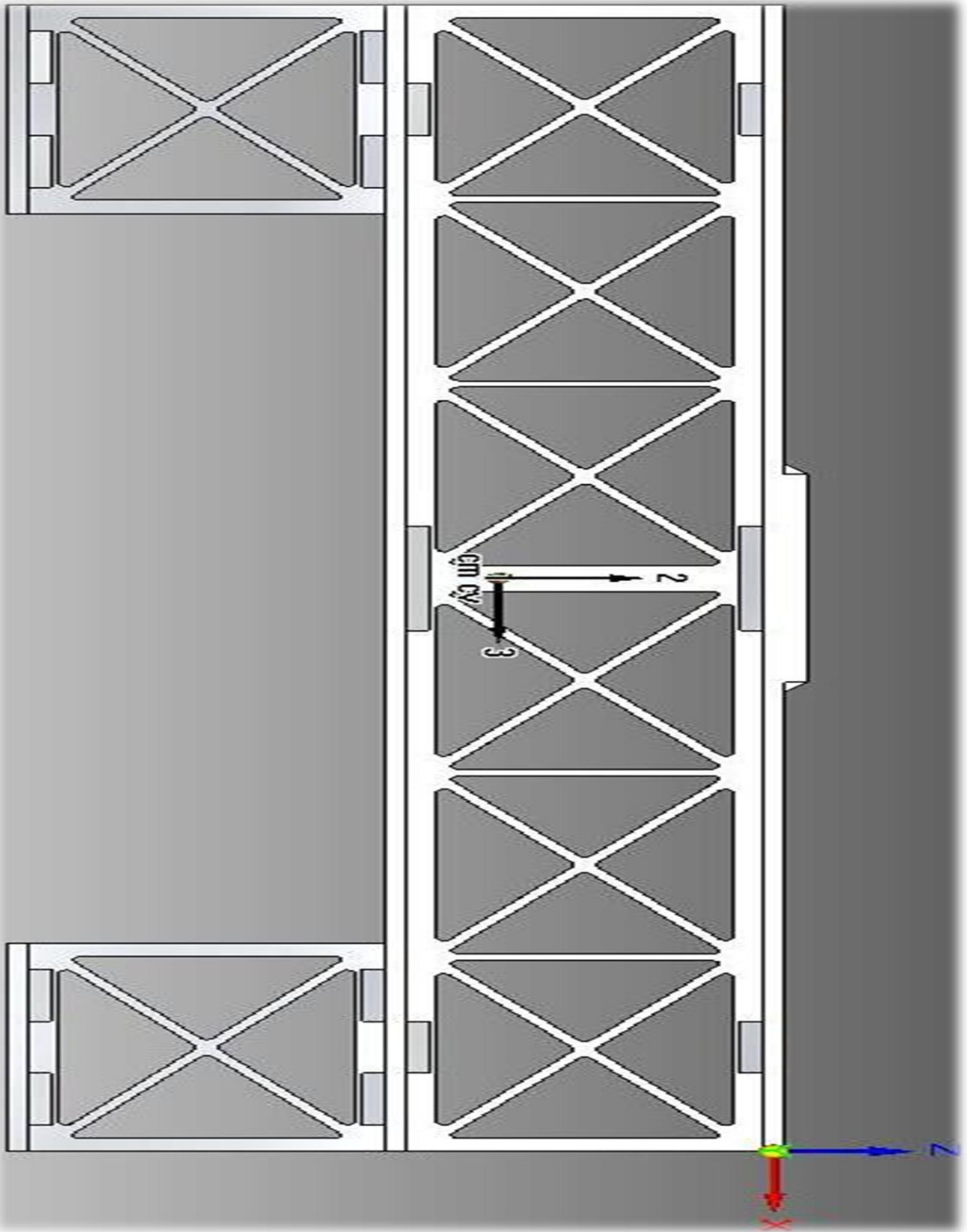
This report should not be used to solely judge a design idea's suitability to a given set of environmental conditions. Siemens makes every effort to ensure that its products provide as much guidance and help as possible. However this does not replace good engineering judgment, which is always the responsibility of our users. A qualitative approach to engineering should ensure that the results of this evaluation are evaluated in conjunction with the practical experience of design engineers and analysts, and ultimately experimental test data. The results contained within this report are believed to be reliable but should not be construed as providing any sort of warranty for fitness of purpose.

