Final Report: Sooner/Exiss Trailers Jig Design

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Prepared for: Sooner/Exiss Trailer
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Customer Requirements & Quantitative Specifications

KTK Engineering Solutions compiled a list of customer requirements for Sooner/Exiss Trailer’s new welding jigs. The most important requirement is that the jig increases the quantity of trailers manufactured from 7 trailers to 10 trailers per day. Another important requirement is that the welders using it like it, and that the ergonomics are pleasing. Sooner/Exiss needs the jig to be long enough to accommodate their longest trailers, which are 42’, but it must also be capable of manufacturing trailer sides as short as 16’. The jig must also accommodate different heights, ranging from 5’6” to 8’2” tall. In addition, the jig must accommodate all 72 different trailer side designs which Sooner/Exiss has in production.

After speaking with the welders at Sooner/Exiss, their requirements were that the new jig be shorter in height than it is now, but be able to accommodate the tallest trailers. Currently, the welders have to climb on the jig; after the redesign this requirement will be eliminated. However, the welders want dedicated footholds to prevent slipping and easily accessible clamps. Additional horizontal cross members on the jig were another specification, purely for the welders to easily clamp aluminum tubing to during placement.

KTK thinks that the requirements from both management and wage workers at Sooner/Exiss can be accommodated with the exception of climbing which is clearly undesirable. The budget for the redesign can be up to $20,000, according to management. KTK also had ideas for a jig that has powered or manual rotation designs which can accommodate Sooner/Exiss funding requirements.

KTK used rectangular steel tubing to build the jig, with it being adequately supported to prevent the jig from sagging and therefore building sag into the sides of the trailer. The jig was built to last, using quality materials and engineering design.

Statement of Work

Background

KTK Engineering Solutions was tasked to redesign a welding jig at Sooner/Exiss Trailer. Sooner/Exiss needed to increase trailer production by 30% per day. The jig needed to be ergonomic for workers while improving their safety. The jig needs to limit the number of handheld measurements, which leads to inconsistencies in trailer manufacturing, resulting in reworks.
Current Setup

Sooner/Exiss Trailer currently uses four fixed jigs to manufacture side walls. KTK Engineering made two visits to observe workers and daily work. Figure 1 shows Sooner/Exiss Trailer’s current jig setup. The figure also demonstrates the unsafe climbing which commonly required of welders in order to reach higher welds. The danger of this action is increased by the opaque welder’s helmets which prevents the workers from seeing to catch themselves in the event of a fall. Eliminating climbing is one of the requirements the new jig will meet.

![Figure 1- Sooner/Exiss Current Jig Setup](image)

Scope of Work

The scope of work only included the redesign and possible fabrication of a new jig which will be used in trailer side production. The engineers of KTK researched relevant patents, and spoke to experienced engineers whom had also previously worked on the project. The general manager at Sooner/Exiss wanted a jig that would not require workers to climb on the jig. KTK needed to
make sure the jig did not deflect when a trailer side was being constructed. The jig needed to increase accuracy of framing posts, window, and door placement so fewer trailers would need to be reworked.

Physical Location

The construction of the project occurred in the Oklahoma State University Biosystems and Agricultural Engineering (BAE) laboratory in Stillwater, OK and at the Sooner/Exiss Trailers factory in El Reno, OK. Solidworks models were used to communicate ideas between Sooner/Exiss Trailer and KTK Engineering. Design work was performed at Oklahoma State University, also in Stillwater, OK.

Period of Performance

KTK Engineering Solutions’ engineers began the redesign of the jig in the Fall Semester of 2012. Design work was to be completed by December of 2012, and the final design review was completed in the weeks of December 3rd-14th. The project was completed in April of 2013. The final design was presented and the prototype delivered to the client on April 25, 2013.

Delivery Requirements

Table 1 – Delivery requirements by date and day of week

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>10/29/12</td>
<td>SOW Due</td>
</tr>
<tr>
<td>Friday</td>
<td>11/2/12</td>
<td>WBS Due</td>
</tr>
<tr>
<td>Monday</td>
<td>11/5/12</td>
<td>Task List Due</td>
</tr>
<tr>
<td>Monday</td>
<td>11/12/12</td>
<td>Engr Design Concepts Due</td>
</tr>
<tr>
<td>Monday</td>
<td>11/19/12</td>
<td>1st Draft Report Due</td>
</tr>
<tr>
<td>Monday-Friday</td>
<td>12/3-12/14/12</td>
<td>Technical Presentation</td>
</tr>
<tr>
<td>Friday</td>
<td>12/7/12</td>
<td>Report due to Sooner/Exiss</td>
</tr>
<tr>
<td>Monday</td>
<td>4/22/2013</td>
<td>Project Complete</td>
</tr>
</tbody>
</table>

Detailed Work

KTK began the redesign in the fall semester of 2012.

