Motorcycle Hitch Carrier System

A Baccalaureate thesis submitted to the
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College of Engineering and Applied Science
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in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

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ABSTRACT

This project was to design and build a way to transport motorcycles that can attach to any standard pickup truck hitch in order to reduce the safety risks pushing a motorcycle up a ramp. It started with going through the concept and design stages, to prove the design works mathematically and then build a physical prototype. It was found that the ground clearance was an issue with the original design and a redesign is necessary for a follow-up porotype. Bellow you will find the detailed information about this project and all the appropriate calculations, figures and models.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

Our group's problem statement is to design a motorcycle carrier system that connects to a standard hitch found on most trucks and SUVs. The carrier will integrate a lifting mechanism which allows you to load and unload a motorcycle by yourself and eliminate the need for a trailer or the use of a ramp. The mechanism will lift the motorcycle off the ground after loading which makes for easy transportation.

BACKGROUND

There is average of 8,410,255 motorcycle riders in the United States (1). Motorcycles are a common source of transportation and recreational fun for numerous people during the warmer months of the year, but it becomes a hassle when there is a need to transport a motorcycle without riding it. There are limited, safe and affordable options available on the market right now. There are trailers but towing a trailer is not always ideal. Other methods involve a stationary platform attached to a hitch of an SUV which can only be loaded by pushing the motorcycle up a long ramp which can be extremely difficult due to motorcycles weighing hundreds of pounds.

RESEARCH

SCOPE OF THE PROBLEM

With over 8 million motorcycles on the road as of 2011, according to the Department of Transportation (1) the need to accommodate motorcycles on and off the road is necessary. Our problem focuses on the transportation of these motorcycles when they are not actually being driven to a destination. For example, if your motorcycle breaks down and needs to be taken to a repair shop, you are unable to ride it there. There is a necessity to have a way of transporting motorcycles easily and safely while also only requiring a single person to do so. With these many motorcycles on the road in just the US, there is a need to have a transportation system on the individual level, just as there are for regular vehicles. Tow trucks, flatbeds and trailers all exist for transporting cars and trucks, so the need for motorcycles to have these options is no different.

CURRENT STATE OF THE ART

There are currently a few options for those who want to transport their motorcycle without calling a tow truck. The first is a motorcycle trailer. The process involves loading a motorcycle up onto a small trailer and towing said trailer behind your vehicle. These trailers can be bought outright or rented through company's like U-Haul. This is a good design but does have a few flaws. One being the trailer itself. It is somewhat a hassle having to tow a trailer behind your vehicle, not to mention trying to back a vehicle up with a small trailer attached is extremely difficult and aggravating. Next the trailer itself takes a significant amount of space compared to the size a normal motorcycle. Another solution currently on the market is a carrier system that mounts the hitch of your vehicle. This allows you to carry the motorcycle on the back of a truck or SUV without towing anything which is a plus, but the loading process is cumbersome. It involves pushing the motorcycle up a long ramp to the top of the carrier when mounted on the car. Considering a motorcycle can weigh anywhere from 300-800 pounds, this is not an easy feat and cannot be done alone.

These technologies do solve the problem of transporting a motorcycle, but they have common flaws. They both require more than one person to properly load and secure the motorcycles to the transporting device. Not everyone will be comfortable towing a trailer either. A product is lacking the ability to load and secure a motorcycle with a single person.

END USER

Our customer requires a mode of motorcycle transportation that can be completed with one single user safely and have an affordable range of approximately $600 without any risk of damage to the bike or the vehicle.

Sport bike, dirt bike, and small cruiser owners are the customers that we are targeting. Survey data from the Motorcycle Industry Council on motorcycle owner demographics states that survey results for 2003 indicated that 90 percent of owners were male, the median age of owners is 41 years (1).

Per the University of Cincinnati Statista: California, Florida and Ohio are the top three states to have motorcycle registration (2). Our product will be marketed to cross country recreation and leisure riders.

CONCLUSIONS AND SUMMARY OF RESEARCH

In summary, we are going to design a product that can safely carry a motorcycle on the hitch of the consumer's vehicle. This product will be available to consumers who want to be able to transport their motorcycles without use of a trailer and can load the motorcycle by themselves. There are other options on the market, but none that can be used safely and without having to push a 300 or more-pound motorcycle up a ramp. Our product will solve this problem.

CUSTOMER FEATURES

After looking at customer reviews of products that are already out in the market, we have a good idea of where we want to focus our customer features. A lot of the reviews gave negative remarks about the overall sturdiness and build quality of current hitch mounted motorcycle carriers. According to customers, the carriers would appear flimsy and wobble on the hitch of the car when loaded with the motorcycle. We also let a few fellow motorcyclists fill out a survey asking them what they would want from a newly designed motorcycle carrier. Some of the highest scoring categories were: single person operation, ramp-less and fits onto a standard car/truck hitch. With all this in mind we want to design a product that features a single-person use as main priority. Another feature we will focus on is the sturdiness and build quality of the product, so users feel comfortable using the device. These features will be the driving factors of our design.

PRODUCT OBJECTIVES

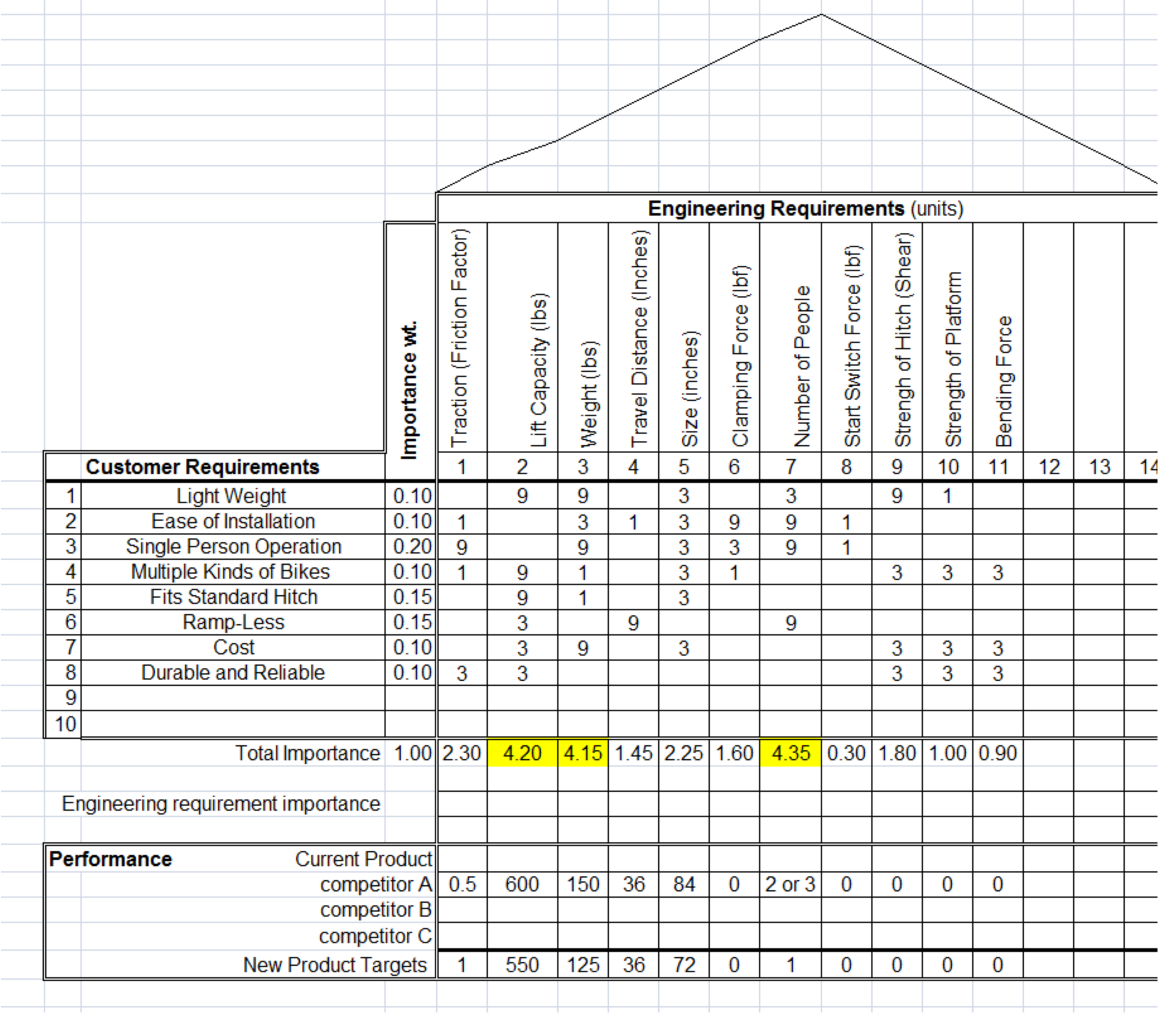
With our focus on the ability to load a motorcycle onto the carrier and secure with a single person, we plan on eliminating the loading ramp that is found on current carriers that require you to push the motorcycle up to secure it to the platform. Our design will incorporate a lifting mechanism that can raise and lower the platform on the back of the bike for a very easy process that one can do by themselves. The lifting mechanism will lower to the ground for loading and unloading the motorcycle but will be raised off the ground during transportation. This eliminates the need for a ramp and can be done by a single user. Our design will also incorporate sturdy materials and proper fitment onto the hitch receiver to eliminate the wobble and flimsy feeling that some of the current products have. Lastly, we will some measure of adjustability for how to motorcycle is secured to the platform to make it usable for a wide range of motorcycles.

QUALITY FUNCTION DEPLOYMENT

After reviewing our House of Quality, there are three elements that have been identified as being more important. Those are the “Lift Capacity”, “Weight” and “Number of People”. Our customers want the hydraulics to be able to lift a wide range of weight. Something able to carry both a child’s dirt bike weighing 150 lbs. and a full-size sports bike weighing 500 lbs. But most importantly, the customer wants to be able to transport their bike without requiring the help of other people.

We are going to design a light weight, hydraulic powered lift that attaches to a standard vehicle hitch and can easily load and unload a motorcycle on a platform.

Table 1 House of Quality



		Importance wt.	Engineering Requirements (units)													
			Traction (Friction Factor)	Lift Capacity (lbs)	Weight (lbs)	Travel Distance (Inches)	Size (inches)	Clamping Force (lbf)	Number of People	Start Switch Force (lbf)	Strengh of Hitch (Shear)	Strength of Platform	Bending Force			
	Customer Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Light Weight	0.10		9	9		3		3		9	1				
2	Ease of Installation	0.10	1		3	1	3	9	9	1						
3	Single Person Operation	0.20	9		9		3	3	9	1						
4	Multiple Kinds of Bikes	0.10	1	9	1		3	1			3	3	3			
5	Fits Standard Hitch	0.15		9	1		3									
6	Ramp-Less	0.15		3		9			9							
7	Cost	0.10		3	9		3				3	3	3			
8	Durable and Reliable	0.10	3	3							3	3	3			
9																
10																
	Total Importance	1.00	2.30	4.20	4.15	1.45	2.25	1.60	4.35	0.30	1.80	1.00	0.90			
	Engineering requirement importance															
Performance	Current Product															
	competitor A		0.5	600	150	36	84	0	2 or 3	0	0	0	0			
	competitor B															
	competitor C															
	New Product Targets		1	550	125	36	72	0	1	0	0	0	0			

DESIGN

DESIGN ALTERNATIVES AND SELECTION

With ease of use and loading on our mind, we first thought of using a flat metal plate with a small groove for the motorcycle wheels to track onto (see Figure 10). We soon realized that the structural integrity of the plate would be flimsy at best unless it was extremely thick which would be extremely heavy. Next, we came up with two metals "forks" that would hold a channel that will act as a guide for loading and unloading the motorcycle. We eventually modified this idea to incorporate a lightweight frame made from aluminum with two upper posts for stability. The frame would hold and secure the lightweight wheel channel that the motorcycle will be placed on.

Next the focus was on how the motorcycle is going to be secured to the platform and keep it from falling off while the vehicle is in motion. Building off the wheel channel, a small indentation was placed at the end to act as a pocket for the front wheel to restrict movement. To go even further, a swivel plate would be place on the ground of the channel. The plate would rotate forward as the front wheel rolled over it, thus lifting the rear of the plate, keeping the front wheel from moving backwards off the channel. we scrapped this idea all together because the need to accommodate a wide variety of motorcycles and sizes. The final design incorporates a clamp for the front wheel. The clamp is fully adjustable, so it will accommodate different wheel sizes of different motorcycles. The clamp has a handle to tighten down 2 arms around the front wheel to restrict movement entirely. The clamp has a back stop, so the wheels cannot travel past the channel. This clamp will be bolted to the frame to incorporate a sturdy base. A rear wheel chock will be wrapped around the rear wheel and pinned to the channel which will further secure the motorcycle to the platform. Lastly, as a precaution we will use ratchet straps to further secure the motorcycle to the frame. This will be used as a failsafe in case the other mechanisms fail.

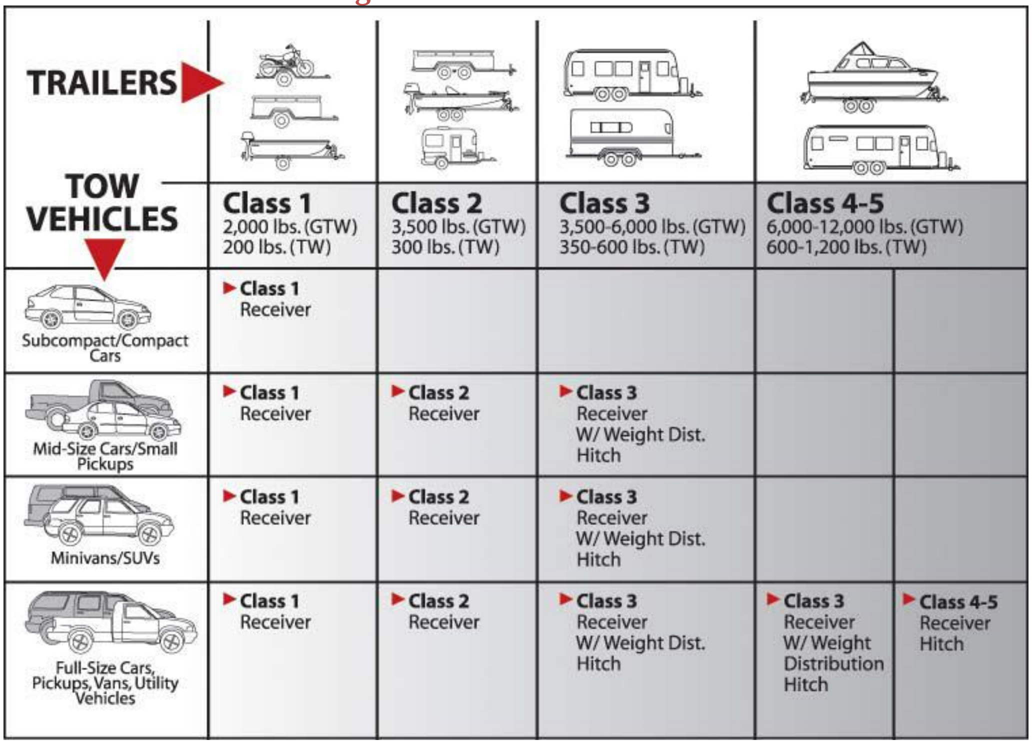
For the upper section of this project we as a team had many different styles on how to raise and lower the motorcycle. The concepts were 2 piston systems, one piston system, gears system, and even a winch system. Once the team pick which system to use, which will be explain why in the piston portion of the document, (one piston system with two vertical supports beams) we could design the hitch.

Now there are 7 different types of hitches including the Pintle Hitch. We based our hitch design on the customer needs and what is standard on the market. For instance, most hitch size for class 3 and 4 is 2” by 2” square hole (see Figure 1). Most trucks and SUVs use a standard bumper hitch. Below are some early stages of the upper hitch design. The one on the far left was modified because it used too much material which equals extra weight and more money. The other two pictures demonstrate how we had to move the hydraulic motor to be mounted. We could add gussets and a support plate to make the joint stronger to endure all the stresses in the system.

For the design of the lifting system, we wanted something that required little physical labor and was safe. After considering cranks, wenches and hydraulic cylinders, we settled on using a double acting hydraulic lifting system. One that can raise and lower the platform at a slow and constant rate and would have the lifting forces necessary.

