Society of Automotive Engineers (SAE) Baja Collegiate Competition: Rear-Suspension

2023-2023

NAU Northern Arizona University

Office of Undergraduate Research and Creative Activity

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Link To Website

Abstract / Project Description

The 2023 Society of Automotive Engineers (SAE) Baja capstone rear-suspension sub team at Northern Arizona University (NAU) has developed a rear end suspension design for off-road vehicles. The rear end suspension team is working closely with two other Sub teams to compete in Washougal, Washington during the 2023 SAE Baja Competition on May 31st –June 2nd. NAU's capstone Team will compete against 99 other universities to determine which team designed the most efficient vehicle capable of performing well in multiple distinct aspects of the off-road environment. The suspension system consists of a triangulated trailing arm setup with two links for lateral stability. The design features adjustable heim joints for fine-tuning of the suspension geometry, and coil-over shocks for improved damping and adjustability. The suspension is designed to withstand the extreme loads and stresses encountered in off-road conditions, while maintaining good articulation and handling characteristics. The team conducted extensive simulations of Shark Lotus Software and SolidWorks to ensure the design meets SAE rules, regulations, and design requirements to perform well on the SAE BAJA courses. In correlation to the rear suspension, the design must also be able to transfer the torque and horsepower provided from the standardized Kohler motor. The resulting suspension design provides a balance between performance, durability, and adjustability, making it ideal for off-road racing applications.

Customer Needs / Engineering Requirements

Customer Needs:

- Meet all Design Requirements
- Meet all Safety Requirements
- 4WD Compatible
- Low Cost
- Manufacture Capability
- Competitive in Events
- Improve Previous Design

Engineering Requirements:

- Reduce Weight
- Rear End Suspension Travel
- Reduce Material usage
- Increase Durability
- Maximum Width = 62in
- Adjustability Within Parts
- Camber Angle
- Toe Angle

Figure 1: SAE Oregon Rock Climb

Figure 2: SAE Oregon Endurance Race

Manufacturing

The goal of manufacturing the rear suspension design is to fabricate all the components with precision, strength, cost reduction, and weight savings in mind.

Tools and Outsourcing Include:

- Manual mill/lathes
- CNC mill/lathes
- Plasma cutter
- Tig Welding
- Grinders
- Saws
- Manual assembly tools

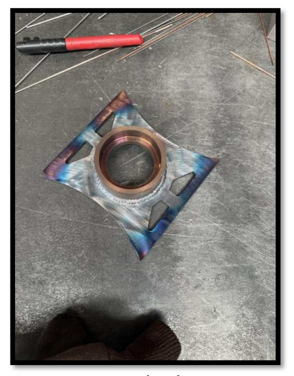

Figure 3: Hub Plate Part

Figure 4: Hub Made Within CNC

Design

The Rear suspension sub team developed a rear trailing arm system with two adjustable lateral links. Both sides of the system includes two trailing arms, a dampening/rebounding shock and spring, and 2 lateral links connected by 4 heim joints for vertical stability. The shape and design of the trailing arm creates a strong and reliable system. The heim joints integrated into the links provide adjustability for the wheel's camber and toe angles, making the system versatile and adaptable to different driving conditions.

