Baja SAE Suspension and Steering

Benjamin Bastidos, Victor Cabilan, Jeramie Goodwin, William Mitchell, Eli Wexler

College of Engineering, Forestry & Natural Sciences

Department of Mechanical Engineering, Northern Arizona University

Abstract

The Northern Arizona University chapter of the Society of Automotive Engineers (SAE) Mini Baja group was tasked with designing and building a one seat, off-road capable vehicle for the SAE Mini Baja Collegiate Design Series at the University of Texas El Paso (UTEP). It must be able to traverse rugged terrain like rough roads or steep hills while offering the upmost level of safety for the occupant.

The suspension and steering team wanted to design a strong, maneuverable, and capable suspension and steering system. The suspension and steering systems allow the vehicle to be able to maneuver over and around obstacles while reducing shock and fatigue on the driver and essential components of the vehicle.

Problem Formulation

Need: The NAU Baja vehicle must be able to survive the rugged, and challenging, environment of the endurance race course as well as several other tests held at the UTEP competition. The team must also perform a sales presentation, which validates the marketability of the vehicle as well as a design presentation which displays any engineering analysis work done prior to building the vehicle.

The suspension systems must be able to withstand repeated large and small impacts while the steering system allows for agile turning and maneuverability throughout the courses. The steering system must also be very strong and able to withstand constant shearing impacts and other larger forces.

Goal: 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 machine-able 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.

Objectives: Survive the entire competition.

Constraints: Unlike the frame of the vehicle, the suspension and steering components were not restricted to a specific material, or dimension. All designs, geometry, and materials were decided by the team.

Proposed Design

The front suspension members are shown in Figure 1. The front and rear suspension members use 1.25” OD piping with 0.095” wall thickness made of 4130 Chromolly steel for high strength even after welding.

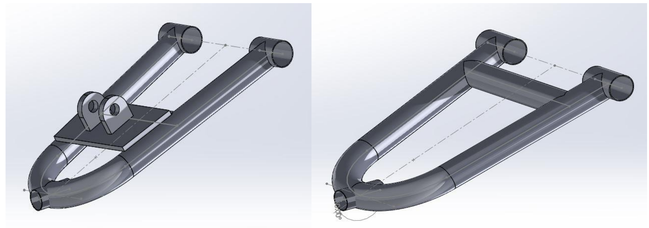

Figure 1: Front suspension

The unequal a-arms were designed to accommodate the front shock on the upper a-arm (top left). This orientation isn’t common, but it provided the team ample clearance for the steering components shown in Figure 2. The a-arms were mounted to the frame with rod ends for easy alignment and adjustability.

The vehicle used rack and pinion steering which is a simple and versatile design and when coupled with a quickener meets all of the teams needs for agile maneuverability. The top left image shows the support brace for the rack and pinion extensions. The original rack was too short, in order to prevent shearing the extensions, the boxed aluminum support was added. The solid tie rods and the FEA analysis done are shown in the top right and bottom center.

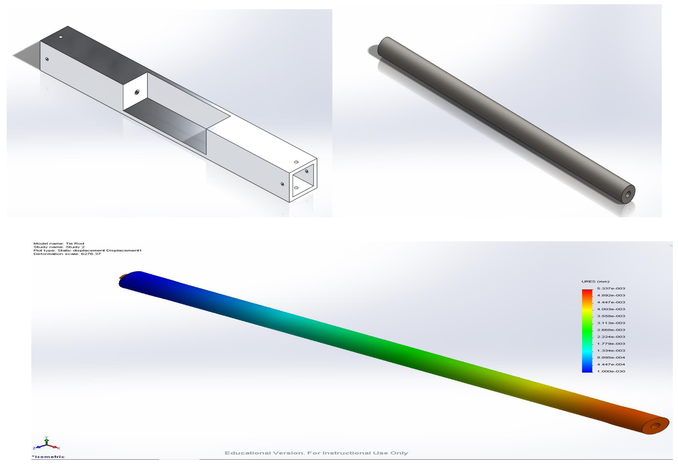

Figure 2: Major steering components

Research was done on the environment that the mini Baja would compete in. Due to the rocky and rugged terrain, long travel suspension designs were considered. The rear suspension is a rear semi trailing arm based 3-link setup. This setup is fairly common for Mini Baja and bolts up to the bearing carrier for a Polaris RZR XP 900 in order to simplify manufacturing cost and time.

Analysis was done on the main body of the trailing arms and the bearing carrier plate. The test simulated a hard impact from below and

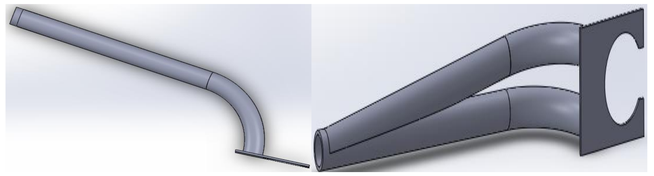

Figure 3: Rear Suspension

side collision ranging from 500 – 1000lbf. The trailing arm assembly survived the impacts with a safety factors ranging from 15 and above. This was most likely due to the design being slightly overbuilt with 1.25” OD and a wall thickness of 0.095”.The trailing arms are mounted to the frame with 0.75” rod end joints in order to have adjustment and durability.

