Spring 2018

ASME R/C Baja Car

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Chassis and Suspension

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June 1, 2018

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Abstract

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How does one build a car? Do they start with the tires and build inward or do they develop separate aspects at the same time? This remote-controlled car was designed and built with the intention of competing in the annual Baja Competition. There are three competitions: sprinting, slalom, and an obstacle course. The suspension system of this car must be designed to support the car for both the physical build and the competitiveness. It must do this without interfering with the drive train and steering mechanism designed by Doug Erickson. The suspension system employs suspension arms attached to the chassis plate through several connecting pieces. The body, suspension arms, and attachment pieces are made of Aluminum 6061-T6. They were machined by Torrie Large using mills, drills, taps, saws, and an automatic mill. All pieces were specifically designed to withstand a drop from a certain height and hit the wall at a specific speed. Engineering equations were applied for maximum efficiency. Through testing, the suspension system proved its ability to perform its functions while supporting the interior aspects of the car (drivetrain and steering features) while not interfering with those parts at the same time. The car has succeeded in competing and finishing the events of the Baja Competition.

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Introduction

Description

This project fulfills the need to create a remote-controlled Baja car capable of competing against other Baja cars. The two team members, Doug Erickson and Torrie Large, will be directly responsible for designing and building the drive train and suspension/chassis, respectively.

Function Statement

This project will address the creation of an RC Baja car by Torrie Large and Doug Erickson. The suspension system of a car consists of rods, arms, tires, and shock absorbers that connect the tires of a car to the chassis and engine. The car will need to be built before the Baja Competition in April of 2018. This paper will focus on the suspension and chassis of the car.

Scope of Effort

The scope of this project is to design and build the chassis and suspension system of a remote-control car within the limits of the ASME RC Baja rules and regulations. It will need to perform to certain standards in all forms of competition. The rest of the car (drive train) will be designed by Doug Erickson. These designs will be assembled together before the competition.

Engineering Merit

This car is being built to perform equally as well as other RC cars in the competition. The goal is to optimize the dimensions, angles, material, and gears to create the best presentation possible. These engineering aspects include making sure pieces of the car do not interfere with other pieces and while not disturbing the design intentions.

Requirements

For the car to be successful, it must meet several requirements. These requirements come from the ASME RC Baja Competition and from the desire to use engineering equations and merit to enhance the car's performance.

The following requirements must be met:

1. The chassis will be smaller than 0.125 m^3
2. The suspension will be able to handle at least 100 N of force from all directions
3. The chassis will be less than 6 lbs
4. The frame will balance the car with a percentage error of less than 6%
5. The car will not cost more than $400
6. The car will not deflect more than 1.25 in when dropped from a height of 2 feet.

Success Criteria

Once the design requirements are met, success is determined by meeting further guidelines. The ASME Baja Competition will show how the car compares to other designs, but specific requirements should be met prior to competition.

1. The car must be able to hit a wall at full speed (8mph) without the suspension arms or turnbuckles buckling or bending

2. The car must be able to return to its original position after hitting any obstacle

3. The car must have a deflection of less than 1.25 inches at the point of impact

Motivation

The incentive to produce this car comes from the desire to create a project from an unknown subject to a competitive car. Having never worked on any kind of suspension system before, this car provides an opportunity to learn a new subject and apply these lessons to the RC car and possible full cars if needed.

Design and Analysis

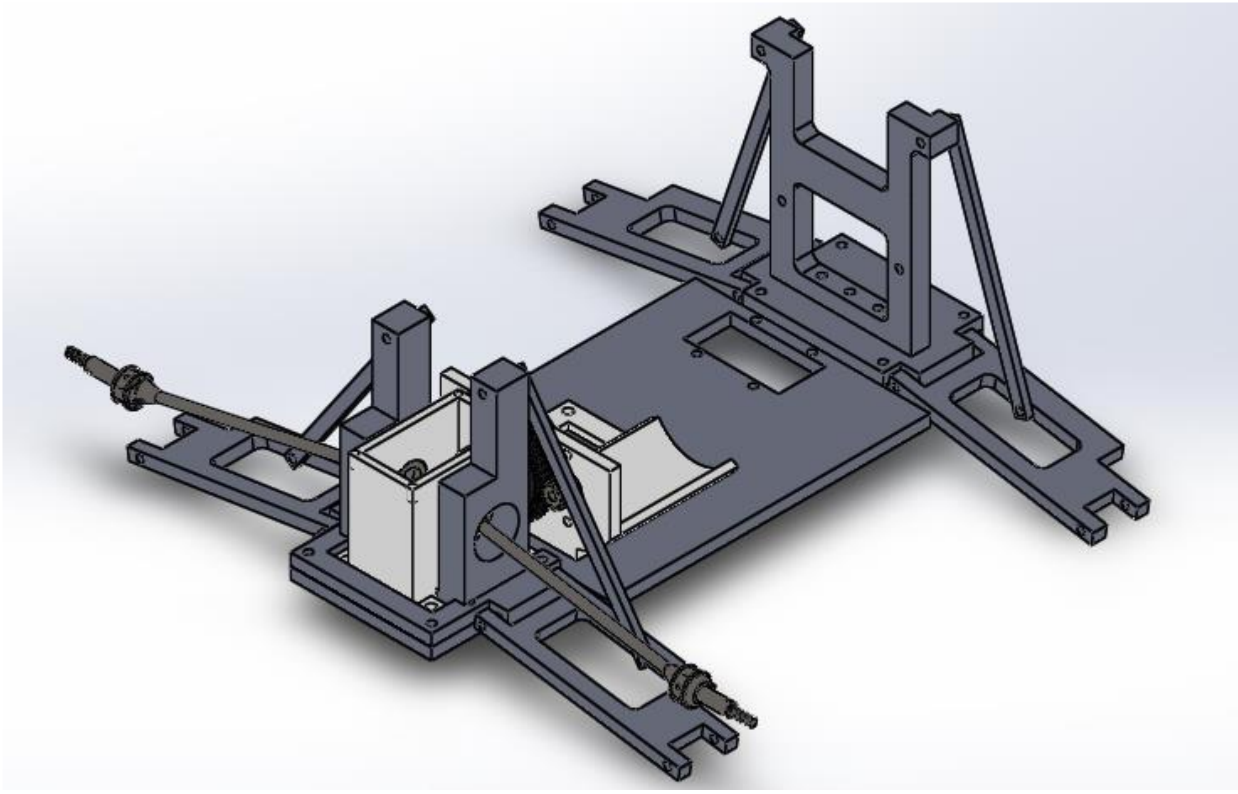
Approach

Building the suspension and body of the Baja car requires the approach of finding the mandatory thickness, width, and length of all metals included in the construction to withstand the force applied from outside sources.

There are three main areas of construction: front suspension, rear suspension, and chassis. The front and rear suspension are composed of both suspension arms and shock towers. The chassis of the car includes the body plate, front mount and rear mount.

Design Description

The following is a drawing of the Baja car design



This drawing also includes the drive train and differential designed by the car partner, Doug Erickson. The design illustrates how the different sections (front suspension, rear suspension, and chassis) are placed and connected.

Benchmark

This is an original design but is modeled after previous Baja competition RC cars. Previous cars have been competing in different categories such as speed, slalom, and a rough road. The parts built by Torrie Large are more concerned with the rough road. Prior cars in this competition focus on possible suspension problems and body integrity.

Description of Analyses

The design and analysis of the car are sorted into the individual parts.

The primary aspects of the car this design was trying to optimize were the strength of the materials coupled with the dimensions of the parts to find a minimum weight and maximum strength.

Suspension Arm- This piece of the car was created to meet the requirements set forward in the introduction. It needs to be able to withstand the force of being dropped two feet. To make sure the arm wouldn't bend, the following equation for bending stress was used:

$$\sigma_{b,max} = \frac{Mc}{I}$$

Since the suspension arm will also have an axial force impressed upon it, the buckling formula was also used to find the width and thickness of the design:

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

Similar analyses were performed for parts such as the turnbuckle and fastening pins.

The chassis plate was analyzed for buckling load and direct shear force. The chassis will need to withstand both the force of hitting a wall at full speed (20 mph) as well as being dropped. The equation for shear stress is as follows:

$$\tau = \frac{V}{A}$$

<u>Suspension Arms:</u>

Analyses 1, 2, and 4 all relate to the suspension arms. The first analysis (Appendix A 1-2) finds the force that would occur if the car hit the wall at full speed (20 mph). Once this force was found, the analysis concentrated on finding the thickness of the bars on the suspension arm so the car would still be operational after the hit.

Analysis 2 (Appendix A3-4) had a similar approach but concentrated on finding the thickness of the suspension arms if dropped from a height of two feet. This ensures the suspension arm will not be damaged if the car goes over a particularly difficult obstacle.

Analysis 4 (Appendix A6-7) finds the bending stress on the arm if all the force of a two-foot fall were to hit one tire. This information was used in conjunction with analyses 1 and 2.

<u>Shocks:</u>

Analyses 3 and 5 concern the shocks of the car. Analysis 3 (Appendix A5) finds the angle to which the shock will be attached to the shock tower and suspension arm. Analysis 5 (Appendix A8) finds the required dampening factor of the springs in the shocks to absorb the fall of two feet.

<u>Chassis Plate:</u>

Analysis 6 and 7 refer to the Chassis Plate. Analysis 6 (Appendix A10) finds the thickness of the plate required to prevent any bending when hit with the force of a two-foot fall. Analysis 7 (Appendix A11) refers to the thickness of the plate needed to withstand any buckling when exposed to the axial force of the fall from two feet. These analyses will be used together.

A drawing of the chassis plate is available in Appendix B.

Fasteners:

Analysis 8 (Appendix A12 and A13) finds the shear force applied to the pins with a fall of two feet. This is used to find the minimum diameter required for the pins.

Analysis 10 (Appendix A16) looks to see if #6 machine screws are acceptable to the amount of shear stress applied.

Turnbuckle:

Analysis 9 (Appendix A14-15) finds the minimum diameter required to withstand the force of a fall of two feet.

Front/Rear Mount:

The front mount will attach the suspension arms, chassis plate, and shock tower. Analysis 11 and 12 (Appendix A16-A17) find the bending stress of the front and rear mount and the force on each screw in the front and rear mounts respectively. Drawings of the front and rear mounts are available in Appendix B.

Methods and Construction

Method

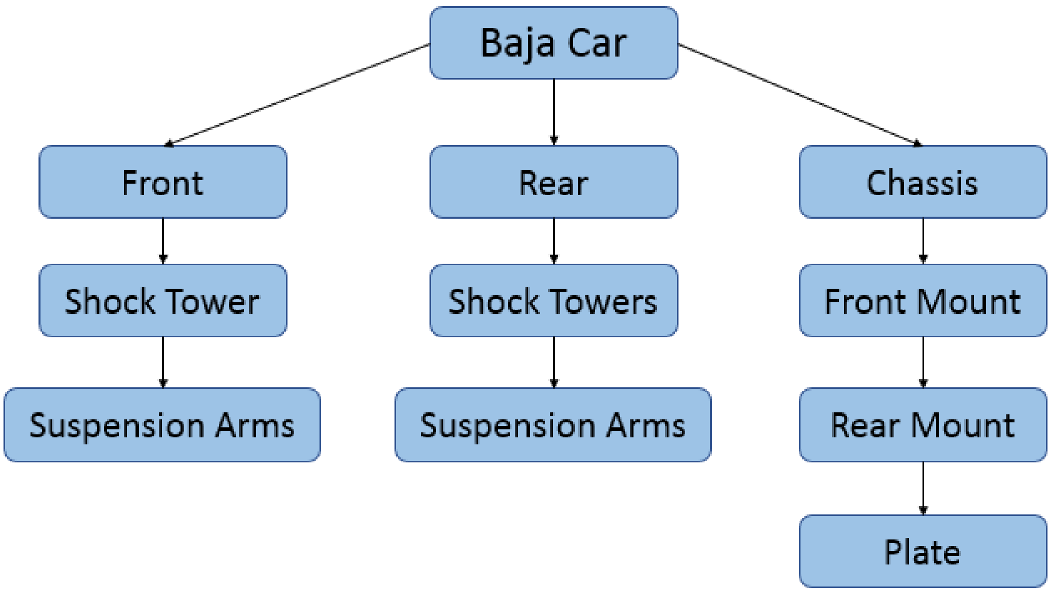
The first choice encountered while designing the car was what kind of steering the car would have. If it had 2-wheel drive, the drive train and differential would be easier to design but it would not climb obstacles as easily as if were 4-wheel drive. If it were 4-wheel drive, it would be more agile but the suspension system would be more complex. Since the suspension system was being machined by Torrie Large, it was decided to make the car 2-wheel drive.

The second engineering choice was which material to use. One option was to 3D print some of the parts. Unfortunately, the plastic of 3D printing did not have the yield strength desired to bear the large forces described in the “Requirements” section of the introduction. Steel was an option that had the yield strength but was also very heavy. Aluminum was lighter than steel but had a smaller yield strength. The decision was made to make most of the machined parts from aluminum and have the pins and fasteners made of steel.

The suspension arms were made for a 2-wheel drive car. They were machined on the CNC machine. They needed to be long enough to keep the turnbuckles within range of the shock towers. This also meant the suspension arms also needed to line up and attach to the shock towers without interfering with the steering rod. Please see the description in the construction section below.

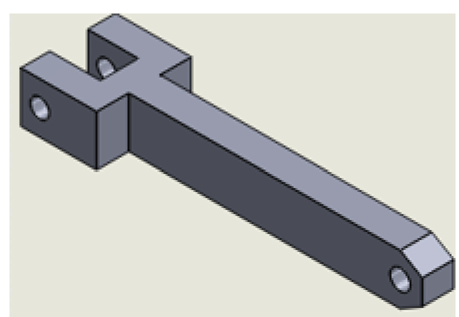
Construction

The primary construction of the frame will take place in the metals lab in Hogue Technology Building. Basic milling and drilling are required and are within talent range. This drawing tree exhibits the basic order of sub-assembly of the car frame. It is also available on Appendix B10.

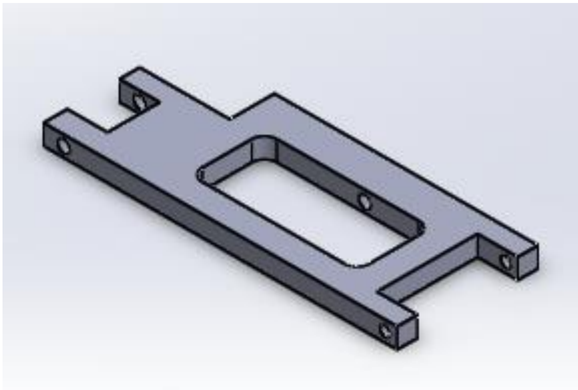


Revisions and Construction

Front Suspension Arms



The original design of the suspension arms was an "A" design. It was decided that this shape was too difficult to machine. The second design was whittled down to a single beam-like structure. The end was chamfered to allow for rotation in the front mount piece. This design did not allow for smooth attachment to the shocks. They interfered with the steering rod and turnbuckles. It was much weaker than having a control arm with a greater width.