Figure 1: Hitch Varieties

Figure 2: Classes of Hitches

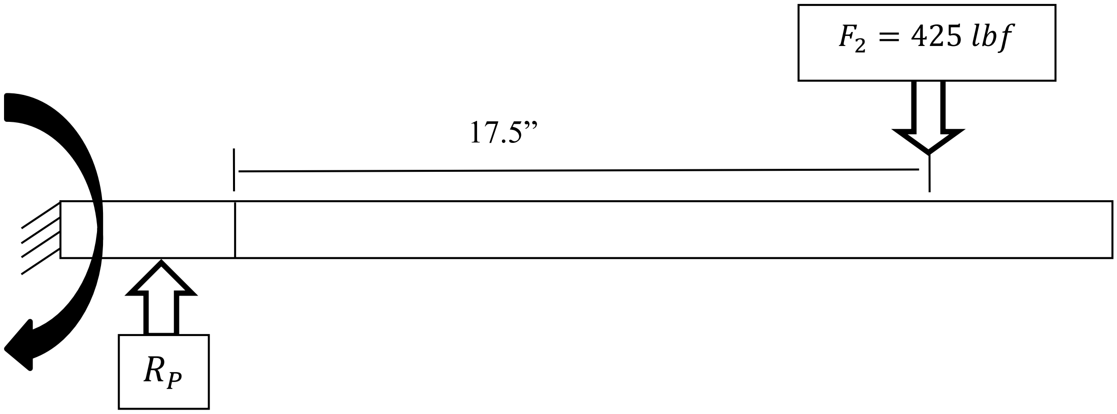


TRAILERS ▶ TOW VEHICLES ▼	Class 1 2,000 lbs. (GTW) 200 lbs. (TW)	Class 2 3,500 lbs. (GTW) 300 lbs. (TW)	Class 3 3,500-6,000 lbs. (GTW) 350-600 lbs. (TW)	Class 4-5 6,000-12,000 lbs. (GTW) 600-1,200 lbs. (TW)	
Subcompact/Compact Cars	▶ Class 1 Receiver				
Mid-Size Cars/Small Pickups	▶ Class 1 Receiver	▶ Class 2 Receiver	▶ Class 3 Receiver W/ Weight Dist. Hitch		
Minivans/SUVs	▶ Class 1 Receiver	▶ Class 2 Receiver	▶ Class 3 Receiver W/ Weight Dist. Hitch		
Full-Size Cars, Pickups, Vans, Utility Vehicles	▶ Class 1 Receiver	▶ Class 2 Receiver	▶ Class 3 Receiver W/ Weight Dist. Hitch	▶ Class 3 Receiver W/ Weight Distribution Hitch	▶ Class 4-5 Receiver Hitch

LOADING CONDITIONS

Loading Conditions-Bottom Frame (Bending):

The loading conditions for the bottom frame consist of a max motorcycle weight of 425 lbs. This is an average weight of a typical sport bike, which will also allow for much lighter bikes such as motorcycles and scooters. Our hand calculated results yielded a max moment of 7,437.5 lb.*in. For max bending, our calculations yielded 4,086.53 PSI per support post. When running this simulation in SolidWorks, the total stress on the bottom frame maxed out at 9,837 PSI. This gives us a safety factor of 4.06 for the entire bottom frame loading conditions.



-$\sum M_p = -M_p - 425(17.5) = 0$
$\sum M_p = -7437.5\ lb * in$

$\sum F_y = 0 = -425 + R_p$
$\sum R_p = 425\ lbf$
$\sum F_x = R_w = 0$

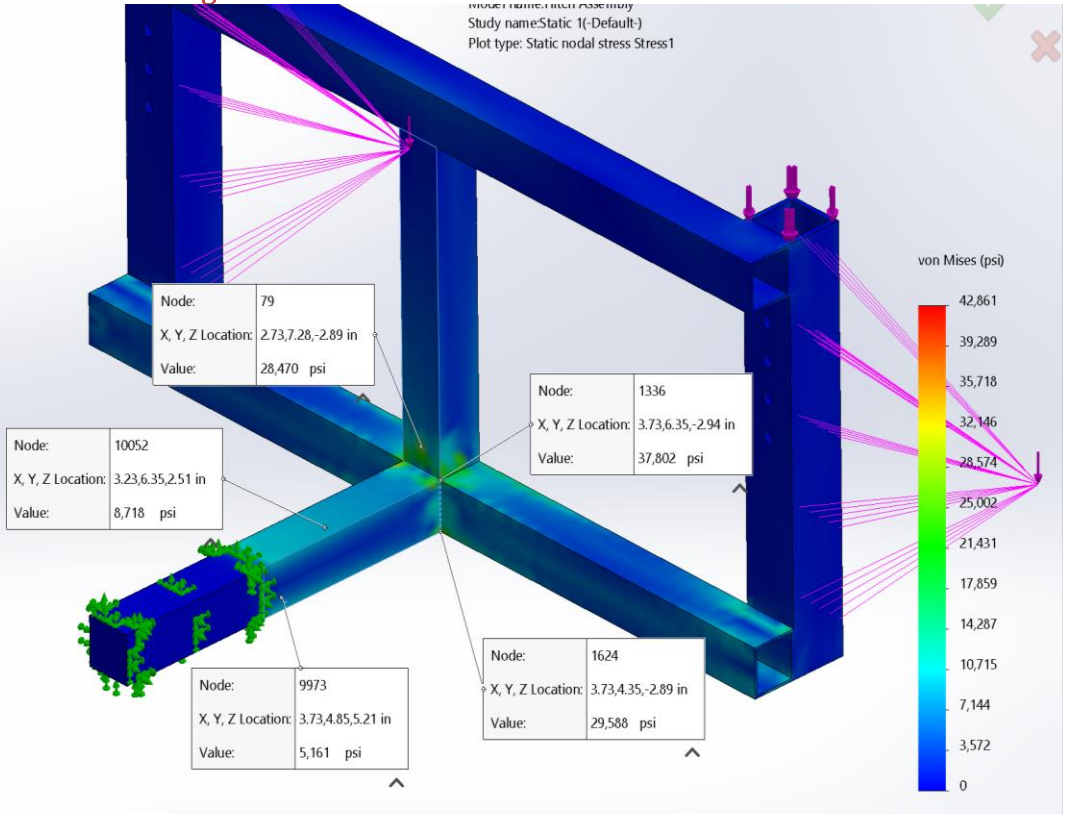
$$I = \frac{a^4 - b^4}{12} = \frac{2^4 - 1.50^4}{12} = 0.91\ in^4$$

$$\sigma_B = \frac{Mc}{I} = \frac{(7437.5)(1)}{0.91} = 8173.07\ PSI$$

$$\sigma_B = Per\ Support\ Post\ \mathbf{4,086.53\ PSI}$$

Loading Conditions-Gussets / Support Plate:

Figure 3: Stresses on Hitch Member without Gussets



Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1

Node: 79
X, Y, Z Location: 2.73,7.28,-2.89 in
Value: 28,470 psi

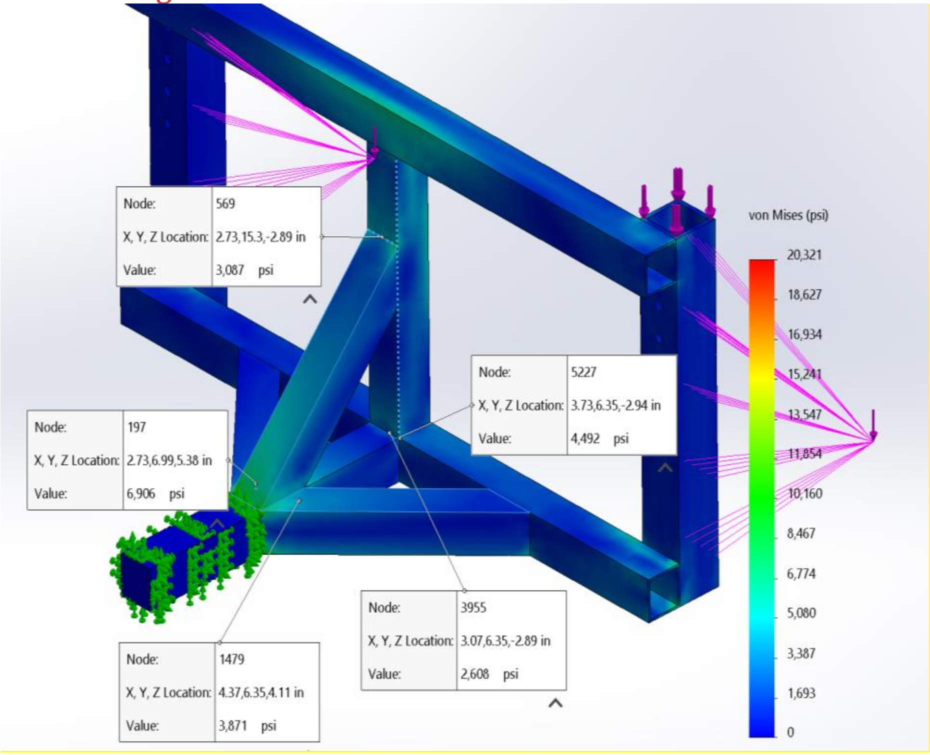
Node: 10052
X, Y, Z Location: 3.23,6.35,2.51 in
Value: 8,718 psi

Node: 1336
X, Y, Z Location: 3.73,6.35,-2.94 in
Value: 37,802 psi

Node: 9973
X, Y, Z Location: 3.73,4.85,5.21 in
Value: 5,161 psi

Node: 1624
X, Y, Z Location: 3.73,4.35,-2.89 in
Value: 29,588 psi

Figure 4: Stresses on Hitch Member with Gussets



Node: 569
X, Y, Z Location: 2.73,15.3,-2.89 in
Value: 3,087 psi

Node: 197
X, Y, Z Location: 2.73,6.99,5.38 in
Value: 6,906 psi

Node: 5227
X, Y, Z Location: 3.73,6.35,-2.94 in
Value: 4,492 psi

Node: 1479
X, Y, Z Location: 4.37,6.35,4.11 in
Value: 3,871 psi

Node: 3955
X, Y, Z Location: 3.07,6.35,-2.89 in
Value: 2,608 psi

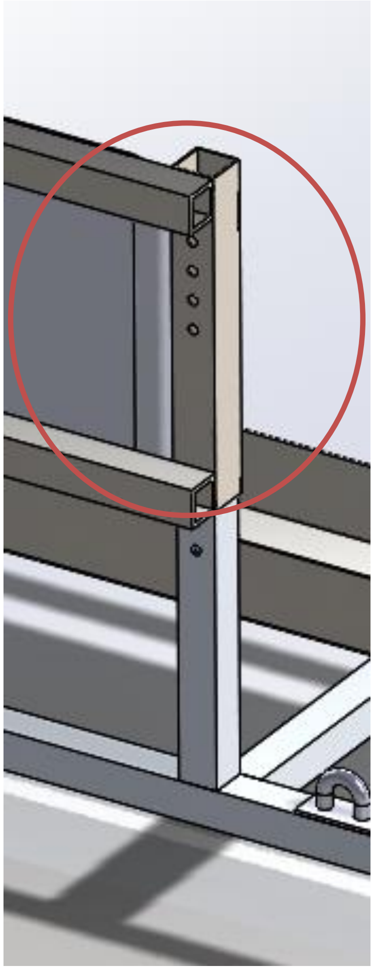
Table 2 Gussett Comparison

	Comparison Chart (PSI)				
	Point 1	Point 2	Point 3	Point 4	Point 5
Gussets	2,529	6,588	4,647	3,378	9,473
Without Gussets	19,263	24,362	26,321	11,490	9,698
Percent difference	762%	370%	566%	340%	102%

The pictures above show by moving the hydraulic motor and installing gussets the stressing is lower tremendously in the hitch bar.

Loading Conditions-Locking Pins:

The following is the calculations for the locking pins for when you get the piston to right level of height the user wants. The design is over kill but the standard is 5/8 on the market and not much more money than a custom size. Also, there will be two pins one on each vertical support beam shown in the picture below. The max shearing is 700 PSI



Pin Size for Yield

$$\tau = \frac{F}{A} = \frac{425}{2\frac{\pi D^2}{4}}$$

$$45{,}000\ psi = \frac{425 * 4}{2\pi D^2}$$

$$45{,}000\ psi = \frac{1{,}700}{2\pi D^2}$$

$$141{,}371 = \frac{1{,}700}{2D^2}$$

$$\sqrt{D^2} = \sqrt{\frac{1{,}700}{2(141{,}371)}}$$

D = 0.08”

5/8 In Hitch Pin With Clip Pol

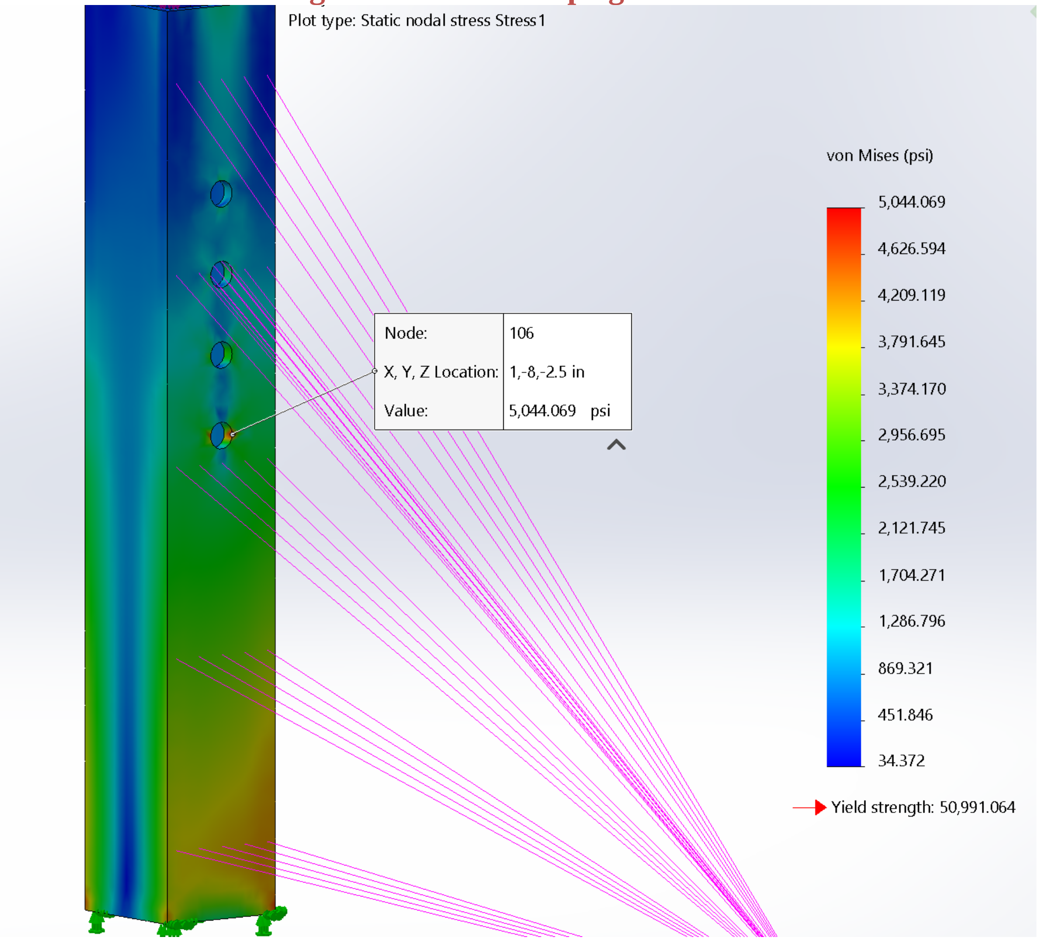
Actual Shear

$$\tau = \frac{F}{A} = \frac{425\ lbs}{2\frac{\pi D^2}{4}}$$

$$\tau = \frac{425\ lbs}{2\frac{\pi(0.625)^2}{4}} = 693\ psi$$

Loading Conditions-Locking Pins Overall stress:

Figure 5: Shear on Upright Beams



Plot type: Static nodal stress Stress1

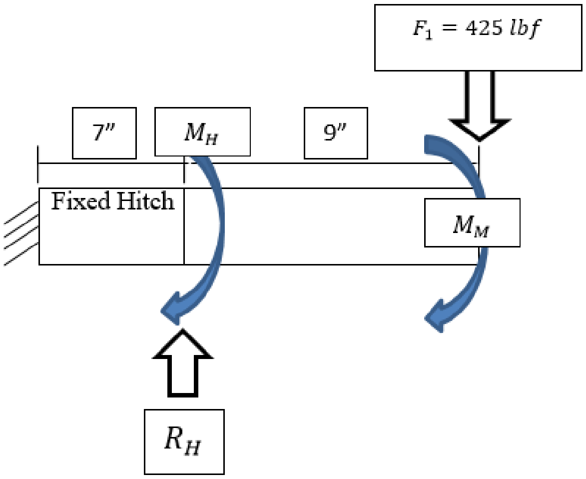
Node:	106
X, Y, Z Location:	1,-8,-2.5 in
Value:	5,044.069 psi

Above is the overall stress the pin holes and pins will be facing. The max stress is 5044 PSI which the yield strength is 45,000 PSI

$$SF = \frac{S_y}{\sigma_B} = \frac{45{,}000}{5044} = \mathbf{8.92}$$

Loading Conditions-Bending: Upper Hitch Frame:

Researching and analyzing the situation showed the most stress in this system is due to bending. The max bending was found to be 9206.52 PSI at the hitch bar. This is from the weight of the frame, piston, motor and bike plus the distance from the fixed hitch point. This will also be checked using Von Mises analysis software in Solidworks, which takes in consideration of all stresses in the system.



$$-\circlearrowleft \sum M_H = -M_H - M_M - 9F_1$$

$$M_H = -7437.50 - 9(425)$$

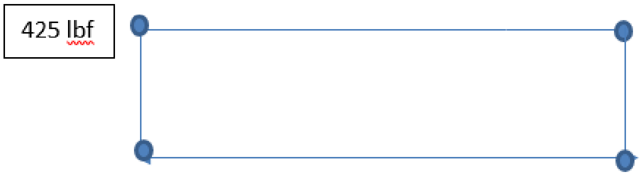
$$M_H = -7437.50 - 3825$$

$$M_H = -11262.5\ lb * in$$

$$-\downarrow \sum F_y = 0 = R_H - F_1$$

$$R_H = 425\ lbf$$

Shear Diagram (lbf)



