Design, Analysis, and Fabrication of a Modified Competition Tractor Chassis

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DESIGN, ANALYSIS, AND FABRICATION OF A MODIFIED COMPETITION PULLING TRACTOR CHASSIS

by

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ABSTRACT

This senior project discusses the design and fabrication processes of building a tube frame chassis for a modified pulling tractor. This report will compare the tube style chassis to the wedge style chassis that is currently used on Mustang Fever and the costs associated with it. The purpose of building a new tube chassis is to rebuild Mustang Fever, allowing it to perform more competitively in a lighter weight class.

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INTRODUCTION

The competitive sport of Tractor Pulling on the west coast began at Cal Poly, San Luis Obispo in 1972. Cal Poly's BRAE Department students and professors have been heavily involved in the sport since then. Numerous tractors and several weight transfer sleds have been designed and built in the BRAE Department. Cal Poly currently owns and operates two modified pulling tractors: Mustang Fever and Poly Thunder. These tractors have been, designed, built, modified, maintained and operated by students. These tractors compete all over California and in parts of Nevada. With Cal Poly being the only University that has a Tractor Pull Team, the students are given a unique opportunity to learn about physics and mechanical systems that they could not experience anywhere else.

Tractor Pulling is a distance competition. Upon hooking up to the sled the tractor begins to accelerate down the track in an attempt to make it as far as possible. As it travels down the track the weight transfer sled is applying more load to the tractor, increasing the amount of horsepower needed to continue forward motion at the same speed. The key to being successful is not only having as much horsepower as possible, but more importantly, being able to transfer that power to the ground. Each competitor's tractor is weighed in at a specified weight prior to pulling to ensure a fair competition.

Over the last decade, there have been many advancements in the design and construction of modified tractor chassis and drive trains. In order to be as competitive as possible there is now a higher demand for tractors with a higher horsepower to weight ratio. By constructing a lighter weight, yet stronger chassis, a tractor can be more competitive in several ways. Not only would a lighter frame allow a tractor to compete in a lower weight class, it also provides more options with what engine configurations can be assembled on the tractor. Additionally, it allows weight to be added in more strategic locations to transfer as much horse power to the ground. This senior project will include the design, analysis, and construction of a tubular frame chassis that could accommodate a variety of drive train systems.

Figure 1. Mustang Fever

LITERATURE REVIEW

Chassis Concepts

Having the proper amount of flex in a frame has been a long debated and misunderstood concept. There is a common misconception that flexure in a pulling chassis affects the weight distribution of the rear tires. Having equal rear tire weight distribution is important not only for driving straight down the track but also optimizes the amount of horsepower that is transferred from the tires to the ground.

If the front wheels are in the air, the chain attached to the hitch is pulling backwards and down on the hitch, centered on the axle, and the ground would be pushing up and forwards on the bottom of the tires, equally (assuming uniform soil).

The clutch shaft puts a clockwise (for most engines) torque on the transmission shaft (viewed from the front). However, the differential pinion shaft opposes the driveline torque with an equal and opposite torque. Assuming a direct drive gear through the transmission, there is virtually no additional increase or decrease in torque as the power is transmitted through the transmission. The portion of the frame in between the differential and clutch experiences the torque produced by the engine(s) in one direction as well as a resisting torque from the axle housing in the opposite direction. Since both of these torques are counter balanced internally to the frame, there is no effect placed on the rear tires, as long as the front tires are not contacting the ground.

"If one front tire was still touching the ground, there would be a vertical force on the frame, acting on the right or left front tire (depending on engine rotation), then, and only then, would the reaction on the rear tires be different. In this case the tractor would be acting like a tricycle with its front wheel significantly off center" (Zohns).

Common Materials

When selecting a material to use for building a chassis there are two main properties that must be considered. Strength and weight are the key factors that should dictate what materials are used. Strength is the amount of stress the material can withstand before yielding. The weight of the material will be affected by both the wall thickness and tubing diameter. Obviously, the weight of the frame is important since each pulling class is regulated by the weight. Having a lighter frame will allow more room to work with to strategically set up the tractor (Stinson).

Drawn Over Mandrel (DOM) steel tubing is commonly used in chassis applications. It is manufactured similarly to mild steel tubing. Drawn Over Mandrel refers to the process in which the tubing is made. The DOM process "trues" the tube and hides the weld, giving it more accurate dimensions, which also strengthens the tube through cold working. The different alloys typically range from ASTM 1008 up to 1035. The alloy numbers signify the amount of carbon in the steel, which is relative to its strength. Depending on the alloy, typical yield strengths range from 55 ksi to 85 ksi, with tensile strengths ranging

from 65 ksi to 95 ksi. DOM tubing can be manufactured to a wide variety of diameters and wall thicknesses by simply changing the sizes of the die and mandrel used. This size range allows end users to save money on material and machining costs because they can choose the exact size of tubing needed and the dimensions of the material will be uniform and matched directly to their design. These tight tolerances, controlled mechanical properties, and dense, uniform surface of DOM will ultimately result in good machining properties and characteristics.

Another common material used in roll cages and vehicle chassis is SAE 4130 chromoly tubing. This is also a true seamless tubing. Chromium and molybdenum are added to the steel for increased strength. This allows for a lighter design. Thinner walled 4130 tubing can achieve greater strength than a thicker wall mild steel tube. Due to its high cost it is most commonly used in larger budget projects or in cases where weight is a major factor. It also requires heat treating after welding to achieve maximum strength, so fabrication costs are also increased significantly.

Current Chassis Designs

There are currently five modified tractors with tube frame chassis that regularly compete in the Pacific Tractor Pullers Association. Of these tractors three of them are constructed of chromoly steel tubing with a wall thickness of .095 inches. The other two tube frames are constructed of mild steel tubing. The frame rails generally consist of two lengths of tubing on the top and bottom connected by tubing sections placed vertically and diagonally. The figures below, and on the next page, illustrate various frame rail designs.

Figure 2. Frame Rail: The Whip

Figure 3. Frame Rail: Deuces Wild

The Whip's main frame rails are 2" diameter SAE 4130 tubing connected by 1.5" diameter diagonals. The total height of the frame rail is 10", with the diagonals placed 14" apart. Deuces Wild has 1.75" diameter tubing as the main frame rails connected by vertical and diagonal 1.5" diameter tubing.

PROCEDURES AND METHODS

Design Procedure

SolidWorks was used throughout the entire design process due to its versatility of modeling features, simulation features, and editing capabilities.

Frame Rails. The design procedure began with a simple two dimensional side view sketch of a frame rail displaying key dimensions that are outlined in the PTPA and NTPA rule books. These key dimensions include required placement of components such as rear axle center location, wheelie bar location, roll cage support structure members, and overall frame length dimensions. Only lines were drawn representing where tubing members would be located.

Once the required dimensions were laid out, more lines (representing tubing members) were drawn in to form a truss style pattern across the length of the frame rail, shown in Figure 4. These lines were then converted to a 3D model view by using the "weldment" feature. This feature allows a profile of a structural member to be extruded following the path of a selected line. Figure 5 shows the same sketch as Figure 4 after the weldments were inserted.