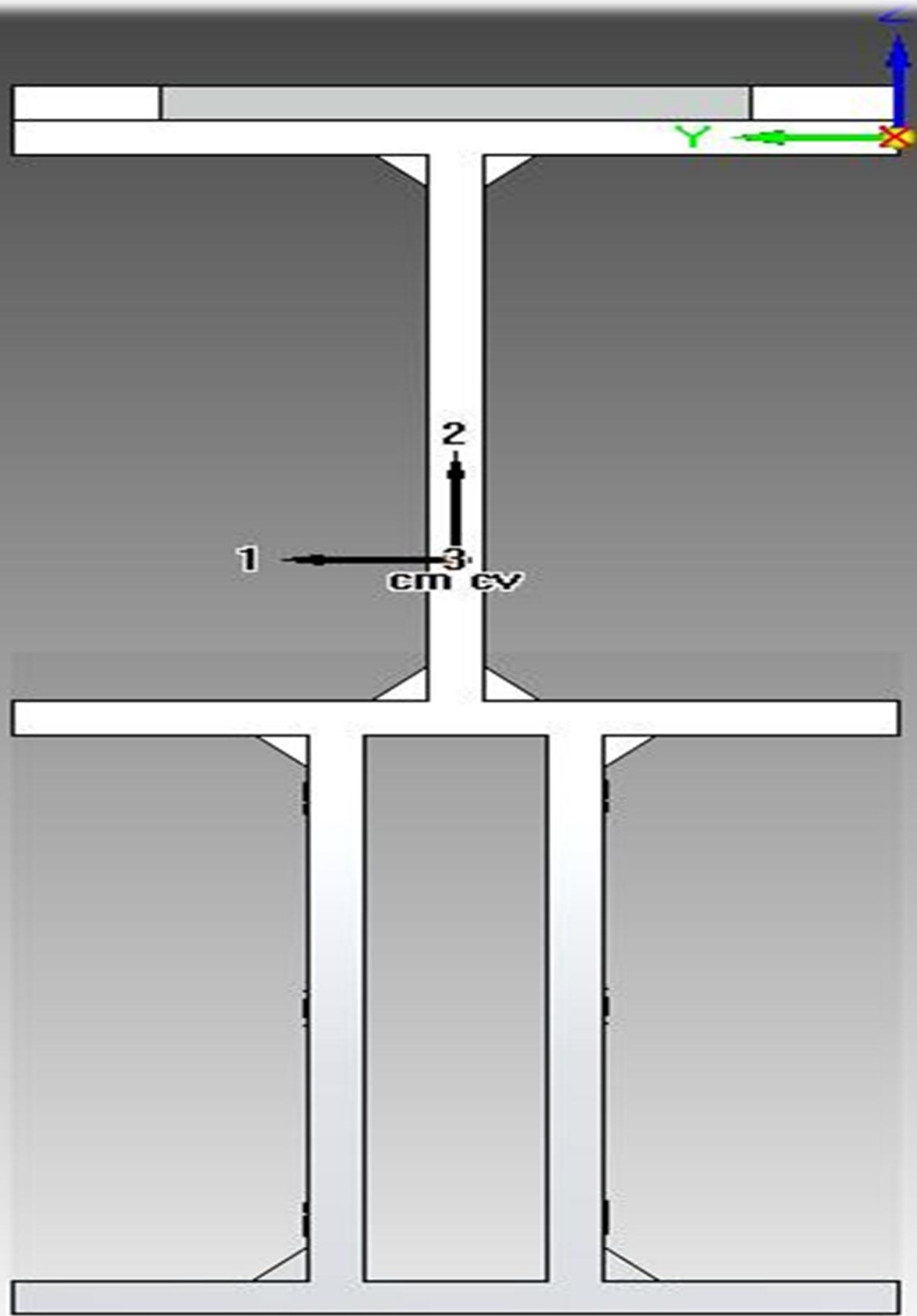
## **Final Design**

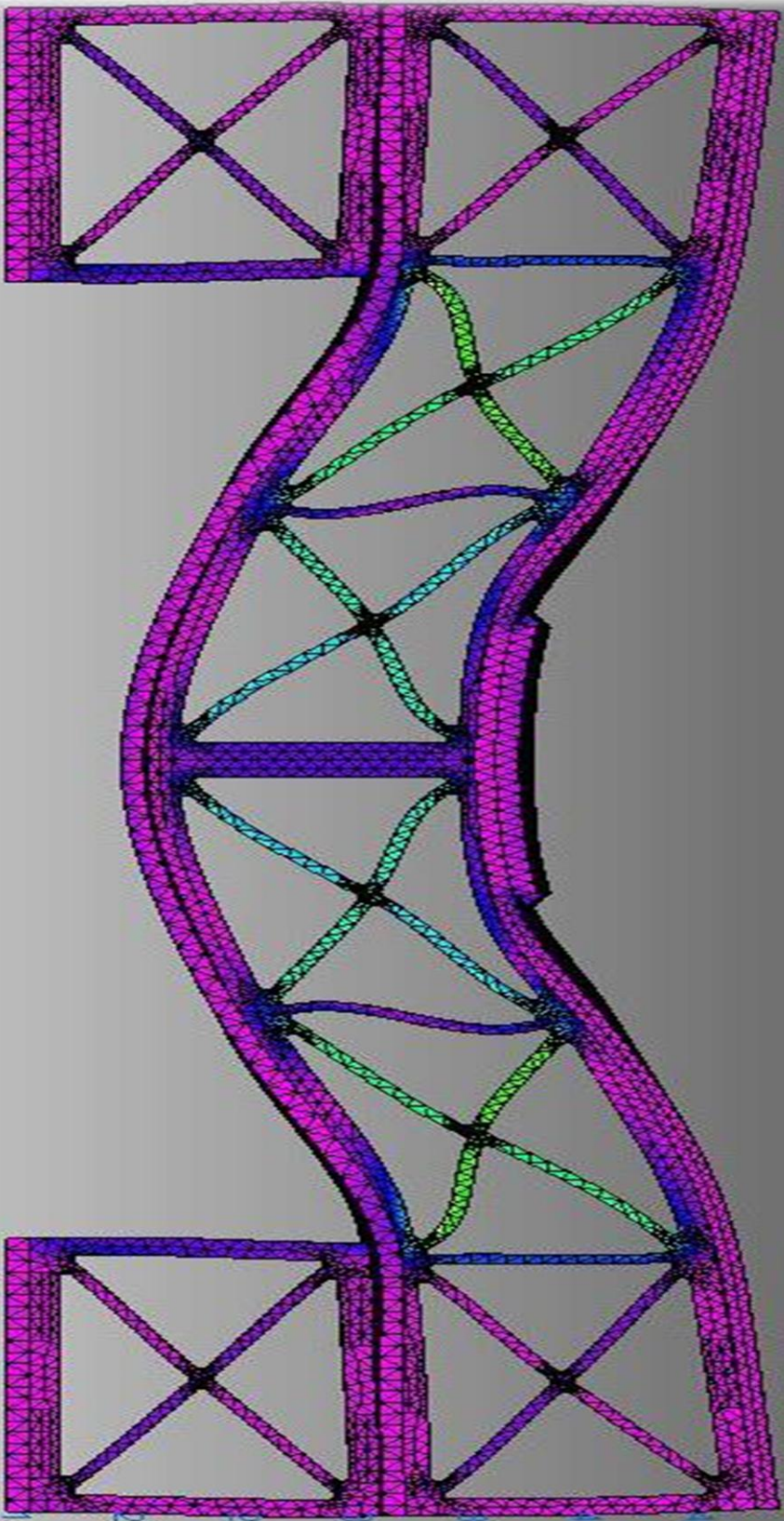
The design that was selected for several different reasons, the main reason for this design was the weight of the structure after it was cut out. With this the only areas that are allowed to have material removed from them were the webbing of the I-beam and the legs. In the beginning stages it was very difficult to figure out where weight could be removed without taking too much strength out of the webbing material. Other difficulties that were experienced in the design of this structure would be how hard or easy it would be to cut the material out of the webbing with the use of hand held tools only that were found in the welding lab or were brought in by others. This was not an easy choice because in earlier designs we looked at the implementation of circular shapes which did not give us enough weight loss to make it under the 4 pound requirement. The thought of the circles was to be easier to cut out with a whole saw and no sharp points which minimize the chance of having a stress riser in a corner that has a sharp point to it.