Avg. Shear

425 lbf

Max Bending Moment

$$\sigma_B = \frac{Mc}{I} = \frac{(-11262.5)(1)}{1.33} = \mathbf{-8468\,PSI}$$

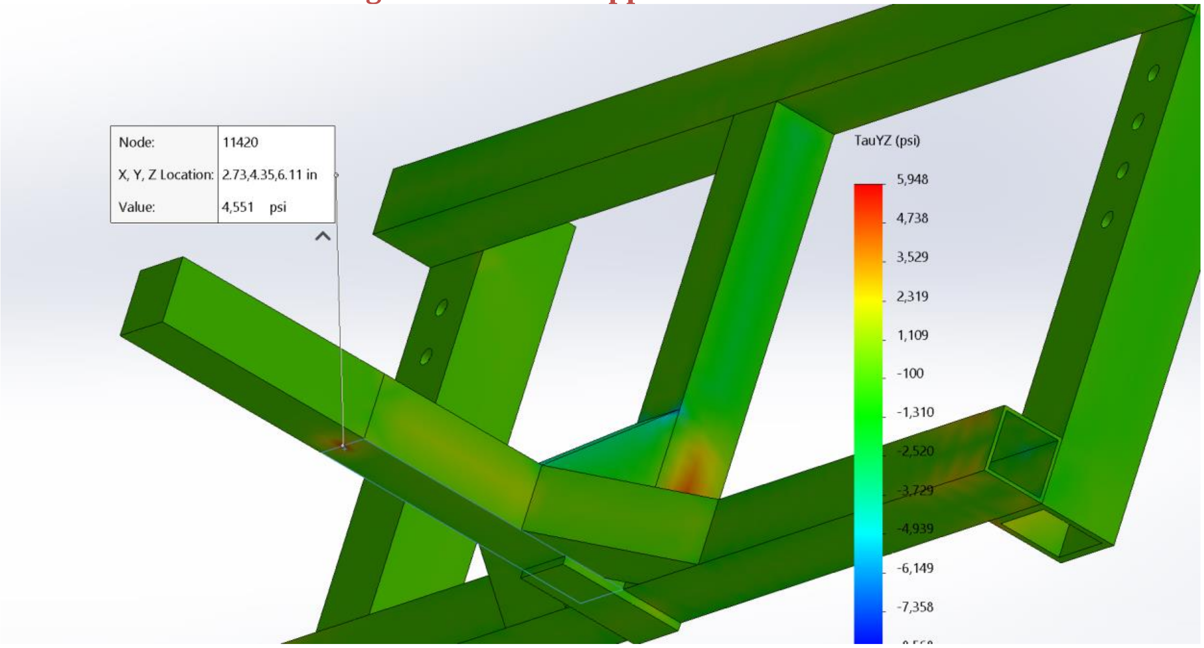
$$I = \frac{a^4}{12} = \frac{2^4}{12} = 1.33\,in^4$$

Safety Factor

$$SF = \frac{S_y}{\sigma_B} = \frac{36{,}000}{8468} = \mathbf{4.25}$$

Loading Conditions-Shearing: Upper Hitch Frame:

Figure 6:Shear in Upper Hitch Frame

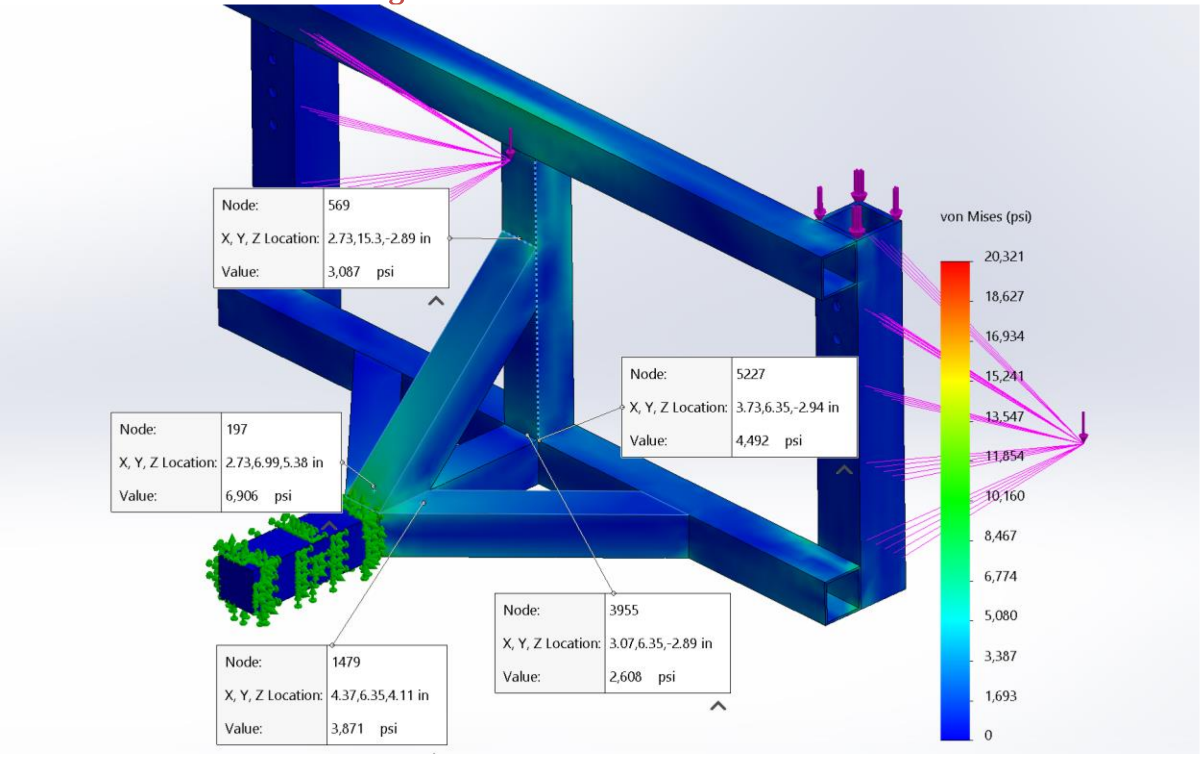


Node:	11420
X, Y, Z Location:	2.73,4.35,6.11 in
Value:	4,551 psi

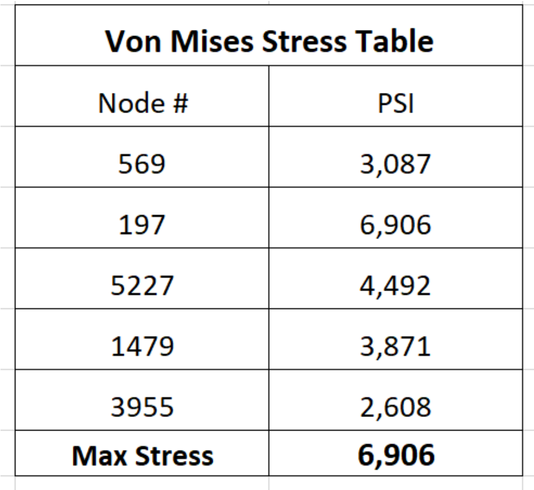
Shear in different directions in the Hitch bar to make sure the system is safe Max shear is 4551 PSI on the side of the Hitch.

Loading Conditions- Upper Frame (Von Mises Analysis in Solidworks)

Figure 7: Overall Stresses on Hitch



The overall stress in motorcycle hitch system at the hitch is around 7,000 PSI from the Solidworks design analysis program. This includes all stresses the system could have.



Von Mises Stress Table	
Node #	PSI
569	3,087
197	6,906
5227	4,492
1479	3,871
3955	2,608
Max Stress	**6,906**

Loading Conditions-Torsional: Upper Hitch Frame:

During the analysis the motorcycle and frame being unevenly distributed was taken into consideration. Solidworks was used to calculate the torsional stress in the system which was 2400 PSI. Even though the stress is low this is a good idea to calculate to make sure your safety factor is high enough for your application.

Loading Conditions-Shear: Cylinder Clevis:

The cylinder and the clevis pin comes with a rating of 3,000 pound per square inch lifting force and a one-inch pin. These are standard sizes and have a design factor approximately 10. Because of this high value, there is no concern for this aspect of the project to see any failure.

Figure 8: Clevis

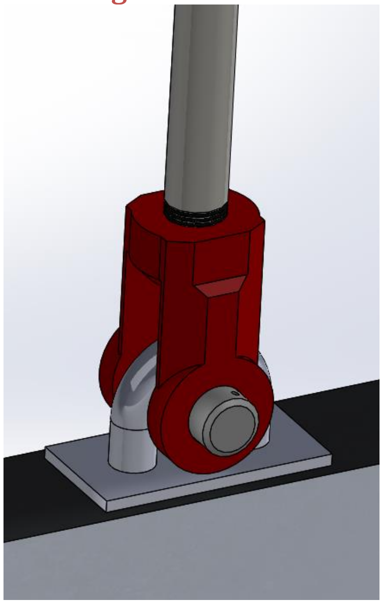
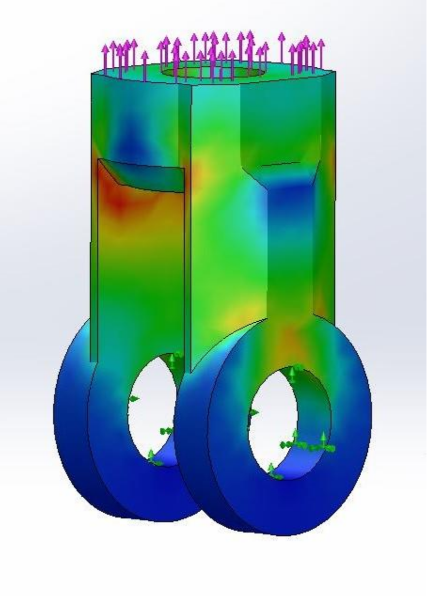


Figure 9: Stresses on Clevis



Cylinder Pin Size for Yield

$$\tau = \frac{F}{A} = \frac{425}{2\frac{\pi D^2}{4}}$$

$$45{,}000\ psi = \frac{425 * 4}{2\pi D^2}$$

$$45{,}000\ psi = \frac{1{,}700}{2\pi D^2}$$

$$141{,}371 = \frac{1{,}700}{2D^2}$$

$$\sqrt{D^2} = \sqrt{\frac{1{,}700}{2(141{,}371)}}$$

D = 0.08”

Actual Shear

$$\tau = \frac{F}{A} = \frac{425\ lbs}{2\frac{\pi D^2}{4}}$$

$$\tau = \frac{425\ lbs}{2\frac{\pi(0.625)^2}{4}} = \mathbf{693\ psi}$$

FACTORS OF SAFETY OF CONCERN (IF NEAR DESIGN FACTOR)

Bottom Frame

Safety Factor Bending

$$SF = \frac{S_y}{\sigma_B} = \frac{40{,}000}{4{,}086.53} = \mathbf{9.8}$$

Safety Factor Overall (SolidWorks)

$$SF = \frac{S_y}{\sigma_B} = \frac{40{,}000}{9{,}837.87} = \mathbf{4.07}$$

Upper Hitch Frame Assembly

Safety Factor Hitch Locking Pins

$$SF = \frac{S_y}{\sigma_B} = \frac{0.625}{0.08} = \mathbf{7.8}$$

Safety Factor Shear

$$SF = \frac{S_y}{\sigma_B} = \frac{72{,}000}{4551} = \mathbf{15.8}$$

Safety Factor Torsional

$$SF = \frac{S_y}{\sigma_B} = \frac{72{,}000}{2400} = \mathbf{30}$$

Safety Factor Bending

$$SF = \frac{S_y}{\sigma_B} = \frac{54{,}000}{9206} = \mathbf{5.9}$$

Safety Factor Overall (SolidWorks) Von Mises

$$SF = \frac{S_y}{\sigma_B} = \frac{36{,}000}{6900} = \mathbf{5.21}$$

Safety Factor Overall (SolidWorks)

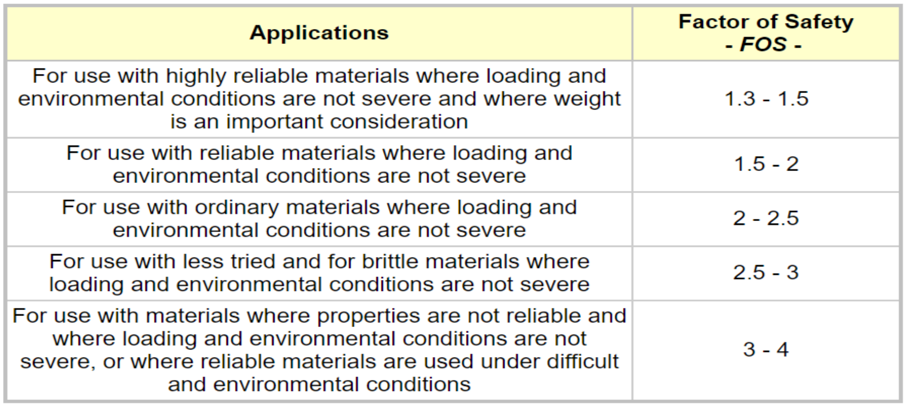
$$SF = \frac{S_y}{\sigma_B} = \frac{36{,}000}{8468} = \mathbf{4.25}$$

Hydraulic Lifting System

Safety Factor Hydraulic Cylinder

$$SF = \frac{Actual\ Pin\ Size}{Yield\ of\ Pin} = \frac{1"}{0.08"} = 12$$

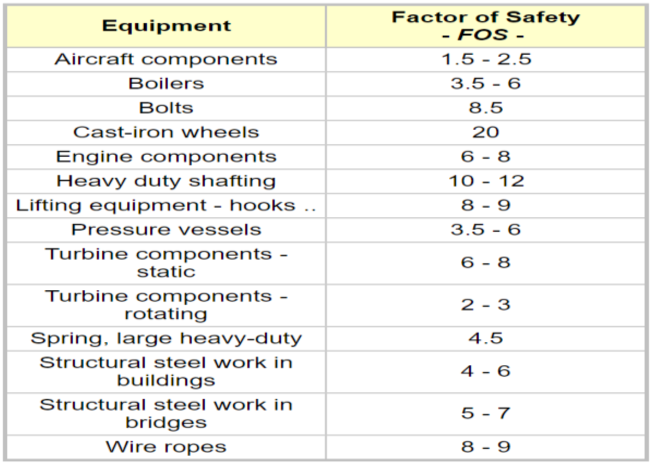
General recommendations



Applications	Factor of Safety - *FOS* -
For use with highly reliable materials where loading and environmental conditions are not severe and where weight is an important consideration	1.3 - 1.5
For use with reliable materials where loading and environmental conditions are not severe	1.5 - 2
For use with ordinary materials where loading and environmental conditions are not severe	2 - 2.5
For use with less tried and for brittle materials where loading and environmental conditions are not severe	2.5 - 3
For use with materials where properties are not reliable and where loading and environmental conditions are not severe, or where reliable materials are used under difficult and environmental conditions	3 - 4

Typical overall Factors of Safety

Typical overall *Factors of Safety*:



Equipment	Factor of Safety - *FOS* -
Aircraft components	1.5 - 2.5
Boilers	3.5 - 6
Bolts	8.5
Cast-iron wheels	20
Engine components	6 - 8
Heavy duty shafting	10 - 12
Lifting equipment - hooks ..	8 - 9
Pressure vessels	3.5 - 6
Turbine components - static	6 - 8
Turbine components - rotating	2 - 3
Spring, large heavy-duty	4.5
Structural steel work in buildings	4 - 6
Structural steel work in bridges	5 - 7
Wire ropes	8 - 9

The lowest safety factor of a 4 is based on research and similar application out in the world. We also took in consideration that the vehicle’s shocks will take a lot of the stresses off the Motorcycle Hitch System.

COMPONENT SELECTION

The material chosen for the bottom frame had to be lightweight while also sturdy enough to house the motorcycle with minimal flex. We went with Aluminum 6061-T6 in 2”x2” square tubing with a ¼” thick sidewall. With a yield strength of 40,000 PSI, it gives a desirable safety factor while also being a readily available material that is in stock at most metal retailers. The wheel clamp will also be made of the same material to take advantage of its high strength and minimal weight. The wheel channel will be formed out of 12-guage galvanized steel gives us a sturdy and durable platform for the wheels to meet.

The upper frame is made of three different materials. Most of the frame bars are made from *A513 Steel Square Tubing-2x2x 12GA* because the material yield strength is 72,000 PSI and affordable. The two-vertical post with the holes in them for the locking pins are made from A*500 Steel Square Tubing* which the yield strength is 46,000 PSI because the beams do not need to be as strong and easier to machine due to the higher carbon level. I also found a telescopic square bar to match the bottom two post perfectly. Finally, the hitch bar is made from 1020 finish cool steel solid square bar for the high stresses in this location (yield strength is 54,000 PSI)

The hydraulic motor and cylinder were chosen because of the affordability and strength ratings on standard parts. One standard single hydraulic cylinder has the capacity to lift 3,000 psi, over ten times the amount we need for our project. A double acting hydraulic motor and cylinder were selected. The hydraulic motor is uses a 12-volt power supply which will be from the existing electrical power supply that is commonly found with hitches on most vehicles.

