2022 University of Cincinnati SAE Baja–Front Suspension Redesign

A Baccalaureate thesis submitted to the

Department of Mechanical and Materials Engineering

College of Engineering and Applied Science

University of Cincinnati

in partial fulfillment of the

requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Bailey George

April 2022

Thesis Advisor:

Dean Allen Arthur

Abstract

The University of Cincinnati Bearcat Baja team competes against other schools by designing, building, and racing vehicles in the SAE Baja tournament. This report will go through the redesigned front suspension of the previous years' (2020) Baja vehicle. With a desired outcome of this project being to provide a suspension solution that would perform better than the previous design. This report will go into detail about the design selection, manufacturing, and results.

Problem Identification and Research

Problem Statement

What is the best geometry for the front suspension system of a 4wd off road vehicle?

Background

The suspension system of a vehicle is designed to absorb the impact of bumps and acceleration of a vehicle and lessen its impact on the main chassis. If the suspension system were ignored completely, and the wheels solidly attached to the frame of the vehicle, the vibration of riding off road would potentially shake the vehicle apart, and every medium sized bump or divot would have a serious chance of damaging the vehicle or injuring the driver (1). With the Baja SAE competition, this is even more important, as the vehicle will be expected to complete difficult and demanding off road courses as quickly as possible. Previous iterations of the Bearcat Baja vehicle solved this by using a suspension system, wherein a piston with a spring, also known as a dampener system, were used to absorb the impact of the terrain and lessen its effect on the vehicle (3).

Research

Problem Scope

This project is limited by time, cost, and materials. Redesigning any significant portion of the frame is prohibitively time consuming and costly, meaning only minor adjustments can me made. Similarly, the wheel hub, spring, and dampener shock system must be used as replacing them is too expensive.

Current State-of-the-Art

The current requirements of the Baja SAE competition require a 4-wheel drive vehicle. The 2017 through 2019 Baja vehicles are not 4-wheel drive, as the 2020 design was intended to be. Additionally, the 2017 through 2019 designs are both double wishbone suspensions (3). The double wishbone is one where there are two “wishbone” shaped suspension pieces on the top and bottom of the tire hub. This has allowed for the restriction of the camber angle as the suspension moves, as well as adjustable ride height and an overall higher ground clearance. However, the double wishbone often used on off road vehicles does not allow enough room for a driveshaft, preventing it from being 4-wheel drive. 2020 attempted to remedy this with a MacPherson strut. The MacPherson strut only has a single support arm, giving it enough room for the driveshaft, but it cannot limit the camber change (4). In doing so, they failed to produce a functional support arm for the suspension. To create a functional 4wd suspension for as low cost as possible, the hub piece purchased by 2020’s suspension team must be used, limiting the options of geometry and suspension type.

End User

The Baja vehicle has an even more limited use pool than most other projects, being specifically the University of Cincinnati Baja team. This will be people in the age range of about 18 to 23, with a vested interest in vehicle manufacture, car design, off-roading, or other closely related subjects.

Conclusion

The suspension system of the Baja vehicle must use a MacPherson style suspension to continue using the existing hub. With the steering, breaks, and tire mount already integrated and complete, this hub would be prohibitively expensive to replace, as well as already being set up for 4-wheel drive. The reduced weight of the MacPherson suspension should also improve the system over previous years. It must also be designed for use in very rough conditions by amateur drivers. This means that it needs to be simple and sturdy, preferably able to be replaced at the competition in the event of a critical failure, ideally incapable of having a critical failure.

Commented [MC1]: Why? How did you come to the conclusion that you must use the MacPherson suspension? Your research doesn't necessarily support this conclusion.

House of Quality

Customer Features

Tire spacing: a narrower wheelbase allows for tighter turns.

Material: Lighter materials of the same strength generally cost more.

Arm length: The arm length will be determined by the tire spacing and ride height.

Upper mounting location: The upper mounting location has several factors controlling it; the travel, the arm length, and the camber angle are the most notable

Driveshaft angle: This will ultimately be controlled by the travel, ride height, and wheelbase, it will be the maximum angle the driveshaft needs to bend

Resting camber: The camber angle of the fully loaded vehicle, determined by the wheelbase, ride height, and upper mounting location.

Engineering Characteristics

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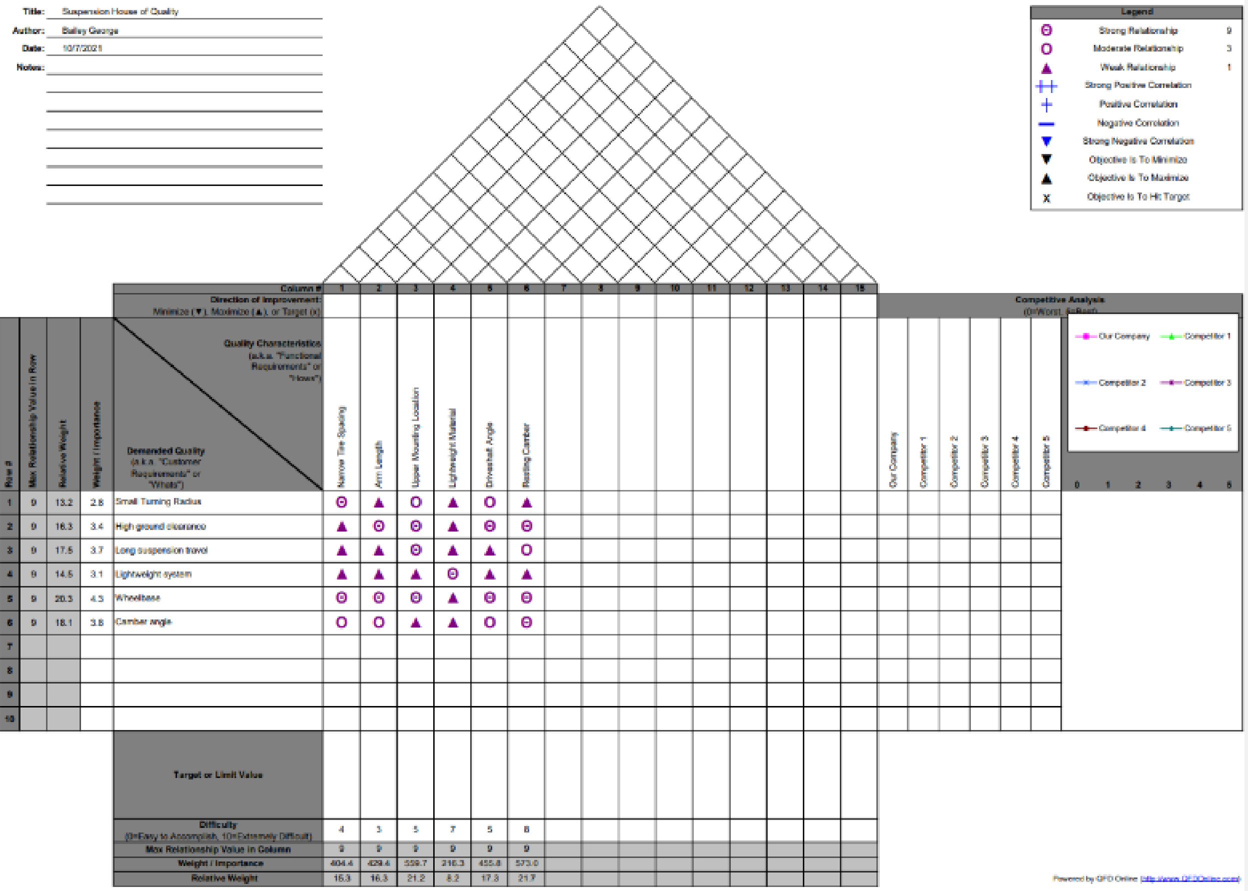
House of Quality



