SAE Mini Baja: Suspension and Steering

By
Benjamin Bastions, Victor Cabilan, Jeramie Goodwin, William Mitchell, Eli Wexler
Team 19

Progress Report

Document

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Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011

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Abstract

The suspension and steering systems of the SAE Baja vehicle needs to be adaptive, durable, efficient, and relatively inexpensive. The vehicle must be able to withstand the harsh environment of off-road competition and recreational driving. The vehicle needs to traverse over large rocks, downed logs, mud holes, steep inclines, jumps, and off camber turns. In order to meet the demands of the race course, the steering and suspension systems were designed and redesigned for a more effective turning radii and efficient use of suspension travel. The rear suspension geometry, profile, and material has gone through a few different iterations, and the final design is near completion. Construction has begun on the other vehicular components, i.e. frame and drivetrain, and the team is on schedule.

Chapter 1. Introduction

1.1 - Project Overview

The Society of Automotive Engineers International (SAE) has contracted the Northern Arizona University (NAU) chapter to design and build a Mini Baja vehicle for competition use. The stakeholders for the project are Dr. John Tester and SAE NAU. SAE is a United States based organization that sets international standards for the automotive, aerospace, and commercial vehicle industries. The Mini Baja competition is one of many collegiate competitions sponsored by SAE, it is designed to challenge each team in the design, planning, and manufacturing process involved in the production of small, consumer based off-road vehicles. The competition itself consists of several different disciplines to test speed and maneuverability as well as endurance racing. The suspension and steering team has been assigned to design effective and efficient systems to support and maneuver the vehicle during competition.

1.2 - Project Need Statement

The Northern Arizona University chapter has not won an event at the SAE Mini Baja competition in years. The competition consists of several events that the vehicle must be able to handle each one effectively. These events include the Presentation, Hill Climb, Endurance, and Acceleration tests. The team must make a sales presentation to a panel of judges on the marketability of the vehicle and therefore must be aesthetically pleasing.

1.3 - Project Goals

The goal of the suspension and steering team is to design efficient, strong, and easily manufactured systems of each system. Having a vehicle that is both maneuverable and capable of handling rough terrain is key for victory at the 2014 SAE Mini Baja competition. To achieve this goal the team will design suspension members with the strongest materials that are easily machineable while still maintaining relative low weight and adhering to all safety regulations. The steering system will be designed with an adequate turning radius to stay competitive in the maneuverability event. Once the frame is completed, construction on the front suspension, rear suspension, and steering systems will be built and installed.

Chapter 2. Design Modifications

2.1 - Front Suspension

The front A-Arms were modified in several ways. The old design used a uniball system that is more appropriate for heavier applications like trucks. In addition to being heavier it would also have been much more difficult to fabricate.

The new design is lighter and easier to fabricate. It will use male Heim joints with studs to attach the A-Arms to the hub. The new design also angles the end of the A-Arms up to match the angle of the mounting points of the hub. This will increase ground clearance and provide smoother articulation.

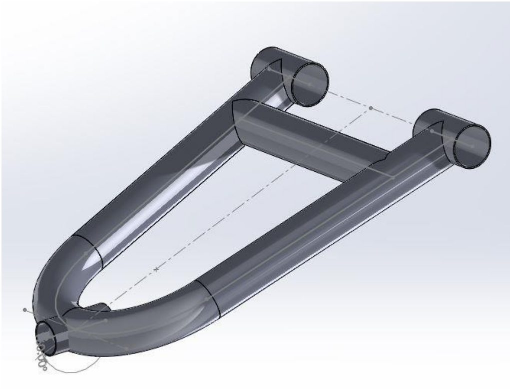

Figure 1 - Top A-Arm

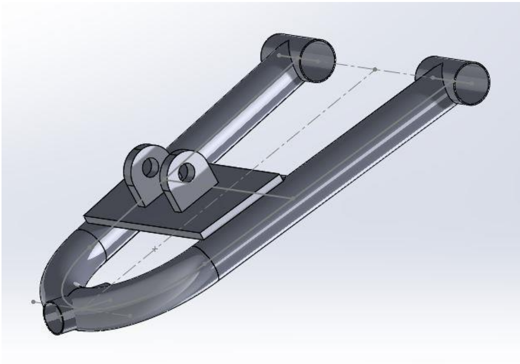

Figure 2 - Bottom A-Arm

The mounts from the frame to the A-Arms have also been redesigned. Instead of facing outwards they are now aligned vertically with the frame. This allows us the same amount of travel but narrows the track width by a few inches.