BILL OF MATERIAL

Table 3 Expected Bill of Materials

Item	Price $
2 x 2 x 12 Gauge A513 - Steel for Upper Frame	$71.88
2-1/2 X 2-1/2 X .238 wall (2.024" Inside) - Steel for Telescoping	$66.34
2 x 2 x 1/4 wall - Aluminum for Bottom Frame	$226.80
2 x 2 - Cold Finish Steel Square for Hitch Member	$61.67
Wheel Rail	$79.99
7 in. W x 10 in. H x 3.7 in. - Storage Boxes	$37.52
7/8 Brushed Nickle Lock	$11.94
12V LED Rear Stop Brake Tail Light	$18.99
Cast 6063 Aluminum Pad Eyes	$39.92
1020 Steel Pad Eye	$8.00
12 Volt DC Hydraulic Power Unit	$228.99
Heavy-Duty Welded Cylinder	$99.99
1/2" x 24" (2') Hydraulic Hose, Swivel End	$13.99
12-gauge wire	$10.00
Lot of 4 Ratchet Straps	$12.99
5/8 In Hitch Pin with Clip Pol	$1.94
Weld Rods	$30.00
Total	**$1020.95**

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Our current idea of a budget is approximately around $1,000 for this project. This design will include:

- Stainless steel and aluminum framework.
- Hydraulic pump, cylinders and hoses.
- Labor and welding rods

Item	Actual Price $
Upper Frame	$ 71.88
Outter Piece for Telescoping	$ 66.34
Bottom Frame	$ 269.25
Wheel Track	$ 81.64
Front Wheel Chuck	$ 118.91
Mailboxes	$ 25.94
Tail lights	$ 35.00
Eye Bolts	$ 15.69
Motor/Pump	$ 429.00
Cylinder	$ 109.98
Hydraulic Hoses	$ 124.00
Wire for Motor	$ 12.00
Ratchet Straps	$ 9.97
Pins for upright and cable	$ 9.96
Paint	$ 10.98
Bolts and nuts	$ 25.00
Total	$ 1,415.54

By the end of the project we did go over our estimated budget. The difference came to be about $400.00. The price of all the hydraulics lines, hydraulic pump, and the front wheel vise were much higher than we anticipated. This took a hit on our budget but they were completely necessary items and we did not want to use cheap parts. We bit the bullet and went over our budget but it was still a reasonable price tag for all the work and materials needed to finish the project.

SCHEDULE, PROPOSED /ACTUAL

Green	Will Be Done by
Yellow	Working on (in progress)/meeting
Red	Presentation
blue	Tech Expo

Table 4 Senior Design Project Schedule

Date:	10/2/17	10/9/17	10/16/17	10/23/17	10/30/17	11/6/17	11/13/17	11/20/17	11/27/17	12/4/17	12/11/17
Design 1 Presentations	🟨	🟩									
Concepts		🟨	🟨	🟩							
Design Decision				🟨	🟨	🟩					
Calculations/Finite Element Analysis						🟨	🟨	🟨	🟨	🟨	🟩
Final Design/ Drawings						🟨	🟨	🟨	🟨	🟨	🟨
Meeting with Advisor			🟨	🟨	🟨			🟨		🟨	
Date:	12/18/17	12/25/17	1/1/18	1/8/18	1/15/18	1/22/18	1/29/18	2/5/18	2/12/18	2/19/18	2/26/18
Final Design/ Drawings	🟨	🟩									
Presentation Jan.	🟨	🟨	🟨	🟨	🟨	🟥	🟥				
Order Materials- 3 months Before						🟨	🟨	🟩			
Build- 6 weeks before										🟨	🟨
Meeting with Advisor	🟨		🟨		🟨			🟨			🟨
Date:	3/5/18	3/12/18	3/19/18	3/26/18	4/2/18	4/9/18	4/16/18	4/23/18	4/30/18	5/7/18	5/14/18
Build- 6 weeks before	🟨	🟨	🟩								
Test-3 weeks before			🟨	🟨	🟩						
Tech Expo						🟦	🟦				
Final Presentation								🟩			

Throughout the project we were able to stay on schedule and never experienced any major setbacks. Meetings were held almost daily through the concept, design and calculation phase and that kept us on track and progressing through the project. When it came time to fabricate and assemble the parts, we were conscious of delivery delays for some materials so we did not experience any major problems in that phase of the project either. We followed our schedule and were able to have the project completed in time for the tech expo without rushing. Overall the project was on schedule from start to finish.

FABRICATION AND ASSEMBLY

Lower Frame

Fabrication of the lower frame assembly started with cutting the 2”x2”x1/4” aluminum square tubing to the correct sizes to make up the bare frame. The cutting was done with an electrical with a cutting wheel. After laying out the frame components and confirming fitment, the aluminum was tig welded together. Once the basic frame was built, we then tested fitment with the upper frame to make sure support uprights fit inside the guides on the upper frame. The edges had to be ground down some with a grinder for a sliding motion to be achieved. Next the aluminum wheel track had to cut down to size and some edges removed for the wheel vise to fit accordingly. The wheel vise also needed some mounting points so 1”x1” angled aluminum pieces were welded to the frame for that purpose. Holes were then drilled for the wheel channel, wheel vise, eye bolts, taillights and strap hookup points. A test fit of all the components attached to the frame was done with successful results. The lower frame was disassembled one last time for cleaning and protective paint coating. Once painted, the lower frame was reassembled. Lastly, the wiring was ran for the lights and was ready to be attached to the upper frame assembly and hydraulic piston.

Upper Frame

Fabrication of the upper frame assembly was similar to the lower frame assembly. First we started with cutting the 2”x2”x1/4” steel square tubing to the correct sizes to make up the bare frame. The cutting was done with an electrical cutting wheel. After laying out the frame components and confirming fitment, the steel was welded together. Once the basic frame was built, we tested it with the vehicles hitch for fitment. The edges of the hitch insert had to be ground down some with a grinder for easier insertion into the hitch. Holes were then drilled for the hitch pin and for the mounting pins to hold the lower frame in place. The upper frame was cleaned, and protective paint coating was applied.

Lifting Mechanism & Electrical

There was little fabrication involved with the lifting mechanism. Both the upper frame and the bottom frame were drilled with a 5/8th inch drill bit. Eye bolts were attached with nuts, washers and lock washers. The extra bolt threads were cut to remove the excess. 10-gauge threaded wire was used to connect the hydraulic motor to the battery. The wiring was crimped and soldered to the appropriate terminals in order to ensure a good electric connection. Lastly, the hydraulic hoses were cut to length and the fittings were crimped on to the required pressure ratings.

Final Assembly

Once the lower frame, upper frame, and the hydraulics were all fabricated and assembled, the final assembly was done. First the upper frame fitted onto the upright supports of the lower frame and grease was applied at the contact points for a smooth operation. Next the hydraulic pump was mounted on the upper frame and secured. The hydraulic lift was then attached to the eyebolts of the upper and lower frame. Hoses were run from the pump to the piston and placed out of the way. The hydraulic pump was connected to a 12V DC battery for operation. Lastly the entire assembly was ready to be attached to a standard truck hitch and the lights plugged into the trailer connecter of the car. That concludes the final assembly of the carrier system and is ready to be tested.

TESTING AND RESULTS

Our plan for testing was as follows:

1. Install onto truck
2. Run 10 cycles with no load and inspect welds/motor for issues
3. Travel 2 miles with no load and inspect for issues
4. Run 50 cycles in a row with no load and inspect for issues
5. Travel 10 miles
6. Repeat steps 2 through 5 with 100lbs, 250lbs, 400lbs.
7. Test fitment with motorcycle and cycle lifting mechanism
8. Complete a speed bump test to confirm motorcycle stability

We used sandbags at first for the weight to make sure a motorcycle was not damaged during testing if any of the components failed. The carrier system successfully installs onto a standard hitch and allows for single person operation. The welds withstood the weight testing and showed no physical signs of failure. The hydraulic motor and piston showed no signs of wear or strain when under operation. The motorcycle fit exactly how we planned and allowed for a single person to load and unload safely. There were little no stability issues when the motorcycle was lifted and ready for transportation. Clearance from the ground to the bottom of the frame was a big issue during testing. As more weight was added to the system during testing the suspension of the truck would compress and drop the hitch lower to the ground. When we finally got the 400lb test, there was only 4” of clearance between the bottom of the frame and the road. With such a low clearance we decided to not do any road testing in fear of the lower frame hitting scraping on uneven roads. This low clearance issue is because of the oversight of how the vehicle will react when this large amount of weight is placed on the hitch. Our test vehicle was an early 2000’s Dodge Dakota which sits fairly low to the ground to start with and has very worn suspension components. With a lower truck and a saggy suspension, it is not a big surprise that the rear of the truck squatted very low during the testing with heavy weights. It was a huge oversight that we did not think of during the design phase. Hypothetically, a newer truck that sits higher and has a beefier suspension could have used this system and completed all of our testing, but we could not get our hands on a vehicle like this. This problem could have been fixed if the upper frame was built taller with a hydraulic piston that had a bigger stroke, but it was too late in the project before we came across this issue to refabricate and reorder components. This mistake arose because we were so focused on just the design of our immediate system, we did not consider how our system would affect the vehicles characteristics when in use. This was a huge lesson learned but our system was still able to fit a sport bike and lift the weight limit of 400lbs. several times without any sign of failure.

CONCLUSION/RECOMMENDATIONS

Overall the design of a motorcycle hitch carrier system was able to accomplish several goals. The system installs onto any standard hitch, runs off of the vehicles DC power supply and was able to accommodate our 425lb. weight limit. Most importantly it allows a single person to load and unload a motorcycle in a safe and timely manner. Unfortunately, we could not do any road testing due to clearance issues. As with any design there is always room for improvement. As a fix for the low clearance, the solution is as simple as making the upright bars of the upper frame a few inches taller and switching out the hydraulic piston for one with a longer stroke to allow the lower platform to raise up higher and result in much more ground clearance. Disregarding the clearance, the system performed exactly how it was designed

WORKS CITED

1. **Morris, Craig.** Motorcycle Trends in the United States. *Burea of Transportation Statistics.* [Online] Burea of Transportation Statistics, May 2009. [Cited: September 12, 2017.] https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/special_reports_and_issue_briefs/special_report/2009_05_14/html/entire.html.

2. **Transportation, US Department of.** U.S. motorcycle registration estimates in 2015, by state (in units)*. *Statista.* [Online] 09 15, 2017. https://www.statista.com/statistics/191002/number-of-registered-motorcycles-in-the-us-by-state/.

APPENDIX A (CONCEPT DESIGNS)