Product Objectives

The objectives pulled from the house of quality are easily determined. The most important feature is maximizing the wheelbase. With a rules limit of 64" maximum (2), this will be the goal, and the feature most things will be derived from. Limiting the amount of camber and having a long suspension travel are next, and we can set optimizing those as the goals of the design (with the wheelbase being the mandatory baseline). Making the suspension lightweight is also important, so cutting weight where available is important. Last on the list is the turning radius, which will likely turn out based on how everything else optimizes to be.

Design Alternatives

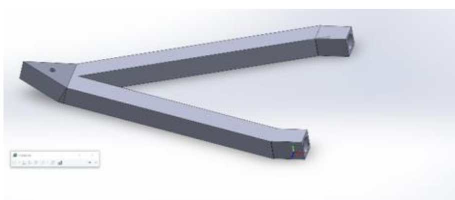


Figure 1. Alternate design of lower support arm

This part was the initial design of the lower support arm, intended to be fabricated out of square steel tubing.

Figure 2. Double arm potential design

This design was suggested but was quickly thrown out as it would have added significantly more weight to the design, as well as more than doubling the workload and cost of materials.

FEA

For the front suspension system, it needs to be able to support all the forces involved in a Breaking-While-Turning maneuver. The braking system is entirely manual, so we used the average kick force of an adult human for the load applied to the brake pedal. The resulting deceleration Is significantly higher than would be used, bringing the car from 35 mph to a complete stop in 0.2 seconds, but when tested, the arm is able to withstand the force with a safety factor of 1.3. As a reminder, this stress is generated when the car changes from maximum speed to a complete stop in 2 tenths of a second, a feat that the brakes themselves are not rated for, but the most extreme case that can occur.

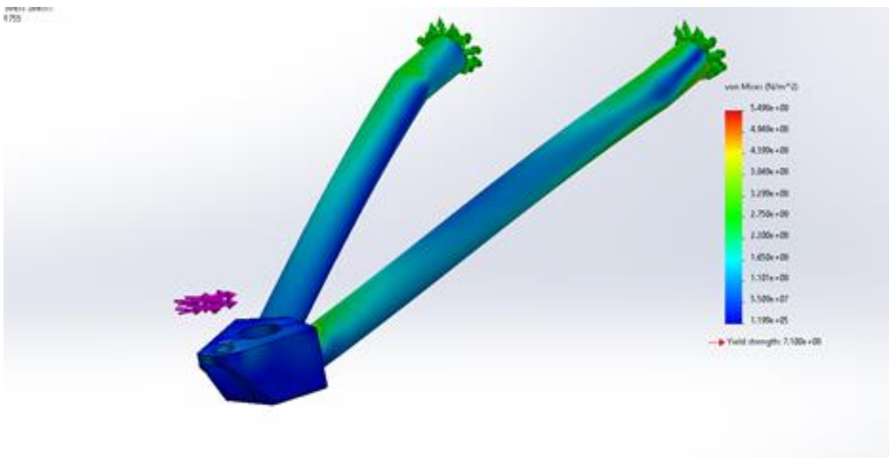


Figure 3. Lower support arm during an extreme breaking-while-turning maneuver

It was specified for the front suspension to have a design that supported the car ~13” off the ground when the car is in resting position (all car parts on, no driver). The suspension of the car must be able to withstand the force that is generated from a six-foot drop. The force is estimated to be about 3000 lbf. The lower support arm simply moves with the force and has very little applied to it from a drop, and the upper arm has no difficulty with unrealistically high stresses, giving a factor of safety of around 2.25. This is with the entire weight of the car landing on a single wheel.

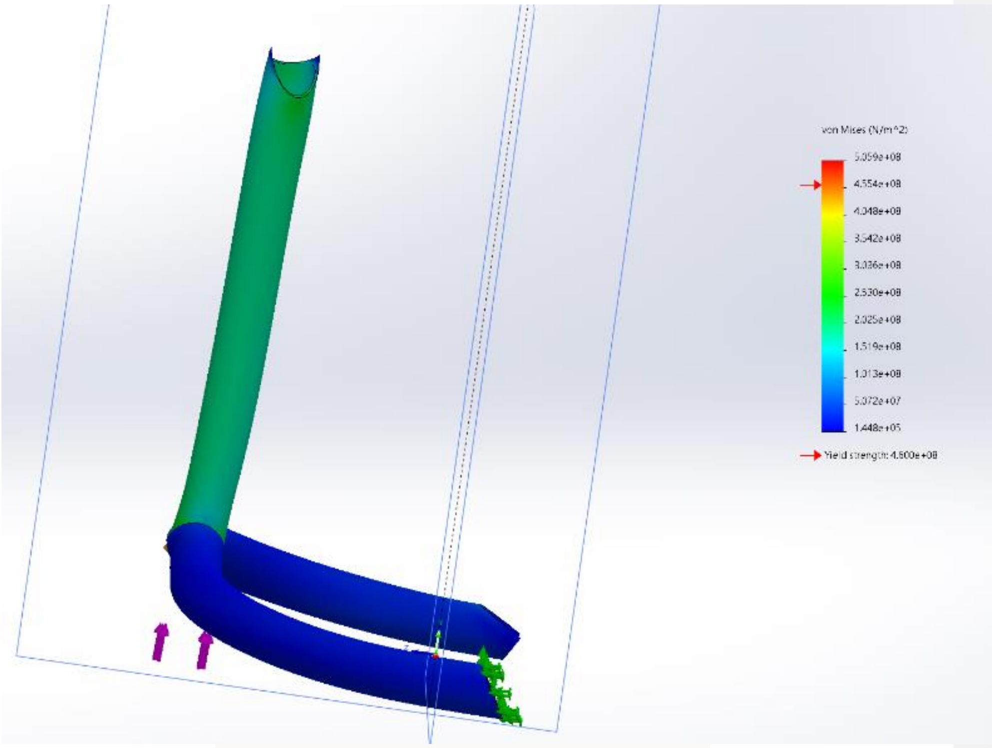


Figure 4. Upper support arm during a 6-foot drop.

