Comparison of HSS Sections Round, Square, Rectangular and Triangular of Similar Mass

Project ID: CEEn_2017CPST_009

by

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A Capstone Project Final Report

Submitted to

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Executive Summary

PROJECT TITLE: HSS Triangular Section Evaluation
PROJECT ID: CEEn-2016CPST-009
PROJECT SPONSOR: American Tubular Products ("ATP"), a Division of Schaeffer Industries
TEAM NAME: MSW Engineers

The objective of this project was to conduct comparison testing to determine the differences in traditional HSS sections (round, square, and rectangular) to a triangular HSS section of similar mass. In order to accomplish this objective, our team conducted hand calculation and finite element analysis on each shape in order to gain a base expectation of potential abnormalities and to isolate key data points on tested elements.

Destructive testing was conducted to assess the load resistance and load bearing capabilities as well as torsion and twist resistance. Tensile tests were performed on sections to determine what impact the induction welding process has on the steel. Testing included tensile testing of "dog-bone sectioned" areas parallel and perpendicular to the weld.

Further testing to reach objective of this project is ongoing.

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Introduction

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Schedule

- January was comprised of fixture/equipment design for the tests to be successful in this project.
- At the end of January, the design of dog-bones began for tensile testing.
- Design of fixtures continued in February and was finalized for bending tests.
- During the month of February, we provided a material list to ATP so that they could begin production of the different cross sections.
- The design of the dog-bones was finalized the last week of February and the order was requested from ATP.
- Dog-bones were picked up February 23, 2018 from ATP
- Tensile testing began and was completed March 1, 2018.

Design, Analysis & Results

Tables 1 through 3 below are the hand calculations that were performed prior to testing and design of testing fixtures/equipment. These calculations helped us to determine the expected reaction forces for each test that was performed. By doing these hand calculations first we were able to design our fixtures robust enough to withstand the forces that each specimen experienced. Also, these calculations give us one more level of comparison rather than just comparing the Finite Element and physical testing results to the capability of the cross sections and material.

Table 1: Bending Hand Calculations

	3.5 Square	3 in Square	2x4	Triangle	3.7 in circle
P (Kip)	35	35	35	35	35
L (in)	84	84	84	84	84
E (ksi)	29300	29300	29300	29300	29300
I (in^4)	4.568	2.799	3.67	2.2113	6.41
Deflection (in)	3.229021596	5.26980016	4.01912	6.67036	2.30111867

Table 2: Buckling Hand Calculations

	3.5 Square	3 in Square	2x4 (y)	Triangle	3.7 in circle
Pcr (kip)	136.10	82.56	40.81	69.39	100.64
E (Ksi)	29300	29300	29300	29300	29300
I (in^4)	4.3375	2.6312	1.3006	2.2113	3.2072
K	1	1	1	1	1
L (in)	96	96	96	96	96
Area (in^2)	2.4177	2.0357	2.0357	2.0869	2.0743
Stress (Ksi)	56.2940	40.5569	20.0473	33.2484	48.5154

Table 3: Torsion Hand Calculations (Circle)

Diameter (od)	3.7
Diameter (id)	3.324
Area (in^2)	2.0743
Torque (in*lb)	10,000
t (in)	0.188
r (in)	1.756
τ (ksi)	2.745

