Agricultural Sprayer Tire Assist

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by

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ABSTRACT

The motivation for this project was to save time, effort, and to increase the safety for all employees when completed the job. Agricultural sprayers have two sets of tires, wide and skinny, that are required at certain times of the year. These tires are very heavy causing them to be difficult to handle and change. I wanted to make a device that allowed a worker to practically do the job from a seat of a tow motor. In my design, I included features that work using the side shift capability of the tow motor to squeeze the tire, rollers along the bottom to aid in the rotation of the tire, and a locking arm to ensure safety at all times of operation. I created my model using SolidWorks 2018. This program can easily do part models, part drawings, assembly models, assembly drawings, and any finite element analysis necessary. I was able to manufacture the device by welding steel together or bolting parts together. The device included a horizontal slide that allowed the operator to squeeze the tire during transport between the two sets of rollers and easily rotating the tire using the slide and rollers. The device also included a locking arm that was set using a set screw. The arm could be released and rotated out of the way to load/unload the tire. When the tire was loaded, the arm could be moved to secure the tire during transport and mounting to the sprayer.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

Changing and moving tires for a large agricultural sprayer is a multiple person task and can take a few hours to complete. I want to make a device to make the job a one-person job and to reduce the time it takes to change the tires.

BACKGROUND

Agricultural sprayers have two sets of tires that get used throughout the planting and growing seasons. One set are wide, while the other set is much skinner. The wide tires are used for unplanted, or barren fields to eliminate any grown weeds before the farmer plants their field. These wide tires are sometimes referred as "floaters" since the operator can drive at a rapid pace that makes it appear that they are "floating" above the field. The skinny tires are used when there is a crop growing in the field. These tires reduce the footprint left by the sprayer once the growing crop has been sprayed. Since the operator is spraying a growing field, they need to travel at a slower speed to leave as little of a footprint as possible. Both tires have the same diameter, only the width is different. Both sets of tires are needed, which requires the process of changing from one form of tire to the other. Currently this process takes 3-4 people along with a forklift. One person operates the forklift, two people balance the tire on the forks, and the other person aligns the tire to the hub so that the forklift driver can drive the tire onto the hub. The time of this process varies but usually takes 45 minutes to an hour to complete all four changes. Along with the lengthy process, the current process offers a slight safety risk if the tire would happen to roll of the forks during travel. The workers balancing the tire along with the operator must be focused not to let the tire roll.

RESEARCH

SCOPE OF THE PROBLEM

I want to make the job of changing tire less strenuous and more time friendly. I am addressing this problem because I am a previous employee of Glandorf Warehouse Inc. and was often tasked with completing this job. Currently the process is simply leaning the tires onto the forks of a tow-motor with two people walking alongside to balance the tire. The tire can not be moved easily, making the task of locating the hub bolts challenging.

CURRENT STATE OF THE ART

Currently there are wheel dolly's that are large enough to store two of the four tires when they are not on the sprayer. Along with the dolly's are highly rated jacks to help hold the machine when performing the tire change, both manufactured by Bierman Sales LLC. (1) These devices are primarily storage options for the large agricultural tires. Bierman Sales

LLC does not offer any devices to help change the large tires, specifically a sprayer tire.

Agri Supply makes a multi tire changer that appears to be pretty effective, however it's maximum size is 16.5" in overall diameter. (2) This is an issue because the size of an agricultural sprayer tire is 81" overall diameter. (3) Since Agri Supply's changer is much smaller, it is also very under sized when it comes to being able to hold a larger sprayer tire.

GVM makes a tire changer, and since they are a specific agricultural sprayer company, it would be perfect for any farmer looking for a tire changing device. There is only one issue, it ranges from $3,800-$4,200 in price depending on the size of the changer. (4) This is expensive for only needing the device in the spring and fall for 3 agricultural sprayers.

Using Glandorf Warehouse's current tire changing system, the process takes roughly an hour for each sprayer. The company would not use GVM's tire changer enough to get their money's value for buying the changer.