Figure 10: Early Concept

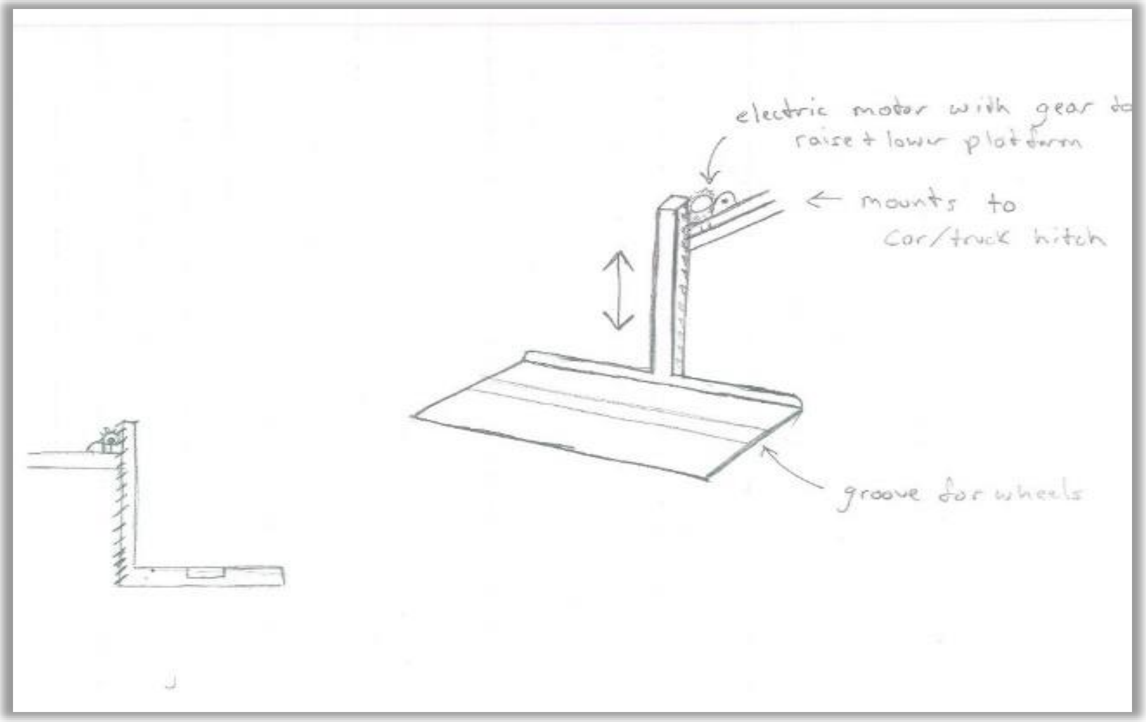


Figure 11: Early Concept

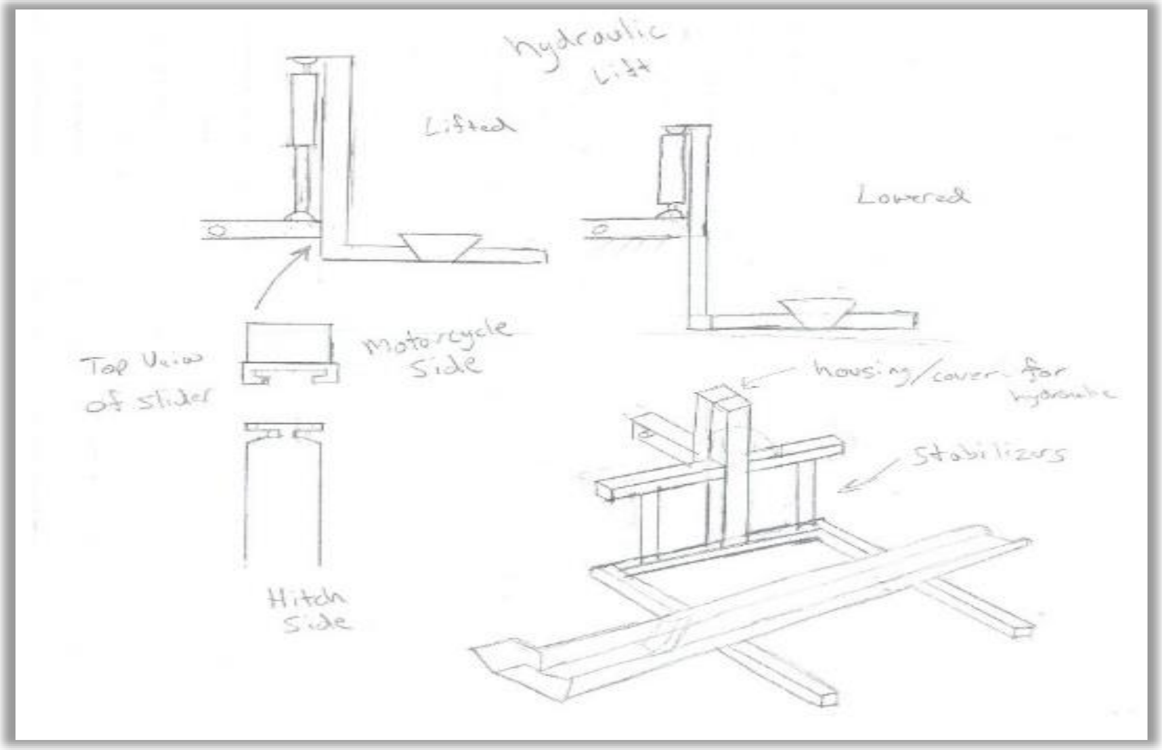


Figure 12: Early Concept

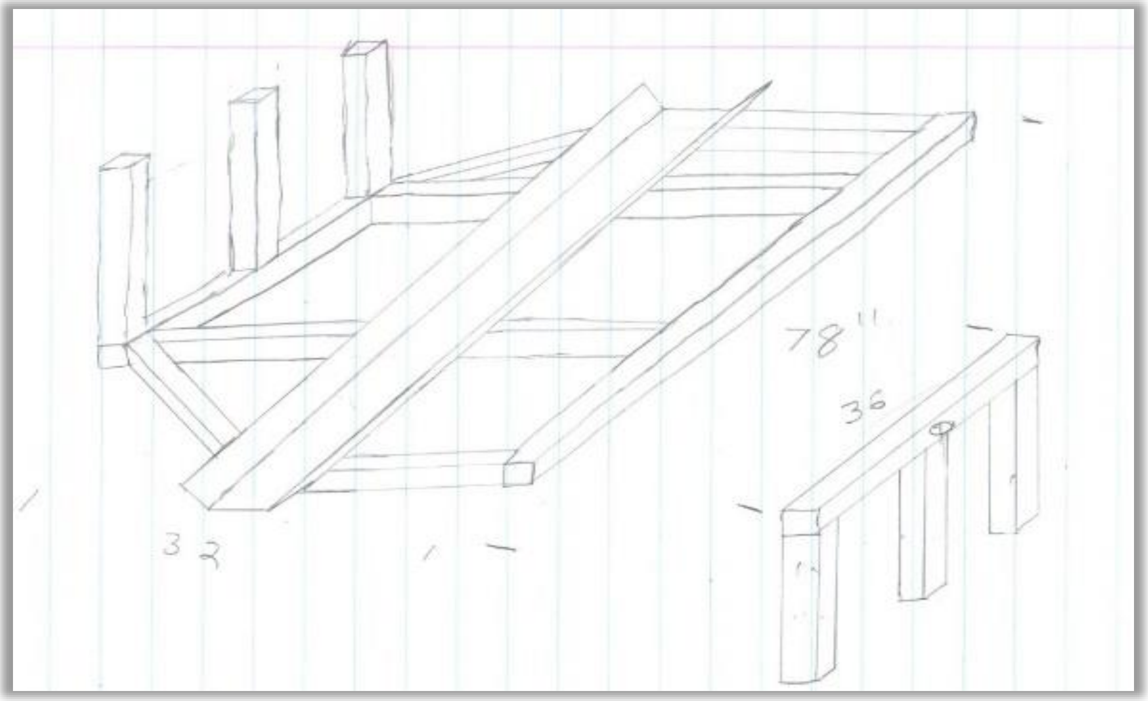


Figure 13: Early Concept

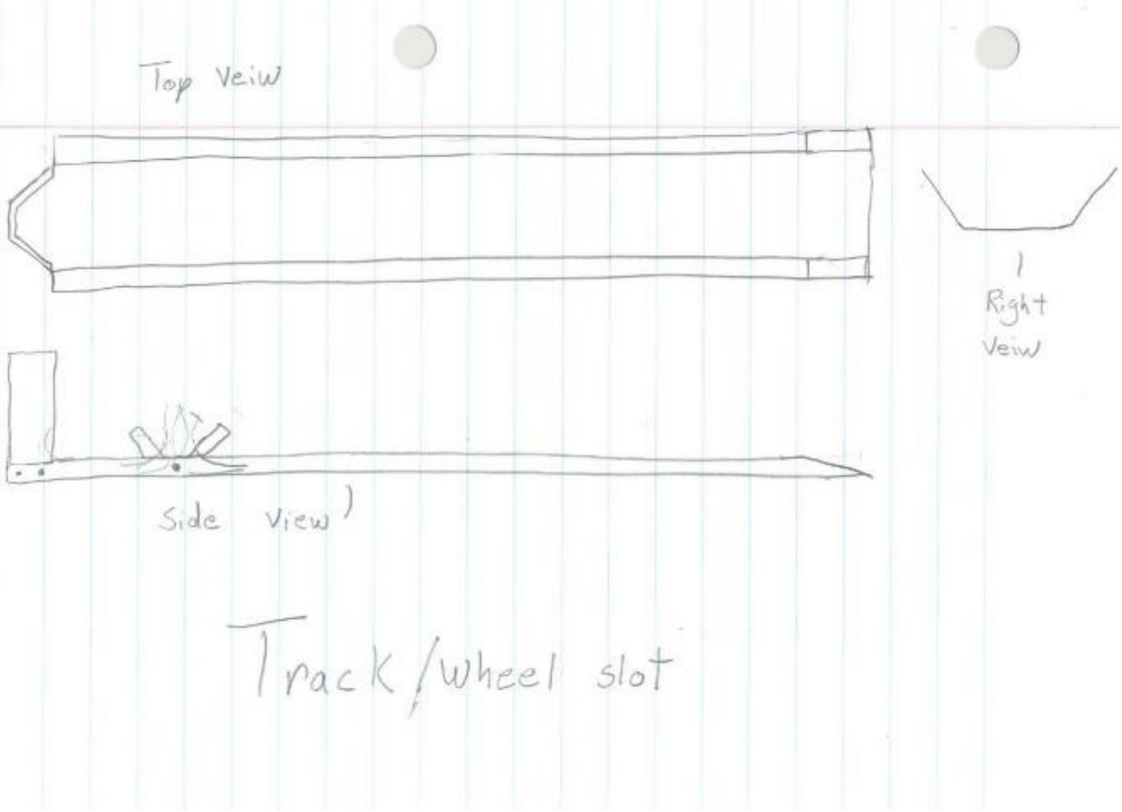


Figure 14: Early Concept

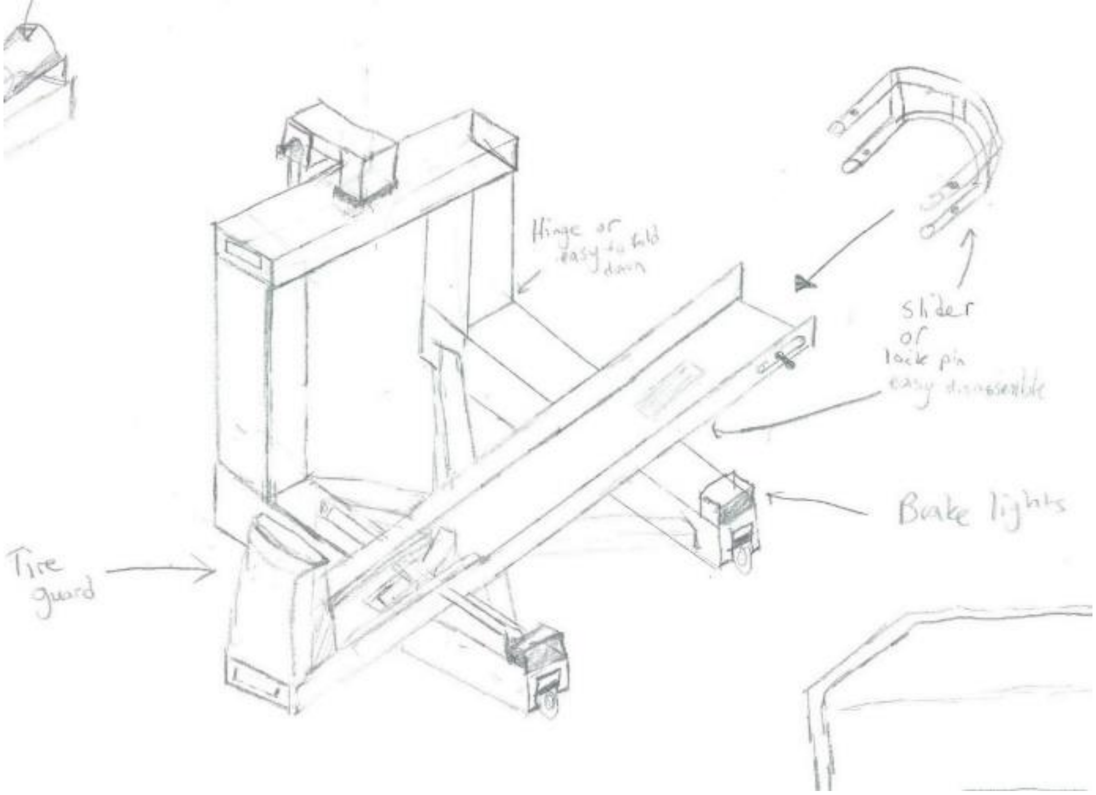


Figure 15: Early Concept

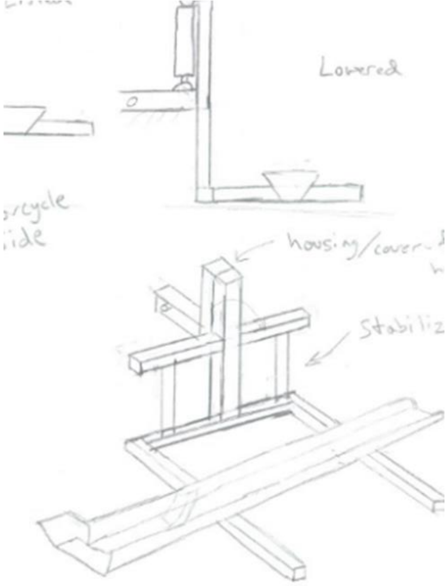


Figure 16: Early Concept

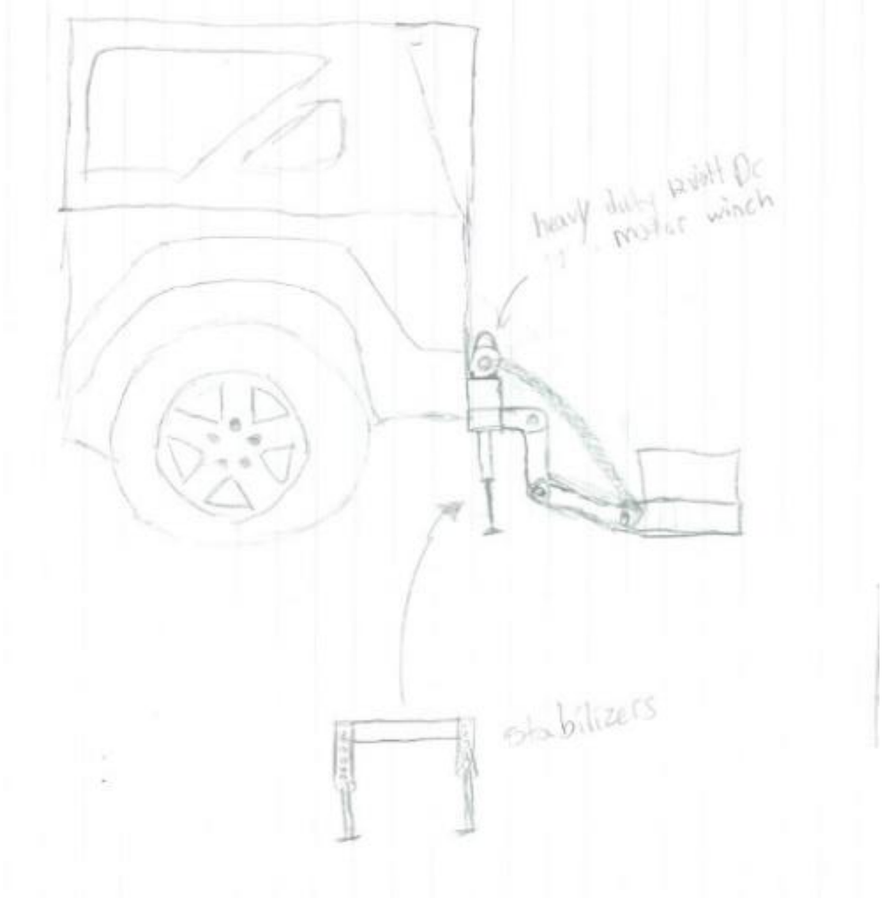
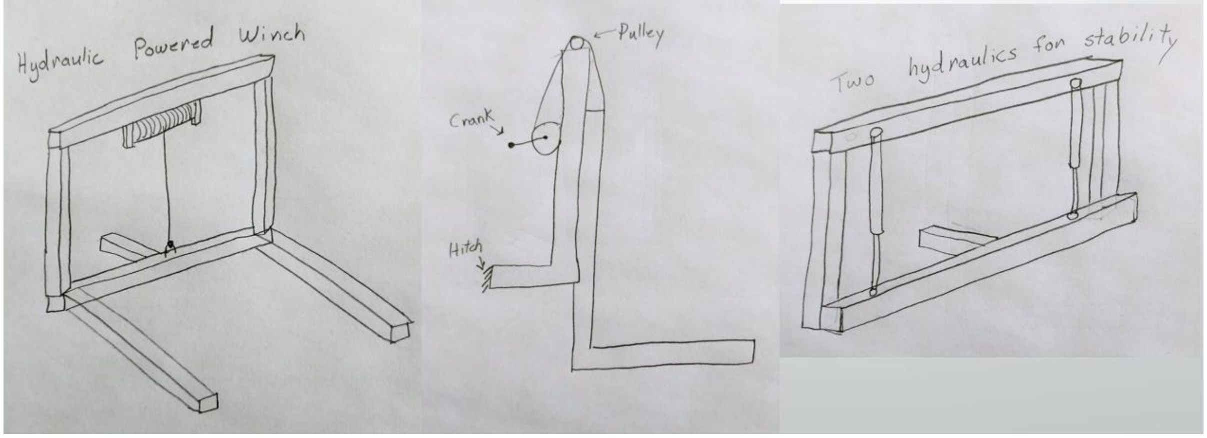


Figure 17: Early Lifting Concepts



APPENDIX B (CONCEPT DESIGNS MODELS)