The current design is similar to the original "A" shape but with horizontal and vertical lines for ease in manufacturability. One side is offset to align the shocks with the shock tower without intruding into the steering rod area. The thickness and height of this piece was calculated in analyses 1 and 2 found in Appendix A1-A4.

A detailed drawing of the front suspension arm is on Appendix B5.

<u>Rear Suspension Arm</u>

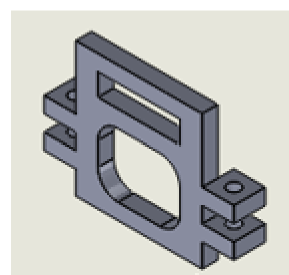
Similar designs revisions were made for the rear suspension arms. The main dichotomy from the front suspension arm is the section of arm that connects to the shocks is thinner in the rear to line up with the shock towers.

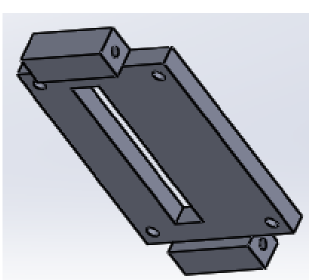
Both the front and rear suspension arms were machined on the CNC machine by Ted Bramble. The holes were drilled with a #31 drill bit.

A detailed drawing of the rear suspension arm is available on Appendix B6.

<u>Front Mount</u>

The first design of the front mount included a section of aluminum cut out of the attachment point to accommodate the original design of the front suspension arms. The slot for the shock tower did not align with the suspension arms so the shocks would have unnecessary torque on them. The hole in the middle was designed to reduce the weight on the piece.

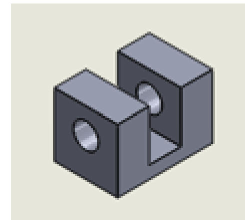




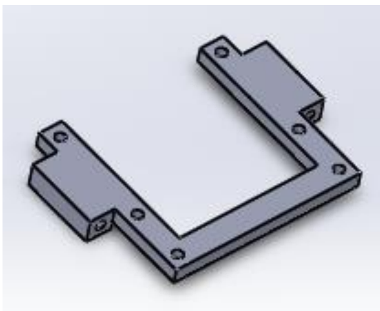
The current design of the front mount (as viewed from the bottom right) has longer attachment point. This allows for less shear to be expressed on the pins. The suspension arm now goes around these attachment areas to supply more steadiness and strength for the shocks and suspension arms.

A detailed drawing of the front mount is available on Appendix B3.

Rear Mount



The original design for the rear mount looked similar to the front mount. Then it was found that the differential was going to be place in between the rear tires. The second design of the rear mount was to have small blocks attached to the chassis plate to have a simple attachment for the design of the smaller rear suspension arms. These mounting blocks did not have the strength required to withstand 100 N of force.

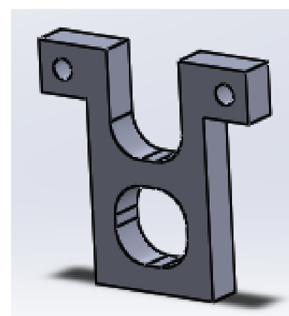


The current design for the rear mount was designed by enlarging the chassis plate at this part of the car. The mount then had room to go around the entire differential housing. It has attachment points for the rear suspension arms similar to the front mount. The width of material on the back edge of the piece was calculated from analysis 11 (appendix A17).

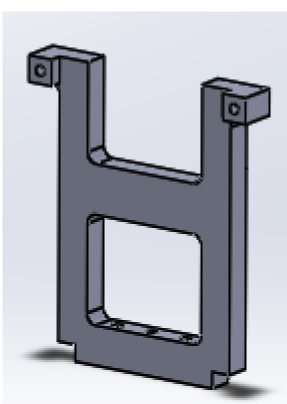
The front and rear mounts were milled by Torrie Large. The holes were all drilled with a #31 drill bit.

A detailed drawing of the rear mount is available on Appendix B4.

Front Shock Tower



The first design of the front shock tower had the same thickness of material on the entire piece. This did not allow the shocks to sit straight when attached at the top. The other problem presented itself when the shock tower could not reach the point closer to the suspension arms because the front mount piece enclosed the sides.



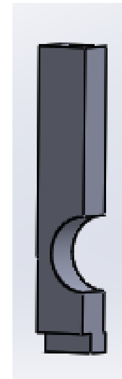
The current design of the front shock tower has made two main changes from the first design. The attachment points for the shocks was extruded another 4mm to allow the shock to sit straight instead of shooting off-center. The second big alteration was the bottom of the piece. By making slight indentations on the lower corners, the piece is now able to sit directly into the front mount piece and still have the full width of the chassis plate at that point.

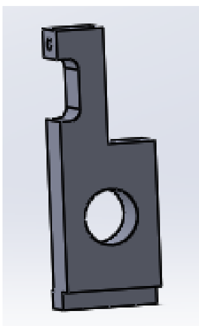
A detailed drawing of the front shock tower is available on Appendix B7.

The front shock tower was milled by Torrie Large. The holes were drilled with a #31 drill bit and then tapped with a #6 tap. This allowed the larger screws to secure the pieces without nuts.

Rear Shock Towers

The first design of the rear shock towers was created to go around the steering rods stemming from the differential. The manufacturing plan was to drill a hole into a single piece and then split the piece into two directly down the middle. Unfortunately, this proved to be impossible. The torque from the mill bent the thinnest point of the piece.





The current design of the rear shock towers looks like the piece illustrated on the left. The thicker width was kept through the bottom half of the piece and a hole was drilled out to allow for the steering rods to emerge from the differential. Another piece was cut from below the attachment point of the shocks to allow the shocks to sit straight.

The rear shock tower was milled and drilled by Torrie Large. The center hole was created with a ¾ inch drill. All other screw holes were drilled with a #31 drill bit and tapped with a #6 tap.

Detailed drawings of the left and right rear shock towers are available on Appendix B8 and B9.

Chassis Plate

The first design of the chassis plate had the appropriate holes for all parts at the time of their design. This included a place for a piece called the servo mount which was later deemed unnecessary. The current design took the holes created by the servo mount but kept the bigger pocket for the actual servo to sit down into the piece. The ends of the plate were made wider and longer to allow for pieces to fit (specifically the differential with the rear shock towers and rear mount). The body of the chassis plate was made wider to accommodate the battery pack, RC control unit, etc.

Analysis 12 (appendix A18-A20) illustrated that fewer screw attachments (four) would maintain the integrity of the pieces just as well as the original plan of six screws for both the front and rear mount.

A detailed drawing of the chassis plate is available on Appendix B2.

The original plan was to use #6-32 screws for all points of attachment to the chassis plate. However, some of the points required a smaller screw that would be held on with their respective nuts. Before testing begins, this will be changed to self-locking nuts. These supplies were bought from Fastenal in Ellensburg, WA.

All pieces were started by using the band saw or horizontal saw to create the approximate size before milling.

Testing Method

The Baja car will need to be tested for at least the following attributes: speed, accuracy, turning radius, strength, and recovery time. Several of these tests will require other space/equipment. For example, the speed will need an open space with a predetermined length. These tests account for the final RC Baja Car that will be the joint effort of both projects.

The frame and suspension are the primary concerns for this project. Particularly the parts created by the designers that can be altered if necessary. For example, if the suspension arms or front mount does not withstand the required force, modifications can be made before testing or competition. Since these requirements also account for weight and length, a ruler and scale will also be necessary.

An example evaluation sheet is available in Appendix G.

Test 1

Method/Approach

The first test was a drop test. The car was raised to a specific height and dropped to the ground. The goal of the test was to make sure the car would stand up to the forces incurred upon it in the Baja Competition. The only hard resource required was a yardstick. The data was not numerical- it was a visual inspection for stress/fractures.

Test Procedure

Equipment needed:

1. Yard Stick
2. Baja Car

The procedure was as follows:

1. The yard stick was set up against a wall to free up the testers hands.
2. The bottom of the tires were raised to the height of 2 feet.
3. The car was dropped.
4. The car was inspected for any stresses/fractures.

The accuracy and precision of the test was reliable in that it is repeatable with the same results.

Analysis of these results was not necessary as the findings were not numerical. If the test had failed, further analyses would have been needed to find new dimensions for the suspension system. The calculations for the parts are available in Appendix A 1-2.

Risks and safety for this lab were minimal. Safety glasses and closed toe shoes were worn to avoid any possible injury.

Deliverables

The parameters for success was a lack of fractures from the drop. The data provides binomial statistics but not numerical. In the three tests performed, there was a 100% success rate. These results show the dimensions of the part were designed correctly and the car was capable of withstanding the force of a fall of two feet. Please see Appendix H1 for the test data sheet.

Test 2

Method/Approach

The second test performed on the Baja car was similar to the first but enhanced the results to include numerical data. While performing the first test, the demonstrated that the front end did not deflect in the drops, only the back. The second test was set up to measure the deflection of the chassis plate while measuring the balance restoration at the same time. Same with the first test, the only hard resource needed was a yard stick.

The tolerance of this test was quite large. Since the test consisted of reading the yardstick at the moment of impact, there was the need to create a larger tolerance so as not to misread the measurements. The yard stick had divisions up to 1/16 of an inch, but the tolerance for this test was set to ¼ of an inch.

Test Procedure

Equipment needed:

1. Yardstick
2. Baja Car

The procedure was as follows:

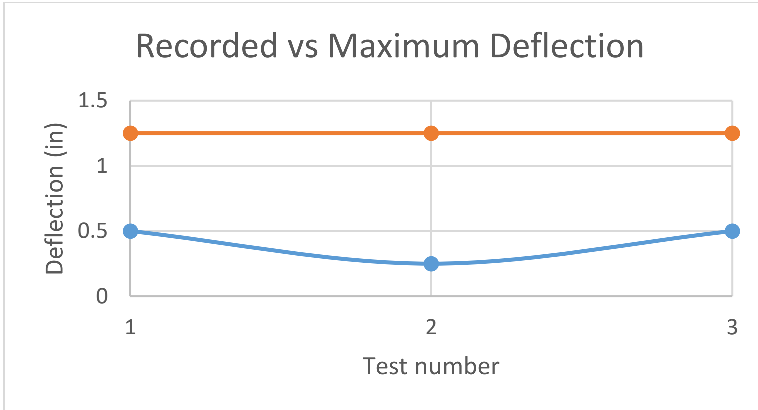
1. Hold the yardstick upright.
2. Raise the Baja car so the bottom of the tires is 2 feet above the ground.
3. Line up the rear of the car with the yardstick so the tester will be able to read the measurements when the car is dropped.
4. Drop the car.
5. Observe and record the amount of deflection in the chassis plate of the car.
6. Wait five seconds and measure the back end of the car again. Record this measurement.

The accuracy of this test was reliable, but the precision varied slightly. One of the three tests resulted in a different measurement. This could be due to the large tolerance or tester error.

Risks were negligible, but safety glasses and closed-toe shoes were worn.

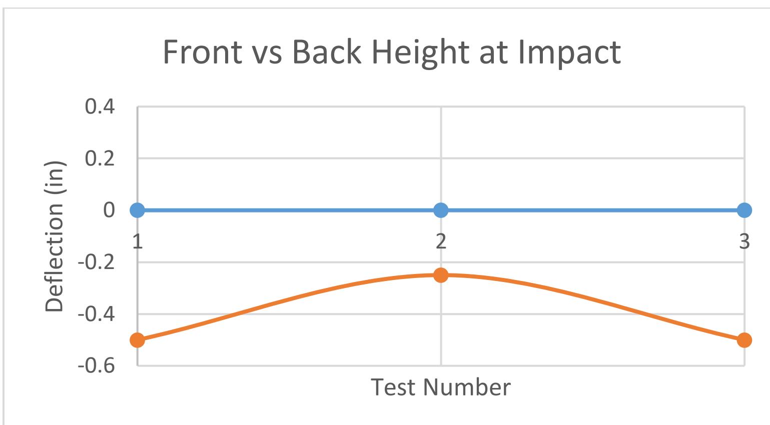
Deliverables

The parameters for success included a maximum deflection limit and a balance percentage maximum. For the first part of the test, the measurements on impact were compared to the deflection maximum. The maximum possible deflection for success was 1.25 inches. This graph illustrates the recorded deflection compared to the maximum deflection:



As shown in the graph, the most the back end of the car deflected was 0.5 inches. This means all three tests were successful.

The second part of the test measured the percent of deflection of the chassis plate on impact and its ability to regain its natural position. The measurements of deflection for the back end of the Baja Car were 0.5 in, 0.25 in, and 0.5 in. If the height of the chassis in its original form (3.5 in) is set at 0 for a reference point, a graph of the collected data is as follows:



At its highest deflection (0.5 in), the car is 14.3% out of balance. When the second measurement was taken (at 5 seconds), the chassis had returned to its original height with an offset of 0%.

Please see Appendix H2 for the testing sheet.

Test 3

Method/Approach

This test addressed the criteria of being able to withstand the force of hitting the wall at full speed. The original calculations for the machined parts of the car were for a speed of 20 mph. Doug Erickson performed the speed test and found the actual top speed to be 8 mph.

This test required the Baja car to hit top speed before running into a wall perpendicularly. Like the first test, the data collected was not numerical. It only required a visual check to decide if the test was successful or a failure. The test was only performed once.

Procedure

Equipment needed:

1. Baja Car
2. Wall
3. Enough space to gain top speed

Procedure:

1. Place the car approximately 15 yards from the wall.
2. Accelerate quickly while steering straight at the wall.
3. Hit the wall with the front of the car.
4. Observe any changes/failures in the car systems.

Since this test was only performed once, accuracy and precision cannot be claimed.

Safety glasses and closed-toe shoes were worn for safety.

Deliverables

The parameters for success in this test were that the car did not have any catastrophic failure after hitting a wall at full speed. The data for this test was not numerical, it was a yes or no option. This data was collected by an observance after the test.

After the car hit the wall, it was thoroughly inspected and found to have no failures or fractures. This test was a success.

One note of importance: The length of the hinge pins extended beyond the front of the car. These pins absorbed much of the initial energy of the impact. This affected the test results.

Please see Appendix H3 for the test sheet.

A test form was created for all information that was tested. These data sheets are attached to this document in Appendix H.

All data in this section is available in Appendix I.

Parts

This primary list in Appendix C includes parts that will be required to create the Baja car's chassis and suspension. This list includes item numbers, names, whether they will be bought or machined, and how many will be required.

The parts of the car that will be bought are listed in the budget in Appendix D. This includes parts such as shocks, turnbuckle arms, and screws.

Some of the parts of the chassis and suspension will be machined. The schedule of machining is available in Appendix E.