END USER

The end consumer needs a device that will allow them to change the sprayer's tires without any needed assistance. The major target audience is any farmer that needs to spray many acres throughout the planting and growing seasons. They will be someone who does not want to waste a lot of time maneuvering the tires to fit perfectly on the hub of the sprayer. They are expecting a changer that will get the job done in a timely fashion with no safety risks. They will be someone who does not want to spend thousands of dollars on a changer for the limited number of times it will be used.

CONCLUSIONS AND SUMMARY OF RESEARCH

There are multiple tire changers for a variety of different sized tires, most of which were too small for the application needed for this project. The only real useable tire changer found was the one offered by GVM. The customer would be interested in the GVM product; however, it is quite costly and would be more suitable for a tire manufacturing company, or someone who would be handling multiple tires daily. The Agri Supply changer is more suited for smaller tires, such as a planter tire or lawnmower tire, not necessarily a large tractor or sprayer tire.

CUSTOMER FEATURES

From research online, there has been a few features that the manufacturers think are important. The following are the features, with their respected weight: one/two-person job (weighted .25/1.00), tire manipulation to locate lug bolts (weighted .20/1.00), ease of tire loading (weighted .15/1.00), travel speed with tire loaded (weighted .15/1.00), system to secure tire from tipping (weighted .15/1.00), and how easy to load/unload device to a forklift (.10/1.00).

PRODUCT OBJECTIVES

To address eliminating two people from the current process to change the tires, I want to design a device that will hold the tire from rocking side to side. This will eliminate two people since they will no longer have to walk along and maintain the balance of the tire across a stone lot. In my design, I want to use rollers along the bottom sides of the tire, and using the side shift feature of the forklift, locate the lug bolts. Tire loading will be similar to the current way of picking up the tires. The next two features will work together in the fact that rapid travel will require limited tire movement, and with limited tire movement there should be no work-related accidents. Along with the bottom rollers, I plan to secure the tire at the top as well. This will prevent the tire from wanting to fall away from the forklift onto a worker lining up the lug bolts to the hub. Finally, I want to make it easy to put on forklift forks with the operator still in their seat.

QUALITY FUNCTION DEPLOYMENT

Based on my House of Quality, a secured tire during travel (relative weight: 21.3) will take top priority followed by eliminating additional help(relative weight: 20.7), safety from tipping (relative weight: 19.5), having bottom rollers (relative weight: 19.5), and lastly how well it fits/ease of attaching to a forklift (relative weight: 19.0).

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	1 Fits on forklift or other device with forks	2 Eliminate helpers during travel	3 Bottom Rollers to Locate Lug Bolts	4 Secured Tire during Rapid Travel	5 Saftey Device to keep Tire from Tipping	6	7	8	9
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)									
1	9	25.0	0.3	One/Two Person Job	▲	Θ	O	▲	O				
2	9	20.0	0.2	Ease of Locationg Lug Bolts	▲	▲	Θ	▲	O				
3	9	15.0	0.2	Tire Loading	Θ	▲	▲	O	▲				
4	9	15.0	0.2	Travel Speed when Loaded	O	O	▲	Θ	O				
5	9	15.0	0.2	Saftey from Tipping	▲	O	O	Θ	Θ				
6	9	10.0	0.1	Load/Unload from Forklift	Θ	▲	▲	▲	▲				
7													
8													
9													
10													
				Target or Limit Value									
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	3	6	6	7	7				
				Max Relationship Value in Column	9	9	9	9	9				
				Weight / Importance	330.0	360.0	340.0	370.0	340.0				
				Relative Weight	19.0	20.7	19.5	21.3	19.5				

Figure 1

DESIGN

Design alternatives and selection

There were two designs being considered. Option one was a device that could be picked up by a tow motor with rollers all the way across the bottom that the tire would sit and ride on. Option two was a device that a tow motor could pick up but have four adjustable arms to grab and secure the tire. After meeting with Glandorf Warehouse Inc, a design combining parts of the two designs was formed and was ultimately the design chosen. The design offers the rollers along the bottom to assist in tire rotation, but the rollers are at an angle that was offered in the second design consideration. The design also implemented an adjustable arm that would grasp the whole tire instead of only two points on the tire. The design picked will require less work for the operator and greatly increased the safety factor than the two proposed designs.