Figure 5: Rear End Cad Design

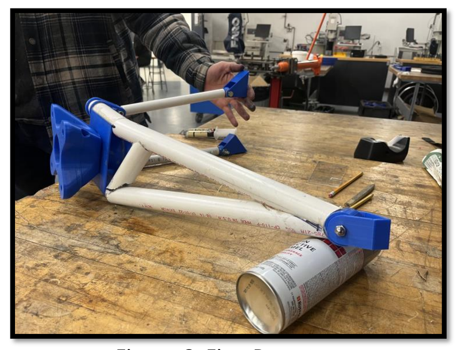

Figure 6: First Prototype

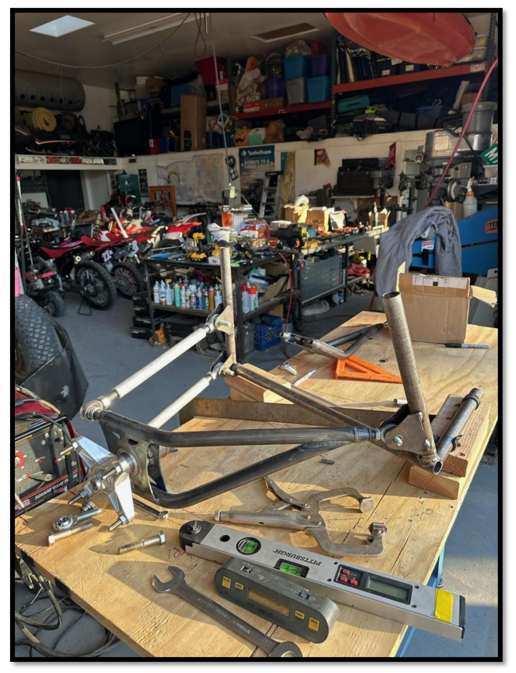

Figure 7: Second Prototype

Calculations

For our existing design, our heims and bolts is where our team designed components to fail before any major parts of our trailing arm, double link set up.

Bolt Shear :