Schedule

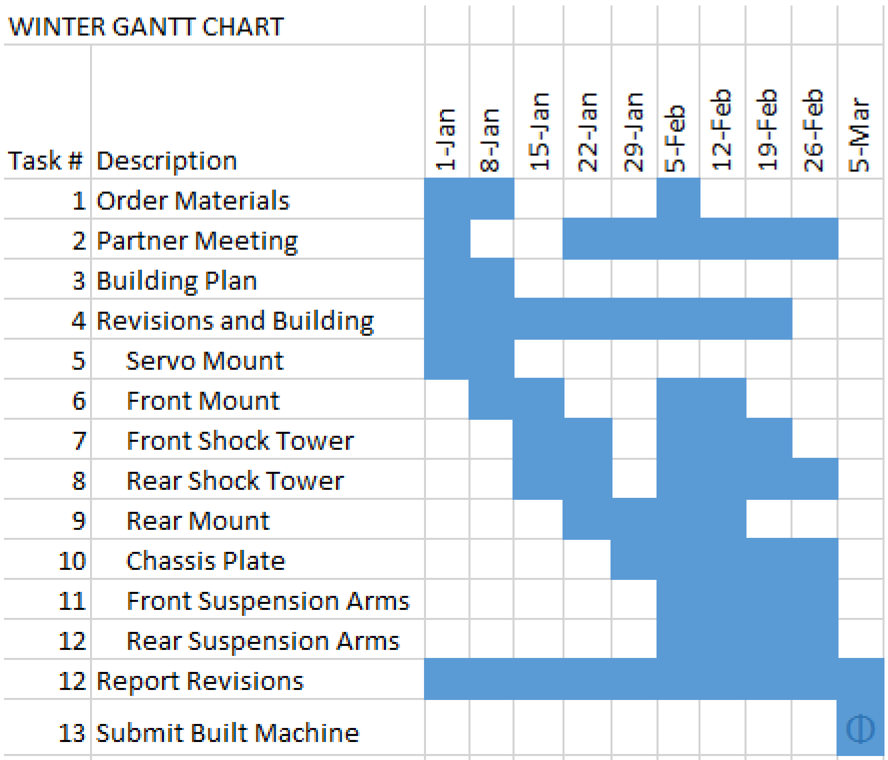
The schedule for the Baja Car project is divided into three main parts: fall, winter, and spring quarters.

The fall concentrates on design and analyses for individual parts of the Baja car which will be collected at the end of the quarter. Each week will produce a new analysis. As the fall continues, designs will be whittled down into drawings.

The first analyses focused on finding how much force would be applied according to the requirements put forth in the introduction. Specifically, how much force would be created by hitting a wall at full speed or from being dropped from a height of two feet.

The next analyses concerned the suspension arms. They found the height and width required for the arms to resist the bending stress created by the forces found in the first two analyses. Similar analyses were calculated for the front and rear mount, pins, and turnbuckles. The next analyses concentrated on compression forces and found the buckling point for the chassis plate and turnbuckles. Finally, an analysis was calculated to find the forces affecting each bolt in a four-bolt pattern to see if that was acceptable over a six-bolt pattern.

Winter quarter concentrates on building or machining the individual parts. Below is a rough schedule of when the individual parts were machined.



Revisions were accounted for by scheduling time each week of the quarter. Parts that were being ordered (shocks, pins, knuckles, etc.) were ordered in the first two weeks of January. Further materials or parts (turnbuckles) were ordered at a later due to design changes.

Partner and mentor meetings were more prevalent during this time period. Torrie Large and Doug Erickson met with Roger Beardsley each Monday to discuss progress, complications, and revisions.

The first piece made was the servo mount. Unfortunately, this piece was scrapped for the final assembly. The front and rear mount were both machined without incident. The shock tower slot was added later when measurements were verified.

The front shock tower was machined without incident. The rear shock towers required more time because they were found to have manufacturability deficits.

The front and rear suspension were designed by Torrie Large and then machined by the CNC machine. Since Torrie Large did not know how to use this automatic mill, Ted Bramble assisted.

The chassis plate was the last piece to be created. Subtle changes in design for the other pieces were shifted to the chassis plate with transfer punches and measurements. This ensured all holes were aligned and the assembly could be held together properly.

Spring quarter includes all testing for the car. This period will see if it meets the design and success requirements. These tests will be a drop test, deflection test, ram test, size, weight, etc.

A detailed chart is available in Appendix E.

Budget

One of the design requirements for the RC Baja Car is the budget be less than $400. To obtain this, some of the parts will be bought while some of the parts will be machined from raw material. Different parts of the car will be ordered at different times to make sure there is no unnecessary payment of funds.

The parts, however are not the only costs attributed to the project. The largest cost will be the labor involved. A starting machinist's pay is an average of $18. This hourly wage is part of the detailed budget available in Appendix D.

The original budget allowed for the purchasing of some of the parts that do not require machining. Parts such as the spindle, caster block, and shocks were priced to see if their price was worth the availability and convenience.

The parts that have been purchased and arrived have only been altered if there was a better price found or a design was altered. For example, the shocks in the original budget were model BQLZR285004 which were 80 mm long but a revised design required shocks to be 100 mm long. The price only varied by $0.20.

The original budget allowed for materials to be ordered. The materials have been provided by Matt Burvee in the metal lab. He had pieces that were extra from other designs and they were donated to this project.

The project has cost $101.97 in parts and materials. This is $31.08 less than the original budget due to donation of materials and other small changes that resulted in monies being saved. Please see Appendix D for budget details of individual parts and Appendix E for a breakdown of the schedule (hourly and weekly) for the labor costs.

Project Management

This project is part of a two-person operation. Doug Erickson and Torrie Large will be the primary labor and human resources. All costs will be covered by them. Other aspects of the project (technical and physical resources) are supported by Central Washington University staff. Soft resources such as software and web support are also supplied by the university.

Risk management will be discussed in the next section of the proposal.

Some large risks of this project are not being able to get parts built in time but this risk will be controlled by spending as much time as possible in the CWU machine shop early in the mornings taking advantage of machine availability. Also to mitigate another risk, a complete car will be assembled in Solidworks before going out to the shop floor for production so that it is known if the whole car will work together or not. If man power is running short, underclassmen volunteers will be utilized to help machine parts.

Discussion

Design Evolution

The design of the Baja Car started with several different ideas. It started with possible frame choices. After reviewing different parts associated with each, it was decided that a simple chassis plate with suspension arms and camber links would provide the best opportunity to machine as many parts as possible.

Once a general style was chosen, the focus shifted to design optimization by using known equations and applying them to possible materials and dimensions. After adjustments, these designs were machined and assembled.

Risk Management

Using this definition, risk management for this senior project may include cost, feasibility, schedule, environment, resources, and interest.

- Cost: One requirement for this project was to keep the cost of building this remote-controlled car under $400. The rough draft of the budget would place the cost of the physical materials at $132.22. The price of labor and machinery needs to be added.
- Feasibility: Since the Baja Car has been a Senior Project for the past several years, the probability of finishing this project is high. This is helped by the use of the Gantt chart.
- Schedule: The biggest risk of this aspect is falling behind. Again, the use of the Gantt scheduling chart allows one to watch the progress and deadlines of the project while focusing of individual problems.

- Environment: The Baja car will not be exposed to outside influences such as rust but will need to be meet the standards of the Baja Competition. For example, it needs speed, a small turning radius, and the ability to drive on an uneven track.

- Resources: Financially, the creators of this projects are the resources. This is why one of the requirements defines the cost of the car.

- Interest: The remote-controlled Baja Car Competition is a nation-wide contest. The skills used to design this car can be applied to design projects in the future and can be used as a stepping stone for employers looking for new personnel.

Conclusion

This project is the design and assembly of a remote-control car to compete in the ASME RC Baja Car competition in Spring of 2018. This car is a simple design allowing the creators to manufacture and machine several of the parts. The analyses performed on the plans allow for optimization of dimensions before building and thus saving money by knowing about any interferences or weaknesses. The car will be comparable to other RC cars and will be built to the best of the designer's ability.

Success can be measured in three different categories:

1. Does it meet the previously discussed requirements?
2. Does it compare against other competing Baja Cars?
3. Did the designers learn from their experience?

First, the car did meet all the requirements. It did not buckle, bend, or crack under any of the extreme circumstances. The analysis of each part was a success since it held up to all challenges. For example, the drop test was made possible because each dimension of the suspension arms was designed with bending and shear stress calculations.

This Baja Car won the 2018 ASME Central Washington University Baja Challenge. While competing against other cars, certain aspects were amplified to show why it performed better than others. The compactness and height of the car helped it climb vertically while the lightweight design put less of a strain on the motor.

Every step of this project has been a learning experience. Both designers had never created something that would need to perform in a predicted manner or compete against other designs. During the initial phase of the project, Torrie Large had to use unfamiliar calculations to predict the behavior of pieces. The second phase needed machining skills beyond any previous experience. Both experiences included mistakes, trying again, and successes.

Acknowledgements

This project would not have been possible without the help of others. First, thank you to the professors of the Senior Project class, Charles Pringle and Dr. Craig Johnson. Without them, this process would not have moved forward at a responsible pace.

Thank you to Roger Beardsley for his mentorship and patience. Thank you for meeting with us every week to make sure things were on track and moving forward.

Thank you to Matt Burvee for providing equipment and guidance in the Hogue Metal lab.

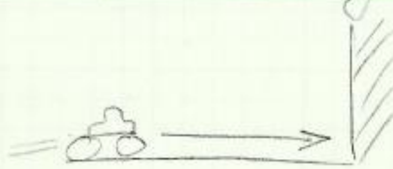
Thank you to Ted Bramble. When Torrie Large's machining skills were lacking, Ted stepped in to make sure all the pieces were made to spec.

Appendix A

1)

① MET 489A | Torrie Large 1/2

G: top speed 20 mph
Vehicle weight = 5 lbs
time = .1 second



F: Force of impact

S: $F = ma \Rightarrow F = m\left(\frac{dv}{dt}\right)$

$$F = (5\ lbm)\left(\frac{.45359\ kg}{1\ lbm}\right)\left(\frac{20\ mph}{.1\ sec}\right)\left(\frac{1\ hr}{3600\ sec}\right)\left(\frac{1609.34\ m}{1\ mile}\right)$$

$$= 202.8\ kg\cdot m/s^2 = \boxed{203\ N}$$

MET 489 | | Torrie Large | 1/1

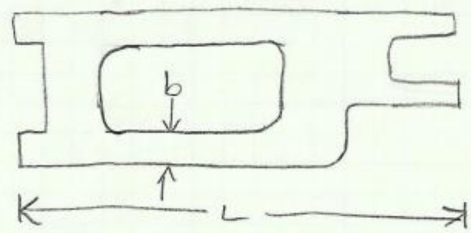
G: $F = 203\ N$

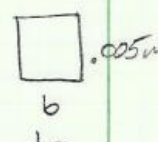
S_{ys} Aluminum 6061-T6 $= \frac{240\ MPa}{2} = 120\ MPa$

suspension arm

$L = 87.9\ mm$

NTS





F: minimum thickness of suspension arm to withstand hitting the wall (203 N) with a safety factor ~~of~~ 2

S: $\sigma_{max} = \frac{F}{A} \Rightarrow A = \frac{F}{\sigma_{max}}$

$$b(.005m) = \frac{(203N)(2)}{120 \times 10^6\ N/m^2}$$

$$b = \frac{(203N)(2)}{(120 \times 10^6\ N/m^2)(.005m)}$$

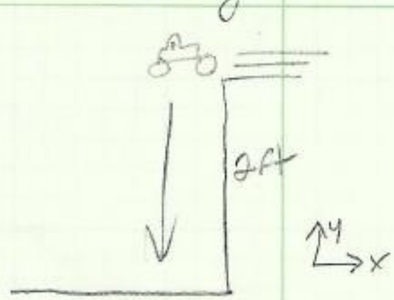
$$b = 6.7 \times 10^{-4}\ m$$

b must be 670µm to withstand force.

b will be a minimum of 5mm.

2)

(2) MET 489A — Torrie Large 1/2



G: $m = 5\ lb_m = 2.26796\ kg$
distance = 2 ft = .6096 m
time = .1 sec

F: Force of car falling from 2 feet

S:

Kinematic equation

$V_f^2 = v_i^2 + 2ad$

$a = 9.81\ m/s^2$

$d = .6096\ m$

$V_i = 0\ m/s$

$V_f^2 = 0 + 2(9.81\ m/s^2)(.6096\ m)$

$V_f = 3.458\ m/s$

$F = ma \Rightarrow F = m\left(\frac{dv}{dt}\right)$

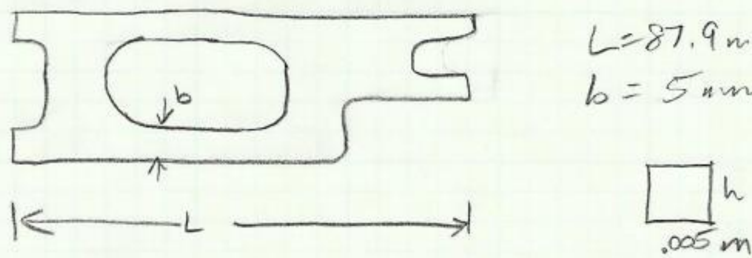
$F = (2.26796\ kg)\left(\frac{3.458\ m/s}{.1\ sec}\right)$

$F = 78.43\ N$

MET 489 | | Torrie Large | 1/1

G: $F = 79\,N$
Safety factor $= 2$
S_{ys} Al 6061-T6 $= 120$ MPa
suspension arm:

NTS



$L = 87.9\,mm$
$b = 5\,mm$

F: height of thickness to withstand force of 2 ft fall (79 N)

S: $\sigma_{max} = \frac{F}{A} \Rightarrow A = \frac{F}{\sigma_{max}}$

$$h(.005\,m) = \frac{79\,N\,(2)}{120\times10^{6}\,N/m^2}$$

$$h = \frac{(79\,N)(2)}{120\times10^{6}\,N/m^2\,(.005\,m)}$$

$h = 2.6\times10^{-4}\,m$

h must be 263 μm to withstand drop.

h will be 5mm.