Drawings

Overall Dimensions:

Maximum diameter of tire that would fit: 57 in.
Minimum tire diameter that would fit: 11.5 in.
Average dimeter of sprayer tire: 53.5 in.

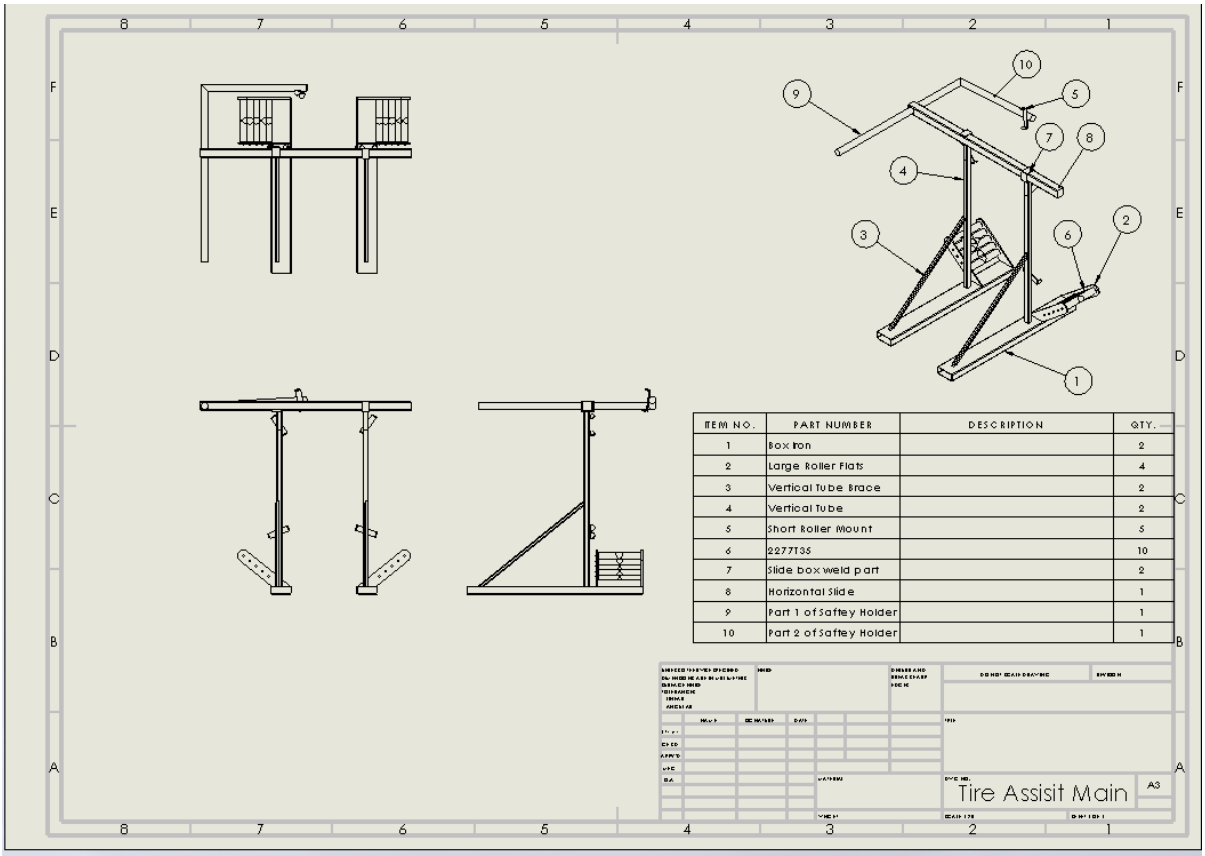

Figure 2

Loading Conditions

I needed to determine the weight of the box iron that the tire will be sitting on, along with the four angle pieces that the rollers mount in. The box iron dimensions are two 4ft and 3/8" long 6x2.5x1/8 (1) and the roller piece dimensions are 3.25x15x3/8 (2). The first calculation can be made 8 ft. 6x2.5x1/8 = 51.68 lbs./ft. (1). The second calculation can be made 3.25x15x3/8 = 5.4*4 = 21.65 lbs./ft. (2). The total weight then equals 73.33 lbs./ft. under the weight of the tire. The area the load is applied is 12.75x47.75 giving 608.8 squared inches. The tensile strength of box iron is 40020 pounds per square inch. Dividing the weight by the area give us a tensile strength of 12.22 pound per square inch. The tensile strength of the flat bar is 95000 pounds per square inch. Dividing the weight by the area gives us a tensile strength of 5.11 pounds per square inch.

Design Analysis