The jig needed to accommodate trailers between 5’6” and 8’6” tall and between 16’ and 42’ long. The jig needed to be structurally sound as to not deflect when in a horizontal position. The jig also needed to accommodate the available floor space in the factory in El Reno.

The design selected is a table type jig with vertical and horizontal square tube for workers to clamp to. The jig will rotate using an electrically powered DC motor. The jig will be balanced to aid ease of movement. The jig will have a braking system utilizing a worm gear for workers to
be able to stop the jig in a desired position. The jig will rotate past horizontal to the backside for welders to weld the top rail in place without having to climb on the jig. The jig will allow workers to place components and weld without needing tape measures by incorporating a measurement system into the jig. The welders will be able to weld in an ergonomic position, without having to weld over their heads. The jig will accommodate moving welding hoses up off the floor, eliminating trip hazards. The jig will also have a bottom rail or fixed toggle clamps for welders to place the bottom rail of the trailer.

KTK spent time on this list of actions for the redesign.

- Brainstorming for ideas for the redesign
- Developing a scope of work
- Drawing ideas in Solidworks
- Calculating deflection in main center pipe
- Calculating torsional deflection in center pipe
- Selecting appropriate materials based on calculations
- Developing different ideas for measurement system
- Analyzing cost difference between different systems
- Designing a 15’ prototype as a proof of concept piece
- Production and testing of the prototype
- Modification of the prototype based upon testing

Incorporating manager and wage workers wants and needs resulted in several design options. Appendix 3 contains a chart of design options. This chart assisted KTK throughout the design process.

**Task List**

KTK developed this task list to help organize thoughts and find the direction to pursue for the redesign.

1) Jig Prototype
   a. Redesign
      i. Determination of Rotation Mechanism
         1. Hydraulic
         2. Counterweight
         3. Manual Crank
         4. Electric DC motor
      ii. Create Alternative Measurement Solutions
         1. Laser measurement
         2. Laser projection
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3. Adhesive ‘tape measure’

iii. Engineering Calculations
   1. Material Determination
   2. Deflection
   3. # of pinions
   4. Torsion
   5. Tipping
   6. Buckling

iv. Determine clamping locations
   1. Type of clamp
   2. Number of clamps

v. Solidworks Drawings
   1. Create 3D model
   2. Stress analysis
   3. Deflection analysis
   4. Create Standard Engineering Drawings

vi. Scale Model
   1. Deflection Testing
   2. Material Validation
   3. Determine Number of Supports needed

b. Purchasing
   i. Price Lasers/Measurement Systems
      1. Design System suitable
   ii. Center Pipe Material
   iii. Table Materials
   iv. Clamps
   v. Measurement System

Work Breakdown

1) Jig Prototype
   a. Redesign
      i. Scale Model
         1. Deflection Testing
         2. Material Validation
         3. Number of Supports needed
      ii. Solidworks Drawings
         1. Stress analysis
         2. Deflection analysis
      iii. Engineering Calculations
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1. Material Determination
2. Deflection
3. # of pinions
4. Torsion
5. Tipping
6. Buckling

iv. Determine clamping locations
   1. Type of clamp
   2. Number of clamps

b. Rotation Jig
   i. Rotation Mechanism
      1. Hydraulic
      2. Counterweight
      3. Manual Crank
      4. Electric DC Motor

c. Price Lasers/Measurement Systems
   i. Design System suitable

d. Alternative Solutions
   i. Everything that may not be financially feasible or practical

Payment Schedule

KTK did not receive compensation for the design work or the manufacturing of the jig. All materials were purchased by Sooner/Exiss. Sooner/Exiss set a ceiling of $20,000 for all expenses.

Acceptance Criteria

Sooner/Exiss required a jig that can produce at least 10 trailers per day, a 30% increase in manufacturing, while being ergonomic and pleasing for workers. The jig must also improve worker’s safety; the workers must not be required to climb on the jig, reducing injuries from stepping down off the older version of the jig. In addition, welding cords need to be moved off the ground, or away from walking spaces, reducing trip hazards.