Calculations

For the calculations on the overall geometry of the arm, a multi-variable equation was set up. This equation used the known distances between parts on the car and the length and travel of the shock piston, combined with variations on the exact location of the upper arm's position, to calculate the resultant geometry. The final calculation goes as followed:

Input:

Upper arm vertical distance from lower arm mounting point: 18.91"

Upper arm horizontal distance from lower arm mounting point: 5.4"

Known Values:

Distance from outside of tire to lower point of connection horizontally. = 7.50”

Distance from floor to lower point of connection vertically. = 9.00”

Distance from lower point of connection to upper point of connection vertically. = 14.00” (measurement on the hub piece with the tire vertical)

Distance from lower point of connection to upper point of connection horizontally. = 4.50” (measurement on the hub piece with the tire vertical)

Width of frame bracket to bracket/2 = 9.50”

Overall allowed width/2 = 32.00”

Vertical distance from lower bracket to driveshaft = 2.50”

Horizontal distance from lower connection to driveshaft = 2.75”

Vertical distance from lower connection to driveshaft = 4.25”

Horizontal distance taken up by wheel hub/2 = 2.13”

Angle between piston and tire = 15.00°

Distance of piston on upper arm = 6.00”

Length of piston covered = 7.75”

Minimum Piston Length = 23.96”

Maximum Piston Length = 28.96”

Width of differential /2 = 3.00”

Ride height from floor to lower bracket = 14” (there is a 1” difference between the bracket and bottom of the vehicle)

Step 1 Calculations:

Length from lower bracket to strut end=

$\sqrt{Upper\ arm\ vertical\ distance^2 + Upper\ arm\ horizontal\ distance^2}$=19.67" (Pythagorean Theorem)

Inverse angle of strut triangle = $90 - \left(tan^{-1}(\ Upper\ arm\ horizontal\ distance / Upper\ arm\ vertical\ distance)\right)$ = 4.06°

(Trigonometric Functions of Sine, Cosine, and Tangent)

Upper to lower diagonal=

$\sqrt{Connection\ points\ vertically^2 + Connection\ points\ horizontally^2}$=14.71"

(Pythagorean Theorem)

Travel Allowed = $Maximum\ piston\ length - Minimum\ piston\ length$= 5.00"

Vertical distance covered by support arm = $Ride\ Height - Floor\ to\ lower\ connection\ vertically$ = 5"

Horizontal Distance covered by support arm = $Overall\ allowed\ width/2 - (Width\ of\ frame + Distance\ from\ outside\ tire\ to\ lower\ connection\ point\ horizontally)$ = 15"

Step 2 Calculations:

Angle of support arm =

tan ($Vertical\ distance\ covered\ by\ bar / Horizontal\ distance\ covered\ by\ bar$) = 18.43°

(Trigonometric Functions of Sine, Cosine, and Tangent)

Angle of driveshaft = $\frac{tan^{-1}(Vertical\ distance\ covered\ by\ support\ arm - Vertical\ distance\ from\ lower\ connection\ to\ driveshaft)}{((Horizontal\ distance\ covered\ by\ support\ arm - Horizontal\ distance\ from\ lower\ connection\ to\ driveshaft) + (Width\ of\ frame/2 - Strut\ distance\ horizontally))}$ = 9.83°

(Trigonometric Functions of Sine, Cosine, and Tangent)

Step 3 Calculations:

Length of support arm = $Vertical\ distance\ covered\ by\ support\ arm/\sin(Angle\ of\ bar)$ = 15.81” (Trigonometric Functions of Sine, Cosine, and Tangent)

Step 4 Calculations:

Length of piston =

$$\sqrt{\begin{matrix}Length\ of\ support\ arm^2 + lenght\ from\ lower\ bracket\ to\ strut\ end^2 - \\ (2 * Lenght\ of\ support\ arm * Length\ from\ lower\ bracket\ to\ strut\ end * \\ \cos(Inverse\ angle\ of\ strut\ triangle + Angle\ of\ support\ arm)\end{matrix}}$$

(Trigonometric Functions of Sine, Cosine, and Tangent & Pythagorean Theorem)

Step 5 Calculations:

Piston angle = $\cos\left(\frac{Lenght\ from\ lower\ bracket\ to\ strut\ end^2 + Lenght\ of\ piston^2 - Length\ of\ support\ arm^2}{2 * Lenght\ of\ lower\ bracket\ to\ strut\ end * Length\ of\ piston}\right)$

= 37.81° (Trigonometric Functions of Sine, Cosine, and Tangent & Pythagorean Theorem)

Step 6 Calculations:

Camber angle off of 90 = $90 - ((180 - (Piston\ angle + Angle\ of\ support\ arm + Inverse\ angle\ of\ strut\ triangle)) + Angle\ of\ support\ arm + Angle\ between\ piston\ and\ tire)$ = 6.88

Results:

These calculations were repeated for the rise and drop height, and the maximums and changes were analyzed to determine if features such as the camber change, resting camber, and maximum and minimum piston lengths were within restrictions and the limits of the physical components.

Manufacturing

To allow for the easiest manufacturing process, the parts were kept as simple as possible, using as few pieces as necessary. To improve the upper arm’s support ability, however, the straight lines were changed to two curved pieces, and the vertical bar given a different angle. Upon finding out that the given tools lacked the ability to adjust the radius of a curve beyond two preset values, it had to be changed again, with the final design being as shown below.