I completed a FEA test using Solidworks for one of the rollers I plan to purchase. I picked a factor of safety of 3.0 reason being that if the device would fail, someone could potentially get injured. With The design factor, the weight used in the analysis was 1500 lbs., but was divided in half since there are two sets of rollers supporting the tire. The yield strength of the roller resulted in 29,573 $\frac{lbs.}{in^2}$. Justifying the yield strength due to 4 rollers being in contact with the tire when it is loaded, the galvanized steel roller should be suitable since it has a yield strength of 88,473 $\frac{lbs.}{in^2}$.

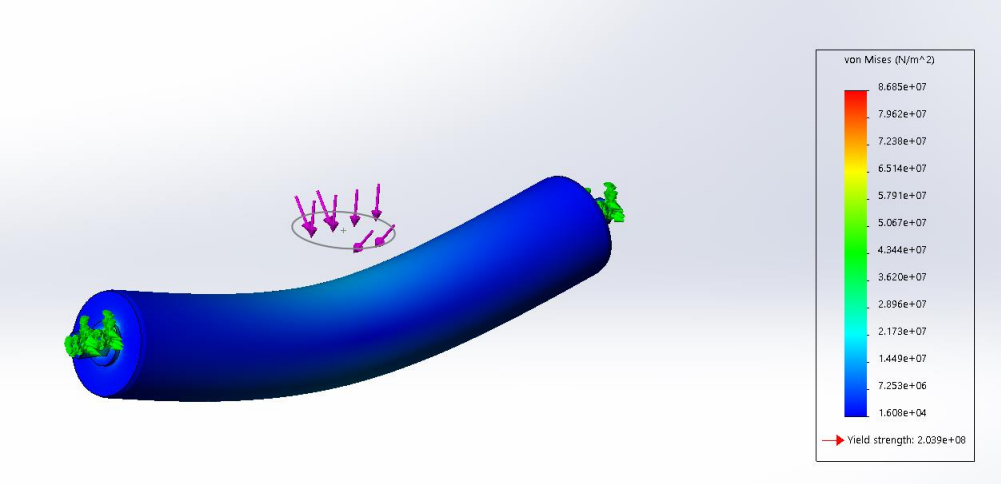

Figure 3

I also ran a FEA analysis using Solidworks on the vertical box iron. Reason behind this test was in the case the tire would tilt toward the forklift mast during travel, I need to know how much deflection there would be. The distance the tube stands past the weld brace is 24.5 inches, but the tire would be leaning towards the top of the tube so I chose to analyze the last 5 inches since that will be the furthest cantilever section. Using the same 750 lbs. on the last 5 inches resulted in a yield strength of 41,002 $\frac{lbs.}{in^2}$. The yield strength of cold rolled steel is 70,000 psi, which satisfies the yield strength for the vertical beam.