Special Requirements

Due to the nature of the project, KTK was required to travel to Sooner/Exiss when a site visit was necessary. Don Lake, Applications Engineering Extension Agent for Oklahoma State University was accommodated by meeting half way, and meeting at times convenient to him when he was in Stillwater, OK, KTK’s base location. In addition, KTK collaborated with Mike Raymond with the Oklahoma Manufacturing Alliance, and Aaron Cain and Dr. Robert Taylor,
both with the New Product Development Center at Oklahoma State University. Biweekly, conference calls were arranged with KTK, Dr. Paul Weckler, Larry Zahasky, Don Lake, and Mike Raymond to discuss the progress being made on the project.

**Technical Analysis**

Existing jigs for trailer side framing consist of steel square and round tube welded into a table-like apparatus. For example, Featherlite trailers has a set of jigs very similar to those found at Sooner/Exiss Trailer’s manufacturing plant. However, Featherlite has positioning jigs (Figure 2). It is worth mentioning that Featherlite does make use of a robotic welding system, which precision welds the frame for the gooseneck. The pieces are placed upon a rotating jig with clamps them in place before the robot welds them (Featherlite, 2009).

![Figure 2 - Featherlight trailer side frame jig (Featherlite, 2009)](image)

The jigs are made of heavy steel tube which is welded together. Considering this, there should not be any maintenance costs associated with the jig, unless a cutting operation or other activity performed by a welder was to damage it by melting or annealing the metal. Considering the melting point of steel is greater than that of aluminum, (2600-2800 °F for steel, vs. 660 °F for aluminum) it is unlikely that any welding or cutting operations should involve high enough temperature to damage the jig. In addition, steel does not transform into austenite below 738 °C.
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(1360.4 °F), which provides evidence that the steel jig should not be in danger of annealing (assuming cold rolled steel is used to build the jig). Due to these factors, KTK engineers chose to use mainly steel components in the construction of the new welding jig.

It would be possible to create a framing jig which can rotate and translate, but only found one working example of a jig which takes advantage of this ability. The example can be found in Figure 3. It should be noted that any jig which incorporates moving components will require more maintenance. At the very least, grease will need to be pumped into the collars holding the rotating shaft.

![Hydraulic, movable trailer framing jig](http://www.mrtrailer.com/t_pic/titan157.jpg)

**Figure 3** - Hydraulic, movable trailer framing jig (http://www.mrtrailer.com/t_pic/titan157.jpg)

According to Sooner/Exiss Trailers employees, they did have a rotating jig that was in use at one point in the past. However, the jig had unacceptable deformation when in the horizontal position. Additionally, the jig was unpowered and had to be rotated by hand. The cost of production and the space required to accommodate a jig which rotates is also an issue.

Several safety concerns have been associated with the current jigs in use. First, the welders are often required to weld over their heads leading to rotator cuff injuries. Secondly, it creates the potential for sparks to fall into the face of the welder. In addition, the welders must climb onto the frame itself to reach some weld points, creating a hazard when stepping off the jig, as seen on a site visit when KTK was told about an employee who suffered a broken foot from just this hazard.
Any powered jig design will have to incorporate a solution to the trip hazard created by any hoses or cords which provide power to the jig, unless it uses manual rotation. Along the same lines, any pinch points and moving components of the jig will require shielding to prevent injury to the welders and a failsafe will be required to prevent accidental operation of the jig (for example, a cover over the operation switch might add protection against accidental contact).

**Patent Searches**

KTK found several relevant patents. The first is a patent for rail box car under frames which uses clamps attached to the jig table to secure the side sills to the center sill. One of the most relevant points made is that the non-fixed clamps used in design of the jig allow the rail car frame to be removed despite expansion in the metal caused by the welding operations. This will need to be a consideration which is examined, should any fixed dimension jigs be designed by KTK (Shipley, 1951).

The second patent, by Sellers, L. (1979), filed for a jig to fabricate side walls for houses. Included in the patent are designs for movable, U-shaped guides which can be used to place studs at the desired center distances. This could help KTK to design a system by which the trailer side ribs can be placed at the desired center to center intervals quickly and precisely. This would help KTK to meet one of the clients most fervently expressed design goals: reduction in the use of measuring tapes and hand measurement.

The third patent found describes a hand-held jig which can be adjusted using a bolt and wing-nut assembly to place framing studs at the proper center distances. This offers KTK a possible alternative method for placing the trailer ribs which may or may not appeal more to the manufacturing personnel at Sooner/Exiss Trailers. However, it is possible that any design produced by KTK which was similar could violate the patent as it was issued in 1997 and is therefore still in effect (Bingham and Stone, 1997).