For this idea of having no sharp points is where we got the idea for our final design which has repeating shapes of X's all the way across the webbing and the legs. As for the corner of these X shapes there is a diameter of a 1/8 inch in all the corners to minimize the chance of there being stress in these areas. Even with this at first just being a thought of having X type shapes and rounded corner there was still a lot of planning and changing that was done to reach the goal of less than 4 pounds. The main part that was changed in the end to come up with our final design was the thickness of the material between the X's. For the final design the material was









5.07e+007

4.57e+007

4.06e+007

3.55e+007

2.04e+007

1.54e+007

1.03e+007

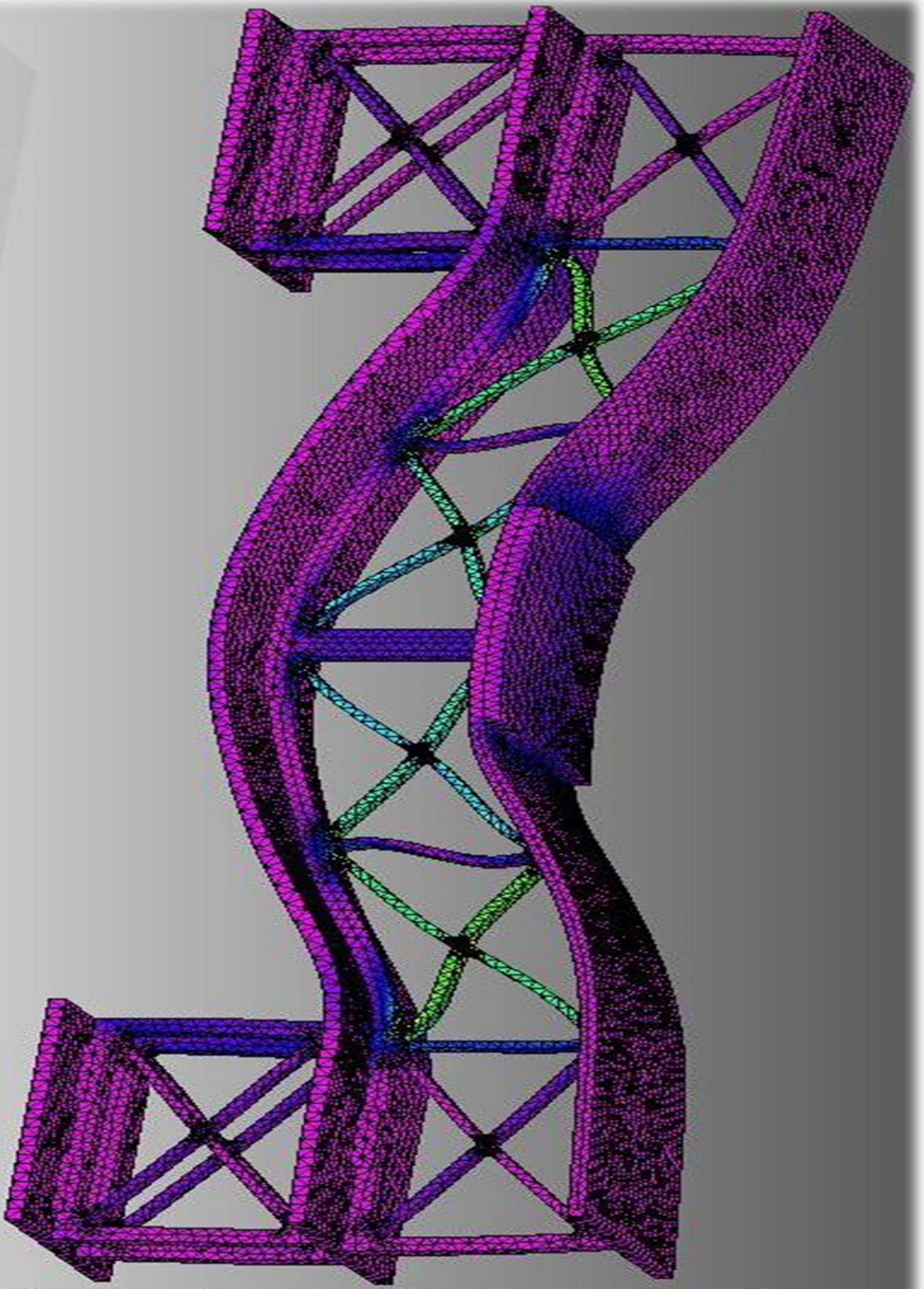
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5.07e+006

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4.06e+007

3.55e+007

3.04e+007

2.54e+007

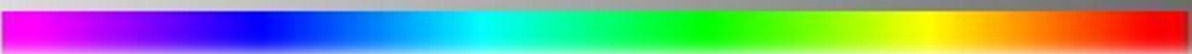
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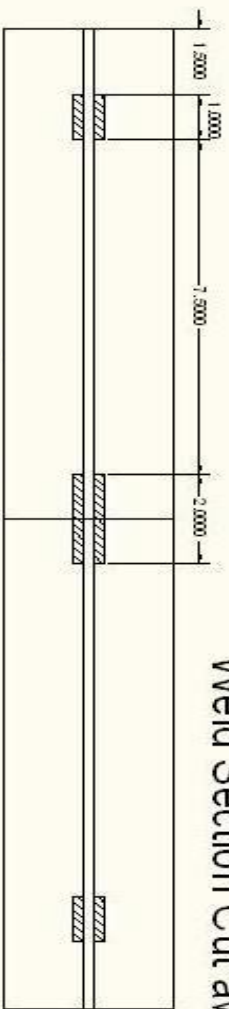
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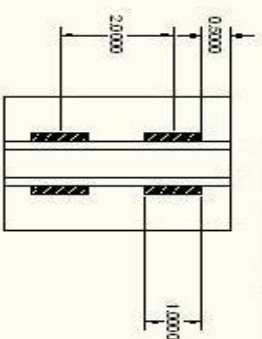
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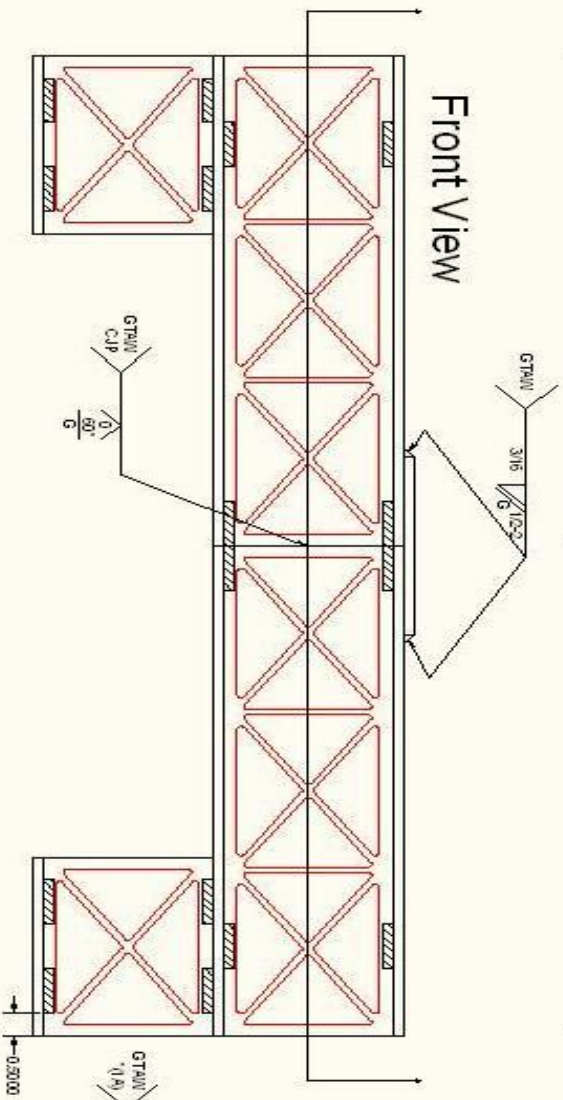