Fabrication and Testing

At first the suspension members were designed and fabricated using 1.25” OD pipe with 0.065” wall thickness like the frame. Due to known problems with strength of both the a-arms and trailing arms, the wall thickness was increased to 0.095” for the final design and fabrication.

The Steering rack was extended to reach the outside of the frame with 0.75” solid shaft extensions. During initial testing, the rack extension sheared on the right side. This lead the team to come up with a new design using a section of square tubing that surrounded the rack and successfully supported the extended parts.

Cost Analysis

Part	Manufacturer	Quantity	Price
14" Steering Rack	Desert Kart	1	$98.00
Steering Quickerner	Desert Kart	1	$85.00
Splined Coupler	Desert Kart	2	$13.00
Shipping and Taxes for Desert Kart	Desert Kart	1	$28.88
3/4 Heim Joint	McMasterCarr	3	$12.34
5/8 Rod Ends	McMasterCarr	6	$14.40
Shipping and Taxes for McMaster	McMasterCarr	1	$7.06
1.25x.095 4130 Tubing For A-arms and trailing arms	IMS	5	$38.12
1/4x2 flat for tabs	IMS	1	$10.80
1/4x1.5 flat for tabs	IMS	1	$9.50
1/4x4 flat for steering	IMS	1	$12.92
5/16x1.5 for tabs	IMS	1	$12.74
1.25 solid round slugs for heim joints	IMS	1	$28.52
3/4x2 for tabs	IMS	1	$14.06
Tax for Material from IMS	IMS	1	$23.18
3/8 Heim Joints	McMasterCarr	4	$9.92
Shipping for Heim Joints	McMasterCarr	1	$5.61
4130 Tie Rod Material	Amazon	1	$35.96

Part	Manufacturer	Quantity	Cost/EA	Total Cost
Steering Knuckle LH	Polaris	1	$99.00	$99.00
Steering Knuckle RH	Polaris	1	$99.00	$99.00
Outlaw Front Hub	Polaris	2	$29.00	$58.00
Rear Hub	Polaris	2	$28.00	$56.00
RZR S 800 Front Fox Shock	Polaris	2	$278.00	$556.00
RZR XP 900 Rear Shocks	Polaris	2	$340.00	$680.00
LH Rod End	Polaris	3	$20.00	$60.00
RH Rod End	Polaris	3	$20.00	$60.00
Stud for Front Wheel	Polaris	10	$1.00	$10.00
Stud for Wheel	Polaris	10	$1.00	$10.00
Radius Rod Blue Upper	Polaris	3	$59.00	$177.00
Radius Rod Blue Lower	Polaris	3	$59.00	$177.00
RZR 900 Rear Blue Spring for Shock	Polaris	2	$36.00	$72.00
Upper Spring For RZR 900 Rear	Polaris	2	$15.00	$30.00
Spacer RZR 900 Rear spring	Polaris	2	$2.00	$4.00
Retainer RZR 900 spring	Polaris	2	$15.00	$30.00
Main Spring RZR 800 S Front	Polaris	2	$26.00	$52.00
Tender Spring RZR 800S Front	Polaris	2	$16.00	$32.00
Spring Spacer RZR 800 S Front	Polaris	2	$1.00	$2.00
Spring Retaining RZR 800 S Front	Polaris	2	$8.00	$16.00
Sleeve for Shock RZR 800 S Front	Polaris	4	$2.00	$8.00

Conclusion

After several FEA calculations and testing before the competition, the suspension and steering team was able to successfully design suspension and steering components that met the needs for the rugged terrain at the SAE Baja competition. This can be validated by the fact that no components designed from the suspension and steering team experienced mechanical failure. Although the lower a-arm experienced a small gash from an impact during racing, no steering or suspension parts experienced catastrophic failure.

In addition to how suspension and steering components performed during the completion, the team was able to stay under the pre-determined budget of $3600 by $152.31. The main reason for this accomplishment was the discounted price offered by our Chromolly steel provider (Industrial Metal Supply Company).

References

• Milliken, W.F. and Milliken, D.L., “Race Car Vehicle Dynaminc Volume 1”, Society of Automotive Engineers, Inc., ISBN-13: 978-0768011272, 2003.

•McMaster-Carr, “Fastening & Joining,” http://www.mcmaster.com/.

•Desert Karts, “8in Kart Rack,” http://www.desertkarts.com/productCat40912.ctlg, Dec. 2013.

•Budynas, R.G. and Nisbett, J.K., “Shigley's Mechanical Engineering Design,” McGraw-Hill, New York, ISBN 978-0-07-352928-8

•The Engineering Toolbox, “Impact Force,” http://www.engineeringtoolbox.com/impact-force-d_1780.html.

•Philpot, P.A, “Mechanics of Materials: An Integrated Learning System,” John Wiley & Sons, Inc., New Jersey, ISBN 978-0-470-56514-8

Acknowledgments

ACEFNS, ASNAU, Babbitt Ford Lincoln, Bill G. Bennett, Copper State Nut and Bolt, CVTech, Imo Fab 316 Motor Works, Industrial Metal Supply, KC Hilites, Northland Motorsports, Page Steel, Polaris, Sabic, Schafer Gear Works Inc.