**Engineering Calculations**

**Weight**

The weight of each component and the overall jig weight were calculated based on known specific weights for each component, the values were then checked with Solidwork’s mass properties tool, the hand calculations can be seen in Table 2 and
Table 2 – Weight breakdown for the prototype section jig (note: sheet metal components, the gussets and sheet metal in the stands have a specific weight in lb/ft² and the length field is the area in ft²)

<table>
<thead>
<tr>
<th>Type</th>
<th>Specific Weight (lb/ft)</th>
<th>Length (ft)</th>
<th>Weight (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCALE PROTOTYPE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Table (x1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6x2x3/16 St. Tube</td>
<td>9.42</td>
<td>88.7</td>
<td>835</td>
</tr>
<tr>
<td>gusset</td>
<td>7.5</td>
<td>2.44</td>
<td>18.27</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>853.27</td>
</tr>
<tr>
<td>Stand (x2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2x2x3/16 St. Tube</td>
<td>4.32</td>
<td>23</td>
<td>99.4</td>
</tr>
<tr>
<td>Girdle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half pipe (8&quot; sch 40)</td>
<td>28.55</td>
<td>1</td>
<td>28.6</td>
</tr>
<tr>
<td>sheet metal</td>
<td>7.5</td>
<td>1.36</td>
<td>10.2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>138.2</td>
</tr>
<tr>
<td>Center Shaft (6&quot; sch 40)</td>
<td>18.97</td>
<td>15</td>
<td>284.55</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>1276</td>
</tr>
</tbody>
</table>
Table 3 – Weight breakdown for the full jig (note: sheet metal components, the gussets and sheet metal in the stands have a specific weight in lb/ft$^2$ and the length field is the area in ft$^2$)

<table>
<thead>
<tr>
<th>Type</th>
<th>Specific Weight (lb/ft)</th>
<th>Length (ft)</th>
<th>Weight (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FULL JIG</td>
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<td></td>
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</tr>
<tr>
<td>Table (x1)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>6x2x3/16 St. Tube</td>
<td>9.42</td>
<td>248.7</td>
<td>2342</td>
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<tr>
<td>gusset</td>
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<td></td>
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</tr>
<tr>
<td>Stand (x5)</td>
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<td></td>
</tr>
<tr>
<td>2x2x3/16 St. Tube</td>
<td>4.32</td>
<td>23</td>
<td>99.4</td>
</tr>
<tr>
<td>Girdle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half pipe (8&quot; sch 40)</td>
<td>28.55</td>
<td>1</td>
<td>28.6</td>
</tr>
<tr>
<td>sheet metal</td>
<td>7.5</td>
<td>1.36</td>
<td>10.2</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td></td>
<td>138.2</td>
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<tr>
<td>Center Shaft (6&quot; sch 40)</td>
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<td>796.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
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<td>3323</td>
</tr>
</tbody>
</table>

**Deflection**

Deflection within the main beam was calculated to ensure that the jig would not sag more than 1/32” which satisfied the requirement that sidewalls built in a lay-flat configuration would not exhibit unacceptable deformation from the welding jig. Equation 1, found in Appendix 1, was used to simulate deflection in any free span of the jig as a simply supported beam with a distributed load.

Microsoft Excel was then used to create an optimization sheet which would allow the user to determine the maximum span of material which would not result in more than the maximum allowed deflection (Figure 4).
As can be seen above, the run resulted in a 10 ft span meeting the 0.0026 ft (1/32 in) maximum deflection allowance with a calculated deflection of 0.0022 ft within each 10 ft span.

**Torsion**

The torsion of the center pipe was calculated by hand and using computer software based finite element analysis (FEA). Hand calculations showed that the torsional deflection of the center pipe would be .988 degrees with a 250 pound point load on the top outer corner of the table, assuming one side fixed with a brake. This torsional deflection relates into a 1.655 inch deflection total at the outmost post of the table. Half of that deflection is the top of the table rotating down due to the point load, and the other half is the bottom of the table rotating up. This torsional deflection is considered worst case scenario, with a 42’ trailer being put on the table and a worker climbing on the jig. Equations to find the torsional deflection can be found in Appendix 1. Solidworks was utilized to do a secondary analysis on the torsional deflection. A simplified model was used, shown in Figure 5. The results from Solidworks are 1.1 inch total deflection, half from the top, half from the bottom. This value was similar to that found by the hand calculations.
A calculation was performed to examine the jig’s tipping potential. The worst case scenario, in which the table center of mass created the greatest moment, was examined. A table angle of 30° with respect to vertical met this condition. Figure 6 shows the results of the tipping calculation which was placed into an excel spreadsheet. The equations used in calculating the tipping can be found in Appendix 1. Based upon the calculations performed, a force of 1,200 lb would be required to tip the jig. However, in reality, at this point along the rotation of the jig, the table should be resting upon the ground, indicating that the point about which the table must tip is actually further from the center of mass, creating a larger moment and requiring an even larger force to actually cause tipping. The designers chose to assume the table was not quite touching the ground in an effort to determine if the jig might tip and cause damage during rotation.
Figure 6 – Tipping calculation. Summing the moments around the center of mass of the combined stands and center shaft allowed the force $P$ required to cause the jig to tip to be calculated. $N_2$ was assumed to be zero in accordance with a ‘just tipping’ condition.