2.2 - Rear Suspension

There rear suspension design for the Mini Baja vehicle was one of the main concerns for the team. The rear suspension system has gone through many iterations with varying materials, geometry, and tubing selection. The Baja team received advice from 316 MotorWorks, a local Rally America race team and fabrication shop located in Flagstaff, Arizona, which inevitably lead to the final design for the rear suspension system.

The first major design change was to switch to a rectangular or square tubing selection for the body of the rear trailing arm, shown in *Figure 3*.

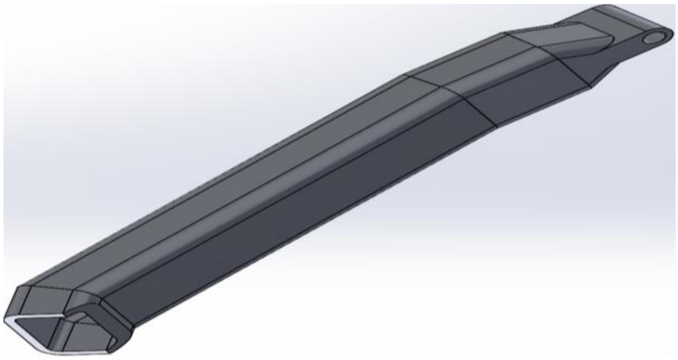

Figure 3 - Rectangular tubing trailing arm

This design proved difficult to not only machine, but fit to the frame without interference. Without the capability of bending rectangular tubing the trailing arm would need to be cut, folded, and gusseted to achieve the desired length, angle, and strength needed for this application. This method did not seem beneficial to the team's goal for a light, strong, and simple rear suspension design.

The updated rear trailing arm design uses AISI 4130 1.25in OD with a .0625in wall thickness round tubing. *Figure 4* shows the updated trailing arm assembly without the heim joint frame mount. *Figure 5* shows the top view of the trailing arm.

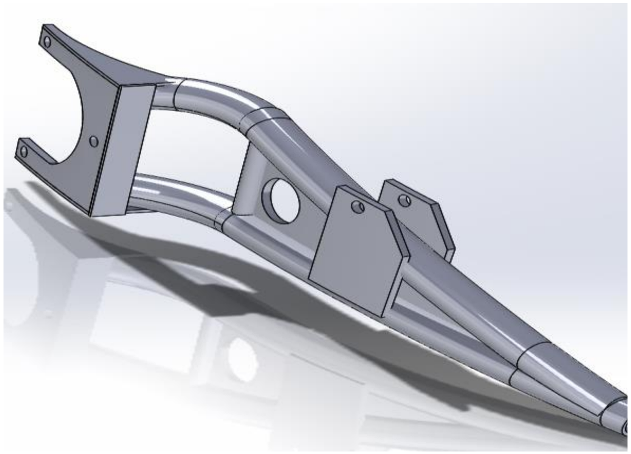

Figure 4 - Trailing arm V3

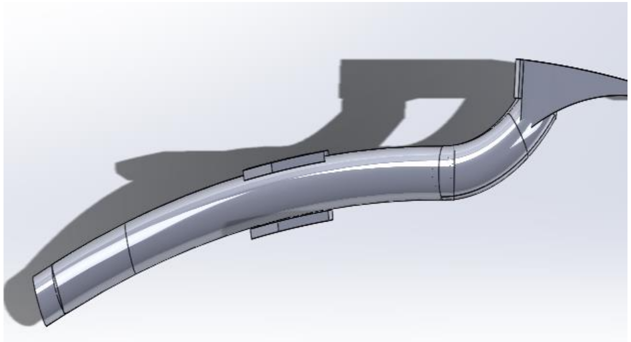

Figure 5 – Trailing arm V3 (top view)

