Fall Report: Sooner/Exiss Trailers Jig Design

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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 jig requirement is that it increases the quantity of trailers manufactured per day from 7 trailers to 10 trailers. Another important requirement is that the welders using it like it, and that the ergonomics are pleasing. Sooner/Exiss needs the jig to be longer to accommodate their longer trailers, which are up to 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”. In addition, the jig must accommodate all 72 different trailer sides which Sooner/Exiss has in production.

After speaking with the welders at Sooner/Exiss, their requirements were that the jig be shorter than it is now, but be able to accommodate the tall trailers. Currently, the welders have to climb on the jig, and after the redesign, they should not need to climb on it. However, the welders want dedicated footholds to prevent slipping and easily accessible clamps. More 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. KTK also has ideas for a jig that has powered or manual rotation designs which can accommodate Sooner/Exiss funding requirements.

KTK plans on using 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 will be 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 as well as improve 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 welders commonly do in order to reach higher welds. The danger of this action is increased by the welder’s helmets which are opaque and prevent the workers from seeing to catch themselves in the event of a fall. The elimination of climbing is one of the requirements the new jig will meet.

Figure 1- Sooner/Exiss Current Jig Setup

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 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 and 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 and at the factory in El Reno at Sooner/Exiss. Solidworks models were used to communicate ideas between Sooner/Exiss Trailer and KTK Engineering. Design work was performed at Oklahoma State University

**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 will be completed in April of 2013.

**Delivery Requirements**

**Table 1 – Delivery requirements by date and day of week**

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<th>Day</th>
<th>Date</th>
<th>Description</th>
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<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>
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<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>
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<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 needs to accommodate trailers between 5’6” and 8’6” tall and between 16’ and 42’ long. The jig needs to be structurally sound as to not deflect when in a horizontal position. The jig also needs 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 manually, manually assisted, or powered. The jig will be balanced to aid ease of movement. The jig will have a braking system 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, due to the measurement system attached to 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 have a set square in the front, eliminating the time to square up the first post. 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 drill stem pipe
- Calculating torsional deflection in drill stem pipe
- Selecting appropriate materials based on calculations
- Developing different ideas for measurement system
- Analyzing cost differential between different systems

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
      ii. Create Alternative Measurement Solutions
         1. Laser measurement
         2. Laser projection
         3. Attached ‘tape measure’
      iii. Engineering Calculations
         1. Material Determination
         2. Deflection
         3. # of pinions
     iv. Determine clamping locations
         1. Type of clamp
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
         1. Material Determination
         2. Deflection
         3. # of pinions
      iv. Determine clamping locations
         1. Type of clamp
         2. Number of clamps
   b. Rotation Jig
      i. Rotation Mechanism
         1. Hydraulic
         2. Counterweight
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, 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 with the New Product Development Center at Oklahoma State University.

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 before the robot welds them (Featherlite, 2009)
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 (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).

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.
Sooner/Exiss Trailers 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 full jig rotation 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 a broken foot.

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**

**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 drill stem was calculated by hand and using computer software. Hand calculations showed that the torsional deflection of the drill stem 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, as it was in hand calculations.
Figure 5-FEA of Torsional Deflection

Current Design

Figure 6 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” rectangular steel tubing. The stands are made out of 2 3/8” Schedule 40 steel pipe, welded together. The table will be welded to the main rotating shaft, which will be 6 5/8” drill stem 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 2 3/8” Schedule 40 steel pipe that will prohibit further rotation. Movement options will determine the method of holding the table in a fixed position, but a braking system or a worm gear are both options available.
Cost Analysis

Base and Table

<table>
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<tr>
<th>Parts List</th>
<th>Quantity (ft)</th>
<th>Price/ft</th>
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<tbody>
<tr>
<td>2x6in Square Tubing</td>
<td>250</td>
<td>$7.00</td>
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<tr>
<td>6-5/8in Drill Stem Pipe</td>
<td>45</td>
<td>$40.00</td>
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<tr>
<td>Drawn over mandrel Pipe</td>
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<tr>
<td>2-3/8in Pipe</td>
<td>175</td>
<td>$1.90</td>
<td>$332.50</td>
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<tr>
<td>1/2in Steel Rod</td>
<td>215</td>
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<tr>
<td>HH-225D Toggle Clamp</td>
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<tr>
<td></td>
<td></td>
<td></td>
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Option 1- Adhesive Tape

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<td>Adhesive Tape Measure</td>
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Option 2- Fixed Lasers
### Options

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<td>$379.00</td>
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<tr>
<td>Tracking 1.5&quot;x1.5&quot;x97&quot; Extruded Aluminum</td>
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<td>.25in Diameter Track Roller</td>
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**Total**  
$1591.1

### Option 3 - Laser Projection

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<td>Laser Projector, Computer, Setup, Software</td>
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### Powered Movement Option

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<tr>
<td>Electric Motor</td>
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<tr>
<td>Worm Gear</td>
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**Total**  
$685.95

### Manual Assist Movement Option

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<tbody>
<tr>
<td>Worm Gear</td>
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<td>Crank Wheel</td>
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**Total**  
$300.00

### Total Pricing for One New Welding Jig

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<td>Base Jig</td>
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<td>Measurement Option 1 + Jig + Powered Movement</td>
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<tr>
<td>Measurement Option 3 + Jig + Powered Movement</td>
<td>$45,369.95</td>
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Recommendations

KTK recommends that Sooner/Exiss Trailer purchase basic jigs with adhesive rules attached to evaluate the increase in manufacturing. After the purchased jigs have been used, and manufacturing times have been determined, KTK Engineering Solutions recommends that Sooner/Exiss Trailer purchase a laser projection system for the new jig setup and purchase another pair of basic jigs.

References


http://www.universaltrailer.com/

http://www.soonertrailers.com/

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

Equations Used:

Horizontal Deflection

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

\( y \) = deflection
\( W \) = distributed load
\( E \) = modulus of elasticity
\( I \) = Moment of inertia
\( l \) = total length

Torsional Deflection

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

\( \theta \) = Torsional Deflection
\( T \) = Torque
\( l \) = length
\( G \) = Modulus of Rigidity
\( J \) = Polar moment of Inertia
Appendix 2

Gantt Chart- Microsoft Project
Appendix 3

Flow Chart of Generated Design Options

- **No Climbing**
  - Move Jig
    - Vertical Translation
      - Rotation
        - Hand Powered
          - Hand Powered with mechanical assist
            - Powered
              - Move jig relative to floor
                - Vertical Translation
                  - Seaway
                    - Platform with Ladder
                      - Lift
                        - Electric
                          - Hydraulic
                            - Pneumatic

- Move People
  - Vertical Translation
    - Rotation
      - Hand Powered
        - Hand Powered with mechanical assist
          - Powered
            - Move jig relative to floor
              - Vertical Translation
                - Laser Distance Measure
                  - Attach Ruler(s) to jig
                    - Use movable C-clamps to locate Vertical members
                      - With Table Saw Fence
                        - Hanheld
                          - Use two rulers to place components in square