**Buckling**

Buckling in the upright member of the stand was also examined. The calculations and equations can be seen in Figure 7. The member was determined to be an strut. The critical load to buckle the member was determined to be 31.9 kip. In addition, based upon purely axial loading, the yield load was determined to be 6590 psi factor of safety for the member was found to be 4.5.
New Stand Deformation

The new girdle design was examined using FEA. The base of the stand was fixed and then a distributed load of 328 lb directly downwards over the half pipe at the bottom of the girdle was applied (the force applied can be seen in Figure 8).

**Figure 7 – Buckling calculations.**
Figure 8 – Fixture (left) and load (right) conditions applied to examine girdle yielding.

The results of the simulation using these conditions are as follows (Figure 9 and Figure 10):

Figure 9 – Simulation stresses found in the stand, max stress is 19.5 MPa (2.83 ksi)
Figure 10 – Simulated deformation within the stand. Deformation is at a scale of 3910.24:1. The maximum deformation is 0.025 mm (9.84x10^{-4} in).

The maximum calculated stress was 2.83 ksi, well below the yield stress for steel (~30 ksi for 1020 HR, a mild, hot rolled steel). Moreover, the simulation results showed a deflection of 0.025 mm or 0.000984 in. In addition, our results demonstrated the middle plate shown in the analysis above did not significantly aid in reducing deformation. Therefore, it was removed in the subsequent design.

**Current Design**

Figure 11 displays the design that KTK Engineering has created for the base model jig. Dimensions are 42’ long by 8’ wide. The table is made out of 2” x 6” x 3/16” rectangular steel tubing. The stands are made out of 2” x 2” x 3/16” square tubing, welded together. The table will be welded to the main rotating shaft, which will be 6” Schedule 40 pipe. There will be fixed toggle clamps on the bottom of each vertical support. The table will rotate to the ground in the front, and approximately 20 degrees past horizontal in the back. The back of the jig will have a steel stop that prevents further rotation. The jig is powered by a DC electric motor and worm gear.
KTK Engineering is producing a prototype in order for Sooner/Exiss to make an executive decision to build a full scale jig. The prototype jig will be built to full length jig specifications, but will only be 15 foot long, as opposed to 42 foot. The jig will be fully rotational. After it is built it can be used in Sooner/Exiss’s facility to manufacture doors and windows, if desired.

Prototype Manufacturing

Base materials for the prototype were ordered by Sooner/Exiss through their distributor and were shipped to Biosystems machine lab for assembly as shown in Figure 12.
Custom designed parts were flame cut out of a 48”x96” piece of 3/16” steel plate. As you can see in Figure 13, the half plates and gussets for the prototype were are all cut from sheet metal. Figure 14 shows the completed gusset pieces cut from the sheet metal.

The supporting stands for the welding table are made out of 2”x2” square tubing. The tubing for the base is welded into a 24”x36” rectangular base with angled vertical tubing members welded to the bottom girdle. The top and bottom girdles are attached by four UNF 3/8” hex bolts. Figure 15 depicts the completed stand fabrication.
The welding table is made out 2”x 6’x 3/16” rectangular tubing. The 15’ pieces of tubing were placed on the ground and the distance between them were measured to drawing specifications. The 8’ pieces of tubing were placed perpendicular to the 15’ pieces and measured to drawing specs. The pieces were squared and tacked into place. Figure 16 shows the center shaft with the gussets premounted being measured and tacked into place.
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After the table was tacked and welded to specifications, it had to be lifted using an overhead crane, as shown in Figure 17.

Figure 17- Finished Table

Figure 18 shows the Ultra High Molecular Weight (UHMW) polyethylene that was used in the center pipe for a bushing. This material makes the jig rotate smoothly.

Figure 18- Material used for bushing
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Figure 19 shows how the UHMW used for the bushing was form fitted to the center pipe stand. The UHMW was heated such that it would form to the stand. The UHMW was then pressed down with a pipe of the same size diameter of the center shaft. After the UHMW cooled the sample center shaft was removed to place the full center shaft in.