3)

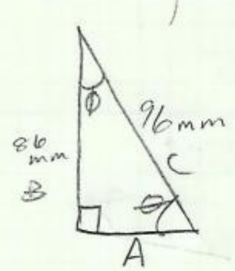
MET 489 | | Torrie Large | 1/1

G: $L_{shock} = 96\ mm$

$h_{shock\ tower} = 86mm$

F: distance to connection point of shock to suspension arm

S:



NTS

use pythagorean theorem

$$A^2 + B^2 = C^2$$

$$A = \sqrt{C^2 - B^2}$$

$$A = \sqrt{(96mm)^2 - (86mm)^2}$$

$$A = 42.7mm$$

what angles do the shocks form when attached to suspension arms + shock tower

law of sines

$$\frac{\sin 90^\circ}{96mm} = \frac{\sin \phi}{42.7mm} \Rightarrow \phi = 26.4^\circ$$

$$\frac{\sin 90^\circ}{96\ mm} = \frac{\sin \theta}{86mm} \Rightarrow \theta = 63.6^\circ$$

4)

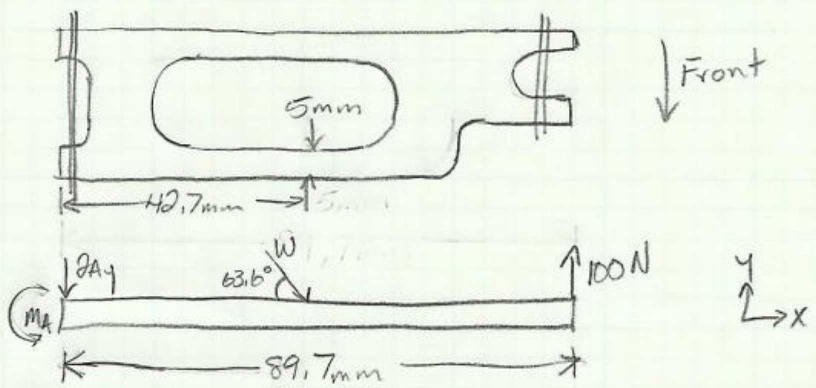
MET 489 | Torrie Large | 1/2

G: Alum 6061-T6 $S_y = 240\ MPa$

Weight of car = 22.25N

suspension arm:

NTS



F: h of suspension arm to withstand a force of 100N on one tire

S: $\uparrow \Sigma F_y = 0$

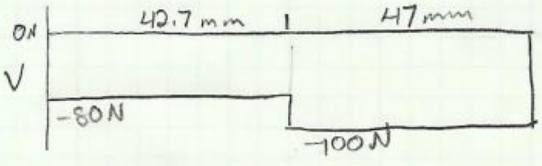
$$2A_y - \sin 63.6°(22.25N) + 100N = 0$$

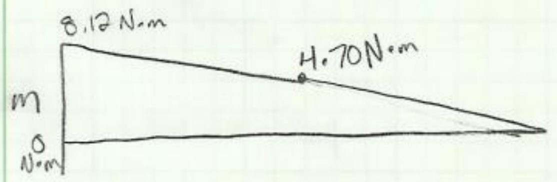
$$A_y = -40N$$

$\circlearrowleft \Sigma M_A = 0$

$$M_A = -\sin 63.6°(22.25N)(.0427m) + 100N(.0897m)$$

$$M_A = 8.12\ N{\cdot}m$$

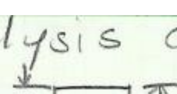




$M_{max} = 8.12\ N{\cdot}m$

suspension arm analysis cont...

$$\sigma_{max} = \frac{Mc}{I}$$



$$\sigma_{max} = \frac{M_{max} c}{\frac{b(2c)^3}{12}}$$

$$\sigma_{max} = \frac{12 M_{max} c}{b(2c)^3}$$

$$\sigma_{max} b = \frac{12 M_{max} \cancel{c}}{8 c^{\cancel{3}2}}$$

$$c = \sqrt{\frac{12 M_{max}}{8 \sigma_{max} b}}$$

$$c = \sqrt{\frac{12(8.12\ N\cdot m)}{8(240 \times 10^6\ N/m^2)(.005\ m)}}$$

$$c = .0032m$$

$$h = 2c = .0032m \times 2$$

$$h = .006m$$

This calculation is a hypothetical where the shock would absorb nothing.

Since the shock will absorb 20% of the force, an h of 5mm is acceptable

5)

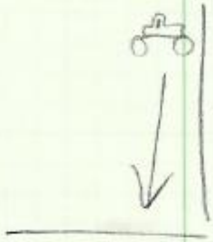
(5) MET 489A Torrie Large.

G: F = 79 N w/ safety factor of 1.5

height = 2ft = .6096 m

mass = 5 lbm = 2.26796 kg

F: k factor of springs in shocks for < 10% error



S: use Energy equation from fall to find k factor

Energy formula (conservation of energy)

Potential energy = kinetic energy

$PE = KE$

$PE = mgh$

$PE = (2.26796\ kg)(9.81\ m/s^2)(.6096\ m)$

$PE = 13.5628\ N \cdot m = \boxed{13.563\ J}$

$KE = \frac{1}{2} k x^2$

spring length = 65mm

$65 \times 10\% = 6.5\ mm$ $\quad x = 6.5\ mm$

$KE = \frac{1}{2} k x^2$

$13.563\ N \cdot m = \frac{1}{2}\ k\ (6.5\ mm)^2$

$$k = \frac{(2)(13.563\ kg \cdot m/s^2 \cdot m)}{(.0065\ m)^2}$$

$k = 642 \times 10^3\ N/m$

Need a spring w/ a $k = 642 \times 10^3\ N/m$ factor to keep a less than 6% error on the suspension

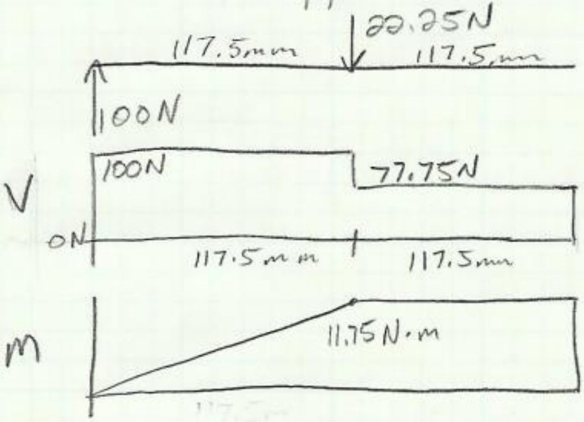
6)

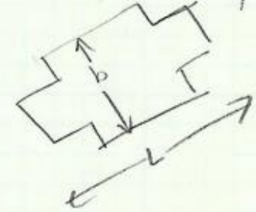
MET 489 | Torrie Large | 1/1

G: Alum 6061-T6 $S_y = 240\,mPa$
Safety Factor = 2
Weight of car = 22.25N

F: thickness of material to maintain integrity if force applied directly to chassis plate (100N)

S:





M_{max} @ 117.5mm $= 11.75\,N\cdot m$

$$\sigma_{max} = \frac{Mc}{I} \Rightarrow c = \sqrt{\frac{12 M_{max}(2)}{8 b \sigma_{max}}}$$

$$c = \sqrt{\frac{12(11.75\,N\cdot m)(2)}{8(.1m)(240\times10^6\,N/m^2)}}$$

$c = .0012\,m$

$h = 2c = .0012m \times 2$

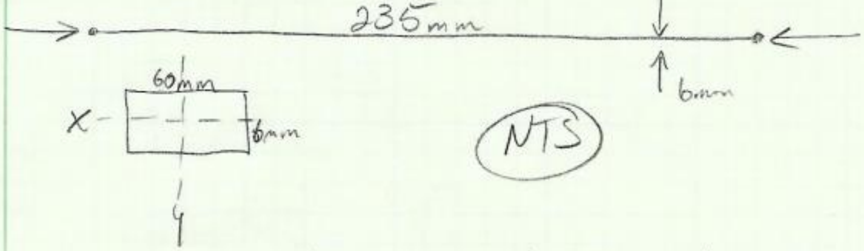
$h = 2.4\,mm$

h will be 6mm thick because it's standard 1/4 inch plate

7)

MET 489 | Torrie Large | 1/1

G: Alum 6061-T6 $E = 68.9$ GPa



F: critical load of the chassis plate before buckling

S: $I_x = \frac{bh^3}{12} = \frac{(.06m)(.006m)^3}{12} = 1.1 \times 10^{-9}\ m^4$

$P_{crit} = \frac{\pi^2 EI}{kL^2}$ $k = 1.0$

$P_{crit} = \frac{\pi^2 (68.9 \times 10^9\ N/m^2)(1.1 \times 10^{-9}\ m^4)}{(1.0)(.235\ m)^2}$

$P_{crit} = 13{,}545\ N$

The chassis can withstand 13kN of compression force without buckling

8)

MET 489 | Torrie Large 1/1

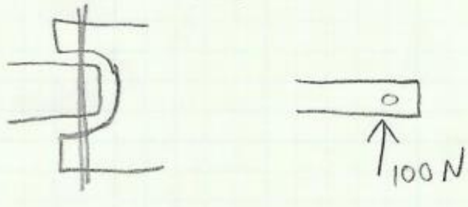
G: $F = 100N$

Alum 6061-T6 $\tau_{max} = \frac{S_y}{2} = \frac{240\,mPa}{2} = 120\,mPa$

safety factor = 2

F: diameter of pin required to withstand force of 100N

S:



$$\tau = \frac{F(2)}{A} \Rightarrow A = \frac{F(2)}{\tau} \Rightarrow \pi/4\, D^2 = \frac{F(2)}{\tau}$$

$$D = \sqrt{\frac{4F(2)}{\pi \tau}}$$

$$D = \sqrt{\frac{8(100N)}{\pi(120 \times 10^6\, N/m^2)}}$$

$D = .0015\,m = 1.5\,mm$

Diameter will be 3mm because of standard sizing

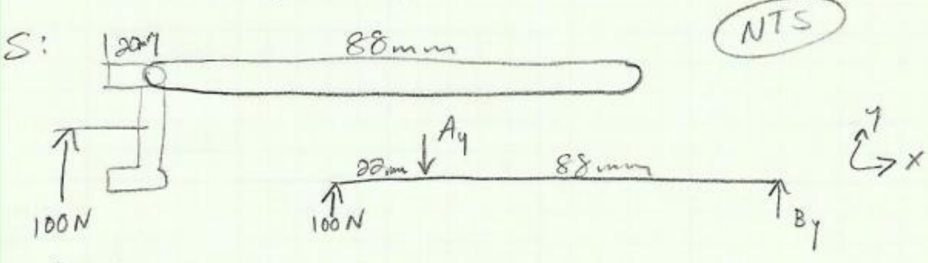
9)

MET 489 | Torrie Large | 1/2

G: Steel $S_y = 276\ GPa$

F: bending stress of turnbuckle
diameter of turnbuckle required to withstand 100N

S:



$\circlearrowleft + \Sigma M_A = 0$

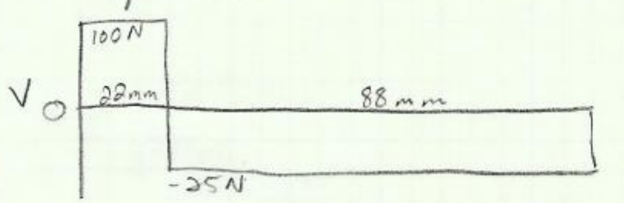
$-100N(.022m) + B_y(.088m) = 0$

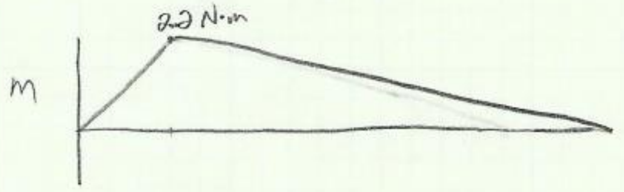
$B_y = 25N$

$+\uparrow \Sigma F = 0$

$100N + A_y + 25N = 0$

$A_y = -125N$

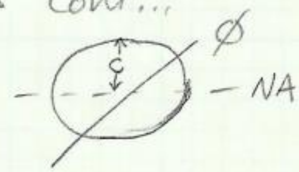




$M_{max} = 2.2\ N\cdot m$

turnbuckle bending stress cont...

$$\sigma_{max} = \frac{Mc}{I}$$



$$\sigma_{max} = \frac{Mc}{\frac{\pi D^4}{64}}$$

$$\sigma_{max} = \frac{64\,Mc}{\pi D^4} \Rightarrow \frac{64\,M(D/2)}{\pi D^4} \Rightarrow \frac{32\,M\cancel{D}}{\pi D^{\cancel{4}3}}$$

$$D = \sqrt[3]{\frac{32\,M_{max}}{\pi\,\sigma_{max}}}$$

$$D = \sqrt[3]{\frac{32\,(2.2\,N\cdot m)}{\pi\,(276\times10^9\,N/m^2)}}$$

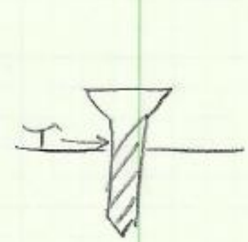
$$D = .0004\,m = .4\,mm$$

Ø will be 3 mm due to standard sizes + can with stand 100 N of Force

10)

(10) MET 489A Torrie Large

G: #6 machine screw
Tensile strength area = .00909 in^2
S_y = 40 Msi
F_{car} = 100N



F: does #6 machine screw not shear when dropped from 2 ft (100N)

S: convert to metric

$$.00909\,in^2\left(\frac{.0254m}{1\,in}\right)\left(\frac{.0254m}{1\,in}\right) = 5.865\times10^{-6}\,m^2$$

$$S_y = 40\times10^6\,\cancel{psi}\left(\frac{6894.76\,Pa}{1\,\cancel{psi}}\right) = 276\times10^9\,Pa$$

$$\tau = \frac{F}{A} = \frac{100N}{5.865\times10^{-6}\,m^2} = 17\times10^9\,Pa$$

17 GPa < 276 GPa

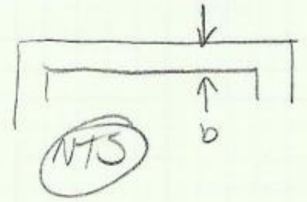
#6 machine screw will not shear on impact

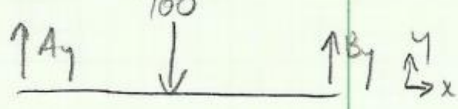
11)

MET 489 | Torrie Large 1/1

G: Alum 6061-T6 $S_y = 240\ MPa$

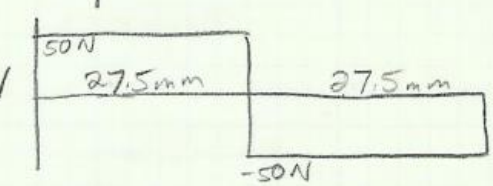
rear mount:

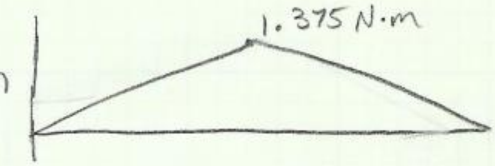




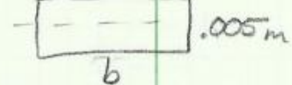
F: width of rear mount plate to withstand 100 N of Force