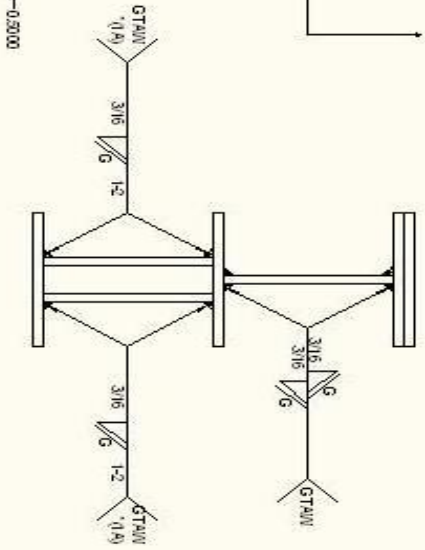
Weld Section Cut away



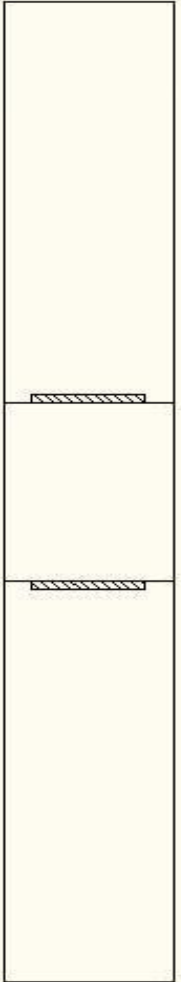
Shoe Cut Away



Front View



Side View



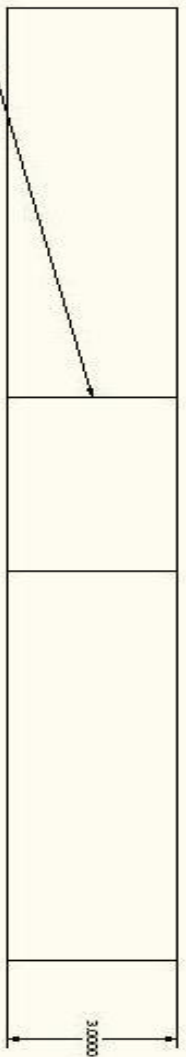
Top View

All dimensions are in inches

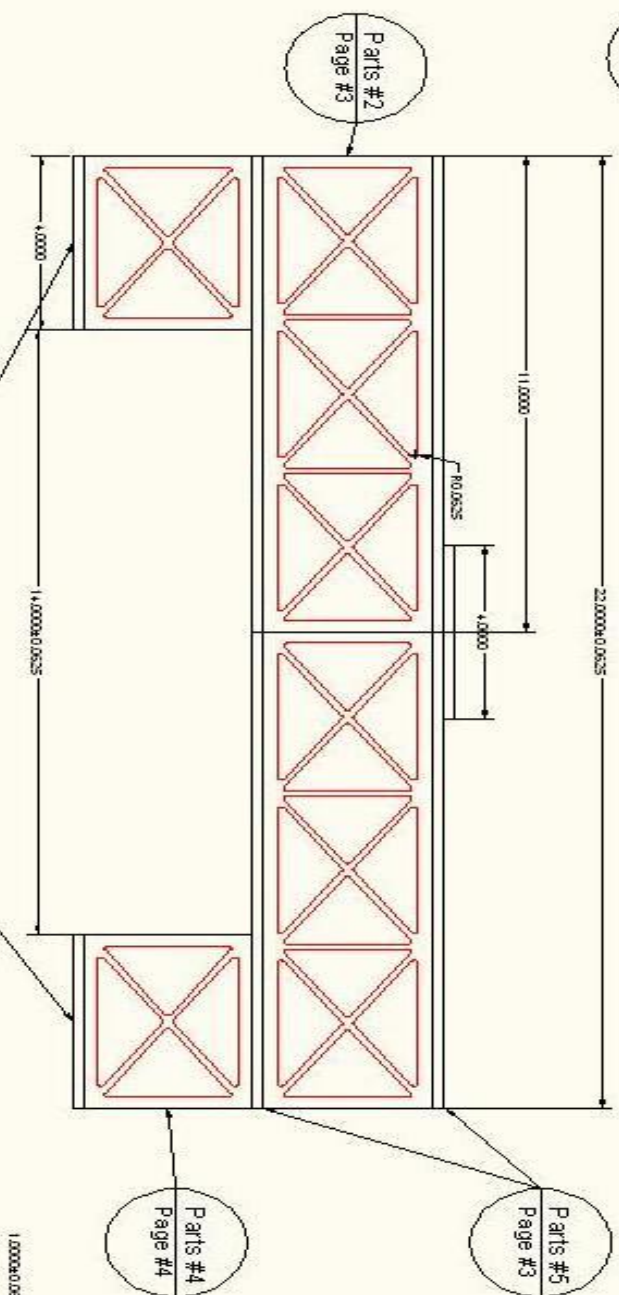
**(1A) weld starts from half inches from the begging of the part**

<b>Team #9</b>
<b>Material 6061T-6 Aluminum</b>
<b>Ferris State University</b>
<b>Welding Detail Drawing</b>
<b>Page #4</b>