Figure 20- Initial bushing test

Figure 20 depicts the sample center shaft holding the bushing material in place during cooling.
After the bushing cooled, the sample center shaft was used to determine how easily the center shaft would rotate. Figure 21 shows that the bushing material would work, and the rest of the stands were fitted with bushings.

**Figure 21- Bushing analysis**

Figure 22 depicts the stands and tables being fitted together.

**Figure 22- Attaching table and stands**
Figure 23 shows an error that was not diagnosed before manufacturing. The material of the stands had been changed from pipe to tubing, and the same dimensions were used, making the stands too tall. This was later fixed using simple engineering calculations.

Figure 23- Initial stand height comparison. 5’3” girl vs table height.

Figure 24 shows that the stands had been modified from the previous dimensions, to an acceptable height. This modification required the stand legs to be notched at a 60 degree angle to preserve the integrity of the degree of the table when it is sitting on the ground.

Figure 24- Modified legs of the table
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Figure 25 depicts the table integrity while another senior design project needed to be worked on. The table has been used for welding, before it was attached to the stands. The table showed no visible deformation.

![Table Image]

**Figure 25 - Testing**

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**Cost Analysis**

KTK performed an analysis of the materials costs for both the 15’ prototype jig (Table 4) and the full 42’ final jig (Table 5). The full price for the prototype components came out to just over $1,300.00 and the full jig material cost came up to $3,100.00, both significantly under the original $20,000.00 budget.
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Table 4 - Price of all materials for the 15’ prototype

### Base and Table Prototype

#### Original Materials

<table>
<thead>
<tr>
<th>Parts List</th>
<th>Quantity (ft)</th>
<th>Price/ft</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x6in Rectangular Tubing</td>
<td>92</td>
<td>$5.10</td>
<td>$469.20</td>
</tr>
<tr>
<td>6-5/8in Drill Stem Pipe</td>
<td>15</td>
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<td>$11.70</td>
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<td>Adhesive Backed Ruler</td>
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<td>$59.40</td>
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Total $1,817.28

#### New Materials

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<th>Total</th>
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<td>$32.86</td>
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<tr>
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<td>$101.00</td>
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<td>$154.88</td>
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<td>1</td>
<td>$74.22</td>
<td>$74.22</td>
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<td>$27.68</td>
<td>$27.68</td>
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<tr>
<td>Adhesive Backed Ruler</td>
<td>2</td>
<td>$29.70</td>
<td>$59.40</td>
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</table>

Total $1,328.89
Table 5 – Price of all materials for the full jig

**Base and Table Full Jig**

**Original Materials**

<table>
<thead>
<tr>
<th>Parts List</th>
<th>Quantity (ft)</th>
<th>Price/ft</th>
<th>Total</th>
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<tbody>
<tr>
<td>2x6in Rectangular Tubing</td>
<td>248</td>
<td>$5.10</td>
<td>$1,264.80</td>
</tr>
<tr>
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<td>42</td>
<td>$40.00</td>
<td>$1,680.00</td>
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<td>Drawn over mandrel Pipe</td>
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<td>$489.00</td>
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<tr>
<td>2-3/8in Pipe</td>
<td>120</td>
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<tr>
<td>1/2in Steel Rod</td>
<td>42</td>
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<td>HH-225D Toggle Clamp</td>
<td>10</td>
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<td>UHMW Plastic</td>
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<tr>
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<td>$35.30</td>
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<td>80 Tooth Sprocket</td>
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<td>$74.22</td>
<td>$74.22</td>
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<tr>
<td>Idler Sprocket</td>
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<td>$27.68</td>
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<tr>
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**New Materials**

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</thead>
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<tr>
<td>2x6in Rectangular Tubing</td>
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<td>2x2in Square Tubing</td>
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<td>6in Schedule 40 Pipe</td>
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<td>5</td>
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<tr>
<td>Adhesive Backed Ruler</td>
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<td><strong>Total</strong></td>
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<td></td>
<td><strong>$3,148.49</strong></td>
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</table>
Recommendations

KTK recommends that Sooner/Exiss Trailer purchase two basic jigs for their production line. We also recommend that the jigs be motorized with adhesive rules and toggle clamps.

Modifications

After prototype demonstrations Sooner/Exiss recommended that some modifications be made to the jig. They recommended that the stands be made vertically taller to increase the angle of the jig when it is resting on the ground. The adhesive backed rules need to be recessed into the jig itself to protect against abrasive damage from the trailer sides. The toggle clamps and bottom vertical members should be recessed to allow for easy installation of the bottom rail.