The redesigned trailing arm is one of three possible final designs chosen by the Mini Baja Team. Because of the limitations the available tools at the Northern Arizona University machine shop, the radical bends in the vertical and horizontal directions this design seemed improbable to build even with the guidance and tools available at 316 MotorWorks.

The following designs are based off of the same platform designed by the SAE Mini Baja Team Captain Chris Bennett. Both the fourth and fifth trailing arm design uses AISI 4130 1.25in OD tubing with a wall thickness of 0.0625in. The tools available at the Northern Arizona machine shop limit each bend radius to about 4.5in minimum.

The fourth iteration of the trailing arm would be connected to the frame by nuts, bolts, and bushings through the end piece shown on the left end of the member.
The steel plate shown in *Figure 6* is a SolidWorks mock-up and will not be used in the final design due to its complexity.

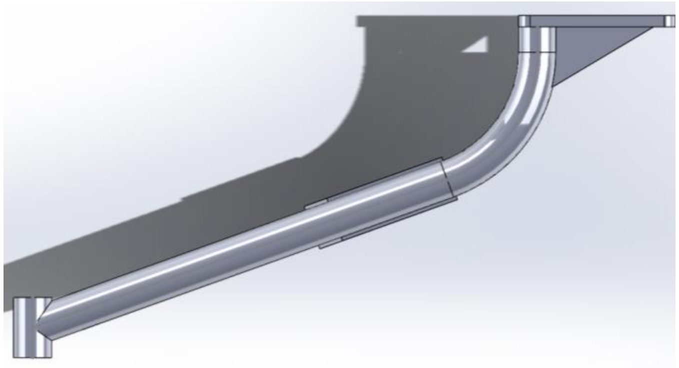

Figure 6 – Trailing arm V4 (top view)

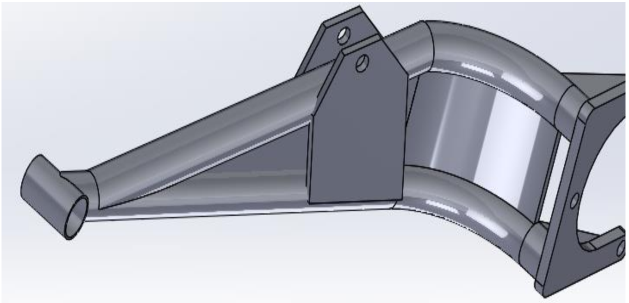

Figure 7 – Trailing arm V4

The final design consideration, shown in *Figure 6*, follows the same template as the previous design with a few modifications. The first modification can be seen in the top tube of the trailing arm. The straight tube was replaced with a gradually curving member for added structural strength. This design modification was suggested by the fabricators at 316 MotorWorks.

The second design modification can be seen at the far left end of the trailing arm member. The laterally fixed end shown in the previous model changed to a heim joint mounting system. The heim joint allowed for better articulation and added flexibility to the system.