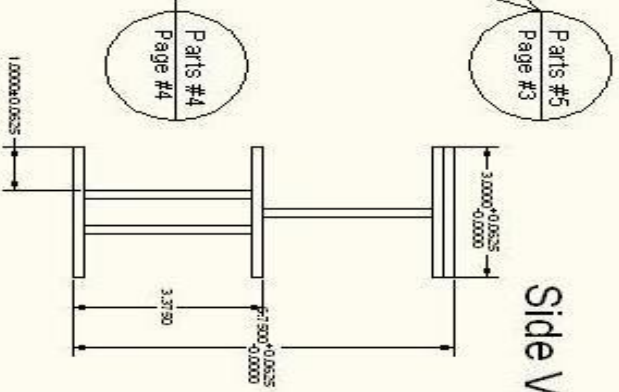
# Top View



# Front View



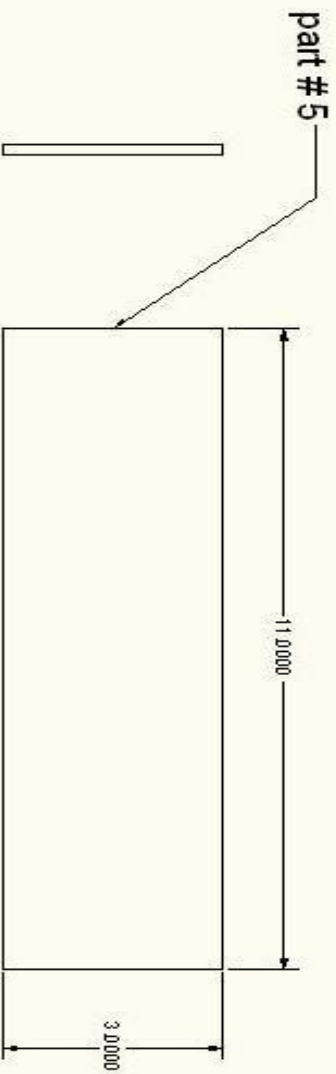
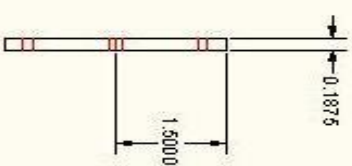
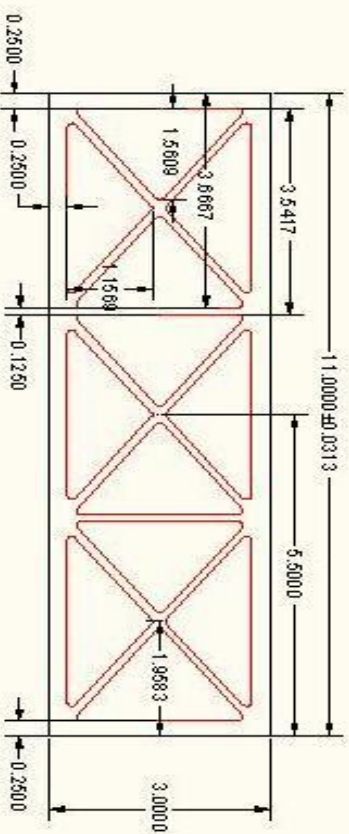
# Side View



All radii are 0.0625  
All tol. are +/- 0.0625, Triangles are +0.0625  
All dimensions are in inches

John Ivan  
Ed Escher  
Abdullah Alhuzain

Team #9
Material 6061T-6 Aluminum
Ferris State University
Page # 1
Assembly Drawing



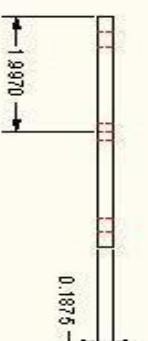
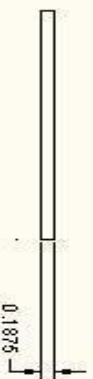
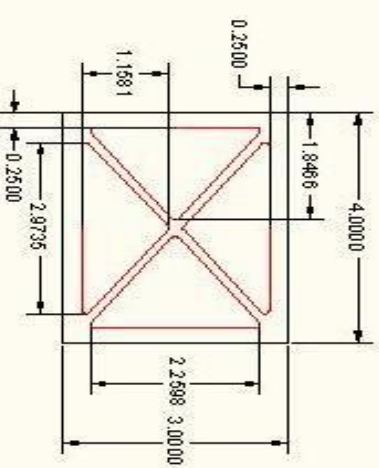
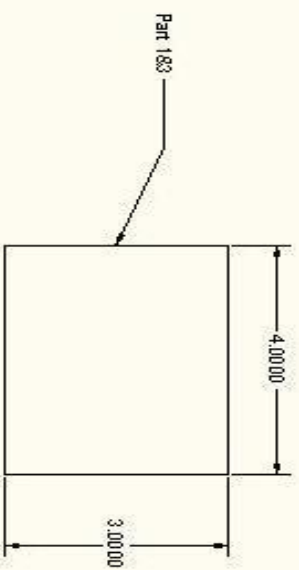
All radii are 0.0625

All tol. are +/- 0.0625, Triangles are +0.0625

All dimensions are in inches

Team #9
Material 6061T-6 Aluminum
Ferris State University
Page #3
Detail Drawing For Part 2&5

John Ivan  
Ed Escher  
Abdullah Alhuzain



All radii are 0.0625

All tol. are +/- 0.0625, Triangles +0.0625

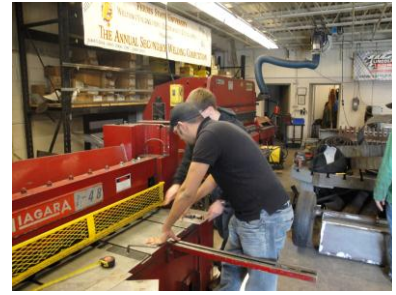
All dimensions are in inches

Team #9
Material 6061T-6 Aluminum
Ferris State University
Page #2
Detail Drawing For Part 1,384

## Product Assembly

From the beginning to the end of this project there were many steps and tools used to make this project come together and form the end product. In the beginning of the assembly of this product we were given a single sheet of 6061-T6 Aluminum cut at 24" x 48". This was the only piece of material we could use in the making of this product.

For the first step we took in the cutting out of our parts we made a nesting sheet on Auto CAD to see how the parts could fit on the piece of material we were given. Once this nesting sheet was completed and we figured out how we were going to cut our parts out we followed up with using the shear found in the welding lab. Using the shear was a big step in this project because with the proper use our parts could be close to the tolerances we were given but with improper use we could have a big mess on our hands. After all the parts were cut to their outside dimension using the shear it was time to figure out how to mark the areas of the material that would be cut out of the webbing and the legs. For the marking on the material a template was used with a scribe. After the webbing and legs were mark we used the drill pressed found in the welding lab to drill a hole in the correctly marked areas.



Shearing Base Metal



Tracing Stencil



Vertical Support after Marking



Drilling holes in the Vertical support

These holes were drilled for the thought of getting a jig saw blade in to cut the areas out later.

Having the holes drilled and the parts marked from before it was time to cut the triangle like shapes out of the webbing and legs. This was not an easy task with the use of a jig saw with the proper metal cutting blade. The trouble with this was that the blade would get plugged up with the Aluminum and cut harder. To prevent this WD-40 was used as a lubricant to stop the blade from getting plugged up. Once all the webbing and leg pieces were cut out using the a jig saw it was time to re check the dimensions of the cuts with our go/no go gauges that we created earlier in class.