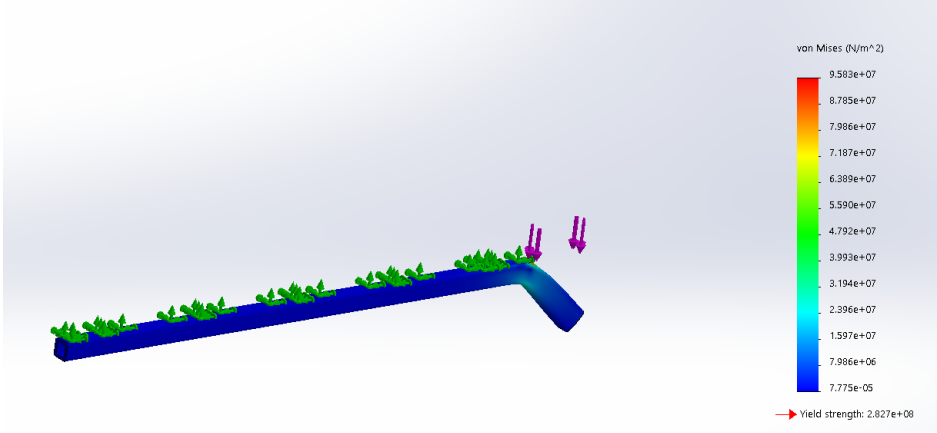

Figure 4

Lastly, a FEA analysis of the locking arm was conducting using Solidworks. I needed to be sure the locking arm would withstand the weight of the tire if the operator had to suddenly come to a complete stop and the tires momentum would continue away from the operator. The locking arm was made of two pieces of round bar steel with a diameter of 1.875 in. welded together at a 45-degree angle. Using the 750 lbs. for the tire, the yield strength calculated was 27,580 $\frac{lbs.}{in^2}$.. The yield strength for 1.875 in round bar is 530,000,000 psi satisfying the condition I needed it for.

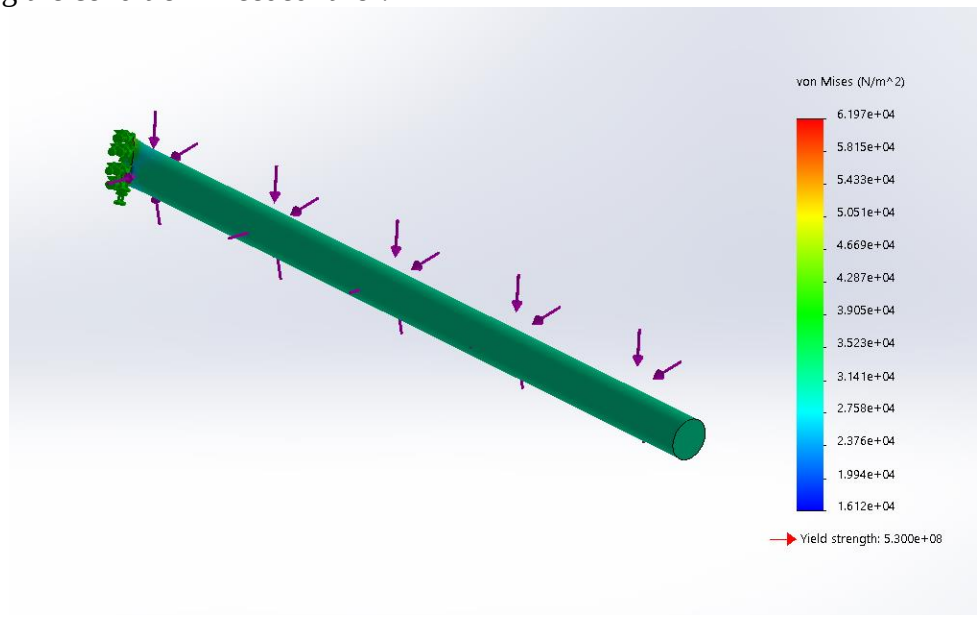

Figure 5

Factors of Safety of Concern

With safety playing a large factor in the design, I chose to use a factor of safety of 4. I chose 4 because it is a high factor of safety to ensure that everything would work.

Component Selection

Box iron was selected for the base of the device for the forks, the horizontal adjustment that is used with the side shift of the tow motor, and the bracing that holds the horizontal adjustment. Box iron was chosen because it is cheap, durable, strong, and easy to work with.