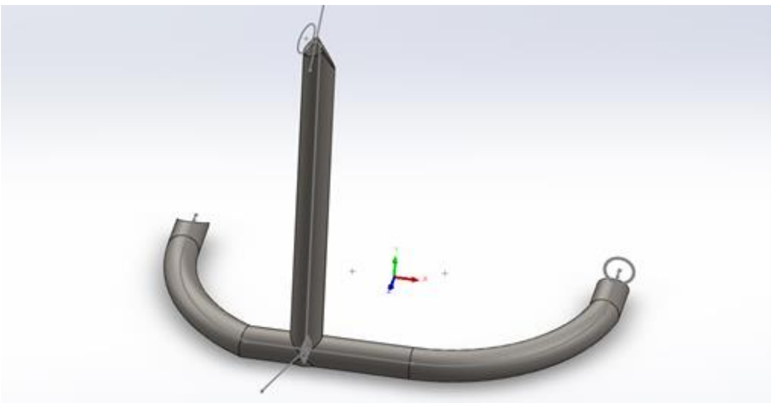


Figure 5. Updated Upper Support Arm

Results

The final geometry for the assembled parts is within recommendations in all fields except for turning radius. The vehicle is able to rest at 13" with no camber, a 6° caster, and 1/16th" of toe outward. The ride height increase of 2" to 15" sees a camber change of -4°, well within the ±10° recommendation for typical Baja tires (6). The caster changes to 8°, 1° above "optimal" caster (7), but the vehicle is moving around the rear tires, not undergoing an even rise and drop, meaning this change is more pronounced than it would be if the vehicle were raised from the center. The toe, however, has reduced to nothing in the 2" rise stage. For the 4" drop of ride height to 9", the camber has a +6° change from ride height, again within recommendation. The caster, however, changes to 2°, 3° below optimal. Given that it is still rotating around the rear tires, and the 9” height is likely only to exist for seconds from landing after becoming airborne, this caster fluctuation is acceptable. The toe for the 9” height has a 2.5” difference between the front and the back. With a 24” diameter wheel, this results in each tire being approximately 3° out from straight. This minor fluctuation is typically considered acceptable within the Baja community (8), and again, exists only briefly after landing.

The biggest flaw in the design of the front suspension comes about in the turning radius of the vehicle. With the displacement of the steering column control arm being so large, the rack and pinion gearing only provides enough change to turn the wheel 27°. With the 70” wheelbase of the vehicle, this results in a 137” or 11.4’ turning radius for the vehicle, while the average is near 8’. This puts the vehicle in the largest 25% of the Baja community, meaning ¾ of the vehicles can outmaneuver the Bearcat Baja vehicle (5).

Project Management

Initial Budget

Item	Qty	Price	Sub total
tube adapters .5 ID .75 OD 20 tpi	4	7.95	31.8
.5 head, .5 shaft 20tpi heim joint	2	21	42
2x Heim joint female .5id, 20tpi	2	9.43	18.86
misalignment spacer pair	2	6	12
steel tubing, 1/16” thickness, aisi 4130 steel, normalized	6	11.38	68.28
steel tubing, 1/8” thickness, aisi 4130 steel, normalized	4	18.56	74.24
1018 cold rolled steel, 3"X3"X6"	1	35.66	35.66
Total			282.84

Final Budget

Item	Qty	Price	Sub total
.5 head, .5 shaft 20tpi heim joint	2	21	42
2x Heim joint female .5id, 20tpi	2	9.43	18.86
misalignment spacer pair	2	6	12
1018 cold rolled steel, 3"X3"X6"	1	35.66	35.66

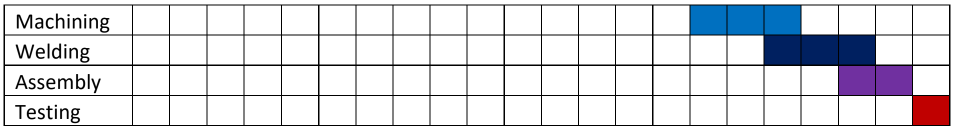
Castle Nut 3/8"-24	2	2.3	4.6
Total			113.12

Proposed Schedule

	10/27/20	11/3/202	11/10/20	11/17/20	11/24/20	12/1/202	12/8/202	12/15/20	12/22/20	2/2/2022	2/9/2022	2/16/202	2/23/202	3/2/2022	3/9/2022	3/16/202	3/23/202	3/30/202	4/6/2022	4/13/202	4/20/202	4/27/202
Suspension Geometry	■	■																				
Solidworks Modeling			■	■	■	■																
Solidworks FEA							■	■														
Welding Practice									■	■	■											
Part Ordering									■													
Bending												■	■	■								
Machining															■	■	■	■				
Welding																			■			
Assembly																				■		
Testing																					■	■

Actual Schedule

	10/27/20	11/3/202	11/10/20	11/17/20	11/24/20	12/1/202	12/8/202	12/15/20	12/22/20	2/2/2022	2/9/2022	2/16/202	2/23/202	3/2/2022	3/9/2022	3/16/202	3/23/202	3/30/202	4/6/2022	4/13/202	4/20/202	4/27/202
Suspension Geometry	■	■																				
Solidworks Modeling			■	■	■	■	■	■														
Solidworks FEA									■													
Welding Practice									■	■	■	■	■	■								
Part Ordering										■												
Bending															■	■	■					



Contact

Bailey George

georgebl@mail.uc.edu

Mechanical Engineering Technology

University of Cincinnati 22’

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Appendices

Weekly Reports

Front Suspension Redesign

10-27

This past week I built an excel document to help calculate the geometry of the suspension system when viewed head-on. I made comparisons between the existing design and the re-design I had come up with the week before (adding a second arm). I was able to determine that with the existing hub and wheel structure, 13” clearance, and a drop of 6” and rise of 2”, the required travel of the piston needs to be at least 6 inches. It is currently mounted to a plate and that will need to be changed to a swinging joint as the piston will swing, and the camber will change, by approximately 12 degrees.

By changing the upper mounting position of the piston, the piston travel can be reduced to ~4.4”, at the cost of increasing the camber angle change to ~18 degrees. Regardless of if that is an appropriate amount of camber sway, that method also directly affects the resting camber, causing the bottom of the tires to kick out to 64 degrees (top of tire tilted towards the car).

For the theoretical double arm shaft, due to the nature of a double arm, there should not be any camber sway (the top arm and the bottom arm are set to be the same length). Using the same clearance, drop, and rise values, I was able to calculate important values for this design. Being able to move the piston along the upper arm allowed me to easily set the required piston travel to be 4.4” and it can be adjusted further.

Also of note, the driveshaft must be able to max out to a 33-degree angle without being damaged and must regularly sit at 19 degrees.

Pending approval of the double arm design over the single arm due to the reduced camber sway and the single arm's inability to use the piston it is fitted with, I intend to spend the next week adjusting the positions of the arms to get the desired resting camber angle, as well as decide the piston to use and fit its' length and travel into the equations for the frame.