References


http://www.universaltrailer.com/

http://www.soonertrailers.com/

http://www.exiss.com/
Appendix 1

Equations Used:

**Horizontal Deflection**

\[ y = \frac{Wx}{24El}(2lx^2 - x^3 - l^3) \]

- \( y \) = deflection
- \( W \) = distributed load
- \( x \) = location along beam
- \( E \) = Young’s modulus
- \( l \) = total length

**Torsional Deflection**

\[ \theta = \frac{TL}{JG} \]

- \( \theta \) = Torsional Deflection
- \( T \) = Torque
- \( L \) = length
- \( J \) = Polar moment of Inertia
- \( G \) = Modulus of Rigidity

**Tipping**

\[ \sum M_{center} = -P(L_t + h_j) - W_t(L_h) + N_1\left(\frac{L_s}{2}\right) = 0 \]

\[ P = \frac{N_1\left(\frac{L_s}{2}\right) - W_t(L_h)}{L_t} \]

- \( P \) = Force
- \( N_1 \) = Normal Force
- \( L_s \) = Stand Width
- \( L_h \) = \( W_t \) Moment Arm
- \( L_t \) = \( P \) Moment Arm
- \( W_t \) = Table Weight
- \( W_s \) = Weight of stands + center shaft pipe
<table>
<thead>
<tr>
<th>Buckling</th>
<th>Spring Report</th>
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<tr>
<td>Euler</td>
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<tr>
<td>( P_{cr} = \frac{\pi^2 El}{I^2} )</td>
<td>( \frac{P_{cr}}{A} = S_y - \left( \frac{S_y}{2\pi k} \right)^2 \frac{1}{CE} )</td>
</tr>
<tr>
<td>( \sigma_c = \frac{P}{A} + \frac{My}{I} )</td>
<td></td>
</tr>
</tbody>
</table>

\( P = \text{Force on column} \)

\( P_{cr} = \text{critical force} \)

\( E = \text{Young's Modulus} \)

\( I = \text{Area Moment of Inertia} \)

\( \frac{L}{k} = \text{slenderness ratio} \)

\( L = \text{Length} \)

\( C = \text{End Conditions} \)

\( A = \text{area} \)

\( M = \text{Moment} \)

\( S_y = \text{yield stress} \)
Appendix 2

Gantt Chart- Microsoft Project

<table>
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<th>ID</th>
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<th>Finish Date</th>
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<td>11/11</td>
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<td>Rotation Mechanism</td>
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<td>Hydraulic Or Countermotion</td>
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<td>2/24</td>
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<td>4/28</td>
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31
Appendix 3
Flow Chart of Generated Design Options

Spring Report
Appendix 4

CAD Drawings:

Spring Report
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<td>Center Pipe</td>
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<td>5</td>
<td>Gusset</td>
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<td>6</td>
<td>Bushing</td>
<td>5</td>
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<td>7</td>
<td>3/8” FLAT WASHER</td>
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<td>8</td>
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<td>9</td>
<td>6-32 x 1”</td>
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**Unless otherwise specified:**
- All materials are mild hot rolled steel.
- Pipes are schedule 40.

**Front View**

**Detail L**

**Scale 1:5**
CENTER SHAFT

DETAIL

SCALE 1 : 5

8.63

7 5

6 IN SCH 40

252 7

8"

DETAIL E

SCALE 1 : 5

CENTER SHAFT

DO NOT SCALE DRAWING SHEET 2 OF 20
HALF PIPE

8 IN SCH 40

2 4 4
ITEM NO. PART NUMBER DESCRIPTION QTY.
1 Top Half Plate 2
2 STRAP 2

TOP GIRDLE

DO NOT SCALE DRAWING SHEET 12 OF 20

UNLESS OTHERWISE SPECIFIED:

SCALE: 1:8 WEIGHT:

REVDWG. NO.

A

SIZE DWG. NO.

REV

TITLE: TOP GIRDLE

DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONAL

ANGULAR: MACH BEND

TWO PLACE DECIMAL

THREE PLACE DECIMAL

APPLICATION

USED ON

INTERPRET GEOMETRIC TOLERANCING PER:

FINISH

MATERIAL

COMMENTS:

INTERPRETER CHECKED

ENG APPR.

FINISHED:

DRAWN

NAME

DATE

Q.A.

MFG APPR.

CHECKED

DRAWN

FINISH

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER:

DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONAL

ANGULAR: MACH BEND

TWO PLACE DECIMAL

THREE PLACE DECIMAL

APPLICATION

USED ON

INTERPRET GEOMETRIC TOLERANCING PER:

FINISH

MATERIAL

COMMENTS:

INTERPRETER CHECKED

ENG APPR.