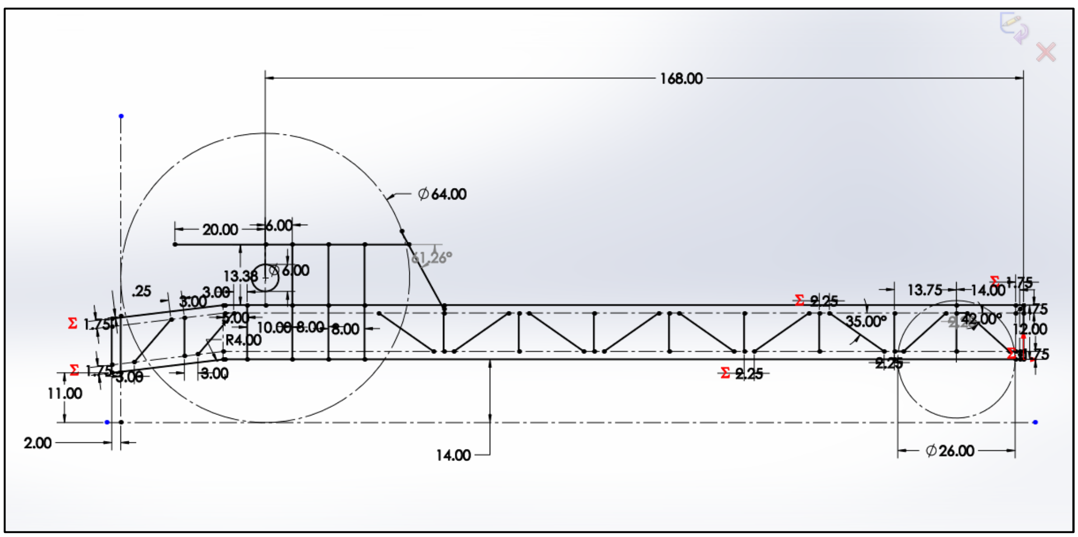

Figure 4. Frame Rail Line Sketch

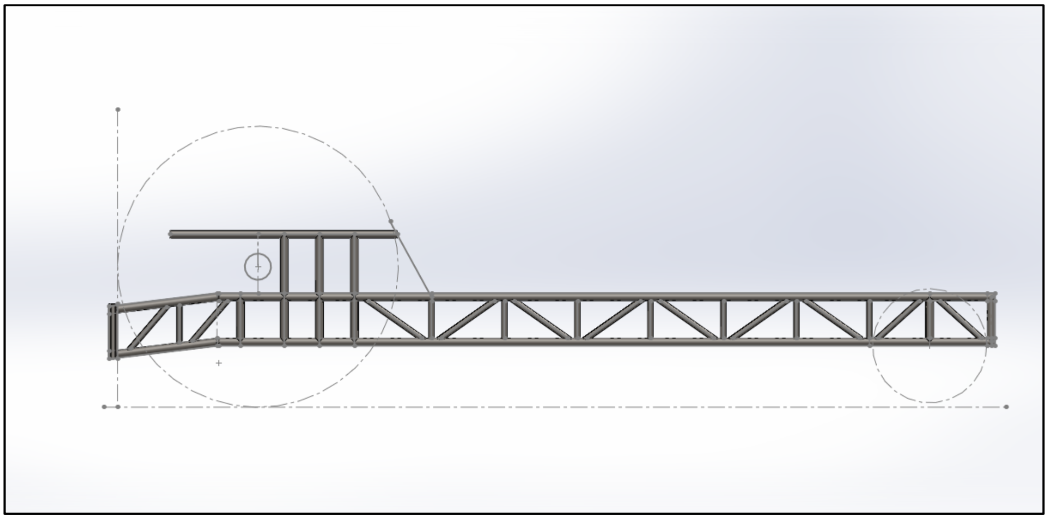

Figure 5. Frame Rail Weldments

The modeled frame rail was inserted into an assembly drawing so that two identical frame rails could be placed side by side and cross members could be drawn in, attaching the rails together. The cross members were drawn through the use of lines and "weldment" features as well.

Roll Cage. Next the roll cage was designed following SFI Specification 47.1, as required by NTPA regulations. The model was created within the frame rail assembly drawing using the 3D sketch tool and "weldment" feature. This method allowed a wire frame sketch of the roll cage to be drawn attached to reference points on each of the frame rails, rather than a fixed plane. If the placement of certain frame rail members are edited the location of the roll cage members will automatically be updated to reference to the new joint locations. Figure 6 shows the completed chassis model.

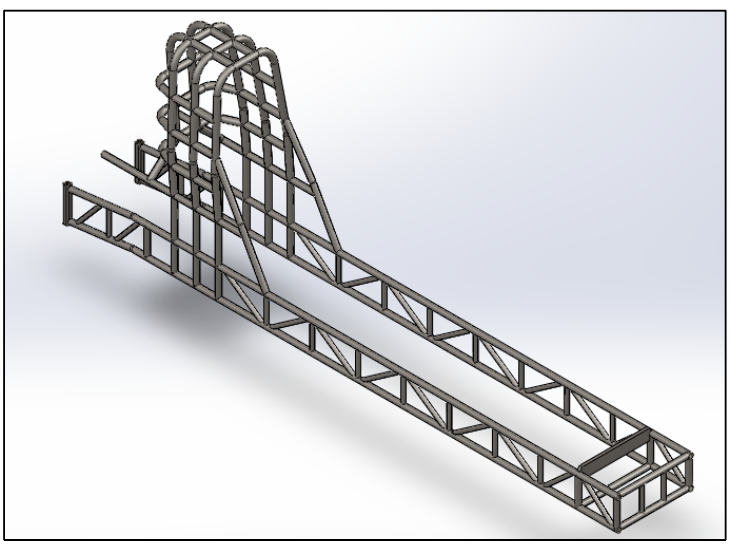

Figure 6. Completed SolidWorks Model

Analysis Procedure

The completed chassis model was analyzed with respect to strength, weight, and cost of production.

Strength. The strength of the chassis was analyzed by performing a Finite Element Analysis (FEA), in SolidWorks, of the torsional stress produced by the torque of the engine. The FEA allows fixtures and forces to be applied to the model and then simulates how the structure will react in the given loading situation. In addition to a visual simulation of the model, data such as stress and deflection are also generated by the FEA.

The strength of the design was also analyzed in a "long hand" procedure by calculating the section modulus of the frame rails in order to determine the factor of safety involved for certain loading situations. Two loading situations were analyzed and the safety factors of each were determined. The first loading situation analyzed was as if the front end of the tractor was off of the ground and the rear end was fixed by the force of the chain, with the length of the frame acting like a cantilevered beam. The second loading condition was analyzed as if the front end was up in the air and then rapidly slammed down on the ground. For the purposes of this strength analysis it was assumed that twice the weight of the tractor would be acting downwards at the center of mass on the frame. In this situation the frame would be acting as a simple beam supported by each axle.

The calculated stresses are shown in the *Results* section.

Weight. The weight of the design was estimated by assigning 1018 cold drawn steel as the material to the structural members in the SolidWorks model and using the mass evaluation tool.

The wedge style frame rails of Mustang Fever were measured and modeled in SolidWorks and the weight of the other members of the frame were estimated by measurements taken. The weights of the two designs were compared to one another and the benefits of the lighter design were analyzed.