11-3

Observations of the piston resulted in 5” of travel for the piston as well as minimum and maximum lengths for the piston. Using the lengths and travel, I put them into the comparison excel document to determine the results on the rest of the system. As the desired vehicle travel is now, with 6” down and 2” up, there is a narrow position where the piston is the right length and has the right travel to reach those parameters. The resultant resting camber is 21 degrees, and I have been advised to keep camber within 10 degrees (aligning with the University of Akron 2015 BAJA design). To this end, the design was tested reducing the drop ability of the vehicle from 6” to 4” to always get the camber within 10 degrees and giving a resting camber of 7.1 degrees in the negative and maximum of 9.8 degrees.

I was also able to measure the plunge of the driveshaft and integrate it into the calculations, fixing the erroneous previous driveshaft angle and adding a variable for integration placement into the gearbox to view its results. I will need to communicate with the drivetrain group, but I believe the best option would be to lengthen the driveshaft enough that it can directly connect to the differential, as a more central driveshaft endcap has less maximum driveshaft angle and will be easier on the knuckle. Set at being 3 inches from the centerline of the car, the driveshaft rests at 9.8 degrees and maxes out at 23 degrees (still using the same 4” drop as opposed to the original 6” drop).

With these results, I intend to begin modeling the upper support for the piston at the indicated distance as well as improving the “hub” piece model so it can be used in the modeling phase.

11-10

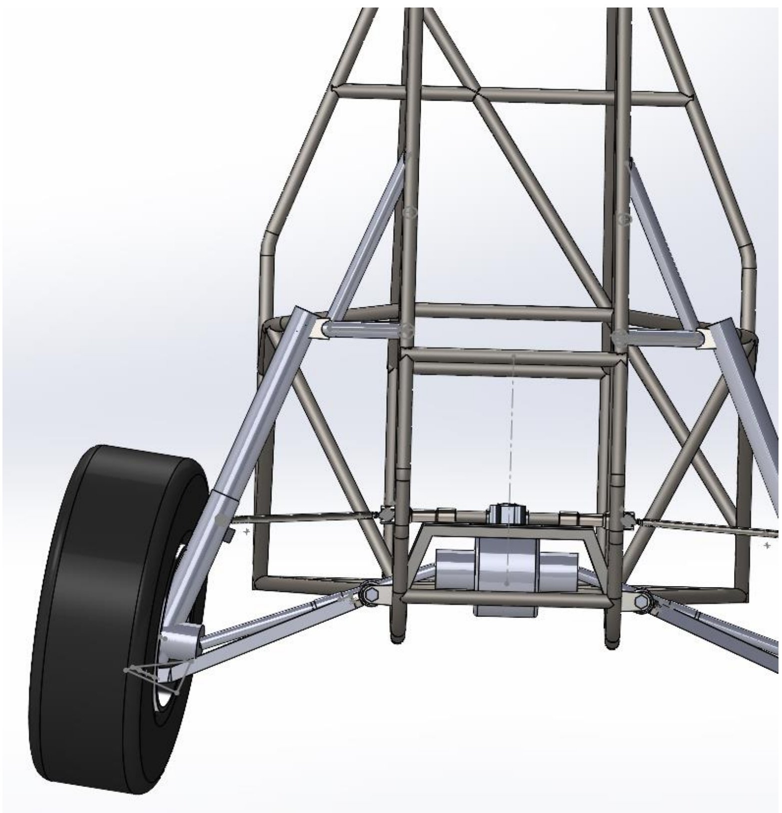
During the past week I have modeled the “hub” piece to an accuracy I find acceptable, modeled an approximation of the piston, modeled the first design of the arm piece, and a placeholder for the upper mounting position. I have also put them in an assembly drawing and have mostly completed the required mates for the assembly.

Over the next 2 weeks, I intend to complete the model and run stress evaluations in Ansys. I do not know what point I will be at next week, but I should be able to complete the initial stress evaluations and probably initial part redesigns within 2 weeks.

11-17

The 3d model has been completed and is showing that my calculations were in error. The 2” rise height is over compressing the pistons, meaning that the position of the upper supports is incorrect. The 4” drop appears to be also incorrect, but I hope that correcting the upper support position will alleviate that problem. As it is now, the structure is in position and the model can be manipulated.

I intend to spend the rest of the week finalizing the position of the upper support and will provide the final model once it is completed, unless there is a better way I do not yet know.



11-24

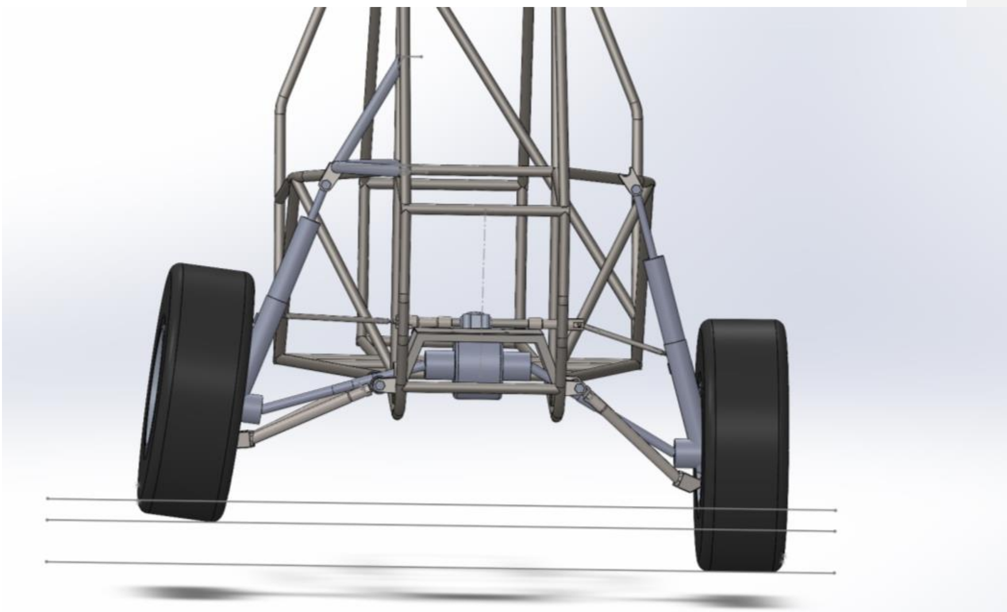
Over the last week I was able to get most components of the model functional. I fixed an error I had with the length of the piston and that allowed fewer design changes than expected. I have attached images showing important variations of the suspension system. I was unable to get the steering to function and will need outside help to complete that. Additionally, the driveshaft may need reworked as it will interfere with the crossbeam.

For next week, I will be focusing on preparing the presentation. If I have time around that, I will get help on the steering system in solid works.