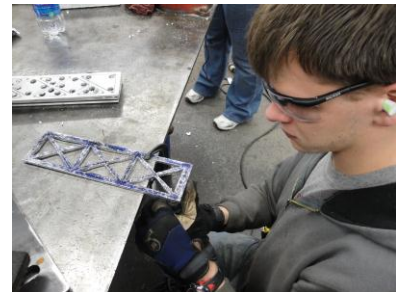
After making sure our cuts were in the right locations with the go/no go gauges it was time to touch up our cuts to get them closer to the proper location. To get closer to the tolerances a Dremel tool with a high speed tool but was use and hand files. For this part of the assembly it was crucial to not remove too much material because of not being able to add material back later. When the final touching up was finished we had to have a second group from our class make sure the parts were to the correct size and shape.



Cutting the parts with the jig saw



Filling the Parts



Cleaning up the parts with the Dremel



Using the fixture

Once the parts passed the tolerances that were given to us it was time to prep the parts to be welded. In this assemble there were two different style welding joint that were used a v-groove weld with the appropriate groove angle for 100% penetration to connect the webbing pieces and a 1F fillet weld to weld the remaining areas together. The bevel for the v-groove weld was cut using the Dremel tool and the high speed tool bit to try to prevent from getting any foreign materials in the weld area. Having the grooves cut properly it was time to weld them with the GTAW process with a 4043 Aluminum filler material. We also made a fixture to help prevent the pieces from moving away from each other or from distorting. After all the v-grooves were welded and hand the welds sanded down it was time to fit the I-Beam looking portion together. For this part of this project we feared not having enough time for only making to product so we did not make a fixture to fit them together but instead used a tape measure and a square to line them up. Also for this step we tacked both assemblies together before fully before welding the fillet weld joints.

Now having the assemblies total tacked together it was time to weld the fillet welds to complete the welding on the assemblies. The process for this is the same as the v-groove weld with GTAW and a 4043 Aluminum filler material.



Beveling the Parts



Fitting legs to shoes



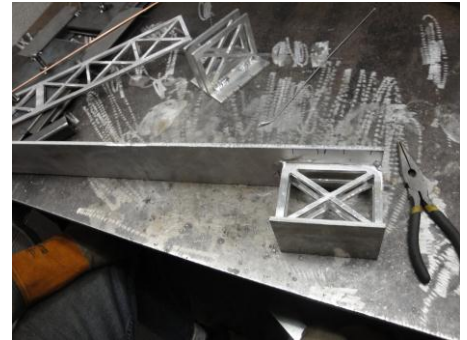
Tacking the parts



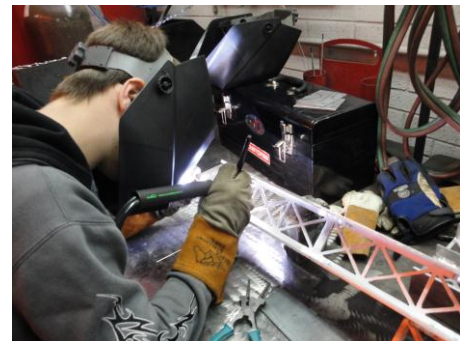
Part Tacked

For these welds we made scribe marks were we had the welds on the prints to make it easier to see and welded them in the 1F position because of the thought of making high quality welds easier. In these steps of welding on this product it was also very important to clean the surface with a stainless wire brush to remove all contaminates. Also for welding these fillet welds it was very important to let the Aluminum cool after every weld to try to help with the distortion.

In the end of this product assembly after being welded and cool the biggest part of the whole project came into to play when it was time to check the weight of the two assemblies and make sure they are under their 4 pound weight requirement. If these assemblies are over the weight requirement it is necessary to try to remove material in area were the tolerances were greater then needed.



Shoes Welded to Part



Welding Part



Part Finished

## Testing

Proudly team 9 followed the AWS D1.2 Aluminum Structural Welding Code book in qualifying the PQRs, WPSs and WQRs for this project. A specific PQRs, WPSs and WQRs were writing only for this project.

According to 4.15.3 Test Specimens-Number, Type, and preparation to qualify PQR for complete joint Penetration Groove welds for 3/8 inch Aluminum it require one sample of weld, visual inspection that meet the criteria in 4.6. Two Reduced Section Tension that meet the criteria in 4.7 “see pictures 2 and 3”. Two Root Bend and two Face Bend that meet the criteria in 4.11“ see pictures 4 and 5” and 4.12. This will qualify our WPS from 1/8” to 3/8”. This well also qualifies the welder for a groove weld and fillet weld for a flat position for thickness from 1/8” to 3/8”.

According to 4.15.3(3) Test Specimens-Number, Type, and preparation to qualify PQR for Fillet Welds. Team 9 followed Fillet weld Test option 1 which required single pass max size to be used in construction. One number of welds per procedure, two face Macroetch and two fracture Test that meet the criteria of 4.17 and 4.18 “ see picture 6”.



Figure1: Groove weld testing plate



Figure2: Reduced Section specimens before tension



Figure3: Reduced Section specimens after tension



Figure4: Bending test specimens before bending

For qualify fillet welder in the flat position we team 9 decided to change the thickness of the aluminum plate and go with 1/8 inch and that will qualify the welder from 1/8 inch to 3/16 inch which is the desirable thickness for this project. According to 4.14 and table 4.8 Number and Type of test Specimens and Range of Thickness Qualified welder and welder operator qualification required one fillet weld Fracture test and one Macroetch test “see pictures 6 and 7”