Figure 18: Early Concept

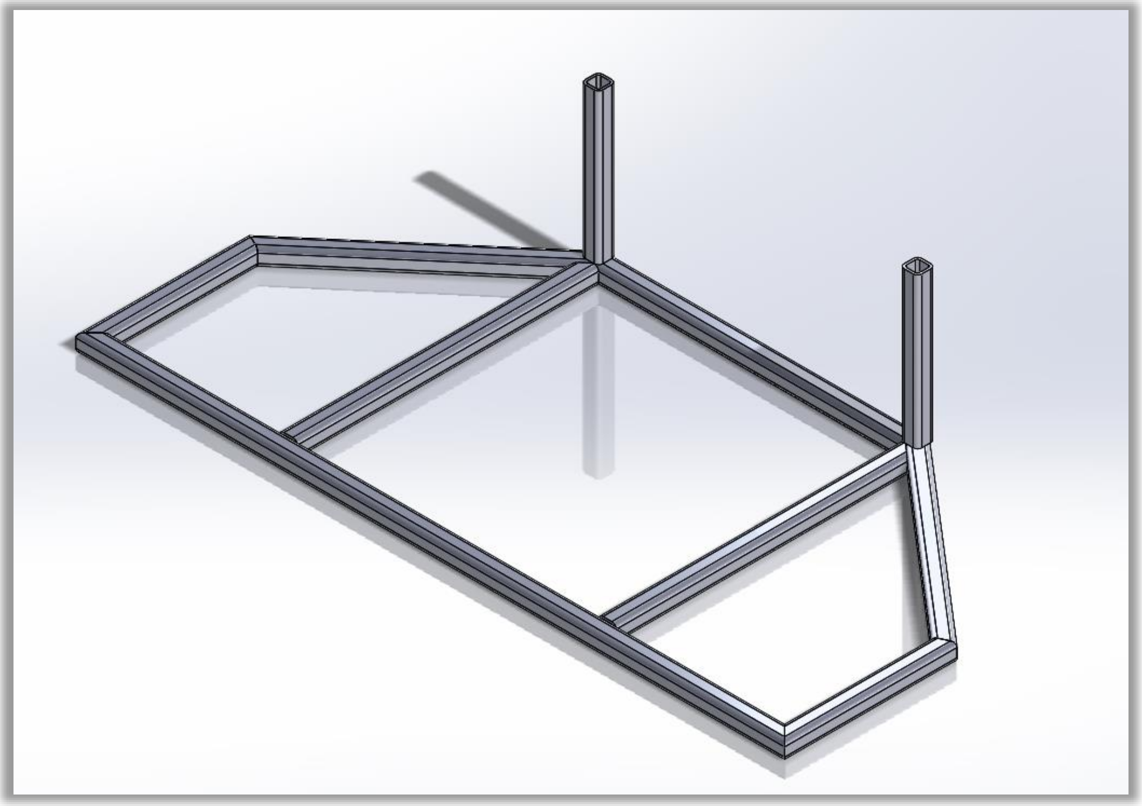


Figure 19: Early Concept

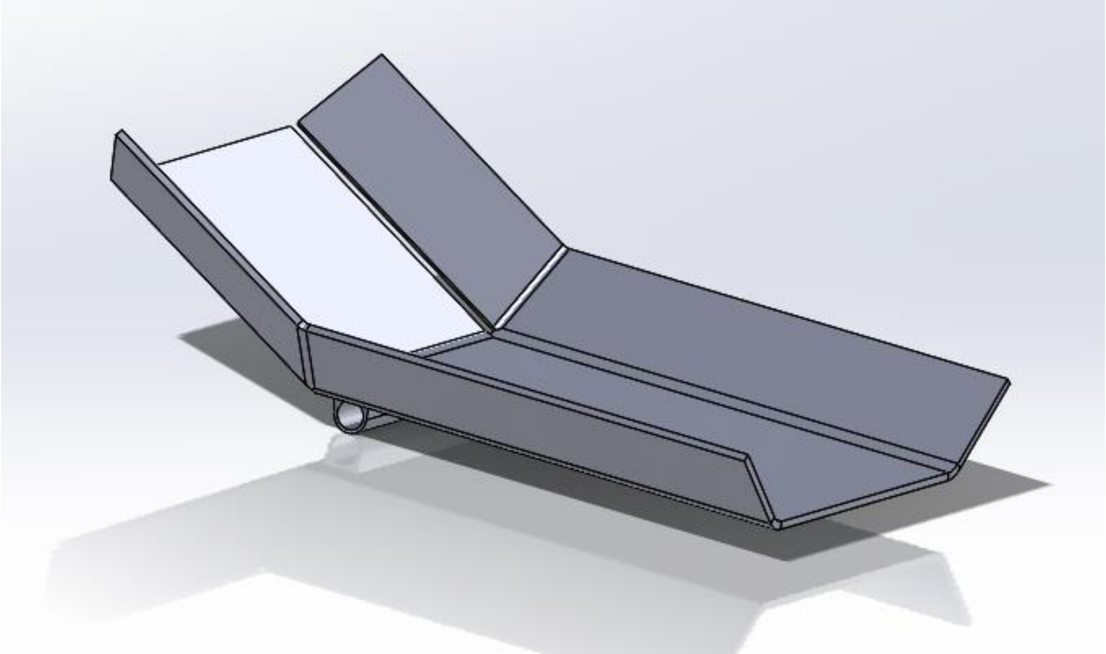


Figure 20: Early Concept

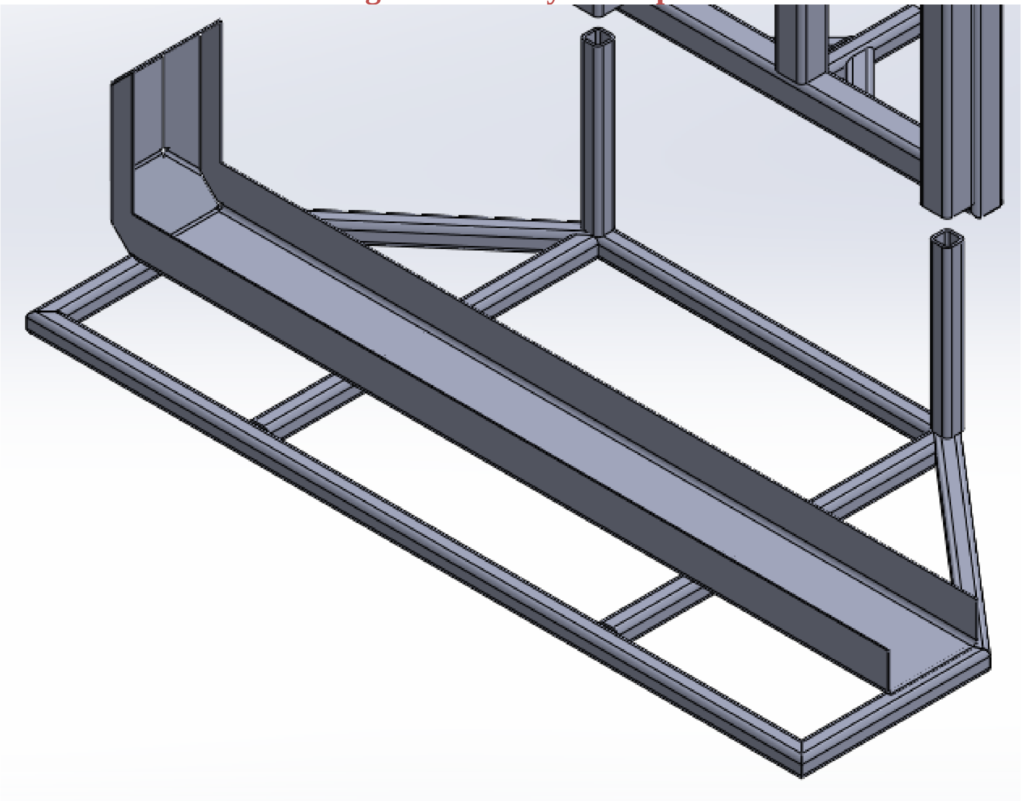


Figure 21: Early Concept

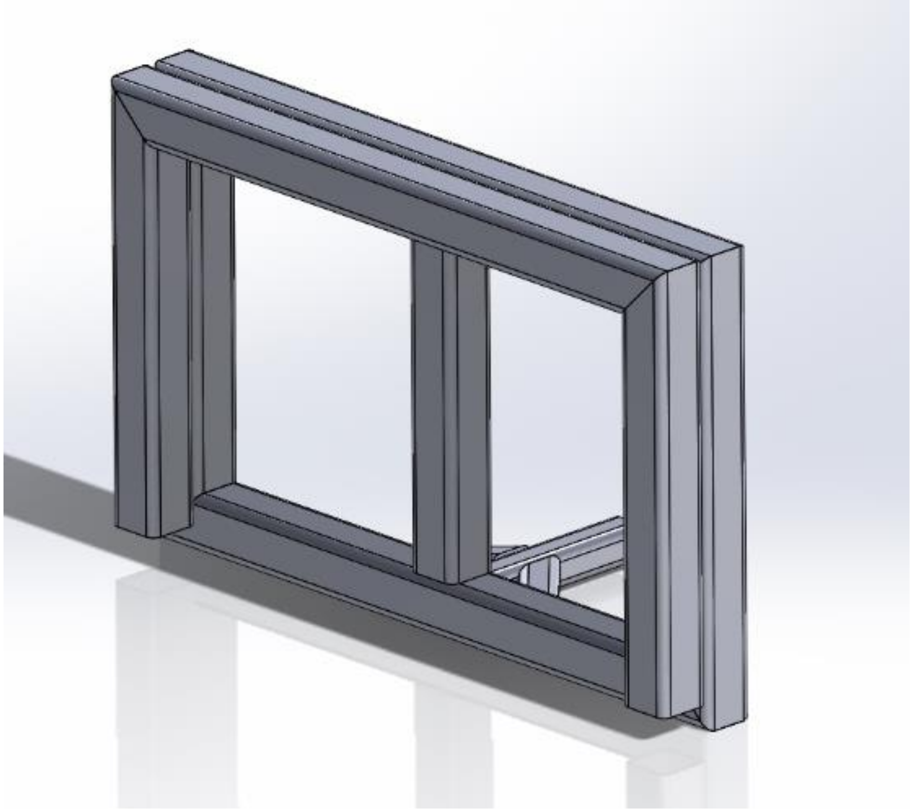


Figure 22: Early Concept

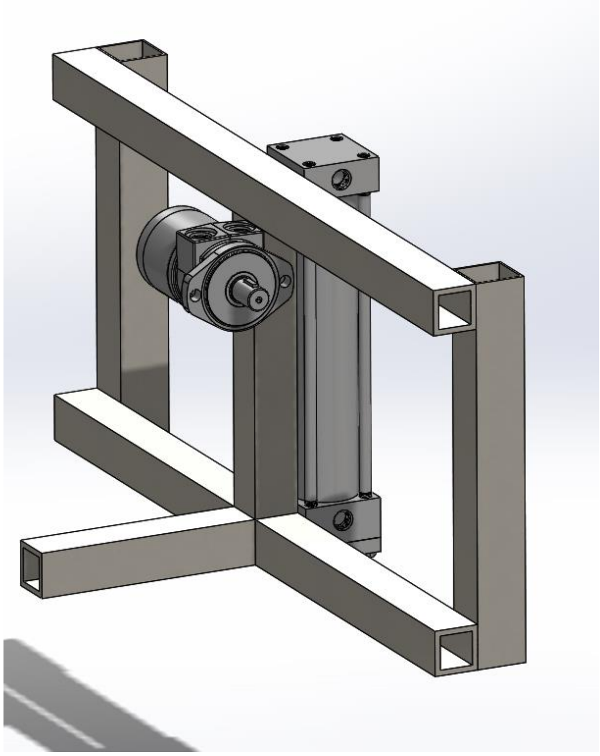


Figure 23: Early Concept

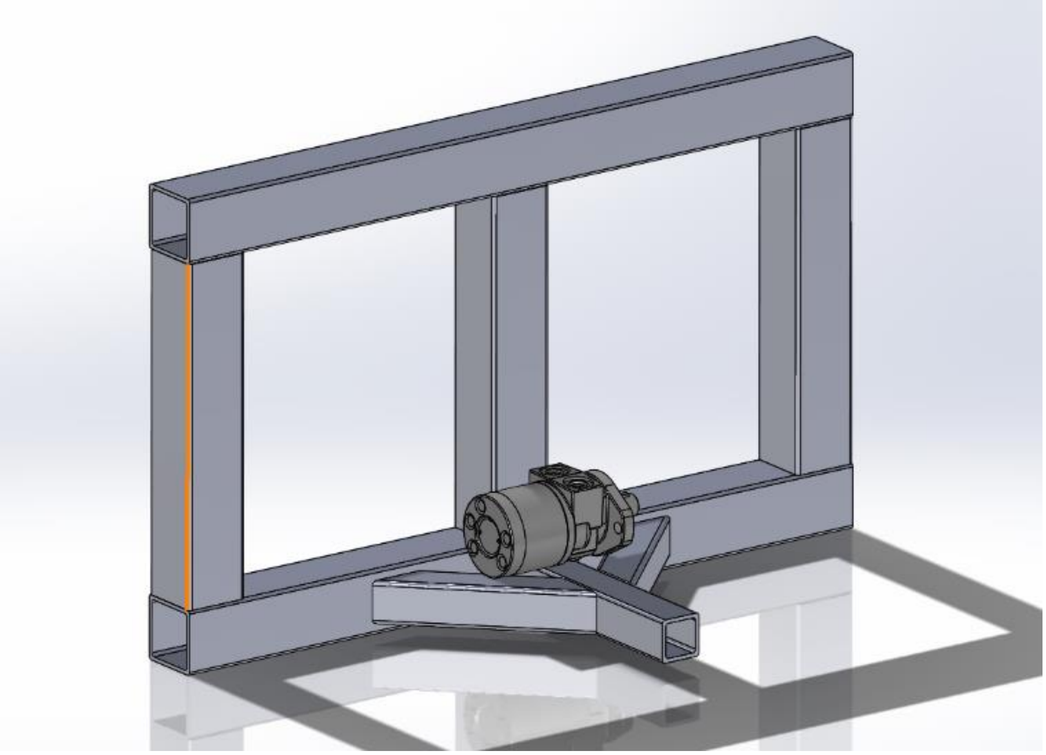


Figure 24: Middle Stage Upper Hitch

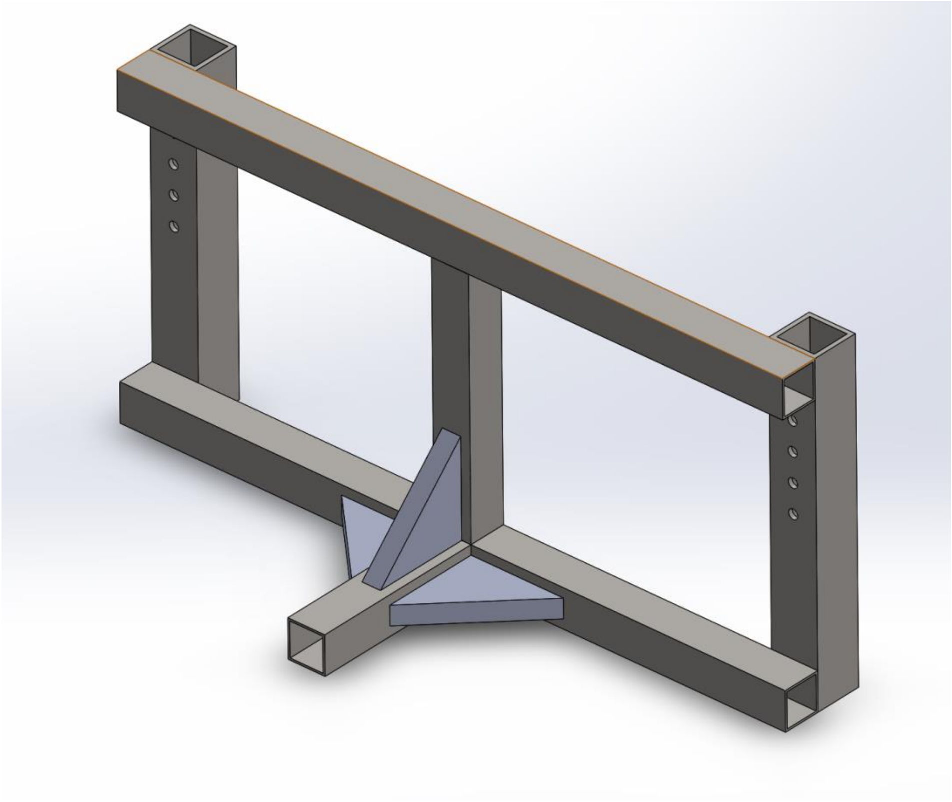


Figure : Final Stage Upper Hitch

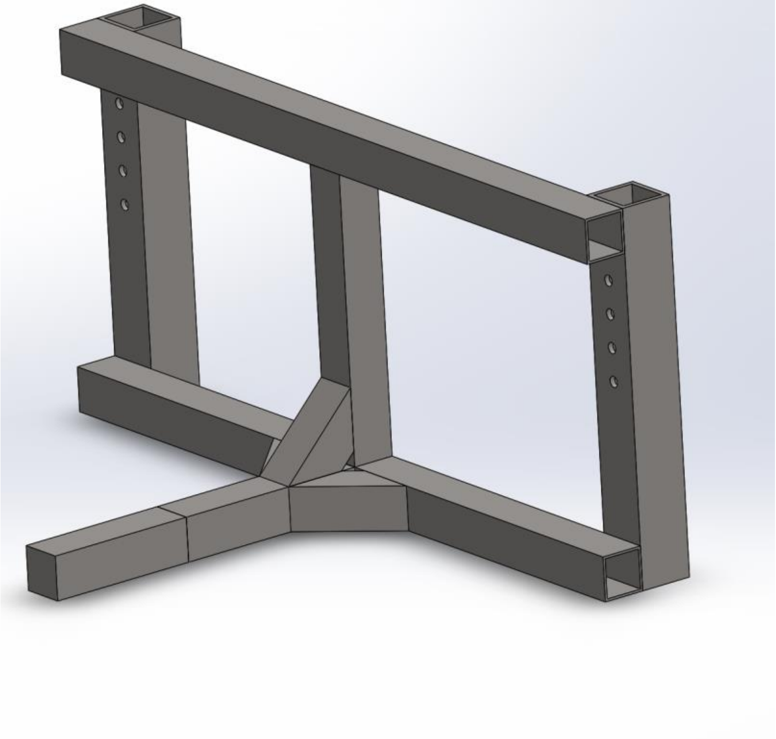


Figure 25: Final Hydraulic System

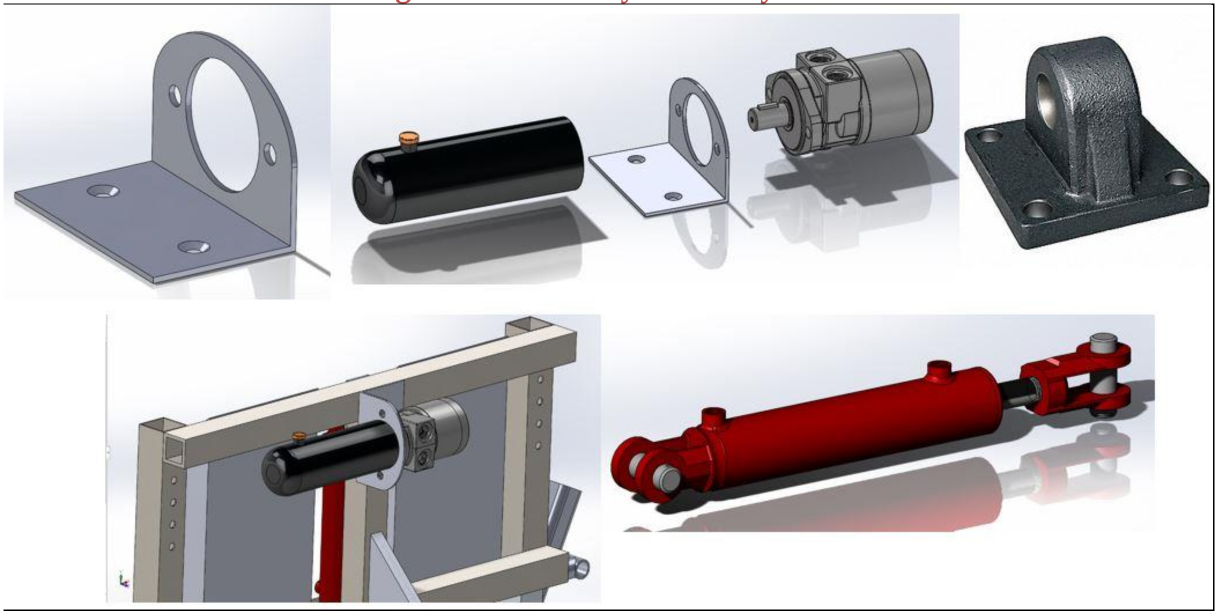


Figure 26: Bottom Frame Assembly (Final)

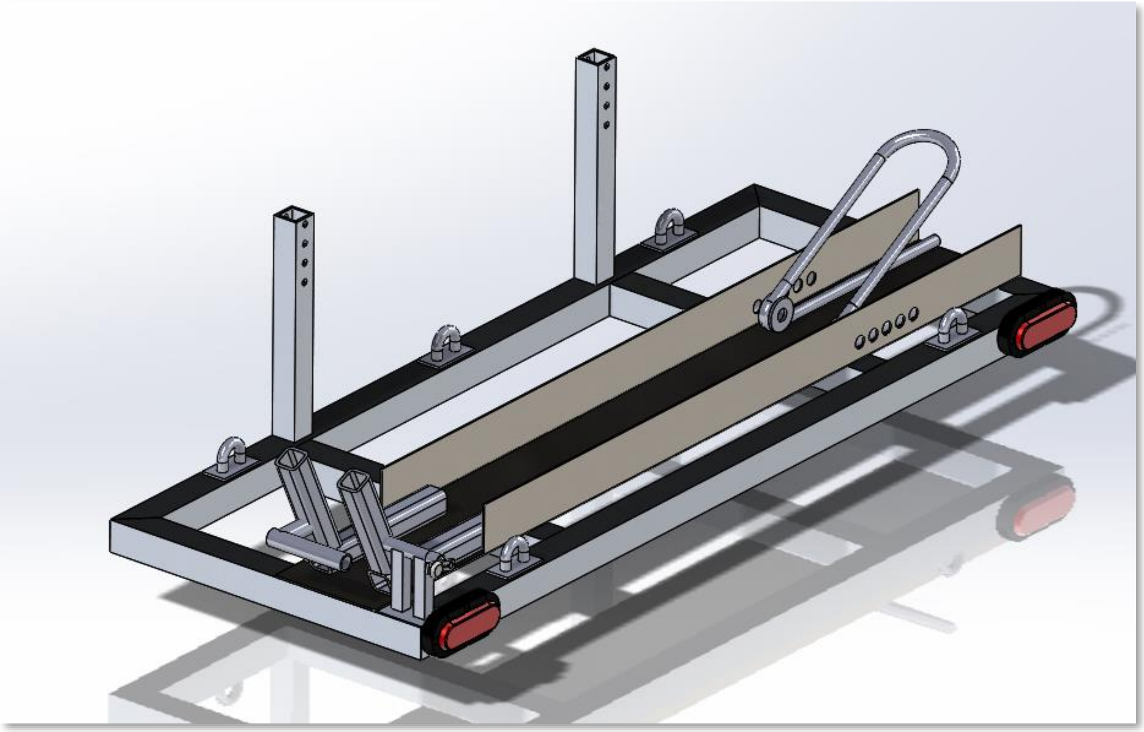


Figure 27: Final Frame Assembly (With Motorcycle)