S: $A_y = 50N$, $B_y = 50N$ By inspection





$M_{max} = 1.375 N\cdot m$



$$\sigma_{max} = \frac{Mc}{I} \Rightarrow \sigma_{max} = \frac{M_{max}(h/2)}{\frac{bh^3}{12}} \Rightarrow \sigma_{max} = \frac{6M_{max}}{bh^2}$$

$$b = \frac{6M_{max}}{h^2\sigma_{max}} = \frac{6(1.375\ N\cdot m)}{(.005m)^2(240 \times 10^6\ N/m^2)}$$

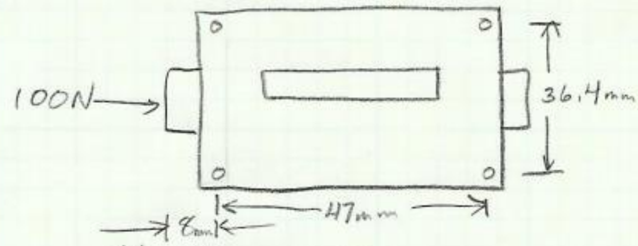
$b = .0014m = 1.4mm$

b will be 8mm to allow for space for screws

12)

MET 489 | Torrie Large | 1/3

G: Front Mount:



#6-32 screws

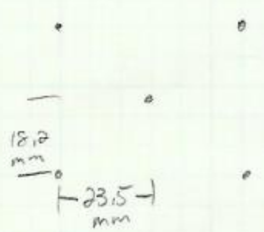
mass/screw = .0027 # = .00123 kg $\quad \phi = .138'' = 3.51$ mm

F: Bolt load

S: Shear load

$$V = \frac{100\ N}{4\ screws} = 25\ N/screw$$

Centroid



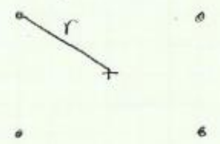
Moment resisted by bolt pattern

$M = Fd$ $\quad$ d = force to centroid = 8 + 23.5 mm = .0315 m

$M = 100N(.0315m)$

$M = 3.15\ N \cdot m$

Radial distance to each bolt from centroid



$r = \sqrt{(.0235m)^2 + (.0182m)^2}$

$r = .0297m$

sum of squares

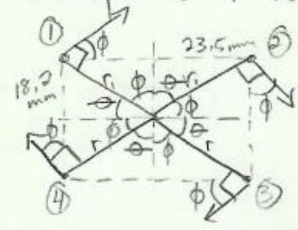
$\Sigma r^2 = 4\,(.0297_m)^2$

$= .00353\ m^2$

Force on bolt

$F = \dfrac{Mr}{\Sigma r^2} = \dfrac{(3.15\,N\cdot m)(.0297m)}{.00353\,m^2} = 26.5N$

Component forces



$r = .0297m$

① $= \theta = \cos^{-1}\left(\dfrac{.0235m}{.0297m}\right) = 37.7°$

$\phi = 90 - 37.7 = 52.3°$

$F_{1x} = F\cos\phi = 26.5N\,(\cos 52.3°) = 16.2\ N$

$F_{1y} = F\sin\phi = 26.5\,N\,(\sin 52.3°) = 21\ N$

② $\theta = \cos^{-1}\left(\dfrac{.0182m}{.0297m}\right) = 52.2°$

$\phi = 90 - 52.2° = 37.8°$

$F_{2x} = F\cos\phi = 26.5N(\cos 37.8°) = 21\ N$

$F_{2y} = F\sin\phi = 26.5N\,(\sin 37.8°) = 16.2\,N$

3 = 1

4 = 2

sum forces in y direction

① = $F_{1y} + F_{shear} = 21N + 25N = 46N$

② = $F_{2y} + F_{shear} = 16.2N + 25N = 41.2N$

③ = $F_{3y} + F_{shear} = 21N + 25N = 46N$

④ = $F_{4y} + F_{shear} = 16.2N + 25N = 41.2N$

Resultant Forces

① $\sqrt{(16.2N)^2 + (46N)^2} = 48.8N$

② $\sqrt{(21N)^2 + (41.2N)^2} = 46.2N$

③ $= 48.8N$ (same as ①)

④ $= 46.2N$ (same as ②)

$\tau = \frac{F}{A}$ $\phi = .00351$ (Fastenal)

① $\tau = \frac{F}{\frac{\pi}{4}D^2} = \frac{48.8N}{\pi/4(.00351m)^2}$

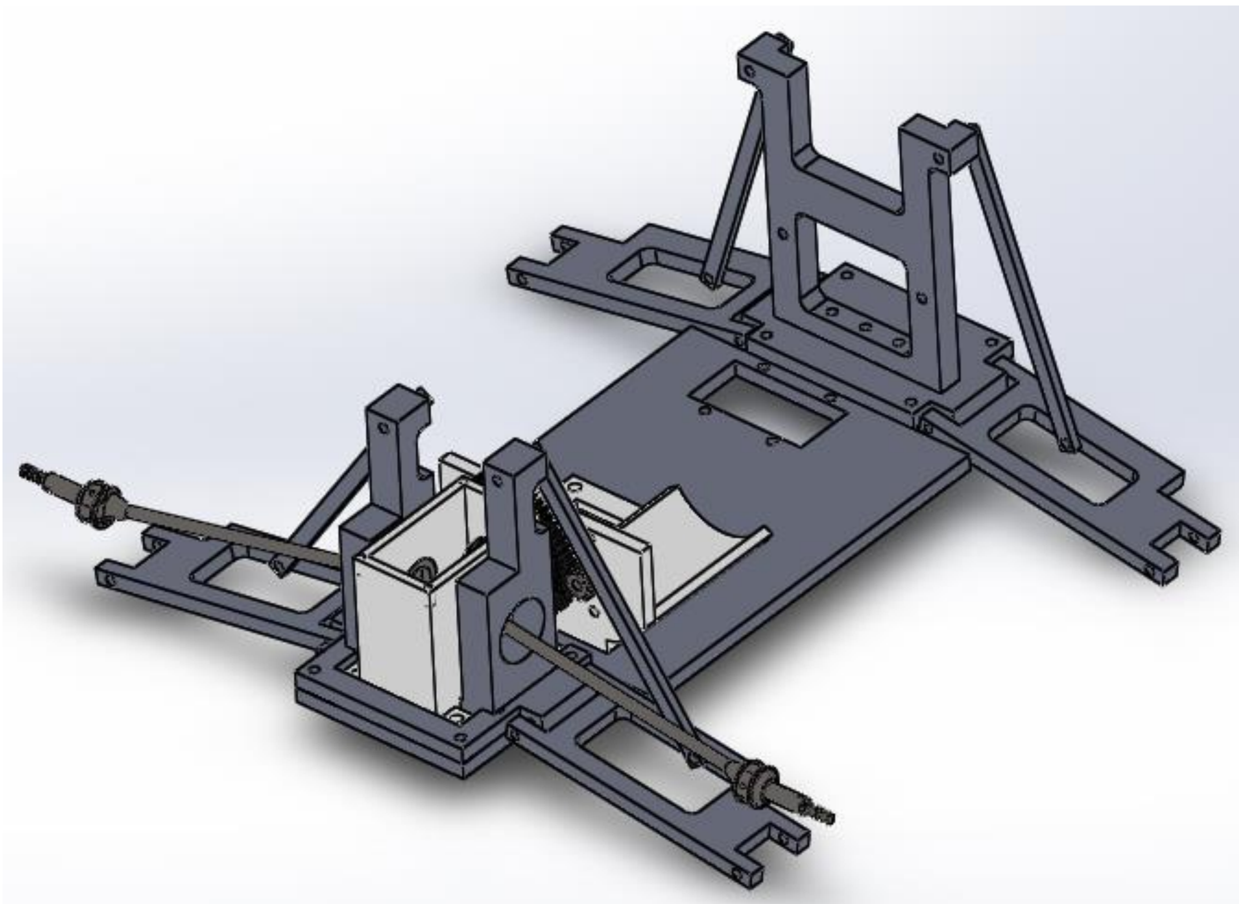
$\tau = 5\,MPa$

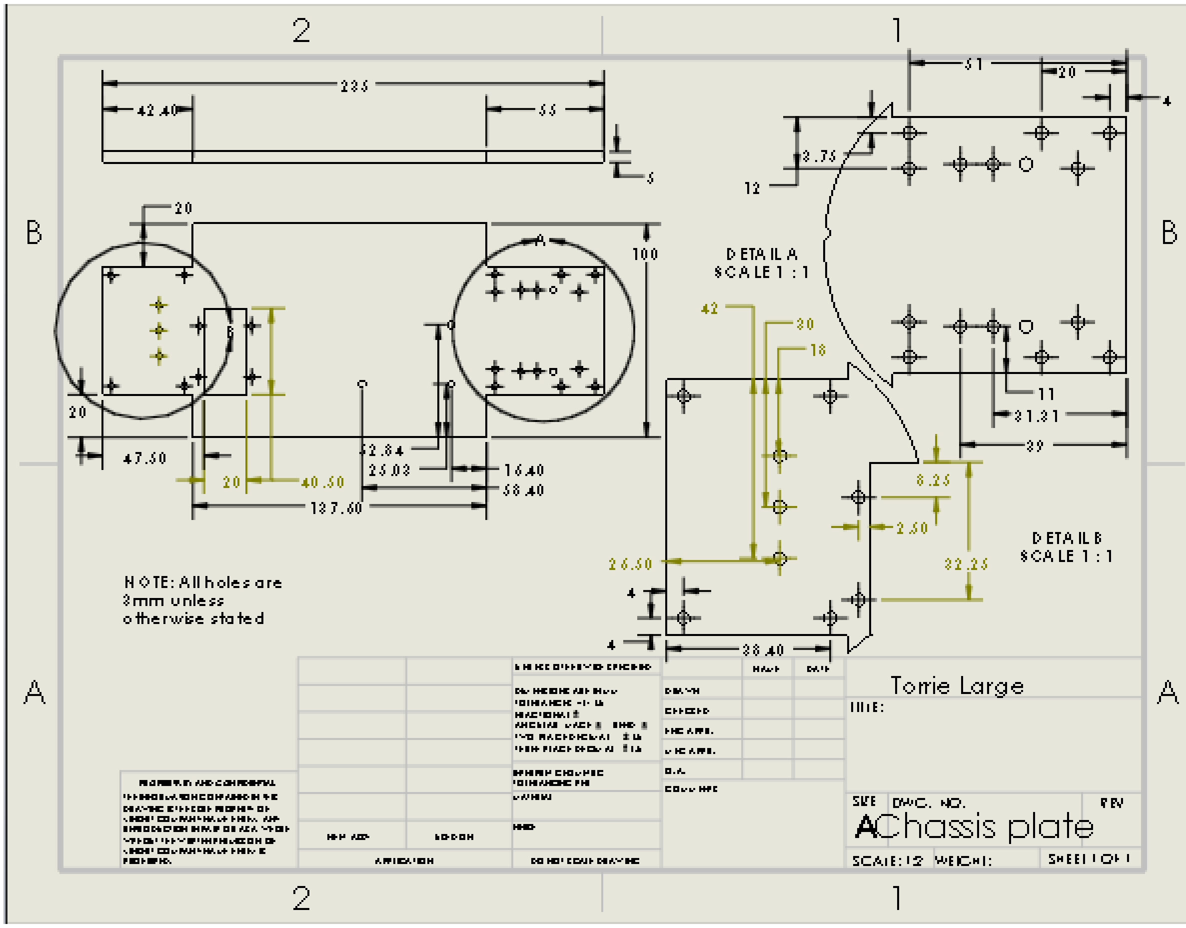
$5MPa < 240MPa$

Screw with the largest force can withstand force of 100N.

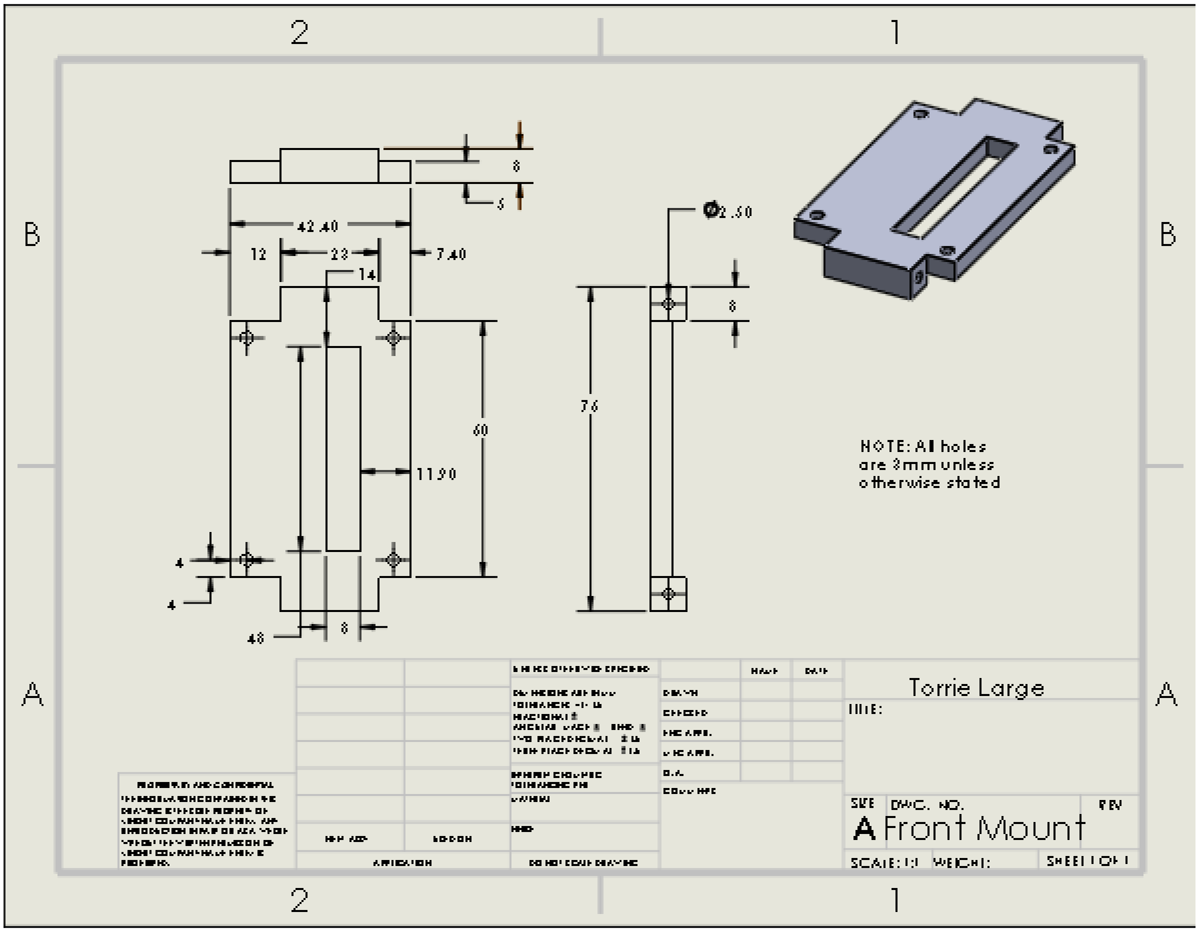
4 screws is enough support. 6 is unnecessary.