12-15

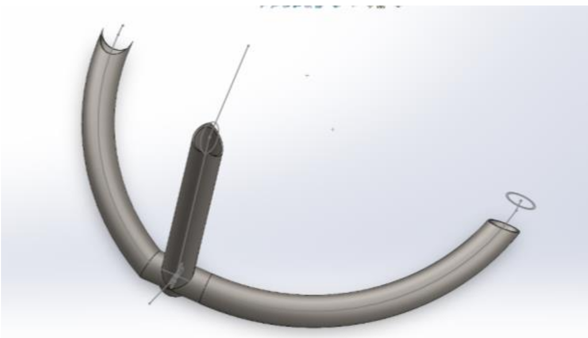
This past week I rebuilt the upper support arm so that the mounting tabs could be placed at a ~22 degree angle. This allows the force to be more completely spread through the part, as opposed to leveraging against it.

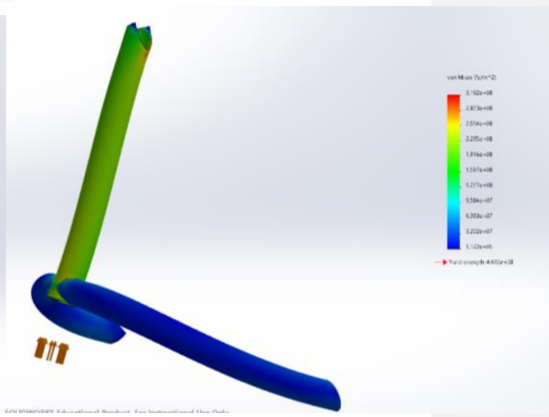
This week I intend to get in practice with my personal MIG welder to get general practice with welding. This is so long as there are no obvious flaws with the design.

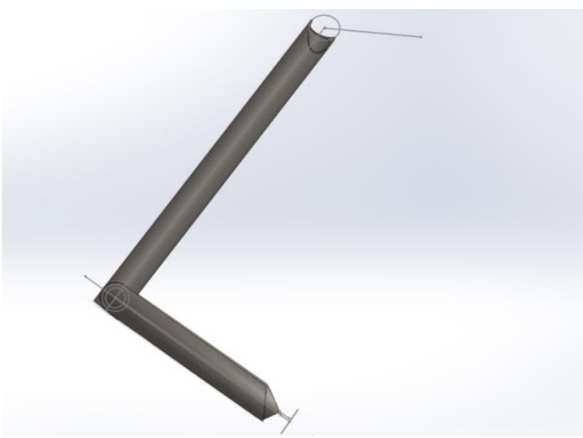


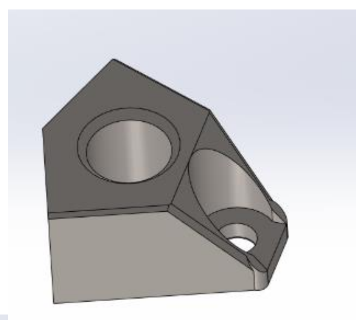
12-22

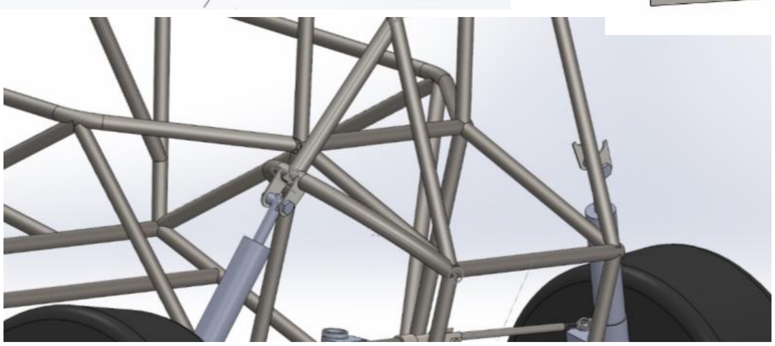
This past week I completed the redesign of the upper support arm and it's FEA. I was also able to finalize the design for the lower arm connection point











2-2

Final Required Materials List

4x tube adapters .5 ID .75 OD 20 tpi

$7.95 each https://www.ruffstuffspecialties.com/R1975.html

2x .5 head, .5 shaft 20tpi heim joint

$21 for both https://www.heimjoints.net/products/copy-of-500-1-2-rod-end-heim-joint-with-jam-nut-left-hand-thread-reverse

These should be in the shop, but they are missing

2x Heim joint female .5id, 20tpi

$9.43 each https://www.mcmaster.com/60645K36/

2x misalignment spacer pair

$6 each https://www.qscomponents.com/products/1-2-to-3-8-hms-kit?_pos=6&_sid=f2a4b8f25&_ss=r

~~6' steel tubing, 1/16" thickness, aisi 4130 steel, normalized~~

~~Steel grade called into question, plenty potentially available in shop.~~

~~4' steel tubing, 1/8" thickness, aisi 4130 steel, normalized~~

~~Steel grade called into question, ~6' potentially available in shop.~~

2x steel block 2.75"x3"x2.8" minimum, aisi 4130 steel, normalized

~~Cannot locate, substitution 1 is A-36 steel, $247.80 for 2'~~

~~https://www.metalsdepot.com/steel-products/steel-square-bar~~

Substitution 2 is 1018 cold rolled $35.66 for 6"

https://www.midweststeelsupply.com/store/1018coldrollsteelsquarebar

With confirmation that the shop tubing is available and the correct steel, I can begin fabrication.