Cost of Production. A cost analysis was performed of the materials by developing a cut list and bill of materials. Each tubing member size and length was collected and organized in a spreadsheet. All the cut length were estimated slightly over the actual length to allow for some wasted material during cutting and notching processes and the pieces requiring bends were estimated having an extra 6 to 8 inches to allow the cut lengths to fit properly in the bending machine dyes. Then the total length required for each size of material was rounded up to the next stick (20 foot increment), since DOM comes in lengths of approximately 20 feet. The numbers of sticks needed were multiplied by prices that were quoted from the local steel supplied and summed to a sub total. The cost of sales tax and consumables were also added to result in a total cost. Consumables refer to additional items that are used in fabrication processes such as shielding gas, filler wire, cutting oil and grinding wheels, etc. The general rule of thumb for estimating consumables is 10% of the materials cost.

The cost of labor was estimated by dividing the various fabrication processes into tasks, estimating the time spent for each task and multiplying by the amount of times each task was performed. The times were estimated as if the tasks were performed by a professional fabrication shop with one person performing the work. The fabrication was divided up into the following tasks: Cutting material, Notching pieces, Layout, Prepping, and Welding. Layout refers to measuring, placing members and tack welding them into place. Prepping includes cleaning of material prior to welding and moving materials and equipment into suitable welding positions. Most of the fabrication and machine shops in the local area charge a labor rate of $60 to $100 per hour, depending on the difficulty of work being performed. Apart from paying the fabricator's wages the shop labor rate must also cover overhead costs such as utilities, equipment, insurance, etc. Since this project involves some machining, bending, and basic steel fabrication, the labor costs were estimated using a labor rate of $80 per hour.

Fabrication Procedure

The rear portions of each of the four 1.75" main frame rail members were bent down at a 7 degree angle on a tubing bender to form the sections that would serve as the wheelie bars. In order to form a strong joint between different round tubing members they must be notched to fit tightly up against each other. All tubing notches were machined on a lathe to ensure a precise fit, which optimizes the strength of the joints. This operation was achieved by installing a reaming tool in the three jaw chuck and using a boring bar holder to secure the tubing material on the tool post. As the spindle rotated, the tubing was fed into the reamer, which cut a notch in the material; see Figure 7. The diameter of the reamer matched the diameter of tubing that each particular piece needed to fit to and could easily be changed out to accommodate different sized tubing joints. The compound was rotated as necessary to machine the notches for angled joints.

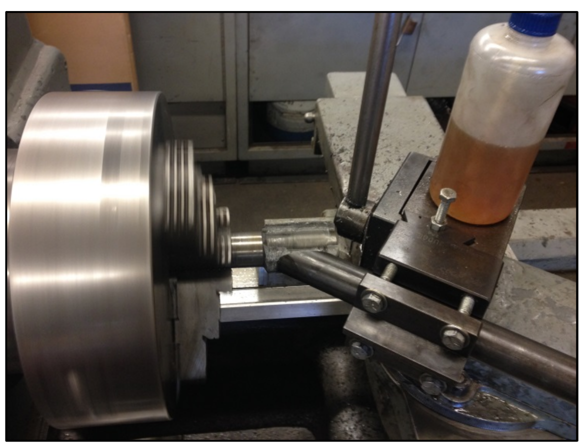

Figure 7. Notching on Lathe

The burs that formed on the edges of the tubing were removed with a belt sander and a die grinder. Next the materials were cleaned at the areas where they would be welded, to

prohibit any impurities from weakening the weld. Oil residue was removed with acetone and the mill scale on the steel was removed with a wire wheel or wire brush.

Once all of the frame rail pieces were prepped for welding they were laid out on a flat surface and held in place by clamps and over straight steel members as they were tack welded in place. To ensure accuracy, measuring tools such as squares, levels, and protractors were used in addition to a steel tape measure to layout the placement of members. Dimensions were checked again after tack welding all members of each frame rail in place.

Each joint was fully welded using around each tube using the Gas Tungsten Arc Welding (GTAW) process. The shielding gas was 100% argon and the filler material used was 1/16” mild steel welding rod.

Vertical members of steel were set up to be square with the table and in line with each other at a width of 28” to serve as an alignment jig. The two identical frame rails were clamped to these jigs and aligned as the cross members were tacked and welded in place. Figure 8 shows how this process was set up. Temporary cross members were also tacked in place at various locations between the frame rails for support as the chassis was moved and rotated to complete welds.

Figure 8. Frame Rails Aligned on Table Jig

The 2” roll cage hoop members were bent using a more precise, hydraulic tubing bender at a local shop. After the pieces were bent, they were cut to the proper length and notched on the lathe using the same process previously described. All roll cage and cross member joints were fully welded in place, except the temporary cross members. The photographs on the next page depict the completed chassis.

Figure 9. Completed Chassis Side View

Figure 10. Completed Chassis Rear View

RESULTS

Strength

The Solidworks illustration below shows a visual representation of how the torque produced by the engine would affect the chassis. The green arrows indicate fixed joints where the axle will be placed. The pink and orange arrows represent the forces being exerted on the frame rails by the engine torque at the anticipated location for engine mounts. The various colors of the tubing members indicate the amount of stress (psi) that they would be subject to, corresponding to the scale shown on the right.

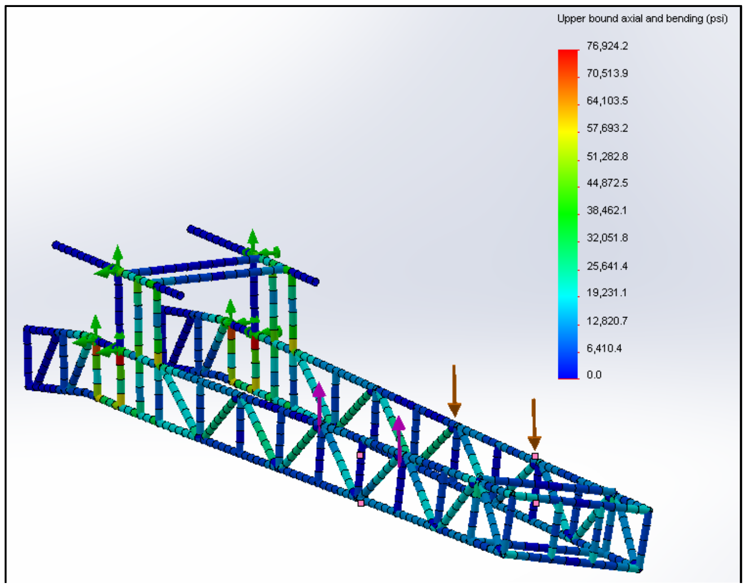

Figure 11. Torsional Stress FEA

According to Acerlor Mittal, a steel manufacturer, the yield strength of SAE 1018 DOM is 70,000 psi. It was calculated that each frame rail has a section modulus of 5.45in^3. Although the FEA shows a maximum stress of 76,924.2 psi, those stresses will not actually be experienced by the frame. This is explained in the *Discussion* section.

For the cantilevered loading situation it was assumed that the front axle weight would be 2,500 lbs. With that weight acting downwards at the location of the front axle it was calculated that the frame would experience a maximum moment of 367,500 in-lbs., requiring a section modulus of 2.63 in^{3}per frame rail. In this case the frame had a safety factor of 2.07.