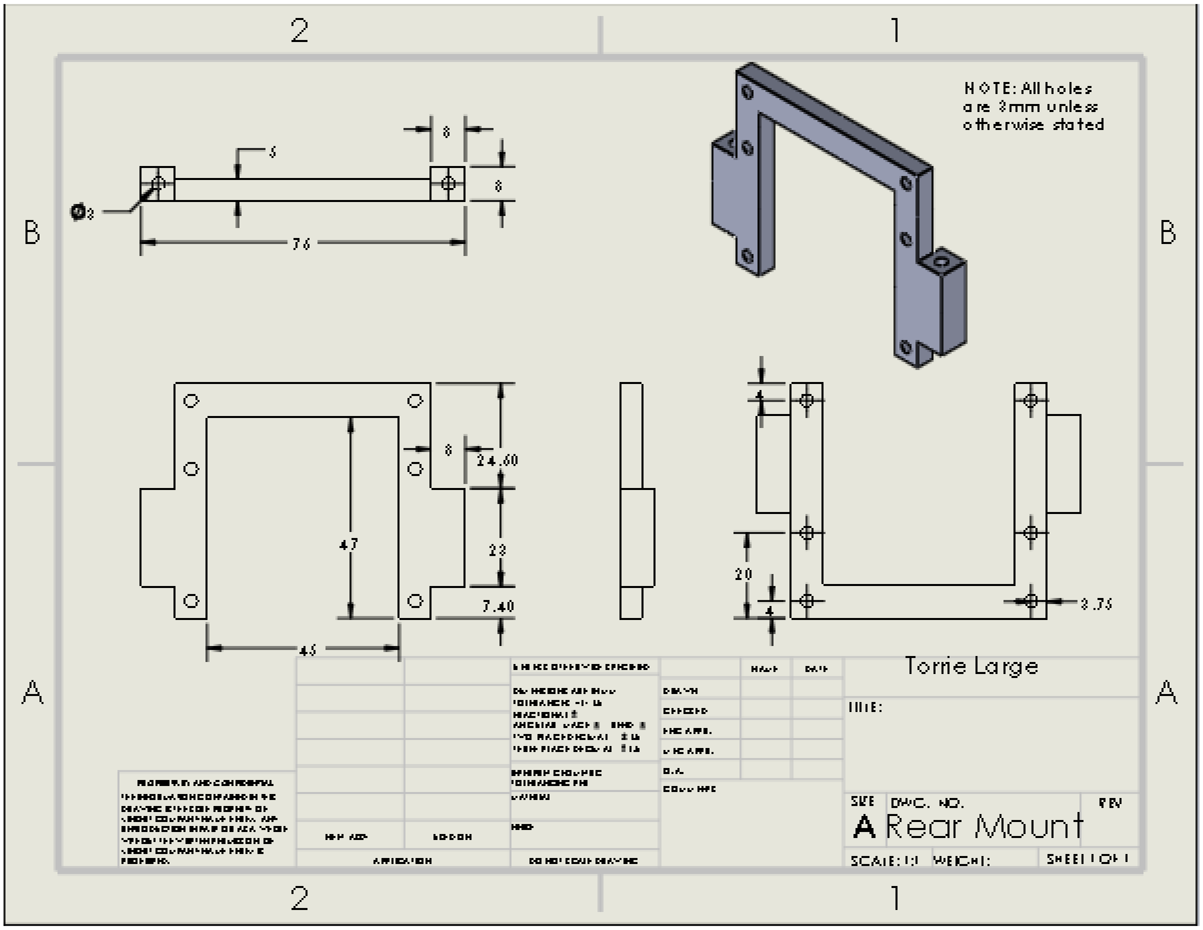
Appendix B



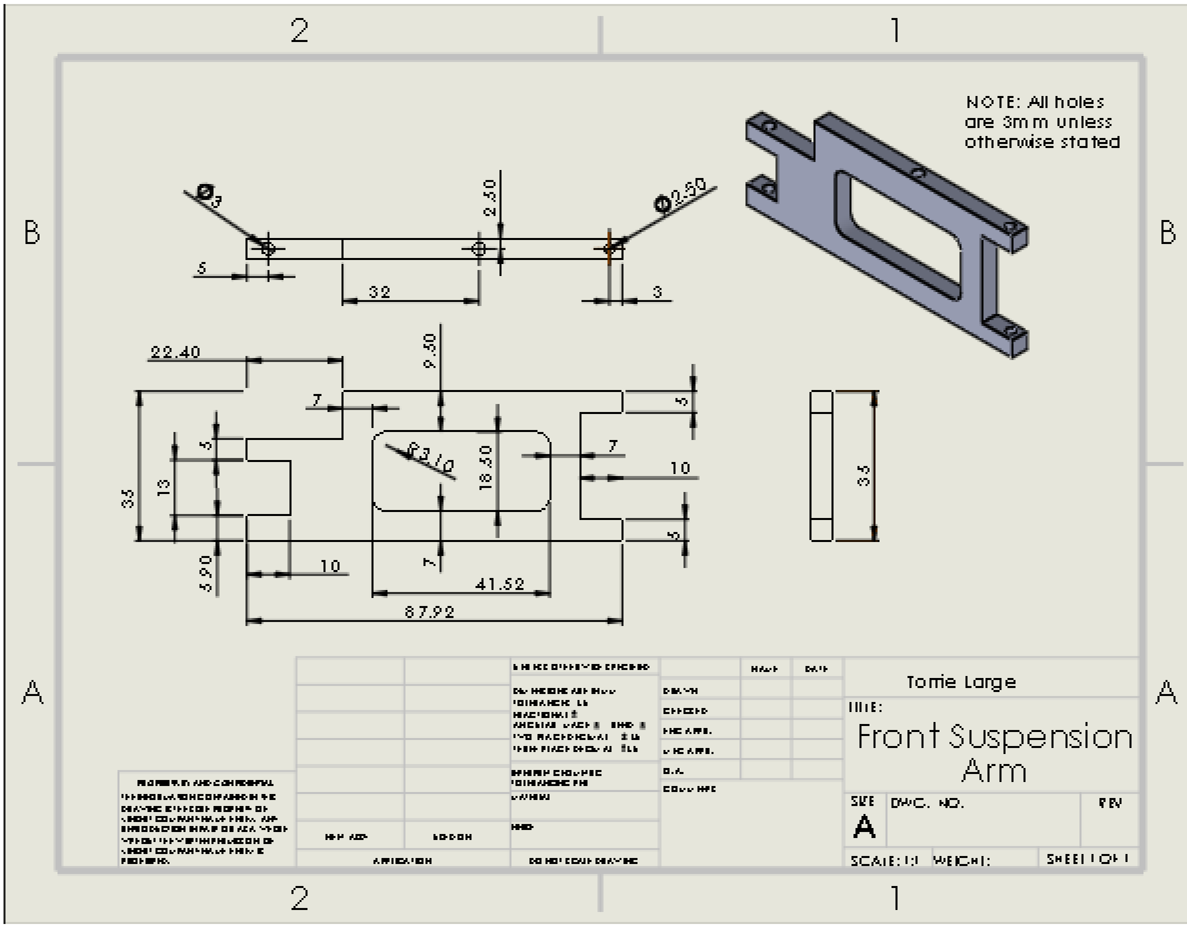


NOTE: All holes are 3mm unless otherwise stated
DETAIL A
SCALE 1 : 1
DETAIL B
SCALE 1 : 1
Torrie Large
TITLE:
SIZE
DWG. NO.
REV
A
Chassis plate
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

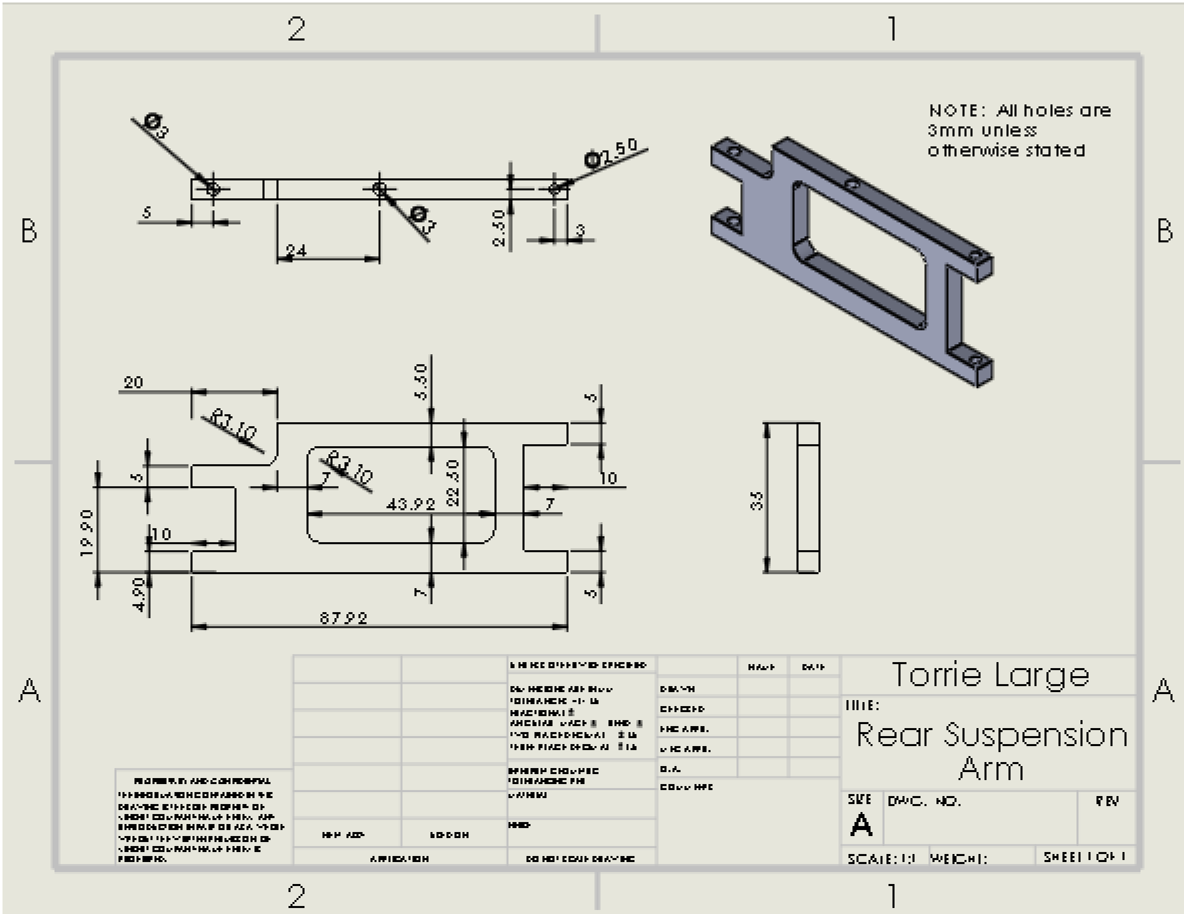

NOTE: All holes are 3mm unless otherwise stated
Torrie Large
TITLE:
SIZE DWG. NO. REV
A Front Mount
SCALE: 1:1 WEIGHT: SHEET 1 OF 1