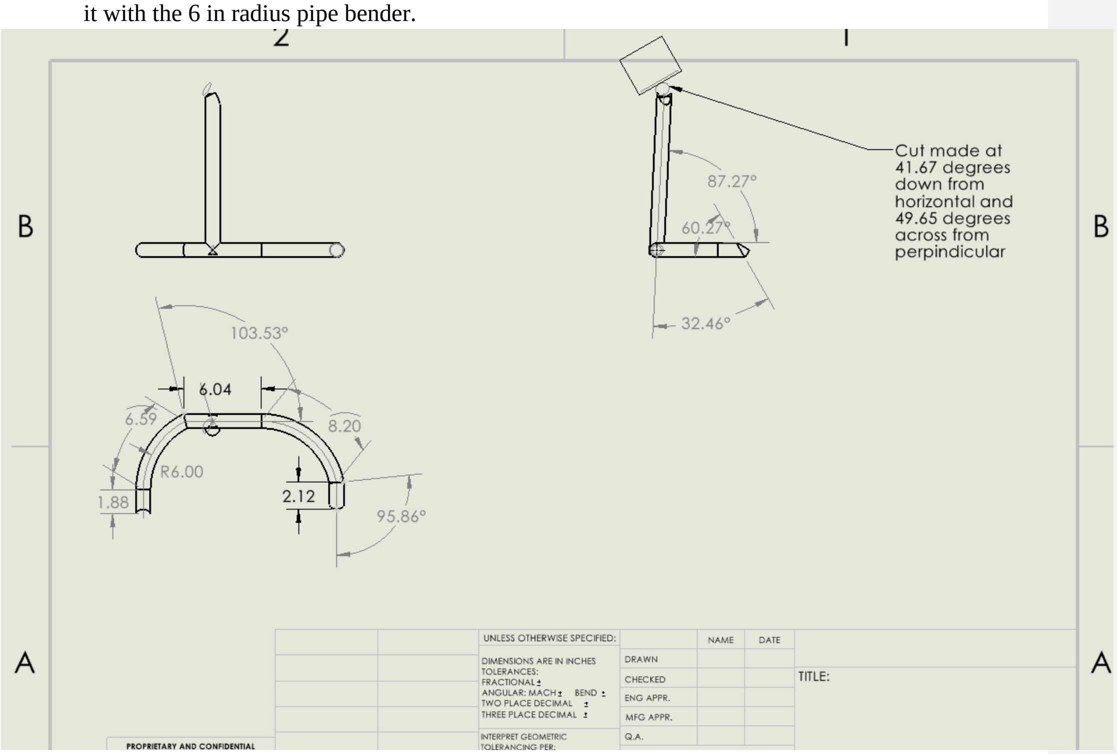
2-9

During the snowstorm I was able to refresh and practice welding using 1/16th thickness pipe. It was a different type, galvanized steel for plumbing, however it helped refresh my skills and practice welding piping. I was also able to cut a few segments for the upper arm brackets.

This Friday, I will use meeting time to bend the upper arm brackets. If I am able to use the shop to weld over the weekend, I will do so and hopefully finish the upper arm brackets. If not, I will use my time Tuesday to get as far as I can.

2-16

Over the past week, I redesigned the upper arm bracket so that we would be able to manufacture it with the 6 in radius pipe bender.



I also spent time using the fishmouth tool. I encountered a difficulty while practicing, however. The drill section has a significant enough sway to it that it is unreasonably difficult for it to be kept centered. If it is held against an edge, in order to be stable, the angle is incorrect. Any advice on this would be much appreciated.

I also had the initial idea of using the pre-made aluminum piece as part of the jig for welding the lower arm, marking the specific distance for the piece to hold the part at the proper height and angle.

2-23

Over the week I got practice using the welder, hole cutter, and pipe bender. I am still not confident in my abilities yet, but I had less time in the shop dur to lab reports and the upcoming career fair that I needed to prepare for.

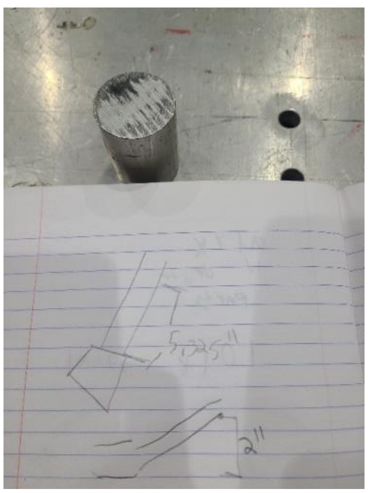
This next week I will continue practicing and work on making jigs for the pieces, having now a better understanding of how it is most comfortable for me to weld.

Below are two of my better welds demonstrating pipe-to-pipe on the left and thin material to thick material on the right.

3-2

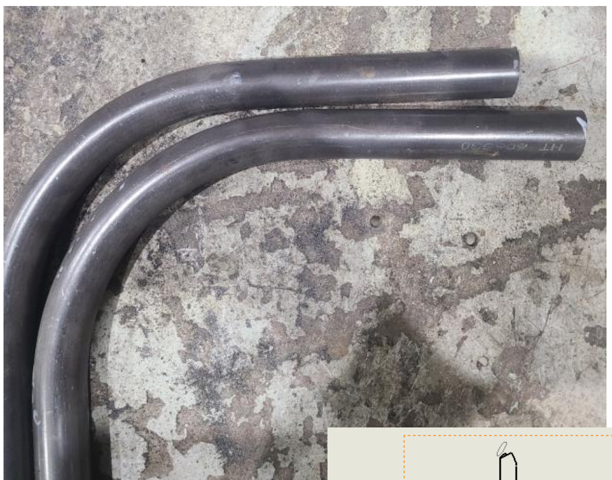
This past week I looked over the angles and found some supports that should work to keep the correct angle for the lower arm. I have also done more welding practice, pictures below.

This upcoming week I plan to make a wooden jig for the upper arms and I would like to start working on the actual parts, unless more practice is deemed necessary.

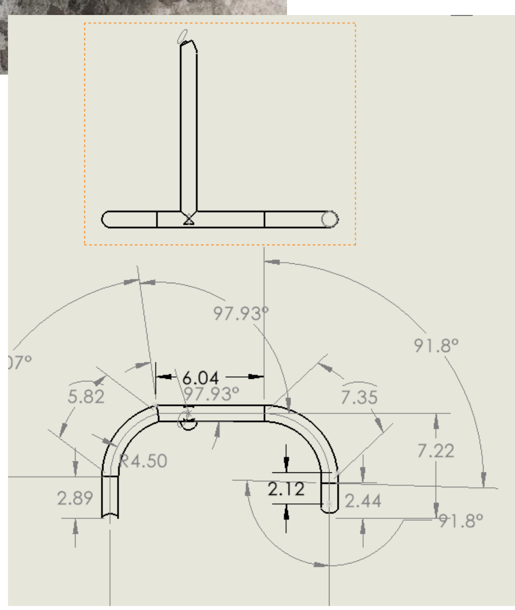


3-9

Over this past week I have completed 1/3 of the upper arm brackets. More was not completed due to a small but frustrating redesign for the radius of the pipe bender die. With this redesign, I should be able to complete the entirety of the upper arm by the 23rd, if I have access to the shop over spring break. I should also be able to cut the pipes for the lower arm. I have not managed to