For the simple beam loading situation a load of 14,400 lbs. was placed at the center of which was assumed to be 51 inches from the rear axle. It was calculated that the frame would experience a maximum moment of 479,608.16 in-lbs., requiring a section modulus of 3.43 in^{3}per frame rail. This resulted in a safety factor of 1.58. For detailed calculations please see Appendix B: Design Calculations.

Weight

The total estimated weight of the tube chassis is 415 lbs. Excluding the roll cage, the frame rails (with wheelie bars), and front cross members weigh approximately 279 lbs.

In comparison, the estimated weight of Mustang Fever's frame rails, wheelie bars, and front cross members is approximately 487 lbs. This shows that the tube chassis weighs over 200 lbs. less than the wedge style frame currently used on Mustang Fever.

Cost of Production

The following two tables summarize the cost of production for the tube frame chassis. Table 1 displays the estimated cost of materials, sales tax, and consumables. Table 2 displays the estimated task times and labor costs as if the chassis was built by a professional fabricator. By adding the materials total to the labor total the total estimated cost of production comes out to be $6376.03.

Table 1. Cut List and Bill of Materials

	Cut List			***Bill of Materials***		
Material	**Cut Length (in)**	**QTY**	**Length Req'd (ft)**	**Sticks to Order**	**Price/ft**	**Total Price**
DOM, 1 1/4" x 0.095"	15	20	25.00			
Sum			**25.00**	**2**	**$ 2.00**	**$ 80.00**
DOM, 1 1/4" x 0.120"	9	14	10.50			
Sum			**10.50**	**1**	**$ 3.08**	**$ 61.60**
DOM, 1 3/4" x 0.120"	201	4	67.00			
DOM, 1 3/4" x 0.120"	10.25	12	10.25			
DOM, 1 3/4" x 0.120"	14.25	6	7.13			
DOM, 1 3/4" x 0.120"	52	2	8.67			
DOM, 1 3/4" x 0.120"	16	2	2.67			
DOM, 1 3/4" x 0.120"	28	4	9.33			
DOM, 1 3/4" x 0.120"	22.5	2	3.75			
DOM, 1 3/4" x 0.120"	11.5	2	1.92			
DOM, 1 3/4" x 0.120"	13	3	3.25			
Sum			**113.96**	**6**	**$ 3.83**	**$ 459.60**
DOM, 2" x 0.120"	112	3	28.00			
DOM, 2" x 0.120"	45	2	7.50			
DOM, 2" x 0.120"	8	16	10.67			
DOM, 2" x 0.120"	19	2	3.17			
DOM, 2" x 0.120"	20	2	3.33			
DOM, 2" x 0.120"	15	2	2.50			
DOM, 2" x 0.120"	42	1	3.50			
DOM, 2" x 0.120"	7.25	2	1.21			
Sum			**58.67**	**3**	**$ 4.03**	**$ 241.80**
				Sub Total		**843.00**
				Sales Tax	**7.50%**	**63.225**
				Consumables	**10%**	**84.3**
				Total		**990.53**

Table 2. Cost of Labor

Task	Time (minutes)	Quantity	Unit	Total time (hours)	Cost of Labor
Cutting	2	102	cuts	3.40	272.00
Notching	8	190	notches	25.33	2026.67
Bending	6	22	bends	2.20	176.00
Layout	10	102	pieces	17.00	1360.00
Prepping	10	102	joints	17.00	1360.00
Welding	0.125	1145	inches	2.39	190.83
		Totals		**67.32**	**5385.50**
	*Estimated with a labor rate of $80 per hour				

DISCUSSION

While the maximum stress of 76,924 psi shown in the FEA may seem alarming, in reality it is nothing to be concerned with. The FEA feature in SolidWorks did not allow the proper types of fixtures to be used which is why higher concentrated stresses are shown at the fixture locations. For this particular situation the higher stresses shown can be ignored. The reason for this is that in reality the axle will act as more of a uniform fixture across those three members between the joints where the fixtures are shown in the FEA, rather than directly at each node of the joints. This will result in a more even distribution of stress along those members, thus reducing the maximum stress. Looking at the next highest areas of stress in the FEA, it can also be expected that those stresses will decrease in reality due to the additional support of the diagonal members that connect the top of the frame rail to the roll cage. Those members will help disperse some of the load to the roll cage lessening the stress on the frame rail joints. Excluding the areas where stresses are falsely concentrated it appears that the maximum stress is around 50,000 psi which is acceptable given the 70,000 psi yield strength of the material. Furthermore the areas experiencing the highest stresses are the joints where there will be additional weld mass present. By having the additional area of weld present the over stress at that location would be reduced.

Since the tube chassis weighs over 200 lbs. less than the wedge frame, this means that there will be an additional 200 lbs. of movable weight on the tractor. Having more moveable weight can be very advantageous to set up the tractor for different soil conditions and different sleds. If the tractor is set up properly the additional movable weight could increase performance enough to place 1st instead of 2nd at pulling events. According to the NTPA Purse Payout at Grand National Events the difference in prize money between 1st and 2nd place is \$550 (NTPA). This means the costs of producing the tube chassis could be recovered by placing 1st, instead of 2nd, at 12 events. The calculation below shows the total estimated cost of the tube chassis divided by the increased prize money per event.

$$\frac{\$6376.03}{\$550\ per\ event} = 11.59\ events$$

Gas Tungsten Arc Welding tends to be a slower more tedious welding process when compared to other methods, however it is the most preferred method when joining materials such as DOM tubing, and especially in chassis and roll cage applications. According to Miller Electric Manufacturing Company there are several major reasons that make GTAW superior to other welding processes. Of those reasons the most beneficial include high quality, clean welds and the ability to weld in any position. When performed properly GTAW has the potential to result in the strongest welds due to the operator’s ability to precisely control the amount of heat going into the weld, which not only results in a uniform weld but also can avoid rapid temperature changes that could affect the material properties. Since the heat is concentrated in a small area it also limits the amount of deformation that occurs in the affected members. GTAW typically results in the most aesthetically pleasing welds as well since there is no slag or spatter that needs to be cleaned up.

By looking at the estimate for Cost of Labor, Table 2, it is clear that the most time consuming tasks in the fabrication process are notching, layout and prepping. Together they account for nearly 88% of the labor for the entire project. Those three tasks are arguably the most crucial steps of the entire fabrication process, to ensure strength, quality and accuracy of the frame. However, there are several ways the labor times associated with notching and layout could be reduced. Performing the notching operation on the lathe is a very accurate and precise method, but using a belt sander as shown below could potentially cut the labor time in half.

Figure 12. Belt Sander for Tube Notching

The belt sander method is used by most fabricators in production environments. The greatest disadvantage of using a belt sander is a slight decrease in accuracy and consistency among pieces. Additionally, it is estimated that the layout labor time could be reduced by nearly 75% by using fixtures to hold pieces in place while they are tack welded. Prepping time could also be reduced by 30% by using a rotisserie to rotate the entire chassis into suitable welding positions. Of course, there are material costs and labor costs associated with building or purchasing these types tools, but their benefits could easily outweigh those costs if multiple chassis were to be built.