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

$$A = \pi r^2 = \pi(.25)^2 = .1963 in^2$$

$$\tau = 27.7\ ksi$$

$$n = \frac{Sy}{\tau}$$

$$n = \frac{30\ ksi}{27.7 ksi} = 1.08$$

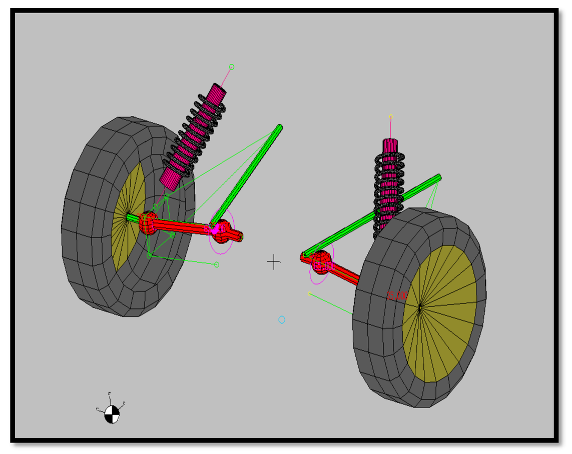

Figure 8: Lotus Shark Software

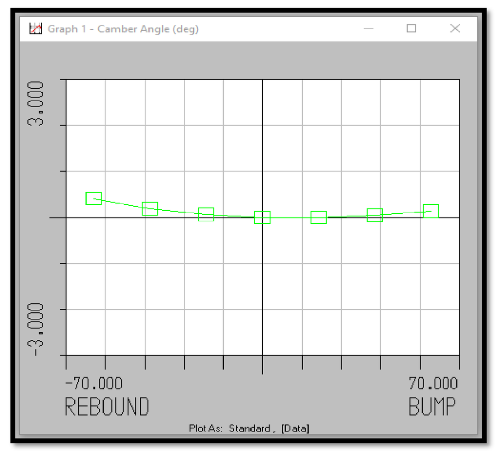

Figure 9: Camber Graph From Shark

FEA Analysis Trailing Arm Set Up

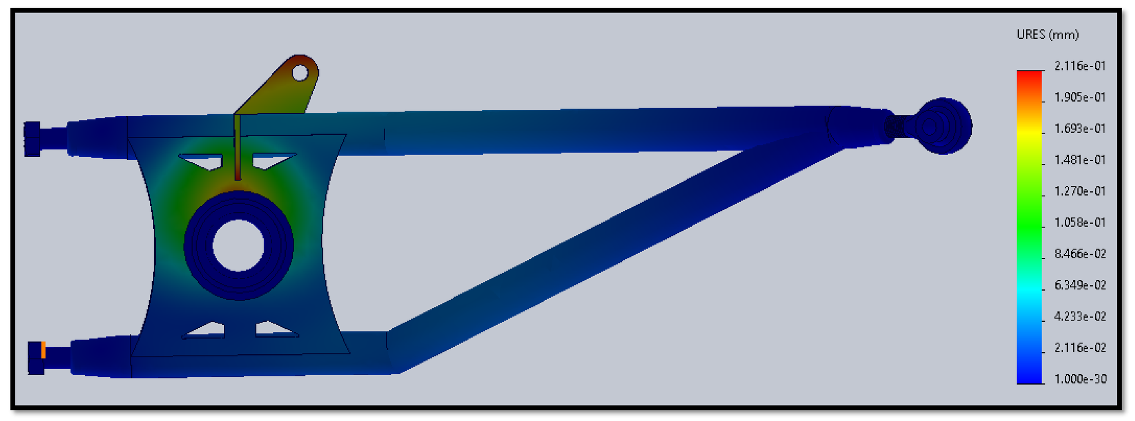

Figure 10: SolidWorks FEA On Control Arm

CAD (SolidWorks)