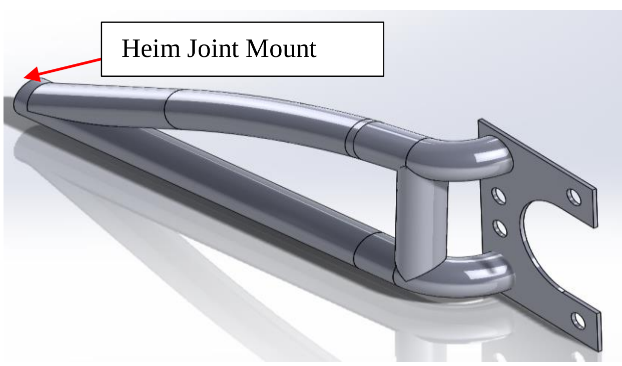

Figure 8 - Trailing arm V5

2.3 – Steering

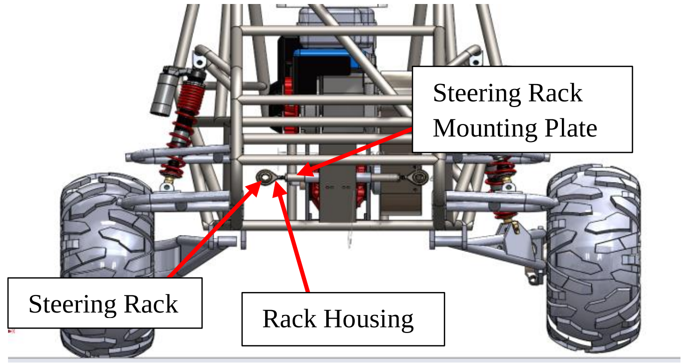

Figure 9 - Rack mount design (front view)

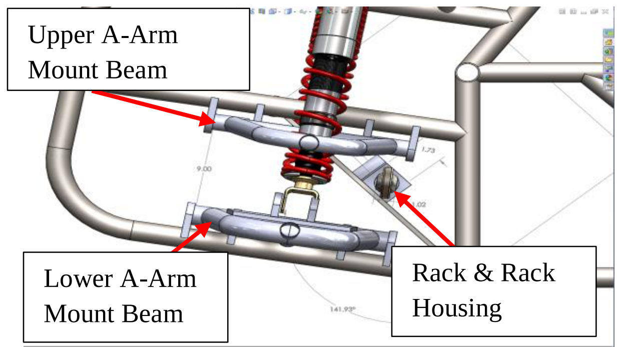

Figure 10 - Rack mount design (side view)

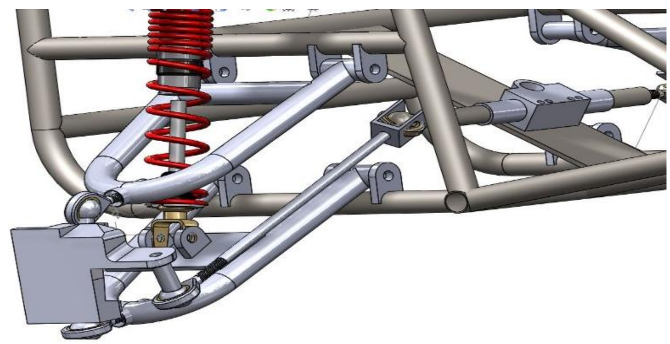

Figure 11 - Full steering and suspension (full droop)

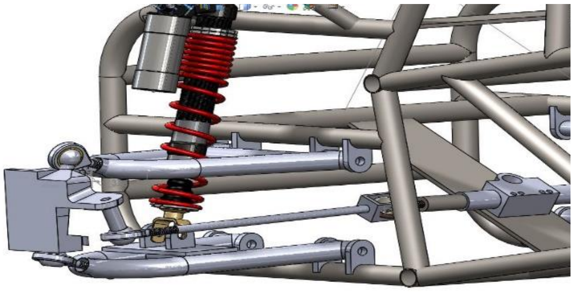

Figure 12 - Full steering and suspension (full compression)

Modifications for steering are not so much towards the parts that are selected for use in the Baja vehicle but towards the placement of each of the components to complete the visual and mathematical geometry of the steering system for the calculation of the steering radius. The rack mount point went through various modifications for an optimal design.

The first design started with one additional bar added to the top with a plate hanging off 90 degrees to the vertical ground, however a bar with a plate would not be strong enough to take the push and pull of the tie rods so more support would be needed. One modification made to this design was the addition two additional bars; one that connects the left and right upper A-Arm mount beams and one that connects the left and right lower A-Arm mount beams. Both additional beams will be horizontal to each other with respect to the natural 10 degree rake that the front of the frame has. This design caused a weight issue considering that adding two more support bars in the front would add more weight than if the team were to use angle iron or used a design that could utilize only one more support bar. Another disadvantage of this design was that the rack would point the pinion vertically into the driver's quarters resulting in an extreme angle at the universal joint.