Figure 13. Rotisserie

RECOMMENDATIONS

It is true that using another welding process to fabricate the chassis could potentially speed up the project it is not recommended because it could result in a decrease in weld strength and quality of craftsmanship could decrease, decreasing the value of the frame. The lathe method of notching the tubing proved to work very effectively during the fabrication of this chassis, however it would be much more time efficient, especially in a production setting, to use a belt sander for notching and investing in fixtures and rotisseries to speed up the layout and prepping processes. The table below shows an adjusted estimate of labor cost if a belt sander is used to notch tubing and fixtures and rotisseries are used to place members and rotate the chassis. By incorporating these methods into the fabrication procedure the total labor cost is reduced by $2,441.33, bringing the total estimated production cost down to $3,934.70, including the same estimated cost of materials.

Table 3. Adjusted Labor Cost

Task	Time (minutes)	Quantity	Unit	Total time (hours)	Cost of Labor
Cutting	2	102	cuts	3.40	272.00
Notching	4	190	notches	12.67	1013.33
Bending	6	22	bends	2.20	176.00
Layout	2.5	102	pieces	4.25	340.00
Prepping	7	102	joints	11.90	952.00
Welding	0.125	1145	inches	2.39	190.83
		Totals		**36.80**	**2944.17**
	*Estimated with a labor rate of $80 per hour				

Assuming the lower estimated cost of production, the amount of pulls required to recover the costs is significantly reduced. Now it would only require the tractor to place higher at 8 events before the investment would be paid back. The calculation is shown below.

$$\frac{\$3934.70}{\$550\ per\ event} = 7.15\ events$$

In a typical NTPA season there are about 15 Grand National Events for modified tractors per year, so the tractor would only have to place higher at about half of the events in the first season to recover the expenses. If properly cared for and maintained, the chassis could easily be used for 15 or more seasons and could easily be modified to support various engine and drive train configurations which could also make the tractor even more competitive. Given these circumstances and estimated projections the tubular style chassis would be a sound investment for most tractors and could result in a more significant increase in performance if the lighter weight frame allowed the tractor to compete in a lighter weight class.

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APPENDICES

APPENDIX A:

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM MAJOR

HOW PROJECT MEETS REQUIREMENTS FOR THE ASM MAJOR

ASM Project Requirements

The ASM senior project must include a problem solving experience that incorporates the application of technology and the organizational skills of business and management, and quantitative, analytical problem solving. This project addresses these issues as follows.

Application of Agricultural Technology. This project involves the use of CAD design programs and fabrication technologies.

Application of Business and/or Management Skills. This project involves skills in the areas of machinery management, cost of materials and labor considerations.

Quantitative, Analytical Problem Solving. Quantitative problem solving techniques include the cost analysis and bending stress calculations.

Capstone Project Experience

The ASM senior project must incorporate knowledge and skills acquired in earlier coursework. This project incorporates knowledge and skill from these key courses:

- BRAE 129 Lab Skills/Safety
- BRAE 133 Engineering Graphics
- BRAE 152 3D Solids Modeling
- BRAE 203 Agricultural Systems Analysis
- BRAE 301 Hydraulic and Mechanical Power Systems
- BRAE 342 Ag Materials
- BRAE 343 Mechanical Systems Analysis
- BRAE 344 Fabrication Systems
- BRAE 418 Ag Systems Management I
- BRAE 419 Ag Systems Management II

ASM Approach. Agricultural Systems Management involves the development of solutions to technological, business and management problems associated with agricultural or related industries. A systems approach, interdisciplinary experience, and agricultural training in specialized areas are common features of this type of problem solving. This project addresses these issues as follows.

Systems Approach. The project involves the integration of multiple functions. Although it only includes the construction of the chassis, the chassis was designed to accommodate various components (engine, drive train, rear end).

Interdisciplinary Features. The project touches on aspects of mechanical design, financial analysis and fabrication skills.

Specialized Agricultural Knowledge. The project applies specialized knowledge in the areas of mechanical and fabrication systems.

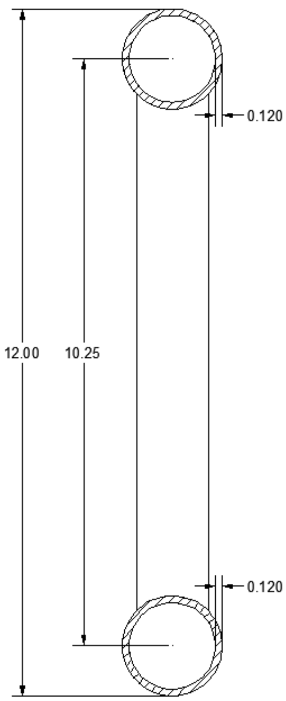
APPENDIX B:

DESIGN CALCULATIONS

DESIGN CALCULATIONS

Moment Area of Inertia (I) and Section Modulus (s)

Given: Cross section of frame rail



Required: Solve for Moment Area of Inertia (I) and Section Modulus (S)

Solution:

$$\boldsymbol{Cross\ Sec.\ Area\ of\ Tube} = \frac{\pi(od)^2}{4} - \frac{\pi(id)^2}{4}$$

$$\frac{\pi(1.75")^4}{4} - \frac{\pi(1.75" - 1.51")^4}{4} = \mathbf{0.61\ in^2}$$

$$\boldsymbol{I_{Indiv.}} = \frac{\pi(od - id)^2}{64} = \frac{\pi(1.75" - 1.51")^2}{64} = \mathbf{0.205\ in^4}$$

$$\boldsymbol{I_{Total}} = \Sigma[Areas\ x\ (Center\ of\ Area\ to\ N.A)^2] + I_{Indiv.}$$

$$[0.61in^2\ x\ (5.125")^2] + 0.205\ in^4 + [0.61in^2\ x\ (5.125")^2] + 0.205\ in^4 = \mathbf{32.69\ in^4}$$

$$\boldsymbol{S} = \frac{I}{C} = \frac{32.69\ in^4}{6\ in} = \mathbf{5.45\ in^3}$$

Cantilever Loading Situation

Given: DOM, SAE 1018 yield strength of 70,000 psi
Assume Yield Safety Factor = 1.0
Section Modulus of each frame rail is 5.45in^3

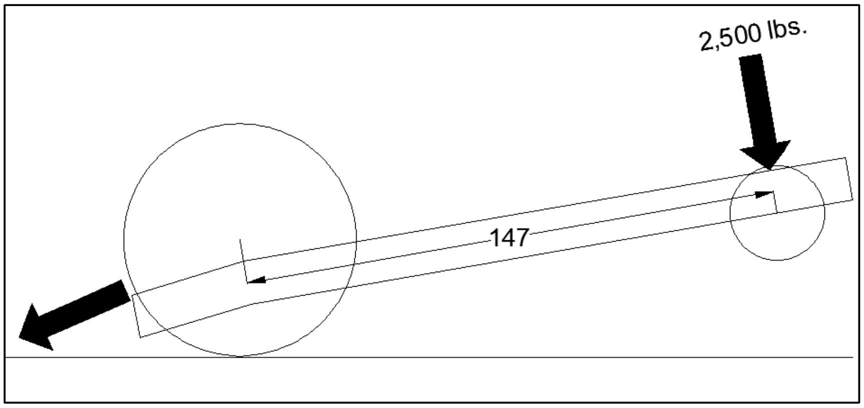


Figure 14. Cantilever Loading Situation

Required: Solve for safety factor

Solution:

$$\boldsymbol{M_{Max}} = P\ x\ l = 2500\ lbs.\, x\ 147" = \mathbf{367,500\ in\ lbs.}$$

$$\boldsymbol{S_{Required}} = \frac{M_{Max}}{F_y} = \frac{367{,}500\ in\ lbs. / 2\ frame\ rails}{70{,}000\ psi} = \mathbf{2.63\ in^3}\ per\ frame\ rail$$

$$\boldsymbol{Yielding\ Safety\ Factor} = \frac{S}{S_{Req.}} = \frac{5.45\ in^3}{2.63\ in^3} = \mathbf{2.07}$$