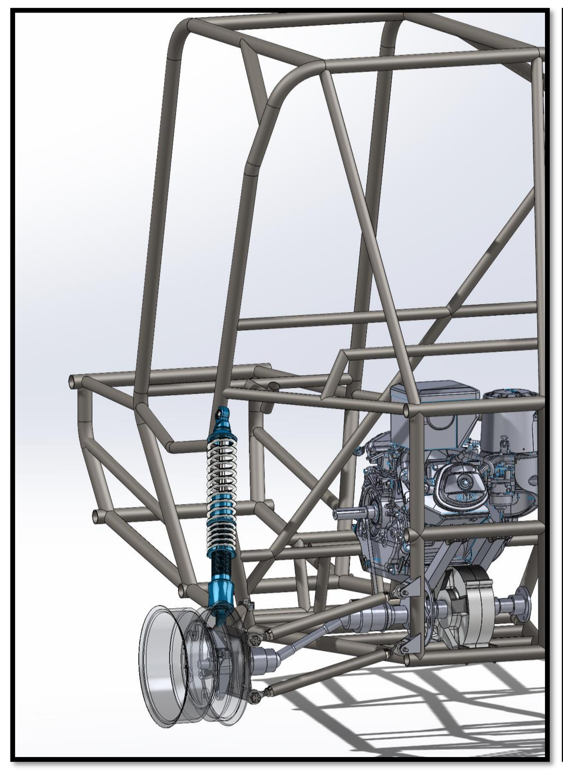

Figure 11: Rear Isometric View

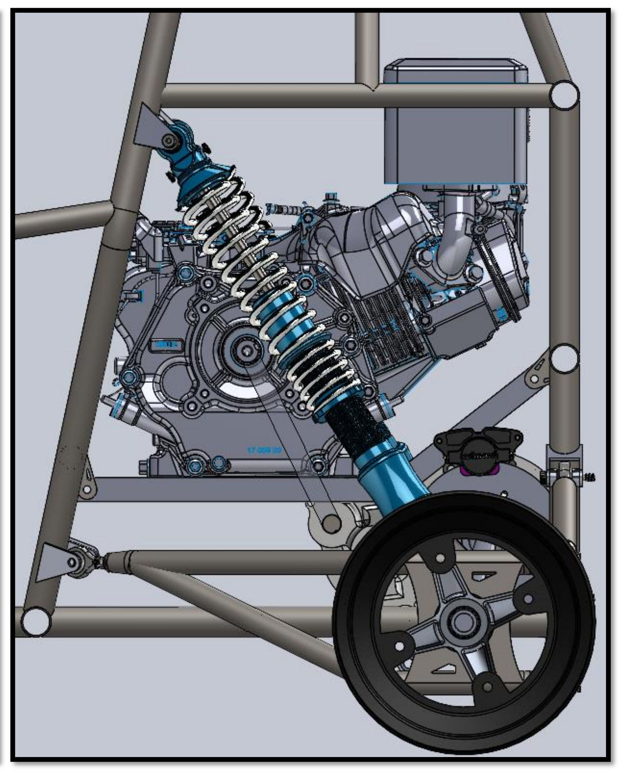

Figure 12: Right View

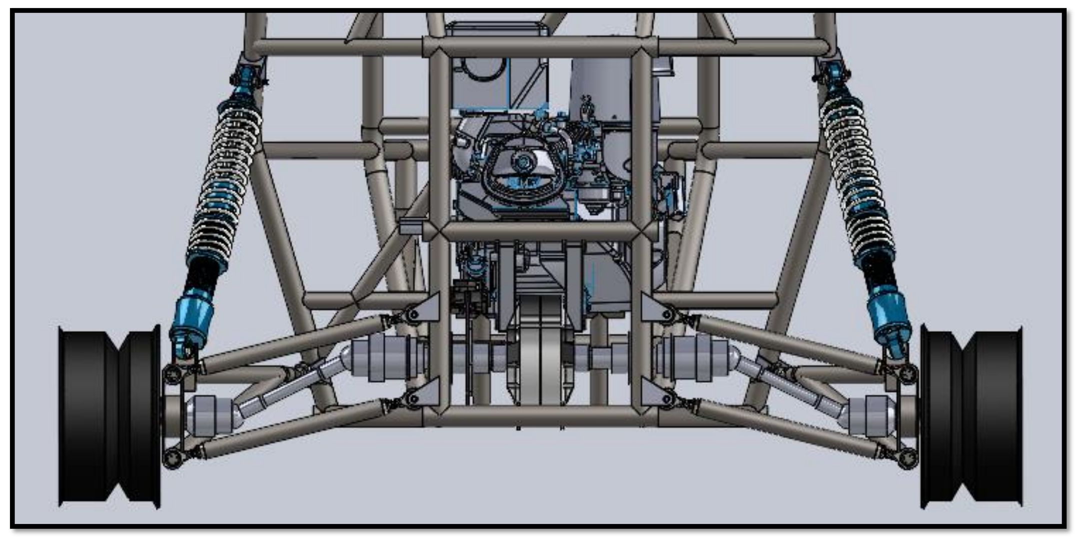

Figure 13: Rear View

Testing (Analysis)

Test: Adjustability/Tuning

Summary: The ability to tune the vehicle's geometry is important to maximize performance. Perfecting the toe in/out and camber in/out throughout the suspension travel will create stability and a larger contact patch where the tire meets the ground.

Procedure: This test is composed of utilizing electronic angle finders. Zeroing the electronic level and setting the device at various height settings, the rear arm will indicate geometry movements throughout the cycle as it is moved up and down in the travel.

Conclusion: It is concluded that when the upper link is rotated 1 revolution, it is consistent that the camber changes 1.2 degrees toward positive camber. When the lower link is rotated 1 revolution, it is consistent that the camber changes 1.2 degrees toward negative camber. Ideally, we want a negative camber of 3 degrees.

Camber Test			
Full Droop Test			
Top Link (revolutions out)	Bottom Link (Revolutions Out)	Degree Measurement	Degree Change
0	0	-4.8	0
1	0	-3.6	1.2
2	0	-2.4	1.2
3	0	-1.2	1.2
4	0	0	1.2
0	1	-6	1.2
0	2	-7.2	1.2
0	3	-8.4	1.2
0	4	-9.6	1.2
Ride Height Test			
Top Link (revolutions out)	Bottom Link (Revolutions Out)	Degree Measurement	Degree Change
0	0	-4	0
1	0	-2.8	1.2
2	0	-1.6	1.2
3	0	-0.5	1.1
4	0	0.5	1
0	1	-4.9	0.9
0	2	-6	1.1
0	3	-7.2	1.2
0	4	-8.4	1.2
Full Compression Test			
Top Link (revolutions out)	Bottom Link (Revolutions Out)	Degree Measurement	Degree Change
0	0	-0.5	0
1	0	0.7	1.2
2	0	2	1.3
3	0	3.2	1.2
4	0	4.4	1.2
0	1	-1.6	1.1
0	2	-2.6	1
0	3	-3.8	1.2
0	4	-5	1.2

Figure 14: Camber Test Results

Brake Test/ Mock Tech Inspection:

Summary: This experiment will be to conduct a mock tech inspection as well as a brake test to simulate the inspections we will see at the competition.