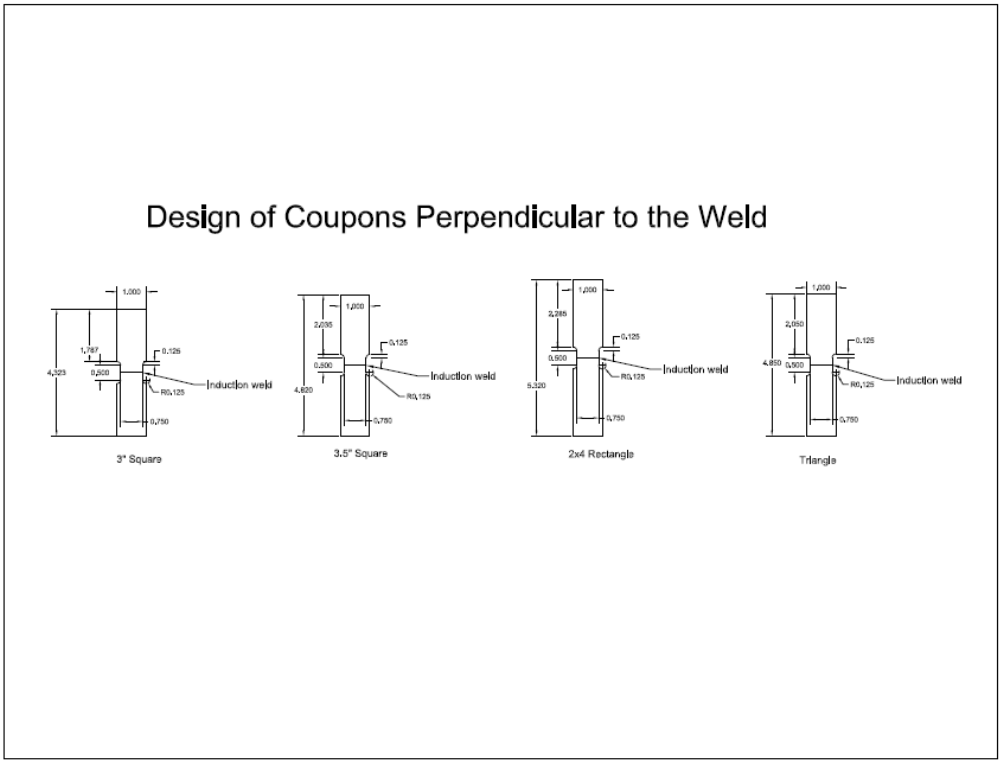

Figure 1: Tensile Test Coupon Designs

The graphic above is the design for the perpendicular welded dog-bones. These dog-bones were designed to half the size of normal dog-bones tested by ATP. To get long enough grip areas at the end of the dog-bones the cross sections needed to be flattened. The tensile tests performed help to determine the weld strength after the material was deformed to its final shape.

Figure 2: Stress vs. Load for Cantilever Testing

The purpose of the Stress vs. Load graph above for the Cantilever test is to show the amount of stress each cross section is feeling during the different load increments. It helps us to understand the loading progression and what we can expect from addition of load.

Below in Figures 3and 4 are results from the finite element analysis, these figures complement Figure 2. These figures show the actual deformation that will take place during the different load increments. The color progression starts at blue and increases to red as the cross section deforms.