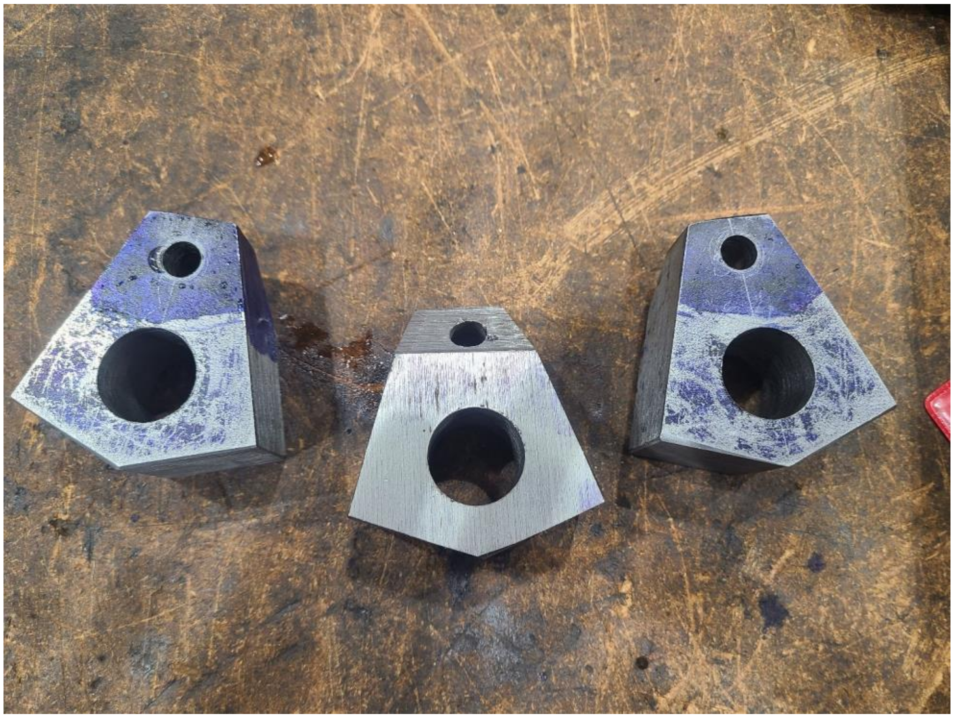
get in contact with Alex yet, and thus have not received the rest of my order, most important being the steel blocks for the lower support arms.



3-23

Over the course of the spring break, I completed all bending that needed to be done, as well as getting ~85% complete on the lower arm hub blocks, still needing to mill out the nut attachment spot and taper the attachment hole.

Over the next week I am going to finish the hub blocks and try to cut the piping to their final lengths.

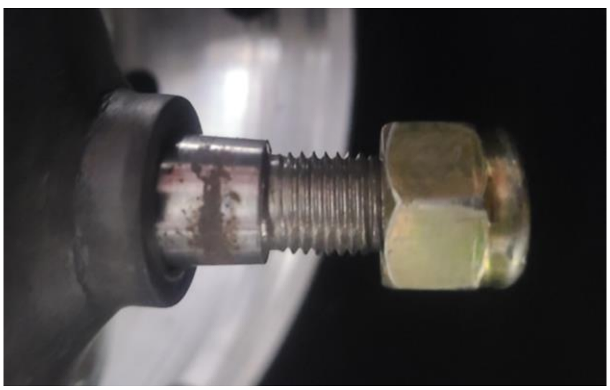


3-30

This past week was hindered somewhat by the new safety restrictions. Once cutting and to a lesser degree welding is allowed again I will be able to finish hopefully quickly.

Over the week, I used the welding room to put together the upper arm main curve, as that was the easiest weld to perform, to ensure the settings were correct. I was also able to complete the socket wrench clearance hole in the lower hub blocks. I also completed the new required safety training.

Looking more closely, I discovered that the previous year's hub blocks do not have tapered holes, easily evidenced by the single point markings on the ball joint pin and batching wear marks on the upper edge of the hole. I have not been able to taper my block's holes yet, and the current idea is to use a minutely-changing cnc code to cut it in a step-by-step way, as the "correct" tool is ~$650 and one that might work is ~$95.



Over the next week, I am going to weld together the arms for the lower suspension, but not weld them to the block yet, and attempt to complete the upper arms if I am able to in that time.

4-6

Over the past week I have been in the shop every day except Monday, on account of a class. I have welded the 2 lower arms together, along with the backup lower arm, welded together the upper arms and begun fitting them to the frame, and taken the old upper arm supports off of the frame and ground down the connecting points.

Left to do is welding the nuts on to the end of the lower arms, finishing the upper arm fittings, adding the mounting tabs to the upper arms and welding them on, attaching the hardware, and testing. Optimistically, I should be ready for testing on Sunday.

There is also the issue of the lower arm block taper, but I am unsure how to proceed on that front.

4-13

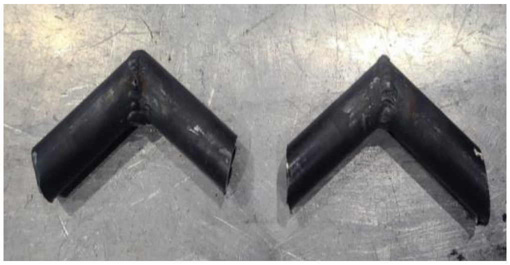
This past week I had attempted, and failed, to tack the upper support arms into the frame. I have since re-ground the upper support arms (the driver left side still needs a little bit of work that I ran out of time on, but the right is as close as I can reasonably get), laser cut my upper mounting tabs and marked their locations on the driver right side and worked through the presentation that was due Monday.

Tonight, I intend to complete grinding on the driver right side so that Matthew can attach them and complete the poster board for tomorrow’s fair. If there is shop time after the fair, I will weld the mounting tabs onto the upper arms. After that, I just need to wait on hardware to be delivered then I can screw everything together.

4-20

Over the past week, in addition to the senior design expo, I completed the arches for driveshaft clearance, got one of the upper arms tacked to the frame, and got all of the hardware attached to the tires.

The only things left to do are attaching the other arm, cutting and inserting the arches, and bolting everything together, which should be done Friday, pending availability of the shop welder supervisors.



4-27

Over the past week I assembled and took measurements of all the required dimensions and found them to be within initial boundaries. Project complete.

Height	Camber	Caster	Front toe	Back toe	Toe diff				
15"	-4	8	48"	48"	0"				
2"	4	2	3.5"	1.5"	0.0625				
13"	0	6	50"	50.0625	.0625"				
4"	6	4	3.0625"	.0625"	2"				
9"	6	2	53.0625"	50.5"	2.5625"		24" wheel diameter		
							2.5625" toe difference		
Within tolerance	Within tolerance	5-7 degrees is optimal caster, perfect at ride height, minor fluctuation at extremes					~= 3 degree toe on each side		
							3 degrees of toe change is typically considered acceptable for Baja		

		https://www.quora.com/What-is-the-optimum-caster-angle-for-a-Baja-vehicle					http://forums.bajasae.net/forum/suspension-discussion_topic2512.html		
~27		~=137 "	Turn Radius						
70"		11.4'							