Procedure: The team will drive the vehicle into a set of 4 cones with someone watching each wheel specifically. The driver will then slam on the brake to ensure all wheels lock up. Then the group will print out the 2023 Tech inspection sheets and thoroughly inspect the vehicle as they will at the event. This consists of various safety requirements and rule checks.

Results: From the video, the brakes are applied, and the vehicle did come to a stop under its own braking power. In tech inspection the brakes will need to lock on a dirt surface.

Conclusion: From this test the team was able to demonstrate a full braking system that will pass the corresponding test at competition. The team also plans on conducting a thorough tech inspection to mimic the inspection that will be seen at competition. Results can be seen in the spec sheet.

Vehicle Images

Figure 15: Rear Isometric View

Figure 16: Rear Isometric View W/ Engine

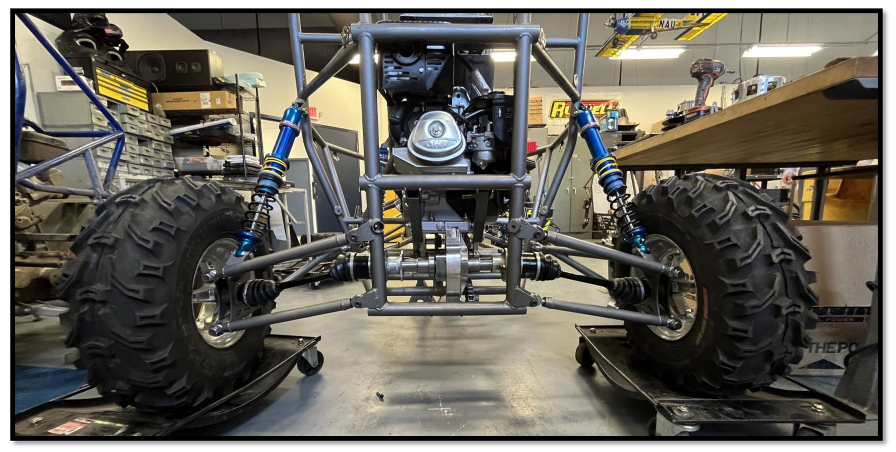

Figure 17: Rear View

Conclusion

The 2023 SAE BAJA rear suspension sub-team demonstrated impressive engineering capabilities by designing and building a successful trailing arm suspension setup. The team's design incorporated strength, adjustability, and performance, all while reducing costs to the entire capstone team. Through their efforts, the sub-team was able to overcome several challenges, including optimizing suspension geometry, selecting appropriate materials, and ensuring proper fabrication techniques. Ultimately, their dedication and expertise resulted in a rear suspension system that not only met but exceeded expectations. Their success will undoubtedly serve as a valuable learning experience for future SAE BAJA teams and demonstrate the importance of collaboration and innovation in engineering.

References

[1] The College of Engineering, Informatics, and Applied Sciences. Senior Capstone Design Projects - Design 4 Practice - Engineering - The College of Engineering, Informatics, and Applied Sciences - Northern Arizona University. (n.d.)

[2] SAE International, "Collegiate Design Series Baja SAE Rules 2023," 2023..

[3] Metals and alloys - young's modulus of elasticity. Engineering ToolBox. (n.d.). Retrieved October 23, 2022, from https://www.engineeringtoolbox.com/young-modulus-d_773.html

[4] Scholfield, C., "Rear Suspension Isolation — Its Effect on Ride and Handling," SAE Technical Paper 620075, 1962, https://doi.org/10.4271/620075.

Acknowledgements

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