The second design consisted of one bar connecting the two top A-Arms with a plate that connects the additional bar to an additional bar that is in the lower corner of the driver's quarters. This design utilizes the structural members that already exist and will lower the amount of weight added to the vehicle. The original design had the rack mounted to the front of the plate shown in *Figure 12*. An additional hole would have to be machined so that the pinion would point outward from the mounting plate towards the driver's quarters.

This mounting orientation, with the additional steering column hole, would have caused a problem with the strength and the adjustability of the rack mount. An additional change was made so that the rack is mounted on the top of the plate to eliminate the need for the additional hole in the mount plate. The rack would also be adjustable to the left or the right of the mount for steering alignment.

Another adjustment to the design would have to be the movement of the A-Arms towards the front of the vehicle to provide more leg room and more room for the brake master cylinder and the pedal cluster for the gas and brake pedal.

Chapter 3. Current Progress

3.1 – Front Suspension

The current progress for front suspension is that the knuckles, hubs and shocks have arrived. This has allowed us to finalize the dimensions for the front A-Arms, with final dimensions being 11in for the top control arm and 12in for the lower control arm. The ends of the control arms will be at a 20 degree angle to compensate for the angle on the knuckle mounts and increase ride height. The knuckle will be mounted to the control arms using 5/8in heim joints threaded through a welded nut attached to the end of the control arms. The 5/8in heim joints will be ordered with the next order from McMaster Carr [1]. In order to fabricate with precision, 316 MotorWorks will assist us in the fabrication of the arms. The frame mounts for the control arms are a bolt through bushing style, the bushings used will most likely be machined out of solid brass to increase responsiveness and eliminate as much unwanted movement as possible.

As of Wednesday March 5th, 2014 the model for the knuckle ordered from Polaris with all important dimensions needed to model steering and suspension components onto the frame was completed. The completed model gives final dimensions for every component and fabrication can start.

3.2 – Rear Suspension

Progress on the rear suspension system has been slow compared to the other vehicle components. Delays in part delivery was the main culprit for this slow build. As of Saturday March 1st, 2014 the parts for all remaining suspension and steering systems are in. The rear shocks and other rear suspension components are shown in *Appendix A.*

The trailing arms have been modeled, analyzed, and are now being finalized. The rear suspension system will be completed within the next week with the aid of 316 MotorWorks. Using the expertise and tools available at 316 MotorWorks, the team will be able to incorporate larger radius bends and strong TIG welds.

3.3– Steering

The current progress for steering is that a design is made and parts are ordered from Desert Karts [2]. The following parts that will be coming soon from desertkarts.com are listed below in the following table:

Table 1 - Steering Parts Cost List

Part	Description	Cost
Steering Rack	14” Rack & Pinion	$98.00
Steering U- Joint	36 spline, Zero bump steer	$28.00
Steering Couplers (x2)	36 spline (Quickener to steering shaft)	$13.00(x2) =$26.00
Steering Quickener	Doubles ratio from 1:1 to 2:1	$85.00

Figure 13 - Steering rack and Pinion

Figure 14 - Universal-joint

Figure 15 - Steering coupler

Figure 16 - Steering quickener

The parts listed above in the table, and the figures shown, are the final decisions on what to use for parts to the steering assembly. The choice was made for these parts are because they are all from the same manufacturer making out an easy assembly for the build. All that is needed are mount points and hardware. The steering wheel will be provided by the old parted out 2010 Baja along with the steering column. The material shown in *Figure 15* is 1/4in x 2in plates that were already purchased from Industrial Metal Supply and will be used to fabricate the steering rack mount.