Steel plate was used to capture the rollers. It was chosen because it is strong, durable, and has high strength that is needed in the agricultural industry. The locking arm was made of round bar steel because of its high strength properties. All bolts and fasteners were stainless steel to prevent corrosion.

Bill of Material

Item No	Part	Qty
1	Box Iron - Bottoms	2
2	Large Roller Mounts	4
3	Vertical Tube	2
4	Mast Support	2
5	Short Roller Mount	5
6	Large Rollers	10
7	Box Iron - Horizontal Slide	2
8	Horizontal Slide	1
9	Locking Arm	1
10	6" Rollers	5
11	Stainless Bolt	26
12	Flat Washer	26
13	Hairpin Clip	14
14	Saftey Clips to Tow Motor	2

Table 1

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

The budget for this project was given by Glandorf Warehouse Inc. because they would use the device once it was completed. They proposed a starting budget of $450 dollars for this project. When pricing parts and materials, I found that I would be very close to my budget of $450. However, when I started fabrication, I found large & small rollers that were from an old industrial conveyor that worked perfectly. With the cost of the rollers out of the budget, I was able to stay under budget by $147.

Starting Budget:

Budget		
Item	Qty	Price
12" Roller	10	$105.90
6" Roller	5	$41.80
Box Iron	8'	$223.08
Tube Iron	24'	$37.20
Flat Steel	4'	$17.20
Bolts	26	$7.28
Flat Washer	26	$4.16
Hairpin Clip	14	$5.60
Saftey Clips for Tow Motor	2.5'	$5.00
	Total	$447.22

Table 2

Revised Budget:

Budget		
Item	Qty	Price
~~12" Roller~~	~~10~~	~~$105.90~~
~~6" Roller~~	~~5~~	~~$41.80~~
Box Iron	8'	$223.08
Tube Iron	24'	$37.20
Flat Steel	4'	$17.20
Bolts	26	$7.28
Flat Washer	26	$4.16
Hairpin Clip	14	$5.60
Saftey Clips for Tow Motor	2.5'	$5.00
	Total	$299.52

Table 3

SCHEDULE, PROPOSED /ACTUAL

I had originally planned to start the fabrication process over Christmas break and into the Spring Semester. Doing this would give me plenty of time to complete the testing required before Tech Expo and Final Presentations. Below is an outline of the proposed schedule:

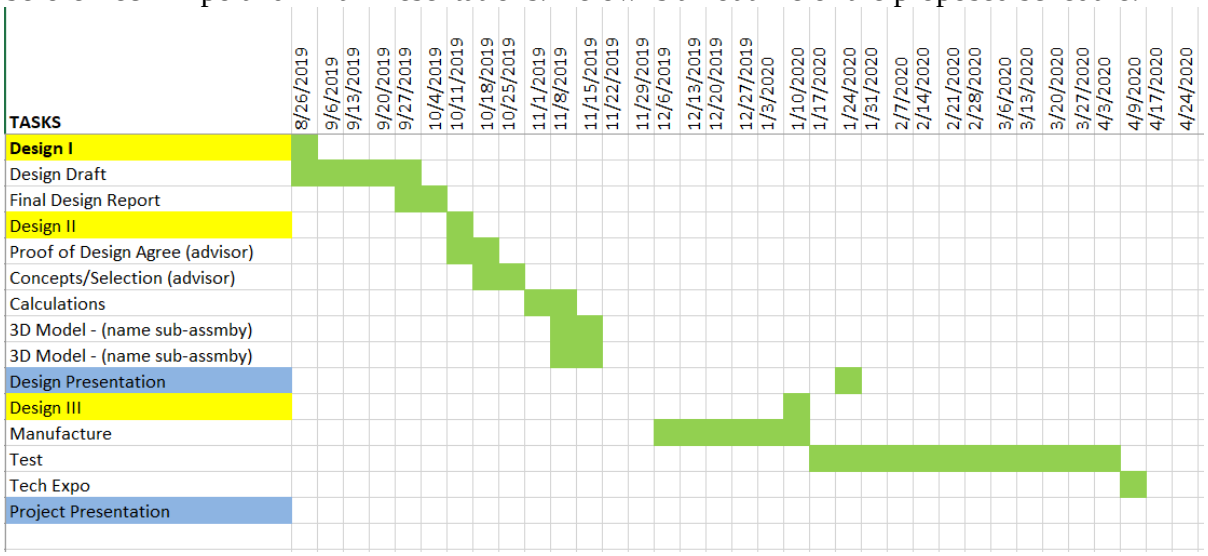

Figure 6

My schedule changed slightly due to not establishing a design later than expected. By the time materials were ordered and delivered, I was not able to start fabrication until January 2020. A delayed start to the fabrication process lead to a delay to the testing process. I was planning on testing over spring break and the following weeks, but COVID-19 set in and I was not able to complete all my testing. Below is an outline of the actual schedule:

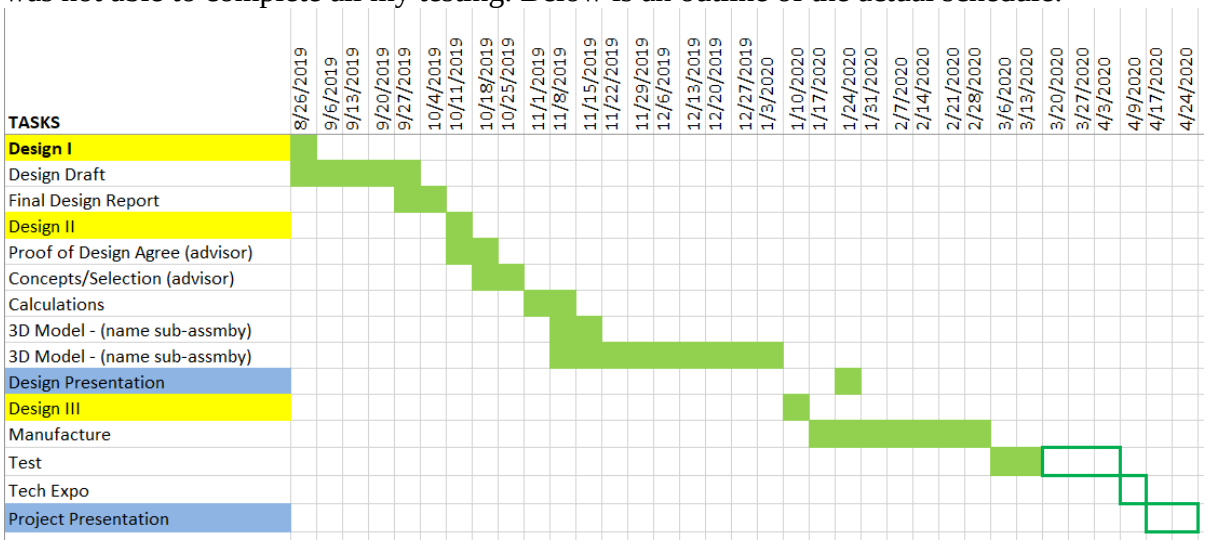

Figure 7

PLAN TO FINISH

I was able to complete everything in the manufacturing stage before COVID-19.

However, I was not able to complete all the necessary testing before officially allowing Glandorf Warehouse to use on a regular basis. I was able to test how well it was to load the device on a tow motor, loading the tire to the device, and rotating the tire. I was planning on running additional tests to test the locking arm when the tow motor comes to a sudden stop, and a timed test to see how much time was saved from the old method to the new method using the device.

Since Glandorf Warehouse's prime usage of the device is early to mid-May, I made an agreement to complete the testing before they use the device.

SUSTAINABILITY AND MATERIAL USAGE

I feel I used the most appropriate materials for this project. I made the device slightly larger than needed to allow for more room to load & unload the tire. If the pandemic would not have set in, I feel that everything would have been completed and presented at Tech Expo and the Final Presentations.

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APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D