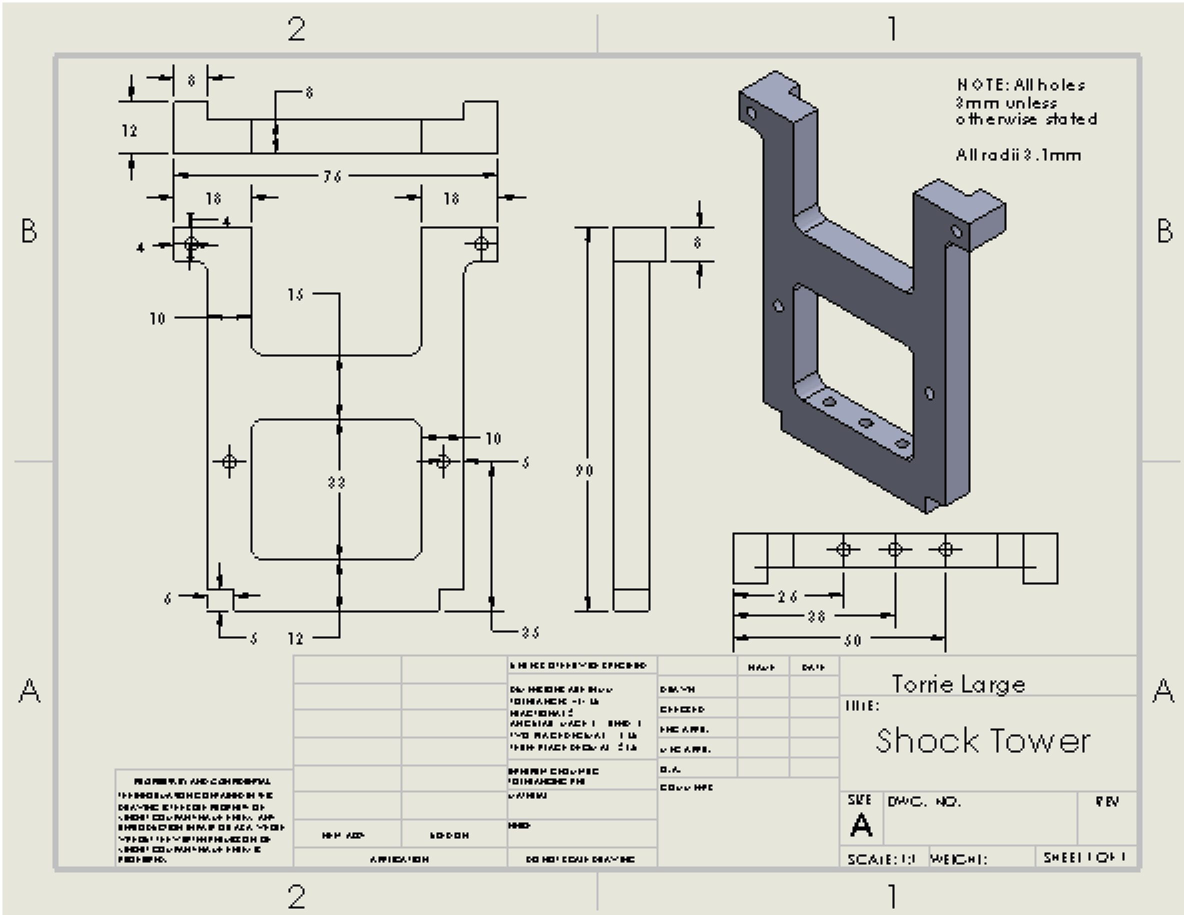


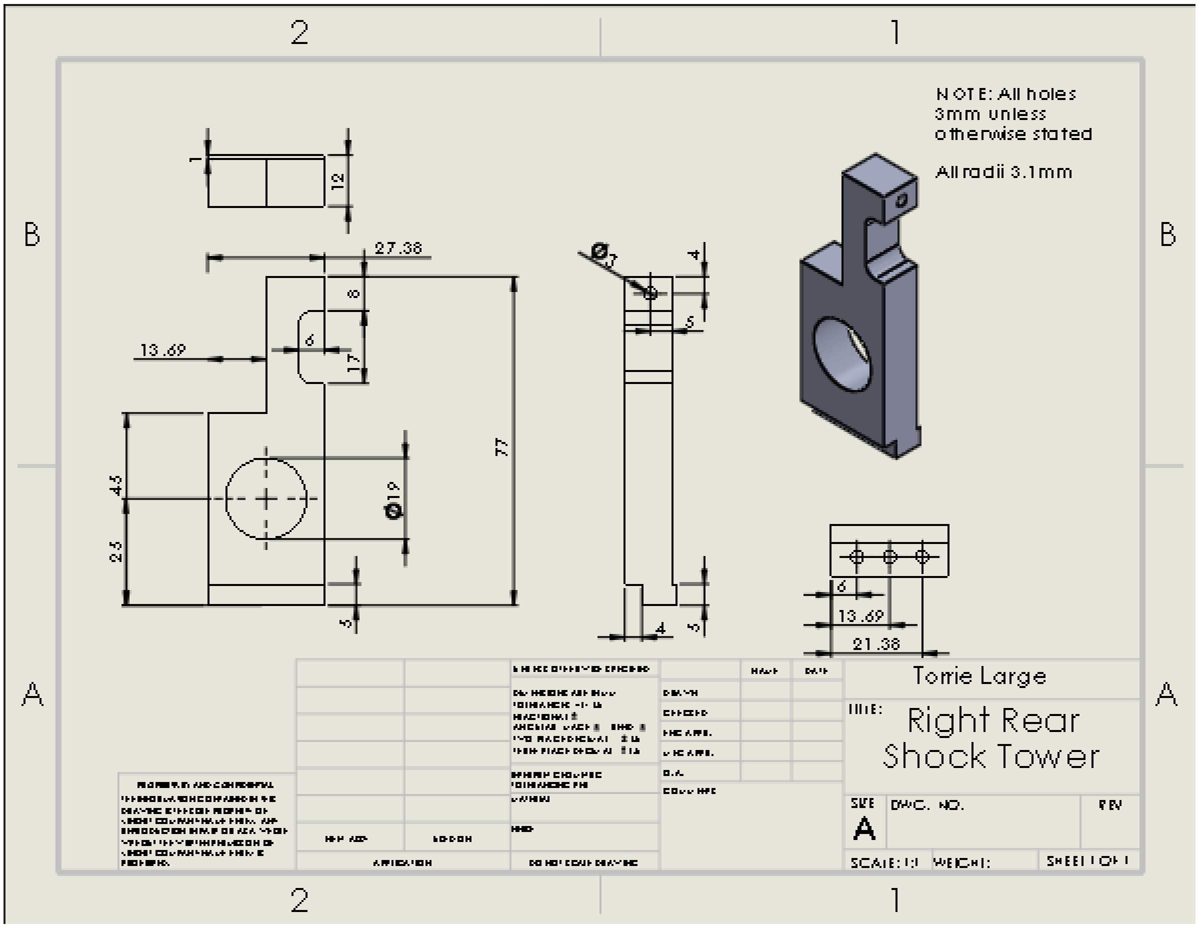
NOTE: All holes are 3mm unless otherwise stated
Torrie Large
Rear Mount
SIZE A
DWG. NO.
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
TITLE:
PROPRIETARY AND CONFIDENTIAL
DO NOT SCALE DRAWING
APPLICATION

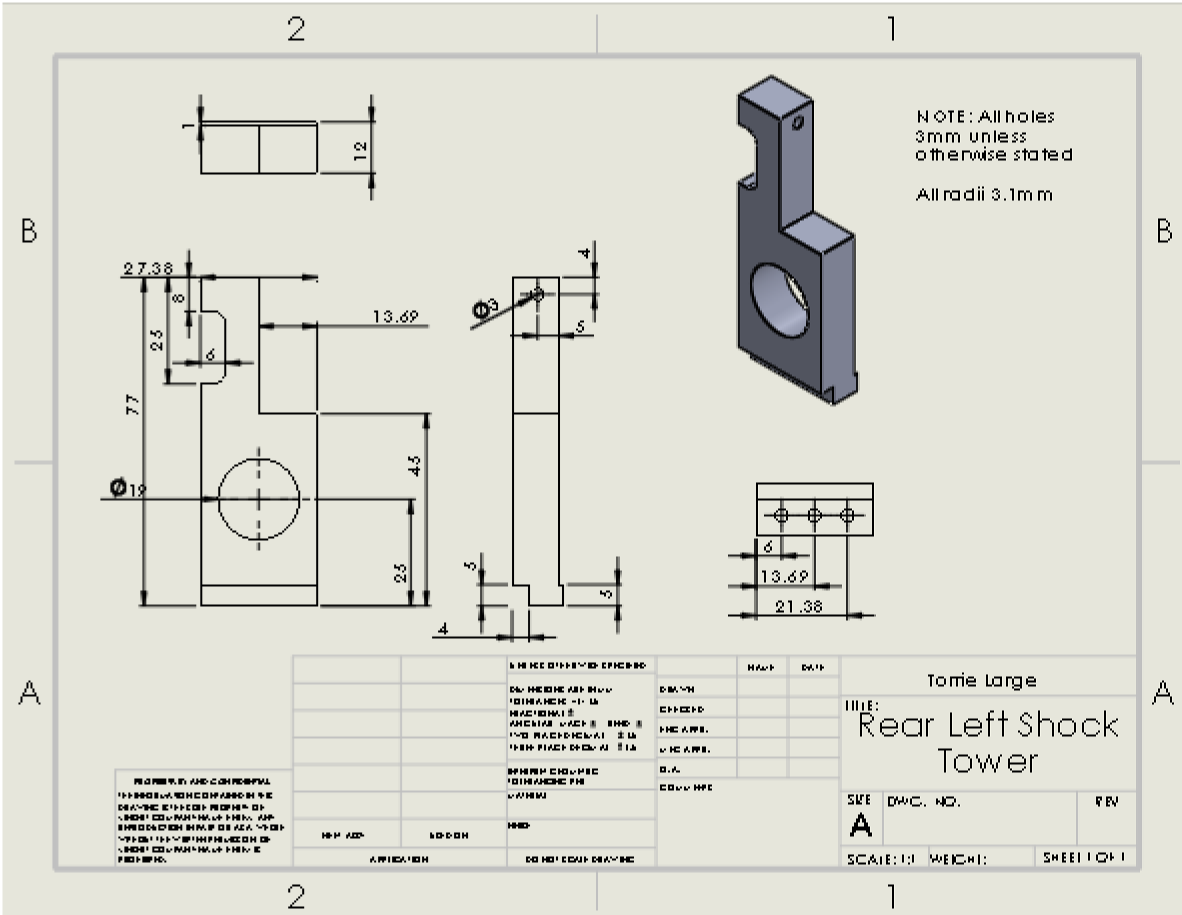


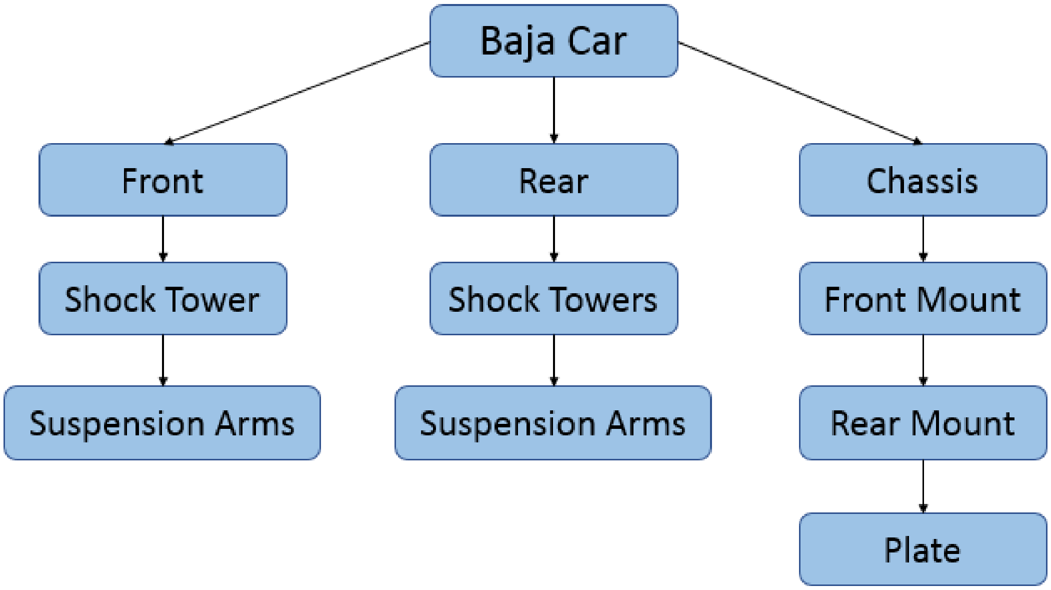
NOTE: All holes are 3mm unless otherwise stated
Tarrie Large
TITLE:
Front Suspension Arm
SIZE
A
DWG. NO.
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1


NOTE: All holes are 3mm unless otherwise stated
Ø3
Ø2.50
Ø3
5
24
2.50
3
20
R3.10
R3.10
5.50
5
5
10
7
43.92
22.50
7
19.90
10
4.90
7
5
87.92
35
Torrie Large
TITLE:
Rear Suspension Arm
SIZE
A
DWG. NO.
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
2
1
B
A


NOTE: All holes 3mm unless otherwise stated
All radii 3.1mm
Torrie Large
TITLE:
Shock Tower
SIZE
A
DWG. NO.
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1


NOTE: All holes 3mm unless otherwise stated
All radii 3.1mm
27.38
13.69
77
Ø19
Torrie Large
TITLE:
Right Rear Shock Tower
SIZE
A
DWG. NO.
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1


NOTE: All holes 3mm unless otherwise stated
All radii 3.1mm
Torrie Large
TITLE:
Rear Left Shock Tower
SIZE A
DWG. NO.
REV
SCALE: 1:1
WEIGHT:
SHEET 1 OF 1
27.38
13.69
21.38


Baja Car
Front
Rear
Chassis
Shock Tower
Shock Towers
Front Mount
Suspension Arms
Suspension Arms
Rear Mount
Plate

Appendix C

Parts List	Made/Bought	# of pieces	Brand	Model #
1. Stub Axle	Bought	4	Traxxas	3637
2. Wheel Nut	Bought	4	Traxxas	3647
3. Hex	Bought	4	Traxxas	3654
4. Spindle	Bought	2	Traxxas	3736
5. Caster Block	Bought	2	Traxxas	3632
6. Suspension Arm	Made	4		
7. Turnbuckle	Bought	4	Traxxas	3908
8. Center Link	Made	1		
9. Hinge Pins	Bought	8	Mini 8ight	LOSB1892
10. Front Mount	Made	1		
11. Shock Tower	Made	1		
12. Shocks	Bought	4	JKShop	B0113T7R3E
13. Screw Pins	Bought	4	Traxxas	4838
14. #6 Machine Screw	Bought	50	Fastenere	3SSMPF06C006
15. Chassis Plate	Made	1		
16. Hub Carrier	Bought	2	Traxxas	1952
17. Servo Mount	Made	2		
18. Rear Mount	Made	1		

Appendix D

Budget

Material Costs

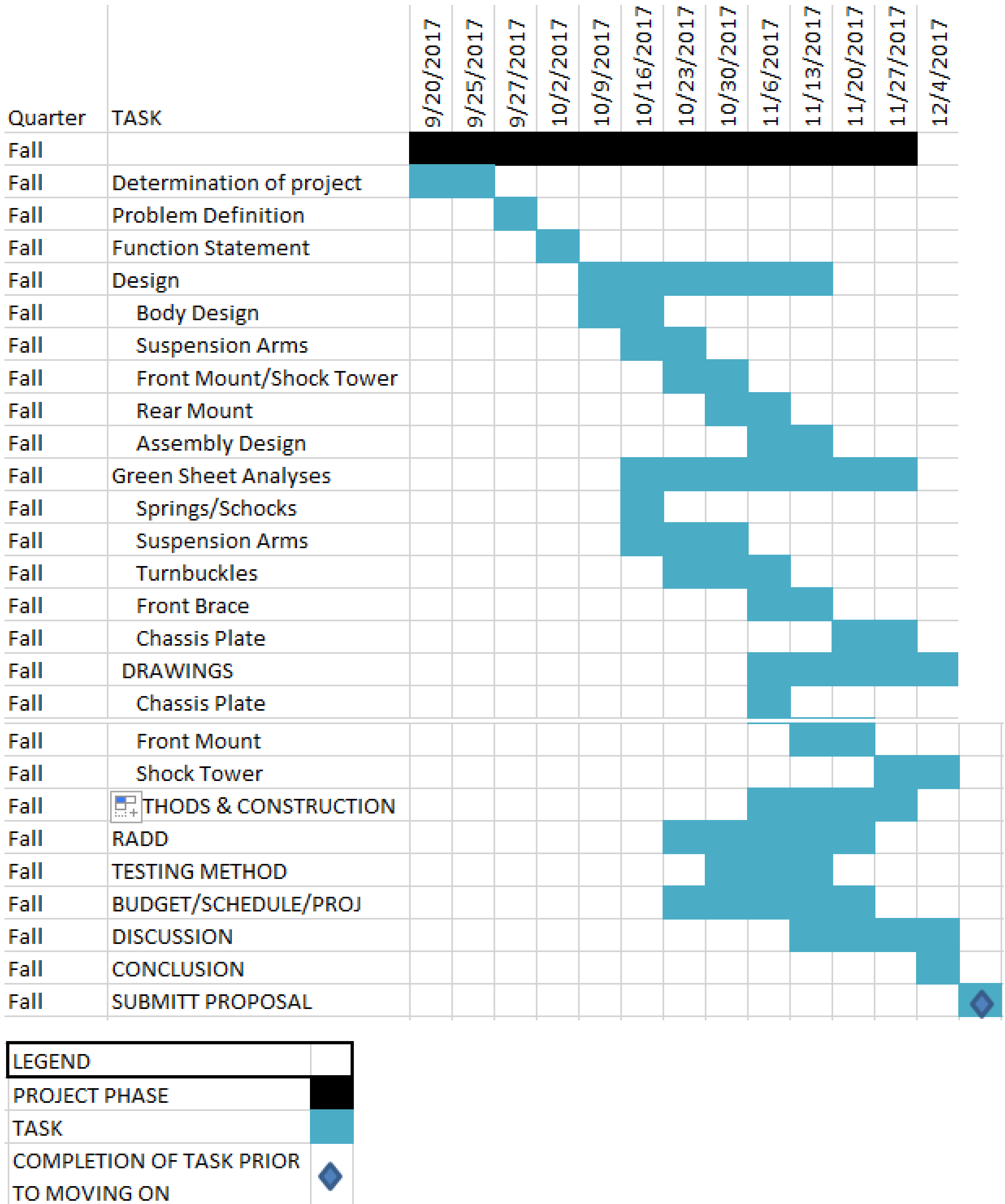
Piece#	Name	Brand/Model #	Source	Price	Quantity
Traxxas Package			Amazon	$38.25	1
1	Stub Axle	Traxxas3637			4
2	Wheel Nut	Traxxas3647			4
3	Hex	Traxxas3654			4
4	Spindle	Traxxas3736			2
5	Caster Block	Traxxas3632			2
16	Hub Carrier	Traxxas1952			2
7	Turnbuckle	Traxxas3908	Amazon	$24.75	1
9	Hinge Pins	TRA4838	Amazon	$8.97	2
12	Shocks	B0113T7R3E	Amazon	$29.99	2
13	Screw Pins	Traxxas4838	Amazon	$3.49	1
			Sub-total	$123.19	