Figure5: Bending test specimens after bending

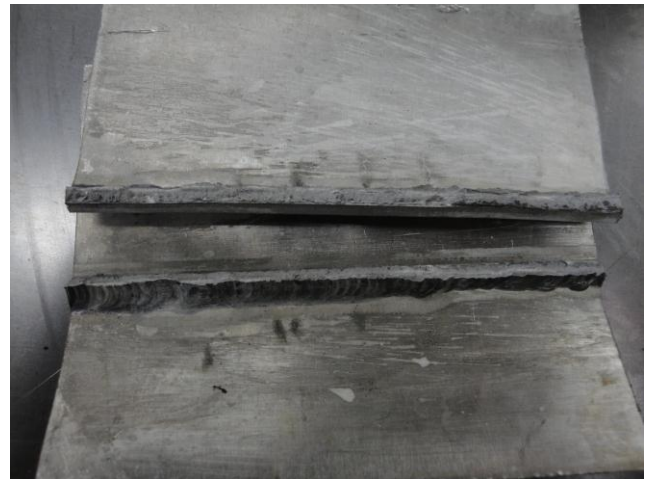


Figure7: Fillet Weld Fracture Test for WQR



Figure6: Macroetch specimens

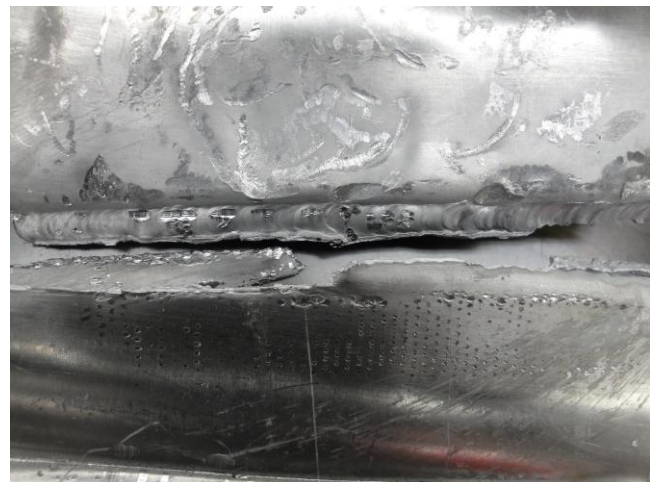


Figure 8: Fillet Weld Fracture Test for PQR

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	<b>WELD 499 PROJECT ENGINEERING AND MANAGEMENT UNIT 499 TEST EVALUATION</b>														
2	<b>TEAM NUMBER</b>	<b>PROJECT TEAM</b>		<b>LOAD RANK</b>	<b>POINTS</b>	<b>ACTUAL WEIGHT (Grams)</b>	<b>ACTUAL WEIGHT (Lbs)</b>	<b>MAXIMUM FORCE (Lbs)</b>	<b>FORCE/WEIGHT RATIO (Lbs/Lbs)</b>	<b>AVERAGE FORCE (Lbs)</b>	<b>FORCE DIFFERENCE (Lbs)</b>	<b>PERCENT DIFFERENCE</b>	<b>TOTAL TEAM HOURS TO DATE</b>		
3															
4	1	Dittmar	Josh	12	40	1783	3.93	3,064	779	3422	715	18.9%	255		
5		Scott	Isaiah	4	48	1776	3.92	3,779	965						
6		Simone	Corey		88										
7		Spielbauer	Paul												
8															
9	2	Elliott	Justin	15	36	1812	3.99	2,802	701	2970	336	10.7%	371		
10		Hart	Steven	8	44	1814	4.00	3,138	785						
11		Woiderski	Travis		<b>80</b>										
12															
13	3	Bartolomucci	Thomas	1	50	1790	3.95	5,947	1507	5290	-1314	-28.4%	205		
14		Peterson	Brian	2	50	1786	3.94	4,633	1177						
15		Wigren	Kevin		<b>100</b>										
16															
17	4	Fitzpatrick	Michael	7	44	1795	3.96	3,194	807	3139	-111	-3.6%	181		
18		Haney	Nathan	10	42	1765	3.89	3,083	792						
19		Koster	Eric		<b>86</b>										
20															
21	5	Blackmer	Nicholas	18	34	1767	3.90	1,757	451	2012	509	22.5%	188		
22		Klein	John	17	34	1758	3.88	2,266	585						
23		Northhouse	Scott		<b>68</b>										
24															
25	6	DelaCruz	Richard	14	38	1791	3.95	2,869	727	2785	-168	-6.2%	164		
26		Kujawski	Lance	16	36	1789	3.94	2,701	685						
27		Maurice	Jason		<b>74</b>										
28															
29	7	Casari	Joshua	5	46	1811	3.99	3,510	879	3753	485	12.1%	164		
30		Kowalski	Cory	3	48	1813	4.00	3,995	999						
31		Mauris	Charles		<b>94</b>										
32		Rehkopf	Douglas												
33															
34	8	Davis	Amanda	11	40	1812	3.99	3,077	770	3052	-50	-1.7%	231		
35		Gelisse	Randi	13	38	1815	4.00	3,027	756						
36		Krosschell	Carley		<b>78</b>										
37															
38	9	Alhuzaim	Abdullah	9	42	1809	3.99	3,086	774	3154	136	4.2%	331		
39		Escher	Edward	6	46	1809	3.99	3,222	808						
40		Ivan	John		<b>88</b>										
41															
42	<b>Averages</b>					<b>1794</b>	<b>3.96</b>	<b>3286</b>	<b>830</b>	<b>3286</b>	<b>60</b>	<b>3.2%</b>	<b>232</b>		
43	<b>Standard Deviation</b>					<b>19</b>	<b>0.04</b>	<b>911</b>	<b>230</b>	<b>911</b>	<b>599</b>	<b>15.5%</b>	<b>74</b>		
44															
45	<b>Load Ranking and Points</b>			<b>1=50, 2=50, 3=48, 4=48, 5=46, 6=46, 7=44, 8=44, 9=42, 10=42, 11=40, 12=40, 13=38, 14=38, 15=36, 16=36, 17=34, 18=34, DQ=0</b>											
46	<b>Maximum Permissible Weight</b>			<b>1815 Grams</b>											

Table: TEST EVALUATION

## Summary

In January of 2010 we were handed a sheet with specifications for our senior project. We then had to take all the design considerations in and produce goals for our team and schedule our projects to meet deadlines. After this was completed and our project was planned we were then left to do the work to design, build, and test our final product. The start for our product was to first to design it to specifications and then test it using some prototyping software. The prototyping software we used was known as FEA (Finite Element Analysis) developed by Solid Edge. This software enabled us to see where critical points were and to design accordingly. After the design that met our preferences was established and was agreed upon, the welds were then designed in. The design was then finalized and welding procedures were then developed to qualify each welder for a specified weld and welding task. This was done with a heavy reference to AWS D1.2 for structural aluminum to see not only industrial standards were but also to see what the experts were using to get the maximum strength out of their material. When the welders were then qualified the parts were the cut out to be prepped to be welded. Specifications for this project dictated that manual tools only could be used for this project, which translated into the negative spacing in the webbing having to be drilled out and then cut out with a jig saw and then filing down to the edges. This was very time consuming and proved to be more difficult than expected to hold onto the tolerances specified. When the parts were ready to be welded a fixture was then developed to ensure that the v-groove but joint stayed in one spot, did not move during welding, and no distortion occurred during welding. This fixture was a success and did its job very well. After the v-grooves were welded the shoes were then tacked

together as well as the I-beam component of the product. The parts were tacked together, measured and then welded together. Finally, after the part was welded together it was then tested and compared to other groups designs.