FINISHED:

DRAWN

NAME

DATE

Q.A.

MFG APPR.

CHECKED

DRAWN

FINISH

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER:

DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONAL

ANGULAR: MACH BEND

TWO PLACE DECIMAL

THREE PLACE DECIMAL

APPLICATION

USED ON

INTERPRET GEOMETRIC TOLERANCING PER:

FINISH

MATERIAL

COMMENTS:

INTERPRETER CHECKED

ENG APPR.

FINISHED:

DRAWN

NAME

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Q.A.

MFG APPR.

CHECKED

DRAWN

FINISH

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER:

DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONAL

ANGULAR: MACH BEND

TWO PLACE DECIMAL

THREE PLACE DECIMAL

APPLICATION

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INTERPRET GEOMETRIC TOLERANCING PER:

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MATERIAL

COMMENTS:

INTERPRETER CHECKED

ENG APPR.

FINISHED:

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NAME

DATE

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MFG APPR.

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DRAWN

FINISH

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER:

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TOLERANCES:

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ANGULAR: MACH BEND

TWO PLACE DECIMAL

THREE PLACE DECIMAL

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MATERIAL

COMMENTS:

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ENG APPR.

FINISHED:

DRAWN

NAME

DATE

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MATERIAL

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THREE PLACE DECIMAL

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MATERIAL

COMMENTS:

INTERPRETER CHECKED

ENG APPR.

FINISHED:

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DATE

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THREE PLACE DECIMAL

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MATERIAL

COMMENTS:

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ENG APPR.

FINISHED:

DRAWN

NAME

DATE

Q.A.

MFG APPR.

CHECKED

DRAWN

FINISH

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER:

DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONAL

ANGULAR: MACH BEND

TWO PLACE DECIMAL

THREE PLACE DECIMAL

APPLICATION

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MATERIAL

COMMENTS:

INTERPRETER CHECKED

ENG APPR.

FINISHED:

DRAWN

NAME

DATE

Q.A.

MFG APPR.

CHECKED

DRAWN

FINISH

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER:

DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONAL

ANGULAR: MACH BEND

TWO PLACE DECIMAL

THREE PLACE DECIMAL

APPLICATION

USED ON

INTERPRET GEOMETRIC TOLERANCING PER:

FINISH

MATERIAL

COMMENTS:

INTERPRETER CHECKED

ENG APPR.

FINISHED:

DRAWN

NAME

DATE

Q.A.

MFG APPR.

CHECKED

DRAWN

FINISH

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER:

DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONAL

ANGULAR: MACH BEND

TWO PLACE DECIMAL

THREE PLACE DECIMAL

APPLICATION

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DIMENSIONS ARE IN INCHES

TOLERANCES:

FRACTIONAL

ANGULAR: MACH BEND

TWO PLACE DECIMAL

THREE PLACE DECIMAL

APPLICATION

USED ON

INTERPRET GEOMETRIC TOLERANCING PER:
TOP STRAP

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR: MACH BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL

PROPRIETARY AND CONFIDENTIAL
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### Table

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Qty.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TR6x2x3/16x180 6X2X1/8 in Steel Tube</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>TR6x2x3/16x96 6X2X1/8 in Steel Tube</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>TR6x2x3/16x180 6X2X1/8 in Steel Tube</td>
<td>3</td>
</tr>
</tbody>
</table>

**Dimensions:**
- 7.65 FT
- 56.00
- 506.00
- 112.00
- 168.00
- 224.00
- 253.00
- 280.00
- 336.00
- 392.00
- 448.00
- 12.00
- 30.00
- 60.00
- 78.00
- 60.00
- 78.00
- 12.00

**Notes:**
- DIMENSIONS ARE IN INCHES
- TOLERANCES:
  - FRACTIONAL
  - THREE PLACE DECIMAL

**Additional Information:**
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- REVISION B
NOTE:
THIS WELD PATTERN IS FOR ALL 4 GUSSETS
GUSSET WELDS
DO NOT SCALE DRAWING SHEET 20 OF 20 UNLESS OTHERWISE SPECIFIED:
SCALE: 1:48
WEIGHT:
REVDWG. NO.
A
SIZE
TITLE:
COMMENTS:
Q.A.
MFG APPR.
ENG APPR.
CHECKED
DRAWN
FINISH
MATERIAL
INTERPRET GEOMETRIC TOLERANCING PER:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR:
MACH.
BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL
APPLICATION
USED ON
NEXT ASSY
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