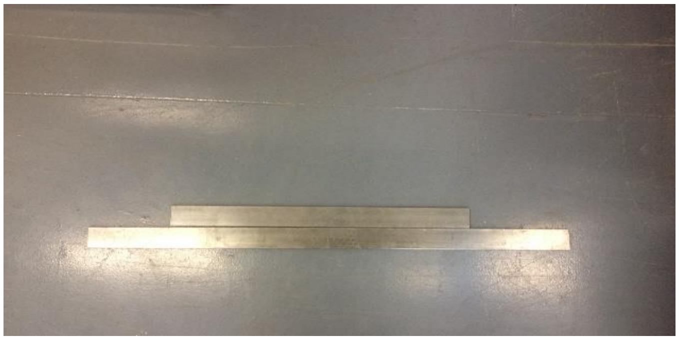

Figure 17 - Rack Mount Material

Tie rods and heim joints are the left over parts of the steering assembly that must be decided on what the goal for heim joints are to go for around a 5/8in bore and a 5/8in shank with a high angled pivot. These types of heim joints are easily obtainable from mcmaster.com

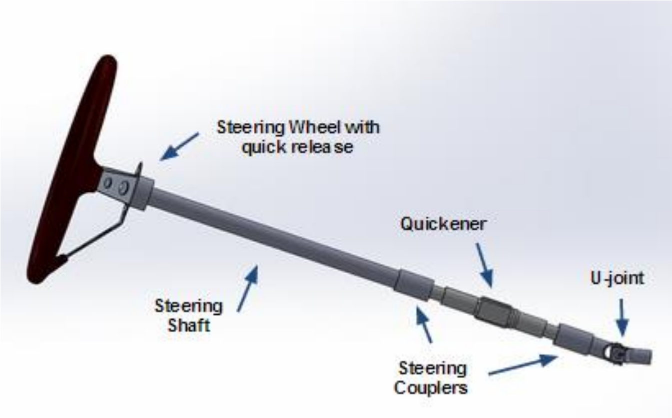

Figure 18 - Steering Column Assembly

The team chose a larger rack and pinion in order to allow more articulation and to decrease turning radius. With the use of a longer rack and pinion and quickener we were able to calculate an approximate turning radius of 9ft, which is much more ideal than our previous 12ft turning radius.

The steering components are shown in *Appendix B.*

Chapter 4. Conclusion

After several modifications the team decided to choose the previously stated steering system interfaced with a quickener in order to increase maneuverability, given the confined space a driver will have when operating the vehicle. The steering system will be composed of a 14in rack and pinion, which would be connected via 36 splines to a u-joint. The u-joint would then be welded to our steering shaft. A few inches above the u-joint, we will weld a quickener coupler in order to attach a 36 spline quickener to the coupler. Another 36 spline quickener coupler will be attached at the opposing end of the quickener, in order to connect the quickener to the rest of the steering shaft by welding the coupler on.

The resulting steering shaft located after the quickener coupler welds, will then have a spline to connect the steering wheel and quick release. In addition, the previous steering wheel will be used for our steering system design. Below is the final steering system design our team will use for our Baja vehicle.

Furthermore, after several proposed designs our team decided on using a circular tubing trailing arm instead of the previous square tubing trailing arm. Also, a local company (316 MotorWorks) with several years' experience in manufacturing frame and suspension components will advise on what trailing arm geometry to use and what geometry to stay away from. As for the front suspension, calculations and geometries have been completed. 316 MotorWorks will also assist in helping manufacture our front A-Arm suspension.

References

[1] McMaster-Carr, "Fastening & Joining," http://www.mcmaster.com/.

[2] Desert Karts, "8in Kart Rack," http://www.desertkarts.com/productCat40912.ctlg, Dec. 2013.

Appendix A: Suspension Components

Figure 1A – Fox Podium rear shock

Figure 2A – Left rear bearing carrier

Figure 3A – 3-link radius rods

Appendix B – Steering Components

Figure 1B – Front steering knuckle (front)

Figure 2B – Front steering knuckle (top)

Figure 3B – Steering column and wheel