Labor Costs:

20	Hours	Torrie Large		$9.00	204
21	Lab Hours	Torrie Large		$18.00	100
			Total with labor hours:	$3770.05	

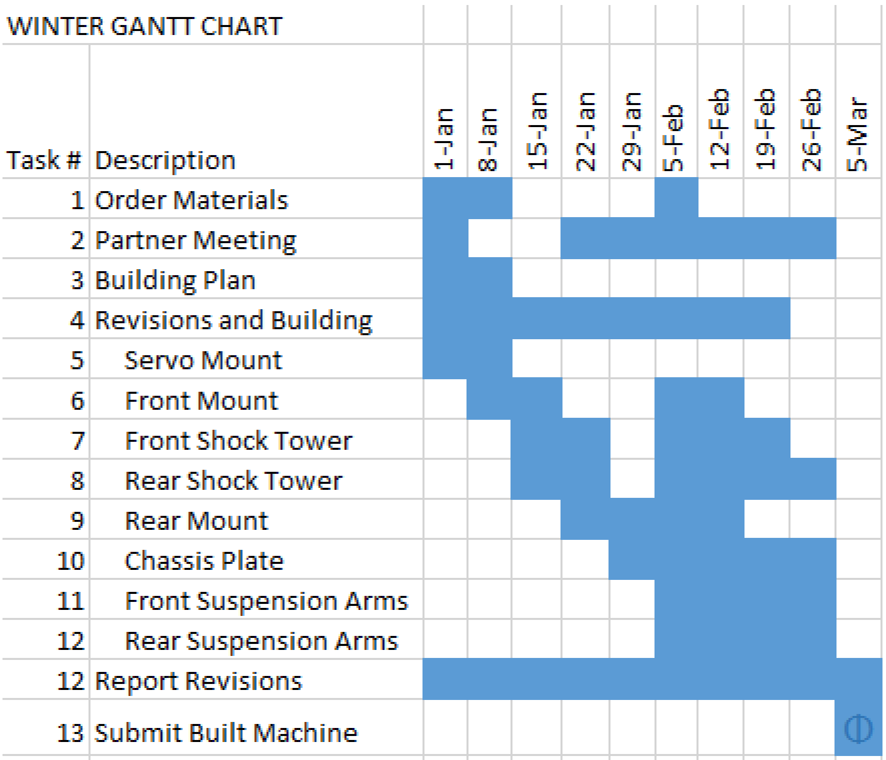
Appendix E

Fall 2017 Schedule

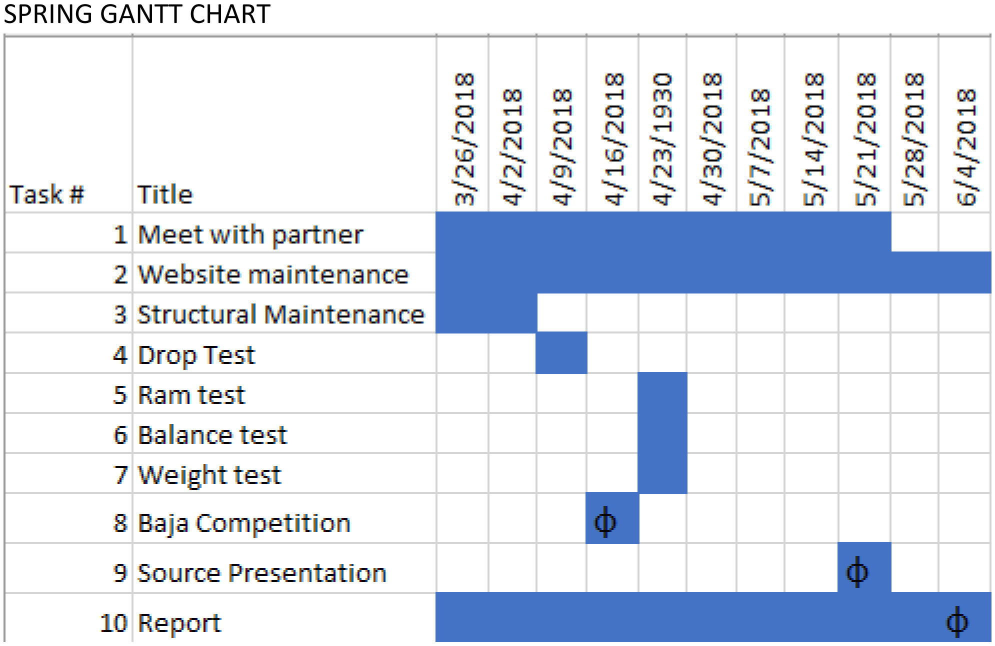


Winter 2018 Schedule

WINTER GANTT CHART



SPRING GANTT CHART



Estimation of Hours

	hrs/wk	wks worked	total
Determination of project	4	2	8
Problem Definition	4	1	4
Function Statement	4	1	4
Design	4	0	0
Body Design	4	2	8
Suspension Arms	4	2	8
Front Mount/Shock Tower	4	2	8
Rear Mount	4	2	8
Assembly Design	4	2	8
Green Sheet Analyses	4		0
Springs/Schocks	4	1	4
Suspension Arms	4	3	12
Turnbuckles	4	3	12
Front Brace	4	2	8
Chassis Plate	4	2	8
DRAWINGS	4		0
Chassis Plate	4	1	4
Front Mount	4	2	8
Shock Tower	4	2	8
METHODS & CONSTRUCTION	4	4	16
RADD	4	5	20
TESTING METHOD	4	3	12
BUDGET/SCHEDULE/PROJ	4	4	16
DISCUSSION	4	4	16
CONCLUSION	4	1	4
SUBMITT PROPOSAL		Total	204

Appendix F

Expertise and Resources

All construction was done in Hogue Metal’s Lab at Central Washington University.

Lab Tech Nolan Stockman used the bandsaw and horizontal saw.

Professor Tedman Bramble programmed the CNC machine for the suspension arms.

Lab Director Matt Burvee supplied all help for basic questions and needs.

Appendix G

Example test sheet

Evaluation Sheet

Date:______________

Tester:_______________

Test #: ________

Criteria being tested:

Testing Environment:

Test Specifics:

Success Criteria:

Success/Failure:

Important details to note:

Appendix H

Evaluation Sheet

Date:_________4/3/18____

Tester:______Torrie Large

Test #: ___1

Criteria being tested:

The car must be able to withstand the force of a drop of two feet.

Testing Environment:

Fluke Lab in Hogue Technology Building at Central Washington University

Test Specifics:

Drop test: Car will be dropped from a height of two feet and then inspected for stresses/fractures.

Success Criteria:

The car will not break from the force of a two-foot drop.

Success/Failure:

The test was performed three times.

All tests were successful.

Important details to note:

Height was measured at the bottom of the tires.

Evaluation Sheet

Date:_______4/25/18______

Tester:______Torrie Large

Test #:__2

Criteria being tested:

The Baja Car must not deflect more than 1.25 in.

The Baja Car must not be more than 6% off balance.

Testing Environment:

Fluke Lab in Hogue Technology Building at Central Washington University

Test Specifics:

Please see the testing section of the report for a full procedure.

Success Criteria:

For the first part of the test, the back end of the car cannot deflect more than 1.25 in.

For the second part of the test to be successful, the percent of deflection must be less than 6%.

Success/Failure:

The three tests performed measured the deflection of the back end of the car measured 0.5 in, 0.25 in, and 0.5 in. All three tests were below the maximum of 1.25 in and considered successful.

The largest deflection was 0.5 inches creating a chassis offset of 14.3%. This measurement would be a failure, but a following observation at 5 seconds showed the deflection recover the original height making the offset 0%. This makes the second test a success as well.

Important details to note:

The tolerance was quite large at 0.25 in. This may or may not influence the resulting measurements.

Evaluation Sheet

Date:_______4/30/18______

Tester:______Torrie Large

Test #:___3

Criteria being tested:

The car must withstand the force of hitting the wall at full speed.

Testing Environment:

Fluke Lab in Hogue Technology Building at Central Washington University

Test Specifics:

Please see the testing section of the report for the full test procedure.

Success Criteria:

The car must be able to hit the wall at full speed without causing any failures to its suspension system.

Success/Failure:

The car did not buckle or fracture under impact. This makes this test a success.

Important details to note:

The design did not account for the extra length of the hinge pins attaching the suspension arms to the chassis. The extra length absorbed much of the energy from hitting the wall. This affected the results of the test.

Appendix I

Testing Results

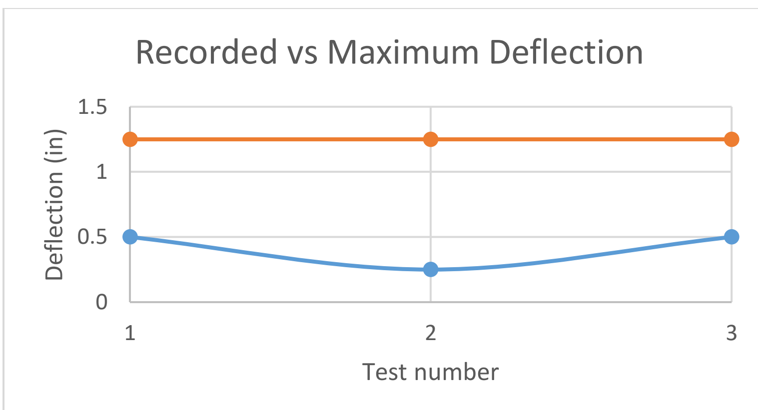
Test 1 Deliverables

The parameters for success was a lack of fractures from the drop. The data provides binomial statistics but not numerical. In the three tests performed, there was a 100% success rate. These results show the dimensions of the part were designed correctly and the car was capable of withstanding the force of a fall of two feet. Please see Appendix H1 for the test data sheet.

Test 2 Deliverables

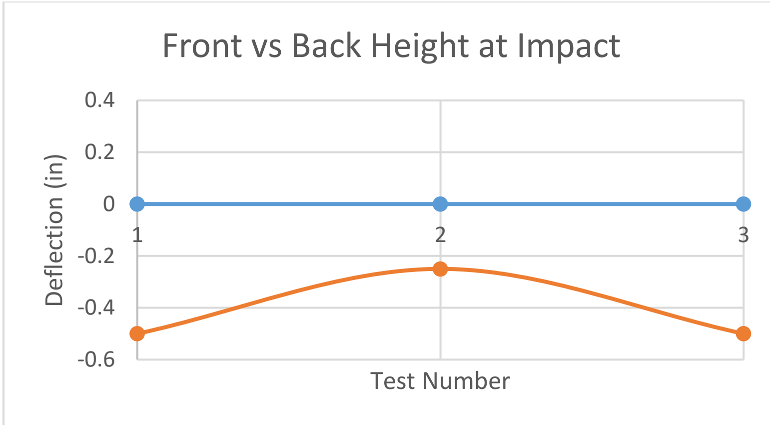
Deliverables

The parameters for success included a maximum deflection limit and a balance percentage maximum. For the first part of the test, the measurements on impact were compared to the deflection maximum. The maximum possible deflection for success was 1.25 inches. This graph illustrates the recorded deflection compared to the maximum deflection:



As shown in the graph, the most the back end of the car deflected was 0.5 inches. This means all three tests were successful.

The second part of the test measured the percent of deflection of the chassis plate on impact and its ability to regain its natural position. The measurements of deflection for the back end of the Baja Car were 0.5 in, 0.25 in, and 0.5 in. If the height of the chassis in its original form (3.5 in) is set at 0 for a reference point, a graph of the collected data is as follows:



At its highest deflection (0.5 in), the car is 14.3% out of balance. When the second measurement was taken (at 5 seconds), the chassis had returned to its original height with an offset of 0%.

Please see Appendix H2 for the testing sheet.

Test 3 Deliverables

The parameters for success in this test were that the car did not have any catastrophic failure after hitting a wall at full speed. The data for this test was not numerical, it was a yes or no option. This data was collected by an observance after the test.

After the car hit the wall, it was thoroughly inspected and found to have no failures or fractures. This test was a success.

One note of importance: The length of the hinge pins extended beyond the front of the car. These pins absorbed much of the initial energy of the impact. This affected the test results.

Please see Appendix H3 for the test sheet.

Appendix J

Torrie Large
(509) 312-0142
tojullarge@gmail.com

Address:
490 Brown Rd
Ellensburg, WA 98926

Summary of Qualifications

- Design techniques practiced in Auto-CAD and SOLIDWORKS
- Basic machining skills to relate to design challenges
- Knowledge of mechanical engineering and mechanical systems
- Ability to use structural calculations to aid in design

Education

B.S. in Mechanical Engineering Technology, Central Washington University, Ellensburg, WA, anticipated graduation: May 2018

Medical Coding Certificate, Perry Technological College, Yakima, WA, 2009

B.A. in Religious Studies, Central Washington University, Ellensburg, WA, 2005

B.S. in Anthropology, Central Washington University, Ellensburg, WA, 2005

Work Experience

Financial Counselor for Ellensburg Dental Clinic, 2009-2011. Provide financial counseling for patients at a low-income dental clinic. Duties include gathering paperwork to allow patients to qualify for various discounts, dental coding for insurance reimbursements, medical record management, and bill collection.

Data Entry, 2006-2010. Enter known data of genealogical information into a database to be transferred to Ancestry.com and paid by an independent party. Duties include putting together multiple sources into a single consistent file, use problem-solving estimations to support known information, and manage my own hours, taxes, and paychecks.

Awards

- Honors GPA in Engineering to date
- Boeing MET/EET/IET Scholarship, 2018
- Kaminski Memorial Scholarship for students in Engineering Fields, 2017
- Heacock Family Scholarship for females in STEM related fields, 2016
- Peabody Scholarship for academic excellence, 2016