Simply Supported Beam Loading Situation

Given: Assume the load to be twice the weight of the tractor upon ground impact
Assume Yield Safety Factor = 1.0
DOM, SAE 1018 yield strength of 70,000 psi
Section Modulus of each frame rail is $5.45in^3$

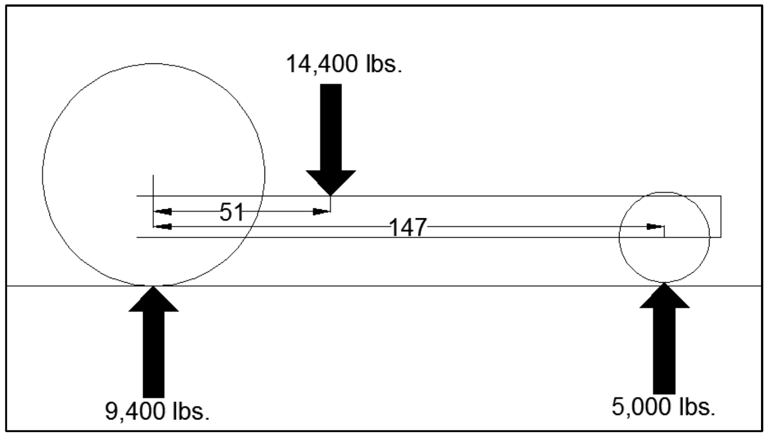


Figure 15. Simply Supported Beam Loading Situation

Required: Solve for safety factor

Solution:

$$\boldsymbol{M_{Max}} = \frac{Pab}{l} = \frac{14{,}400\ lbs.\ x\ 51"\ x\ 96"}{147"} = \mathbf{479{,}608.16\ in\ lbs.}$$

$$\boldsymbol{S_{Required}} = \frac{M_{Max}}{F_y} = \frac{479{,}608.16\ in\ lbs. / 2\ frame\ rails}{70{,}000\ psi} = \mathbf{3.43\ in^3}\ per\ frame\ rail$$

$$\boldsymbol{Yielding\ Safety\ Factor} = \frac{S}{S_{Req.}} = \frac{5.45\ in^3}{3.43\ in^3} = \mathbf{1.58}$$

APPENDIX C:

CONSTRUCTION DRAWINGS

CONSTRUCTION DRAWINGS

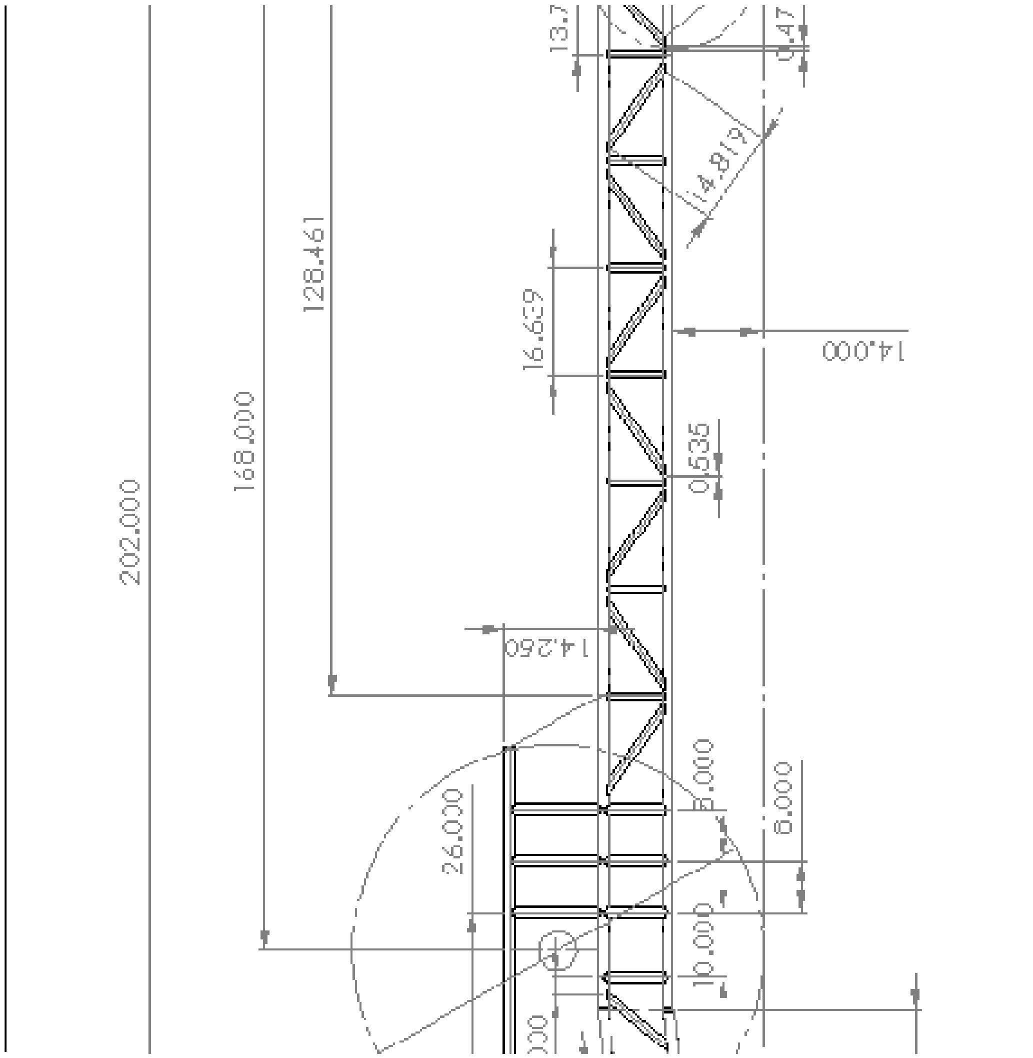


Figure 16. Frame Rail Layout

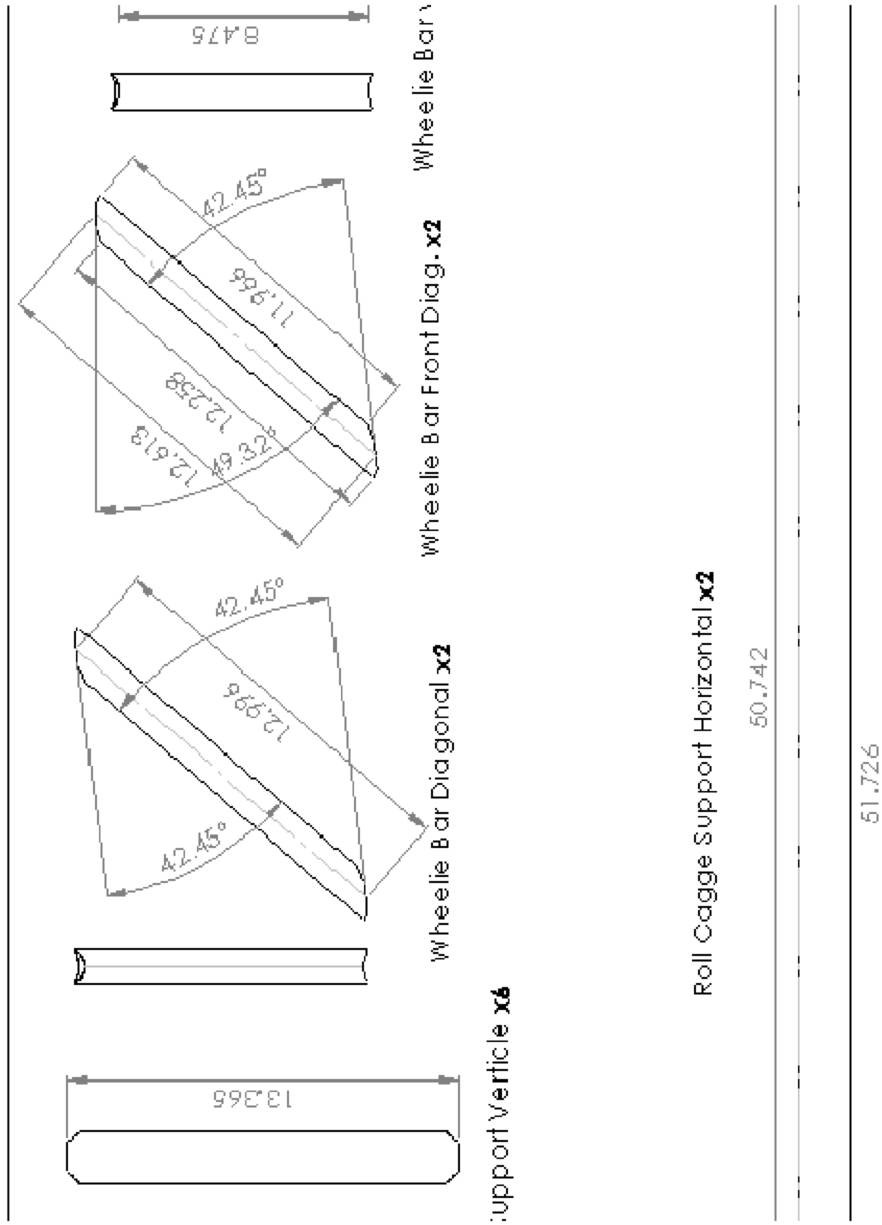


Figure 17. Wheelie Bar and Roll Cage Support Parts