APPENDIX C (STRESS ANALYSIS MODELS)

Figure 28: Bottom Frame Stresses (Bending)

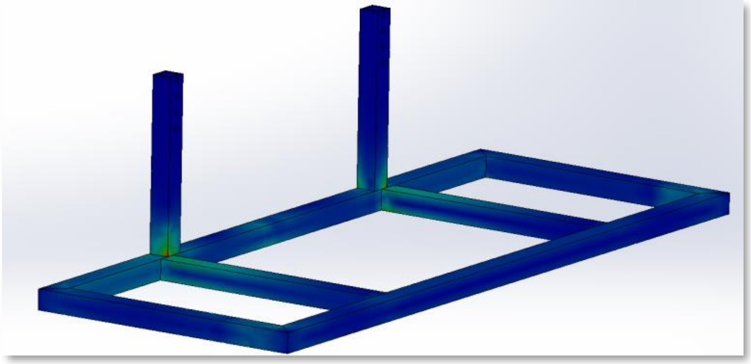


Figure 29: Bottom Frame Stresses (Bending)

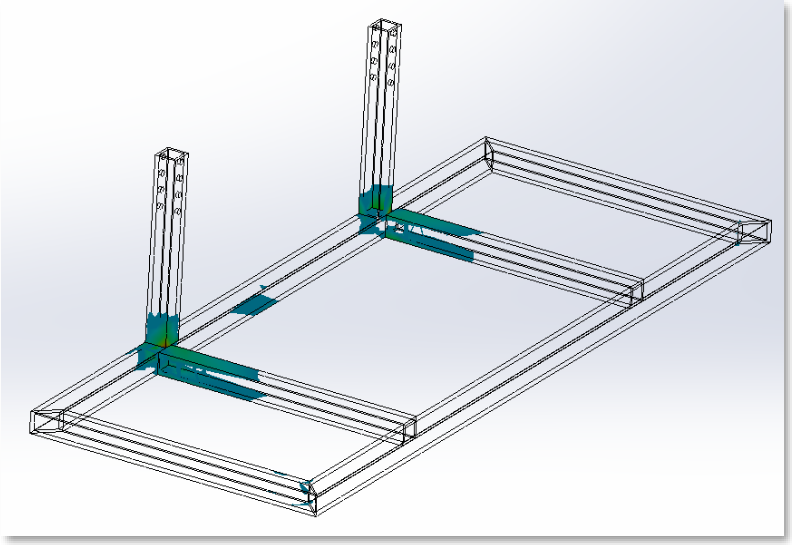


Figure 30: Bottom Frame Stresses (Deflection)

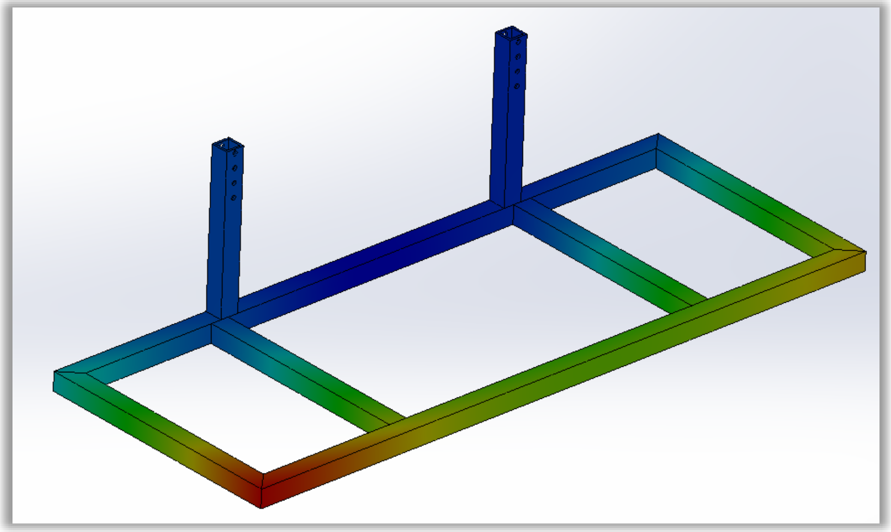
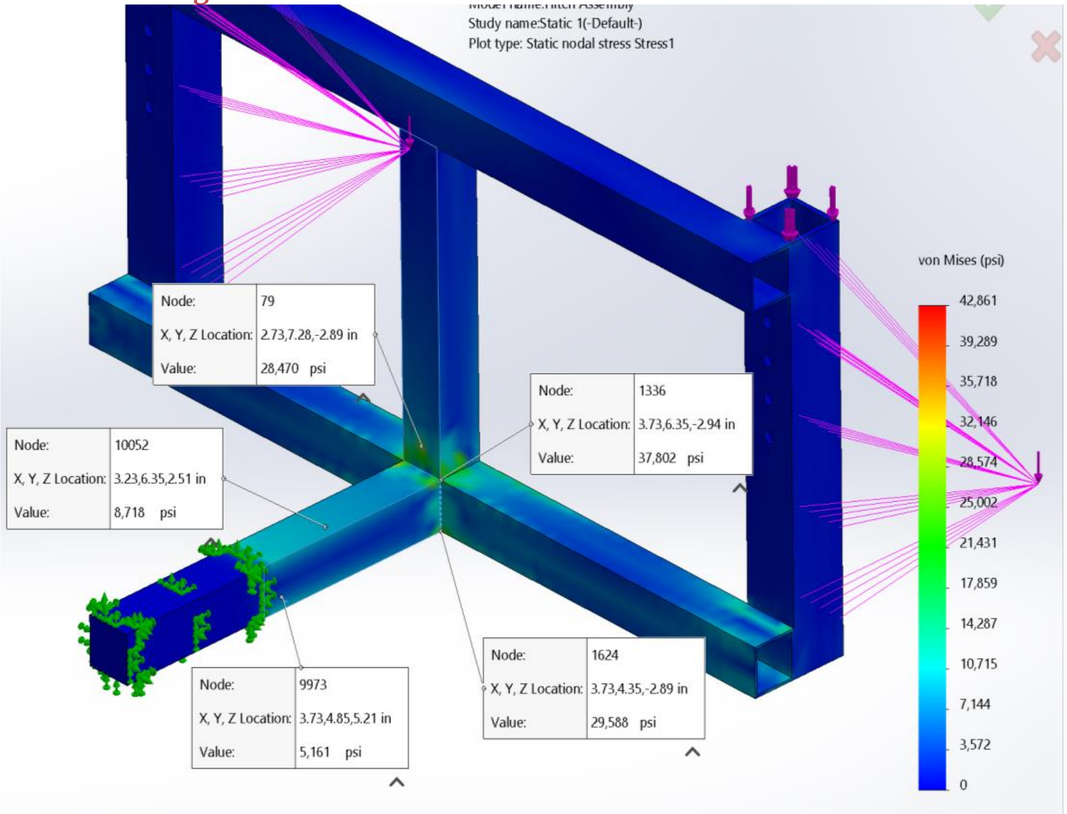


Figure 31: Stresses on Hitch Member without Gussets


Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1

Node: 79
X, Y, Z Location: 2.73,7.28,-2.89 in
Value: 28,470 psi

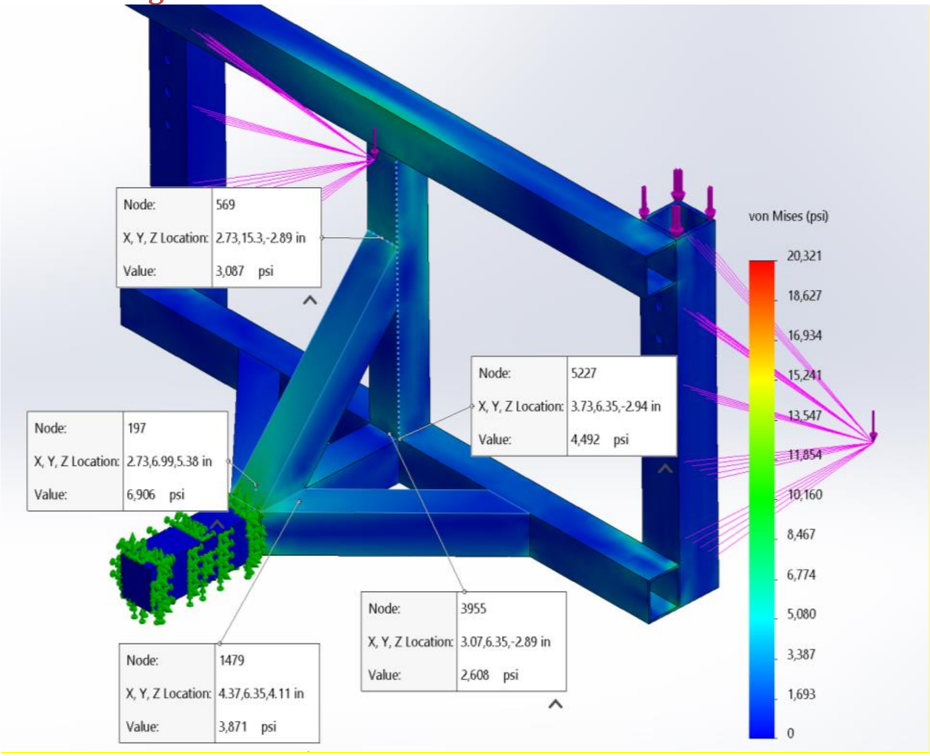
Node: 1336
X, Y, Z Location: 3.73,6.35,-2.94 in
Value: 37,802 psi

Node: 10052
X, Y, Z Location: 3.23,6.35,2.51 in
Value: 8,718 psi

Node: 1624
X, Y, Z Location: 3.73,4.35,-2.89 in
Value: 29,588 psi

Node: 9973
X, Y, Z Location: 3.73,4.85,5.21 in
Value: 5,161 psi

Figure 32: Stresses on Hitch Member with Gussets


Node: 569
X, Y, Z Location: 2.73,15.3,-2.89 in
Value: 3,087 psi

Node: 5227
X, Y, Z Location: 3.73,6.35,-2.94 in
Value: 4,492 psi

Node: 197
X, Y, Z Location: 2.73,6.99,5.38 in
Value: 6,906 psi

Node: 3955
X, Y, Z Location: 3.07,6.35,-2.89 in
Value: 2,608 psi

Node: 1479
X, Y, Z Location: 4.37,6.35,4.11 in
Value: 3,871 psi

Figure 33: Torsional Stress

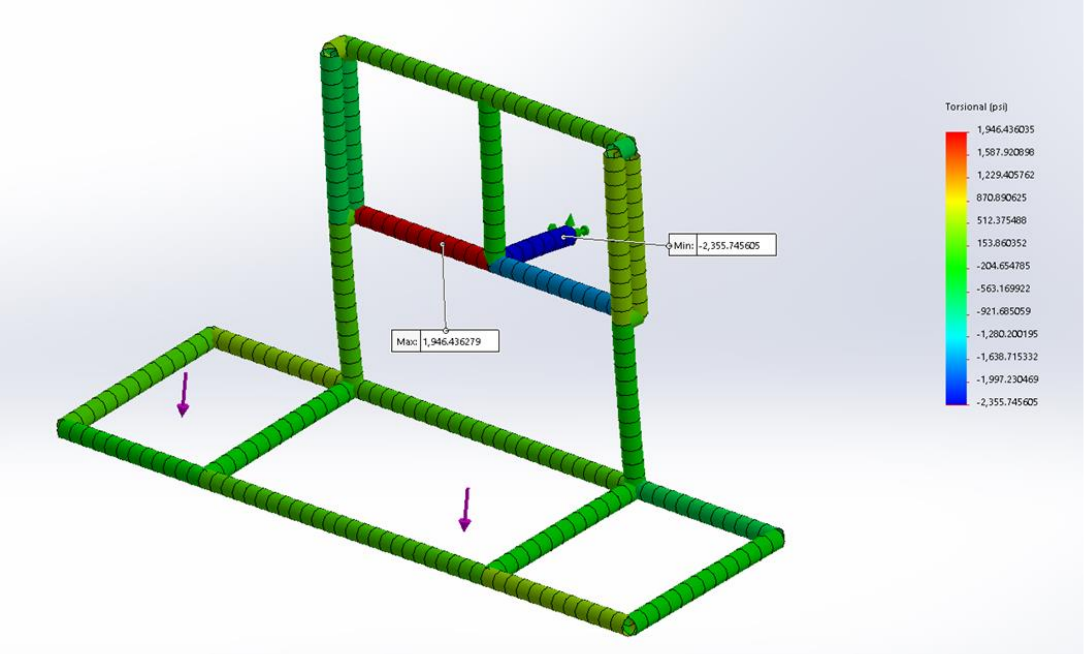
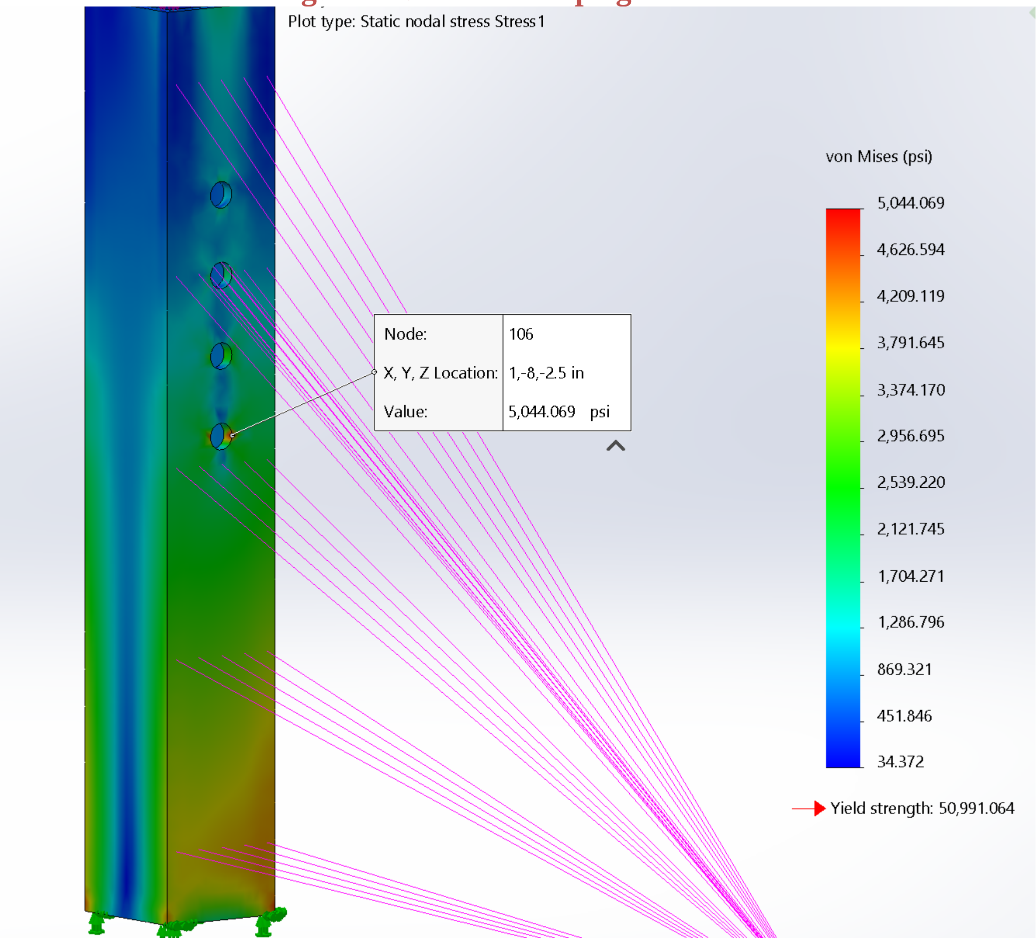
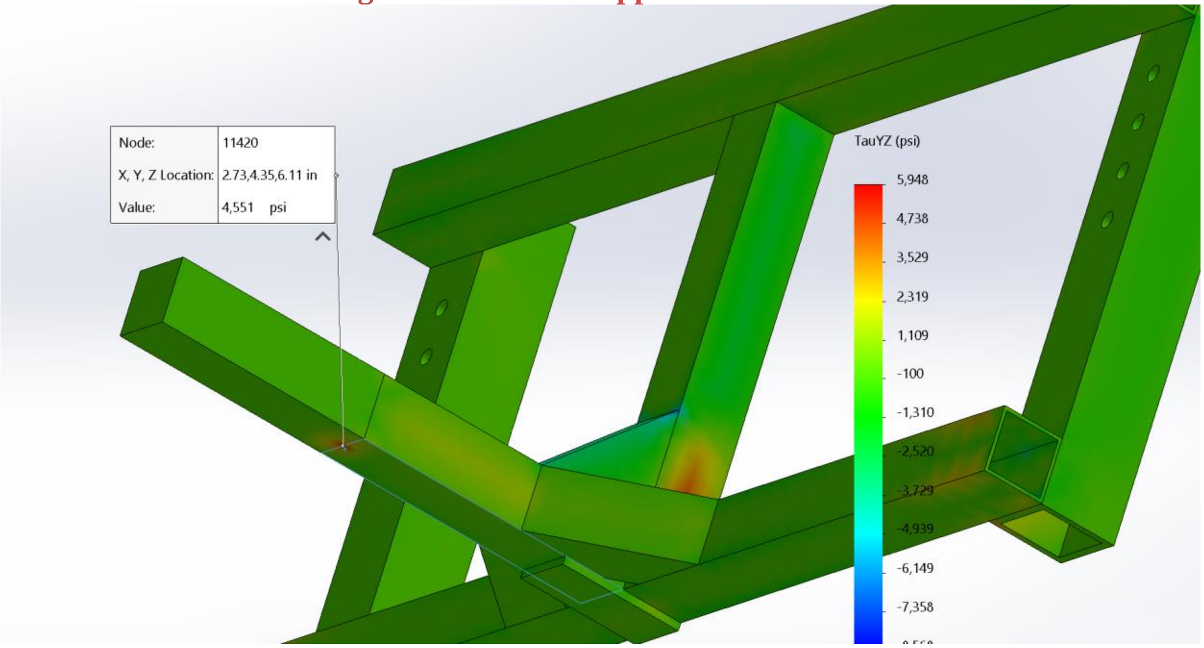