Design considerations would be probably the first thing that we as a team would, in the future need to do differently. The material that we were specified to use was 6061 T-6 aluminum. What we should have done looking back would be to do more research on the material and what welding does to it. For example this material is precipitation hardened, and the main concern with it is loss of hardness due to over aging. In industry this material is usually re-aged in ovens, to maintain its strength. Re-aging in an oven was not an option to us since there was not an oven with the right payload to fit our part into it. There was at least one oven that would have handled the size of our part, but was not available to us to use. This then changed the design factors since the welding of the part would weaken the construct the new name of the game was to minimize the welds and put them in strategic locations instead of just anywhere. This we as a group should have realized early in design so that the design wasn't changed halfway through the weld stage at the deduction of some points. Also in the design considerations, there was a definite need to have better understood the tolerances and how to maintain them. This conclusion was reached after several hours of filing and that if the part is allowed to be bigger because of design tolerances, then you need to apply the same tolerances to the weight. This was part of the reason that the designs were changed, the welds that were originally required would have not only made the part a lot more weaker but would have put the part over weight so much that it would have been hard to bring it back down in weight, even more so than already was.

Goals were one of the things that we, as a group, were suppose to develop as well as follow. There were certain criteria that were ascribed to the goals that were required so that the goals would make sense. Some of the requirements for goals were that they be formulated to achieve a single specific result, realistic and attainable, be continuously reviewable, and have specific deadlines. For the most part our goals were on task, just not well written. Our team goals, although good goals, did not convey what we were about and wanted to achieve as an end result, in the end they were rewritten in crisp and concise statements so that what our team was trying to accomplish was realized by others. If done differently, the goals that we were trying to convey to our audience would be written right the first time so that the even the casual reader would know what we are trying to accomplish. The reason our goals were poorly written the first time due in part to the lack of the scope of the project, in the future it will be pertinent to fully know about the project that one is about to undertake before one writes the goals about it.

The literature review was meant to give us good reference material to reference during our project, and a few sentences had to be written about each source to tell why we were using it as a reference. Our group had no lack of references for aluminum alloys or welding on aluminum. As accordance with our educational careers in welding we have all compiled a great deal of literature dealing with aluminum, whether it be welding or alloy content. The downside to this was that not all of our references were directly related to what we were doing or had usable information that could readily be used. Out of all the references listed, only about half of them were truly usable. This was mostly due to not fully knowing the material we possessed, ever welding book does

in fact have a little bit to say about aluminum. To think back to what information we had as compared to what information was usable as compared to what information that was used you cannot just use info that has to do with a topic, you also have to evaluate it before you decide that it is something that could be used for a report or a reference.

Project management tools were also used during the planning phase and throughout the progression of this project. The two main types of chart that were used were a Pert chart and Gantt chart. These two charts were different but did very nicely to complement one another. One kept track of deadlines while another updated progress. Charts were very useful when used right, but it was us that made them not as useful as they could have been. The problem was that our time estimates were off for how long it would take to complete each of the tasks. The factor that did us in was that when our group thinks about working on something we think that we will start on it and work on it several hours until it is done. Our schedules did not permit us to do this and as it turned out we ended up working on things in sprints and bounds. What we came to realize is that once you stop doing something it takes a little while to start things back up and get back to where you were before you stopped. If these estimates were to be done by us again, we would be more conservative with them as well as take into account that you can't walk away from something and then come back a day later and think you can pick it back up from where you were.

There were several alternate designs for our project, and even fewer that made it into the FEA software. The two main factors that kept us from using a lot of our designs were weight and ease or unease of manufacture. The weight limit for this project was four pounds; this was a major determining factor in what our designs could look like. All

of our designs were well thought out but did not always meet the weight restriction. The next problem was that after the part met the weight restriction was to make sure that the part was manufacture able. One of the parameters to challenge us were that no machining could be used on this project for anything, only hand tools were approved for general use. This in the end made it so that the tolerances that could be held were a lot bigger than would have been preferred. This had to be factored into our designs and concepts. After decent groupings of designs were approved, they were then put into the FEA program. FEA stands for Finite Element Analysis which is part the Solid Edge software. This software was a big part of prototyping our project without actually building it. This program also helped to identify where severe stresses were going to be. If we were to do anything differently it would probably be to pay more attention to where stresses were and where we could of taken weight out and where to place more reinforcement.

When all of the designing and software prototyping was done it was then our task to come up with the engineering drawings for our final design. The most important part of the design drawings was so that we would have something to carry with us to be able to build our part. The final design was mostly a compellation of several double diagonals boxed in on all the webbings. This design looked to be easy to build as well as have the rigidity that our group desired. Each of the different parts were drawn and then the whole assembly was draw with and without welds. One of that changes we made about halfway through the build was to change the placement of the welds and make fewer of them. This is partly because we had to make weight as well as new information became apparent to us that more welds on the part would weaken it and

that there was no way to re-precipitation harden the part. If we were to redo this part of the project we would probably do these adjustments before the design was submitted. Also for the final design we would of liked to change a good amount of things. The first thing to do would probably be to take mass away from parts of it that did not require as strength as other parts did, for instance the end supports could have been designed different and the material taken and put more towards the middle. All and all though, our design did quite well as compared to the other design presented and tested.

The welding procedures and qualifications were then undertaken to ensure that the welds and the welders were up to par. The AWS D1.2 was referenced for test and qualifying both the procedure and the welder. This was done because this code was one of the best references for this kind of work, especially since our desire was for structural soundness. If we were to change anything it would be to write our own code that would have been derived from D1.2. The problem we had in the end was that there was nowhere to post weld heat treat our part. This meant that we could not follow D1.2 to the letter and can only claim a strong reference and not a direct reference.

What is funny about this project is that even though the bridge is the only component that is the only noticeable final result to most people; it is only a very small part of the entire project. Our parts were put together within the specifications provided on our print. The only part that a fixture was used for was the v-groove, everything else was measured together and tacked together measured again and then welded. This did in the end give us the results we desired. The fixture for the v-groove performed as it needed to. The only thing that could have been changed with the fixture is to make it a fixture with a hinge so that the part could be placed inside and clamped down, welded,

and then removed without any worry about the build up on the joint. On ours you slid the part in, clamped it in, then welded it and hoped you could slide it out the other end. Finally, there was a need to have developed more fixtures to ensure that both assemblies were built the same both times. One of the worries during the build stage was that the measurements be checked and double checked. This took up time and slightly opened us up to error.

The final part of the product's phase was to test it and compare it's performance to all the other designs. This became a somewhat religious experience and was indeed a lot of fun. The parts were loaded into a fixture that was placed on the tensile machine and then pressure was applied until the values no longer went up in value, which then was decided that the part had reached failure and the value was recorded and compared to everyone else's. There was nothing wrong with the method of testing, if anything this is what our projects were designed for. The only complaint would be that the load marshal be better trained and that two people watch the numbers as it is loaded. This is said because something happened to where we did not see the maximum values on the pendant and were only saved due to someone else watching the values as they progressed.

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