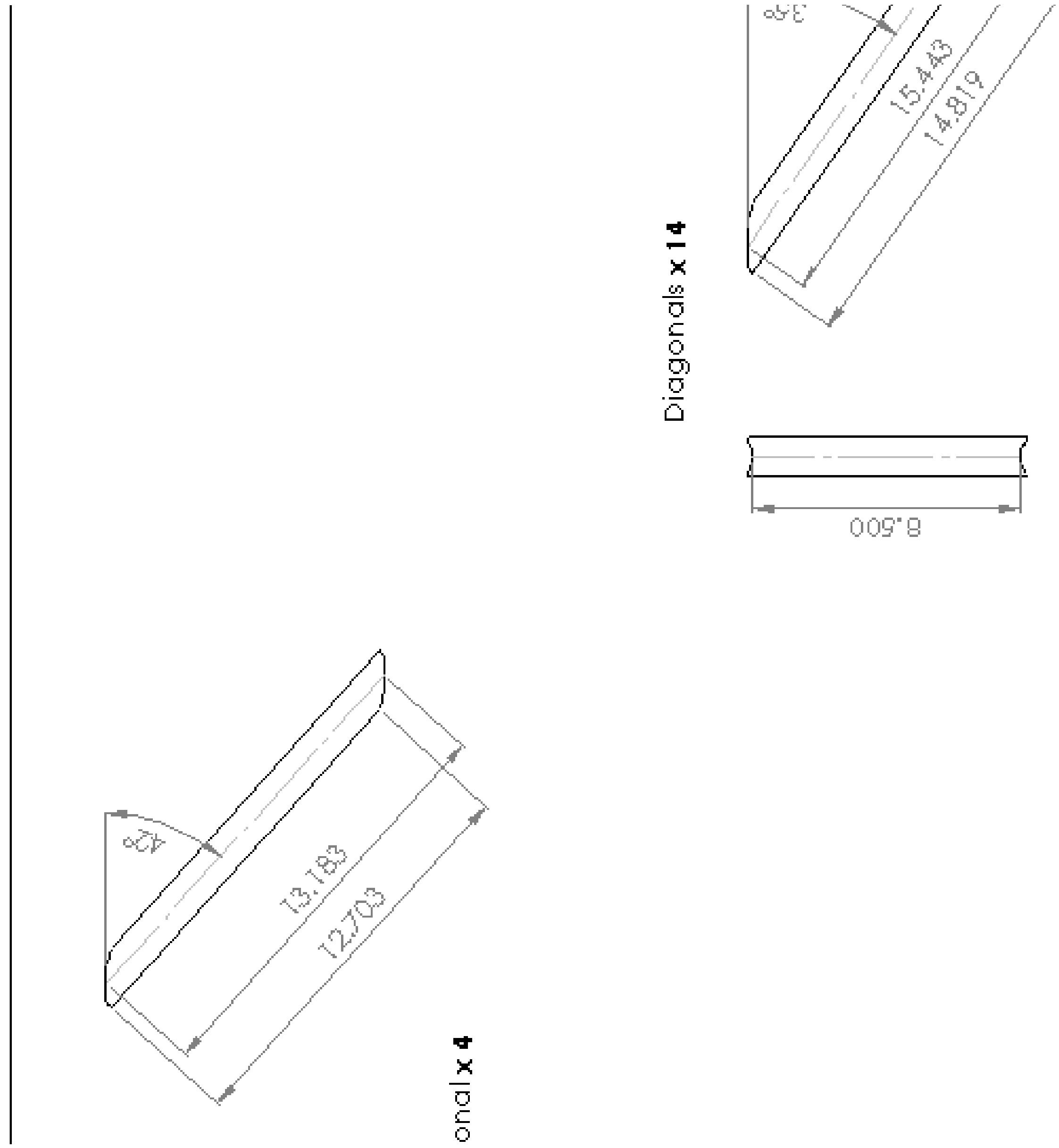


Figure 18. Frame Rail Diagonals

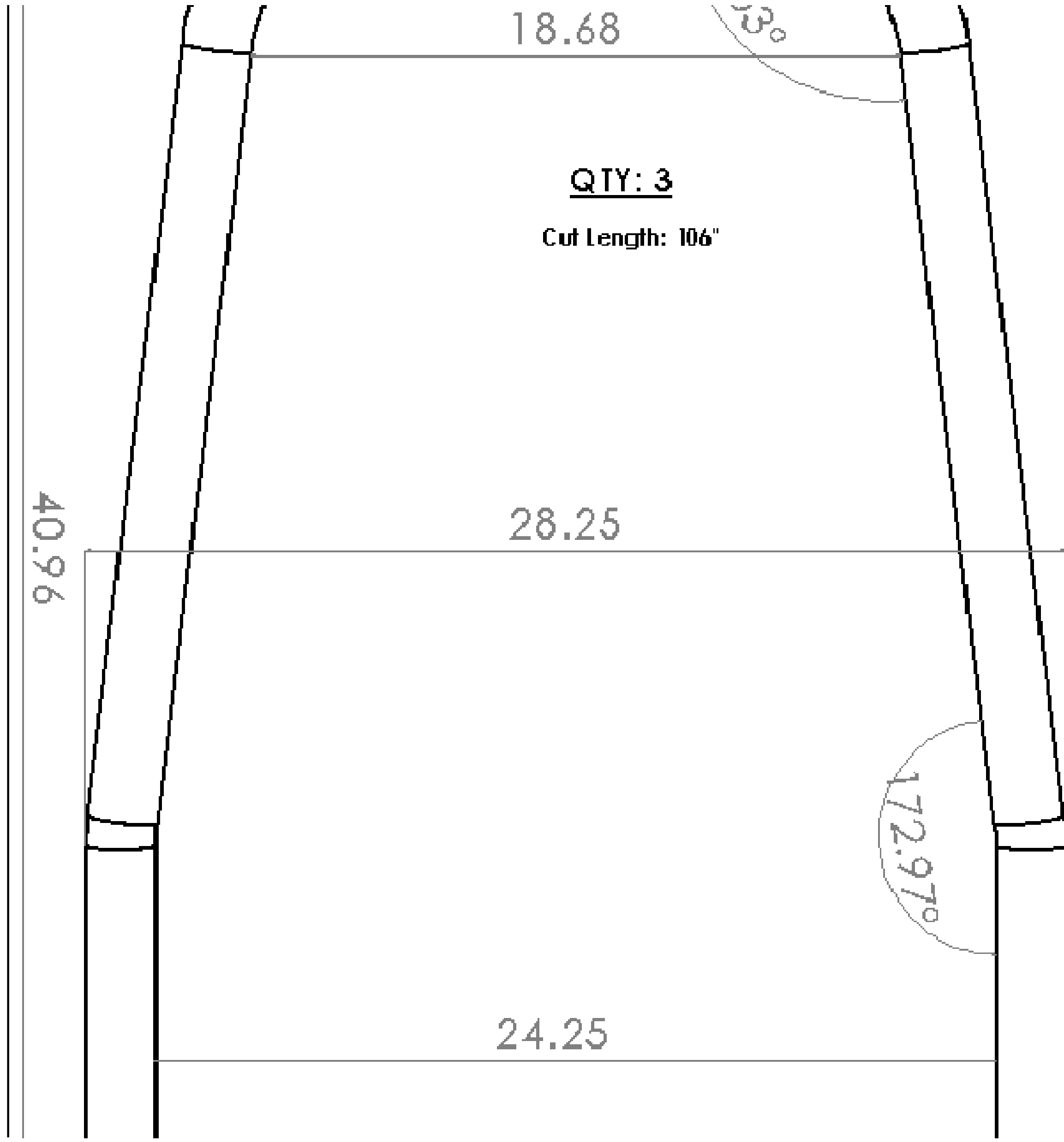


Figure 19. Roll Cage Hoops

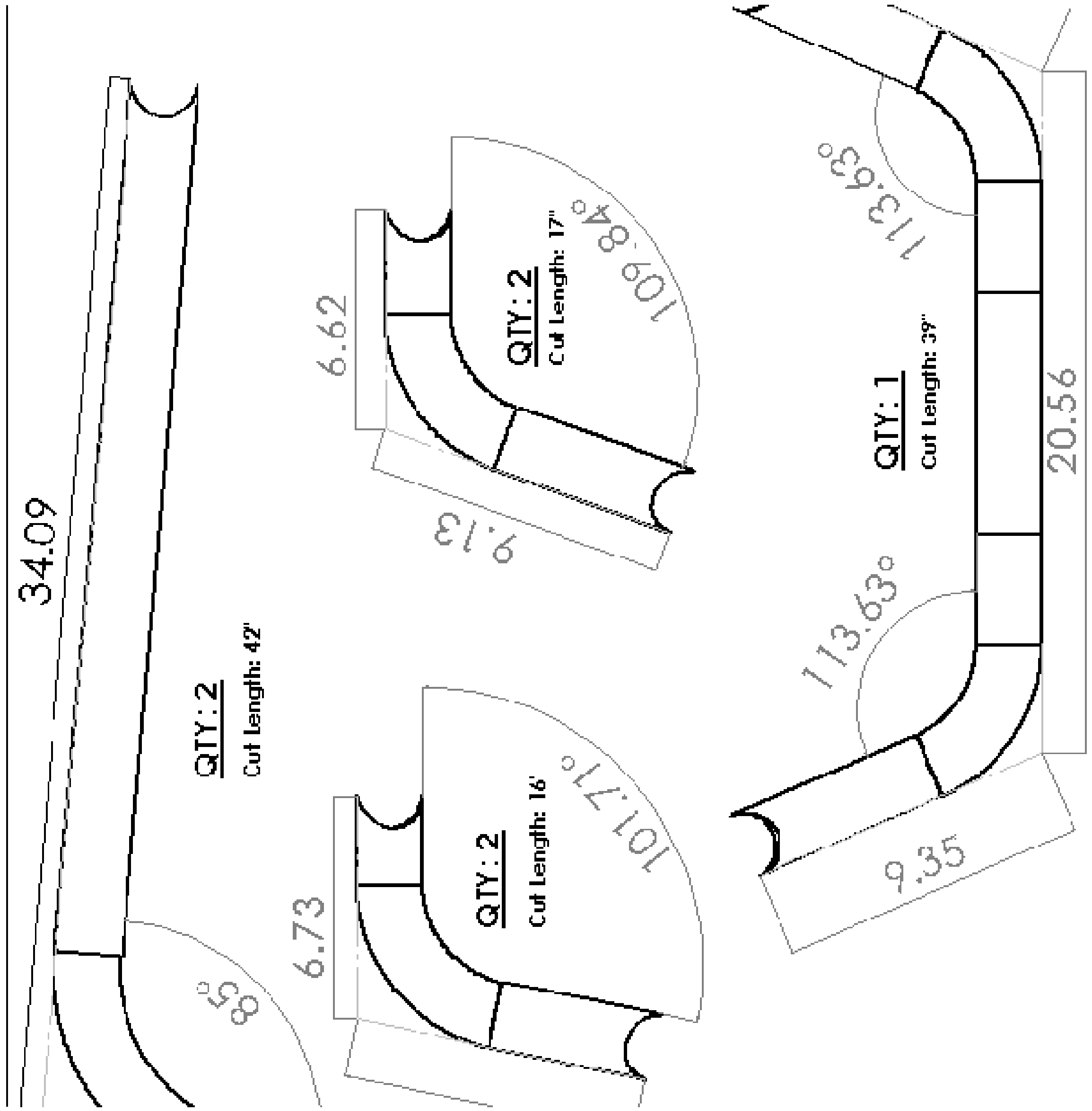


Figure 20. Roll Cage Bends