Figure 34: Shear on Upright Beams



Node:	106
X, Y, Z Location:	1,-8,-2.5 in
Value:	5,044.069 psi

Figure 35:Shear in Upper Hitch Frame



APPENDIX D (ENGINEERING DRAWINGS)

Figure 36: Front Wheel Chock

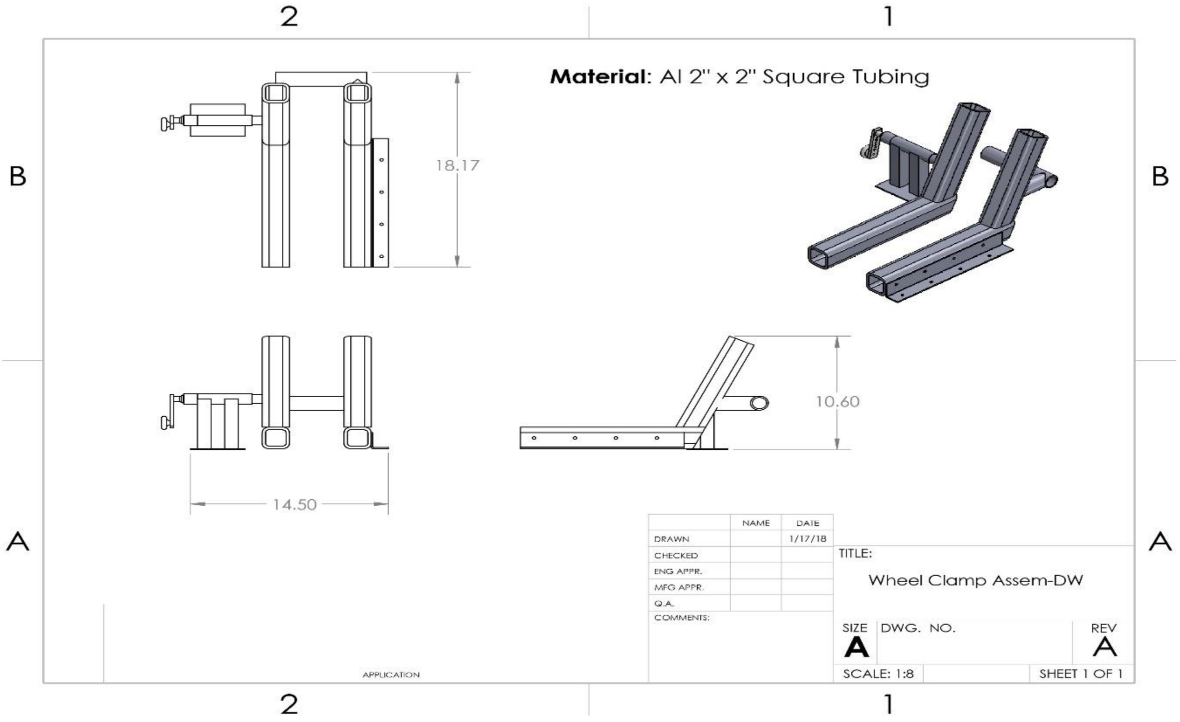


Figure 37: Bottom Frame Assembly

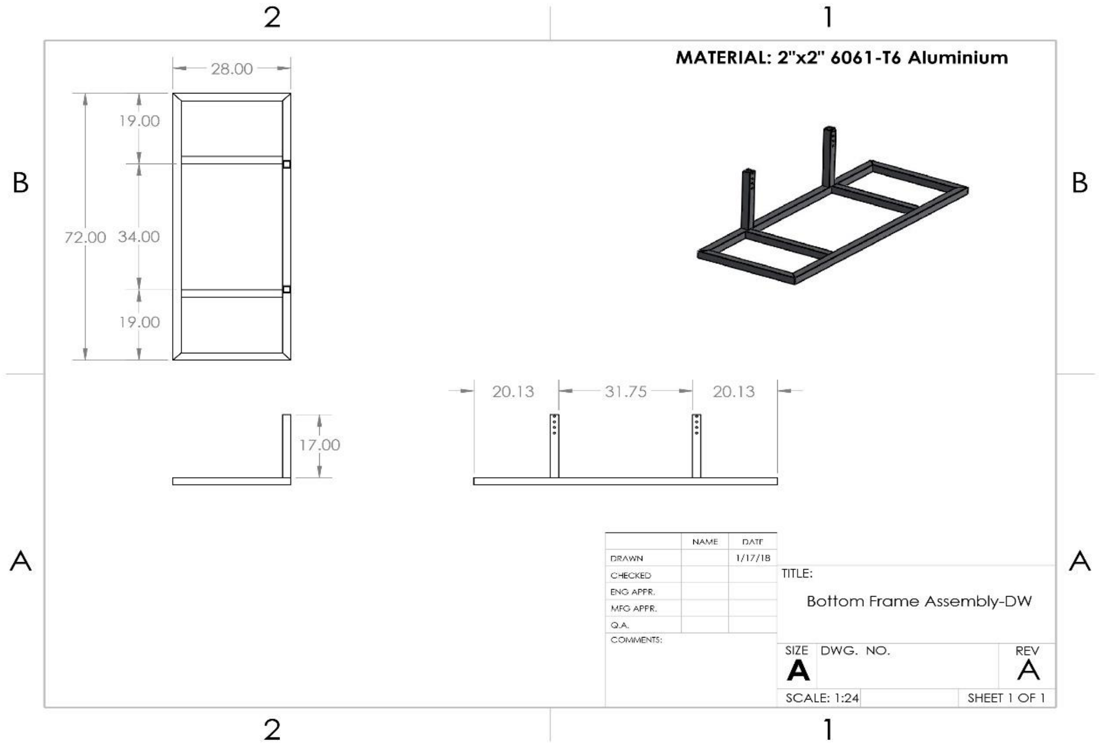


Figure 38: Wheel Rail

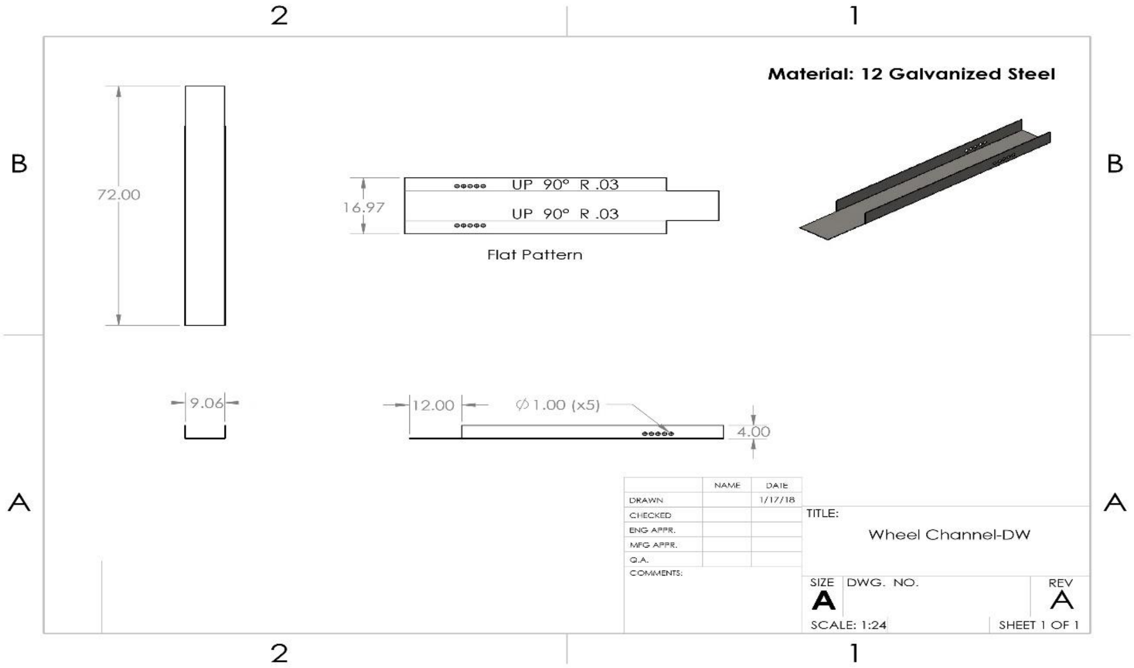


Figure 39: Rear Wheel Chock

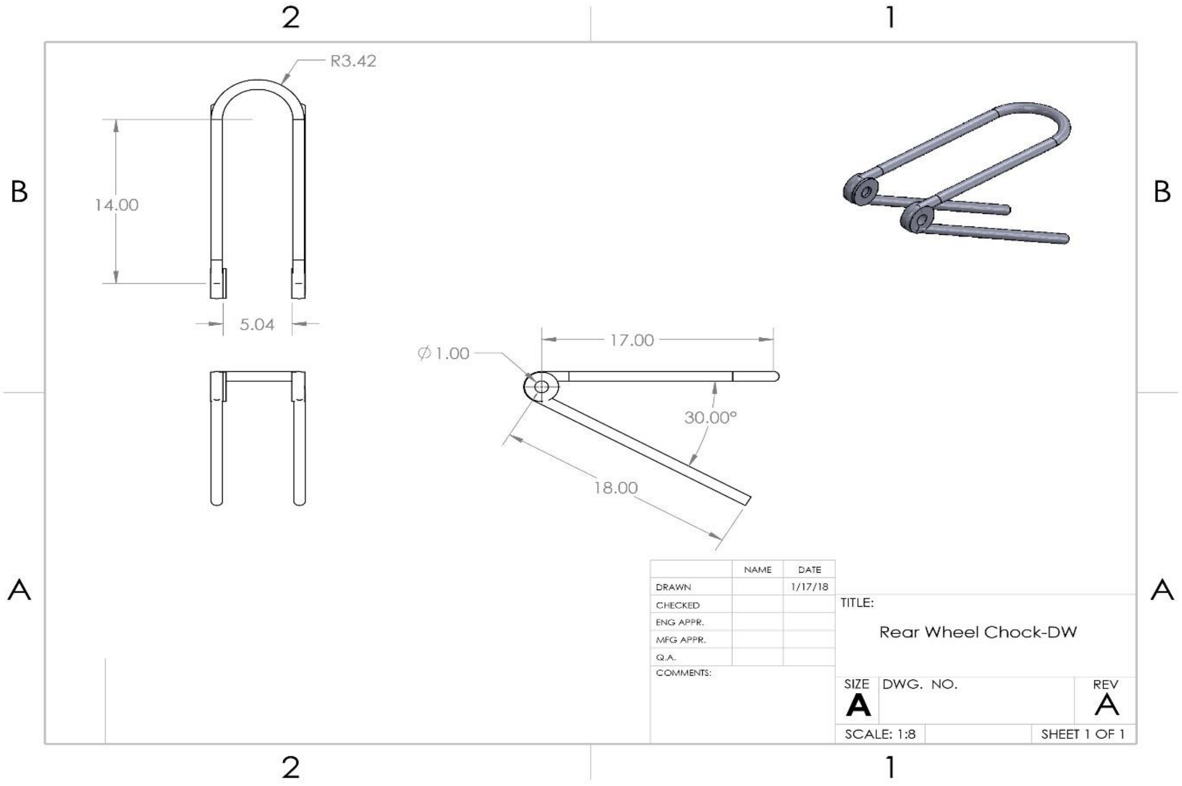


Figure 40: Upper Hitch Assembly

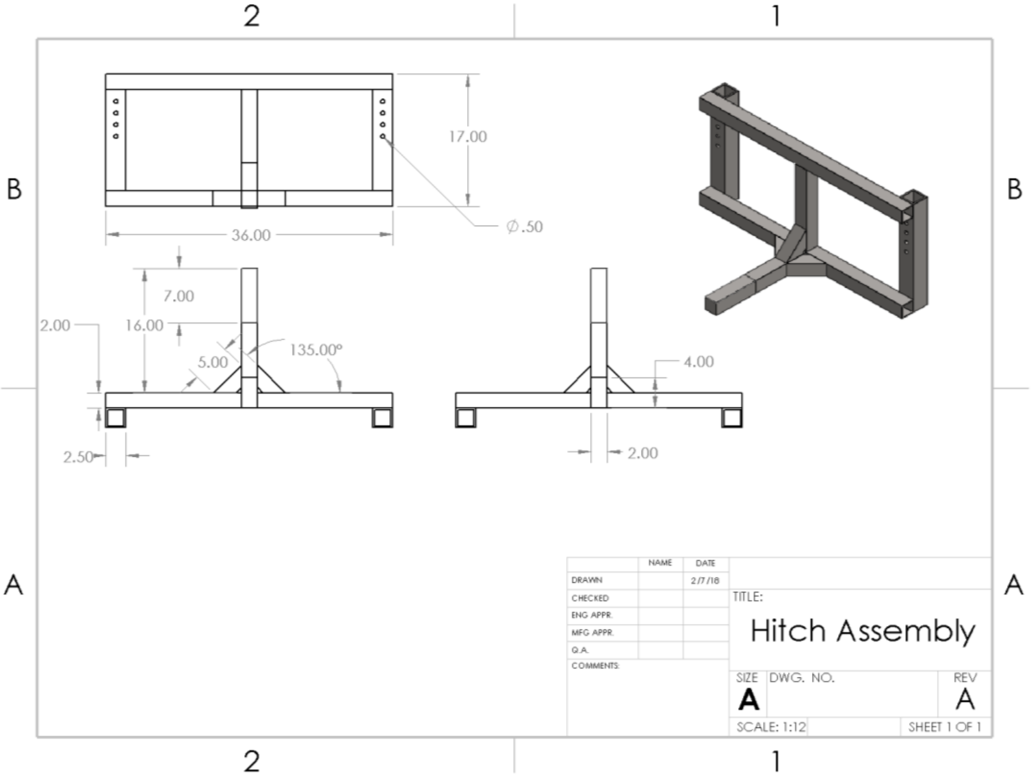
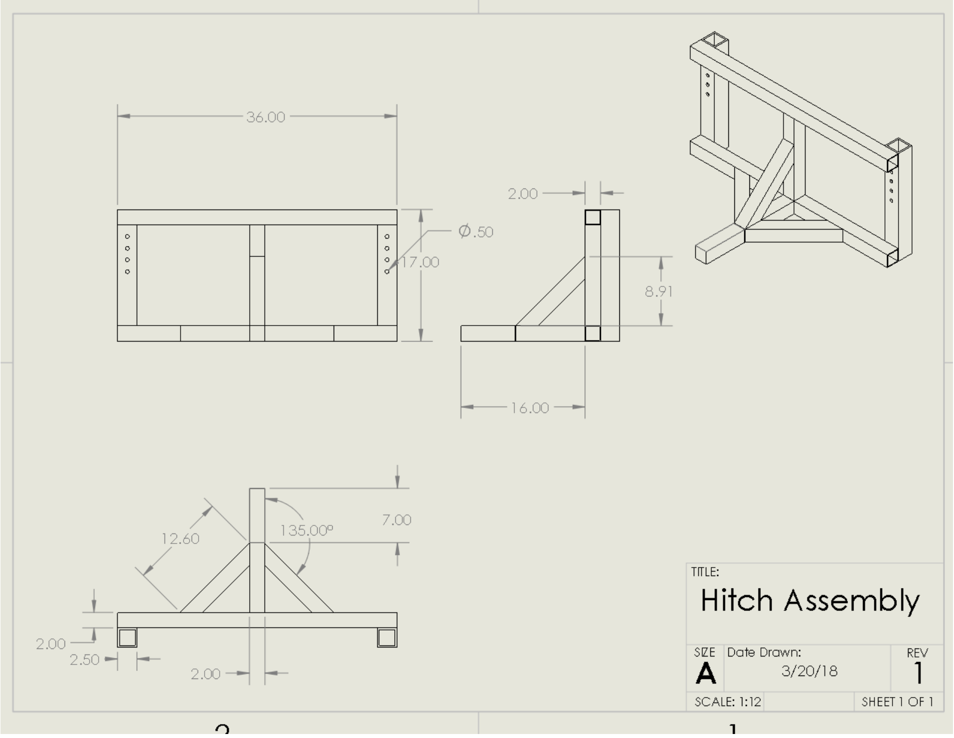


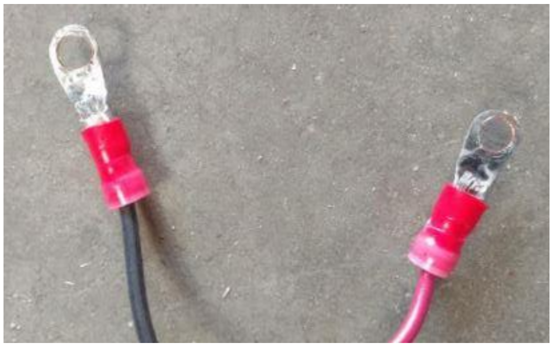
Figure 41: Final Upper Hitch Assembly



APPENDIX E (ASSEMBLY PHOTOS)

[redacted]


DGE
DAKO



DODGE
DAKOTA

DODGE
DAKOTA
4x4

TRIUMPH
TRIUMPH

DODGE

DODGE
DAKOTA