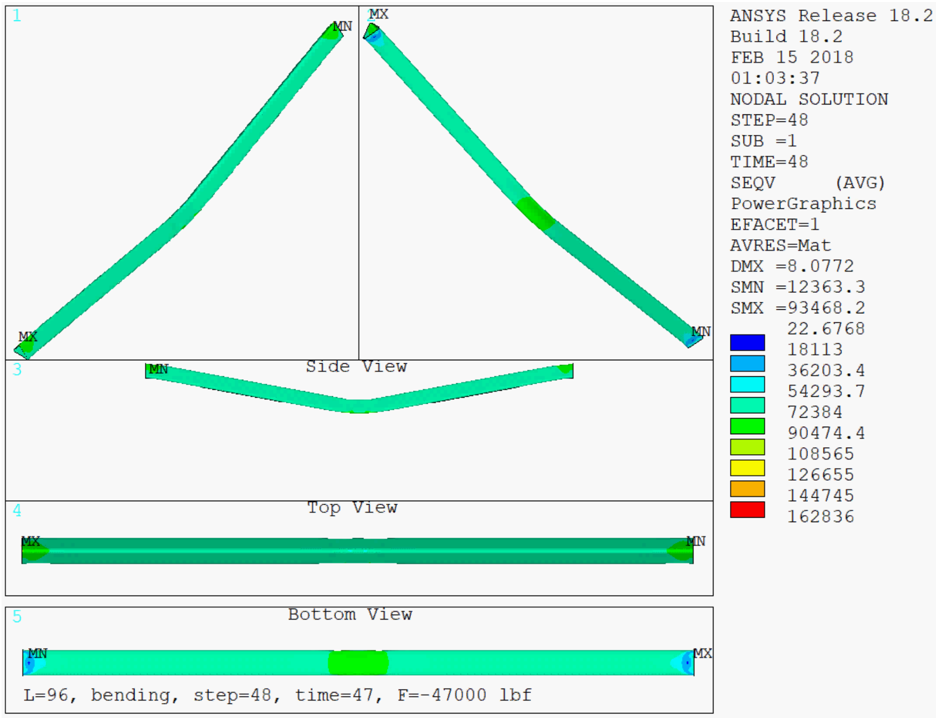

Figure 3: Finite Element Analysis Triangle Fixed-Fixed

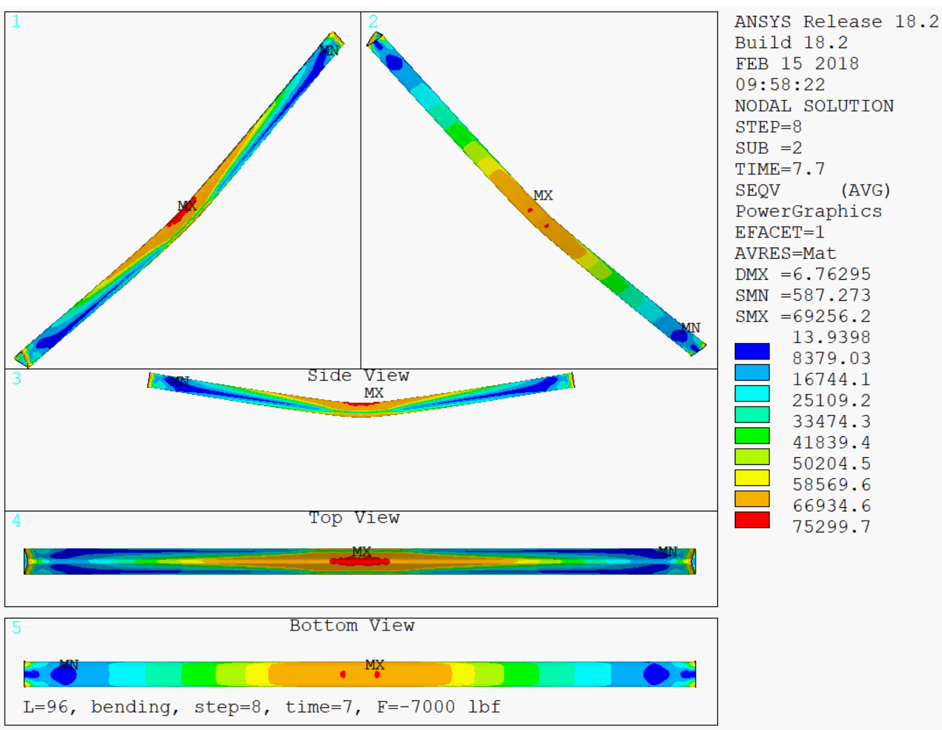

Figure 4: Finite Element Analysis Triangle Cantilever

Lessons Learned

Challenges:

- Difficulty in determining the ultimate bending strength and buckling of the materials
- Designing fixtures.
    - We are trying to design a fixture that can be used for multiple tests to reduce time between tests.
    - How to appropriately apply a swivel head to portray a true pinned condition.
- Evaluating plate strength to determine thickness of fixture endplates.
- Determining dog-bone specimen sizes and how to fit them to the machine has caused delays.

Overcoming Challenges:

- Our predicted buckling testing loads have been confirmed by Dr. Jensen
- We now know the maximum capacity of the laboratory equipment for the bending tests
- We designed a setup that will be used for the simply supported bending test as well as the double cantilever.
- Our hand calculations determined that ½" plates will work.
- We determined that folding the area that will be gripped by the machine will allow for accurate testing.