SAE Baja Roll-Cage

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Introduction

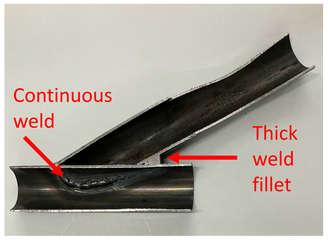
"Baja SAE challenges engineering students to design and build an off-road vehicle that will survive the severe punishment of rough terrain and in some competitions, water. … Each team's goal is to design and build a prototype of an all-weather, rugged, single-seat, off road recreational vehicle intended for sale to the nonprofessional weekend off-road enthusiast." — bajasae.net

Objectives:
Design, analyze, and manufacture a roll-cage that promotes safety, comfort, and complies with the 2025 Baja SAE ruleset.

Design Metrics

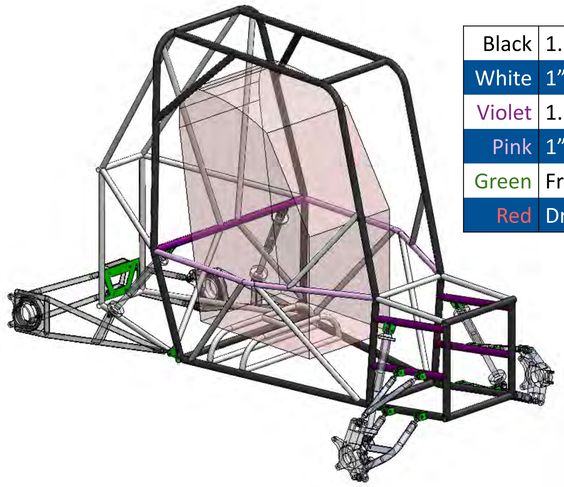
Metric	Units	Target Value	Actual Value
Frame is lightweight	kg	< 30	36
Weld is stronger than base metal yield strength	MPa	> 703	> 1015
Weld fillet is thicker than tube material	in	> 0.065	> 0.065
Weld bead is continuous	binary	yes	Yes
Frame does not yield when loaded under 5G of deceleration	MPa	< 703	335
Frame deformation does not cross the safety zone	mm	< 30 = min. clearance	8.5

Weld Quality Testing



- 90-degree sample: failed occurs outside of weld under bending, meaning the weld is stronger than the base metal.
- 30-degree sample: weld fillets are thicker than the tube thickness and the weld line is continuous, meaning the welding technique is of good quality.

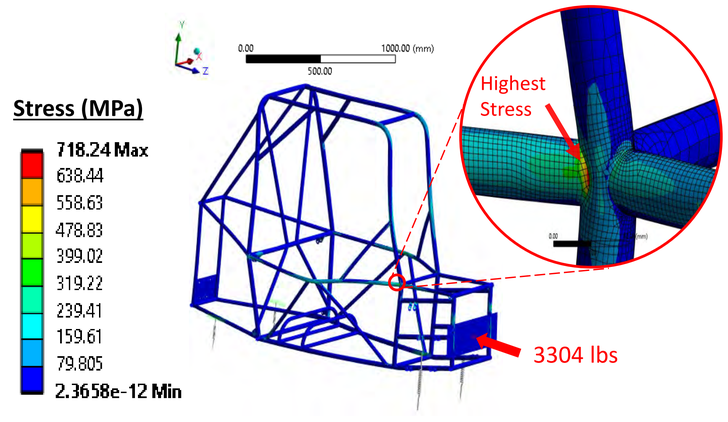
ROPS Model



Black	1.25"x0.065" Tubes
White	1"x0.035" Tubes
Violet	1.25"x0.095" Tubes
Pink	1"x0.065" Tubes
Green	Frame-Suspension Joint
Red	Driver Safety Zone

Designed roll-cage following the 2025 SAE Baja Rules. Worked with the suspension, auxiliary, and power train teams to ensure their subsystems are accommodated.

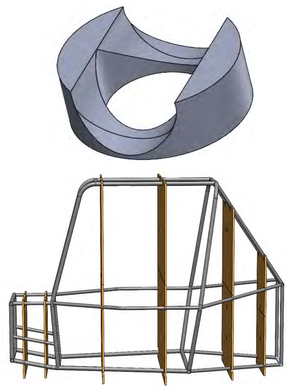
Finite Element Analysis



A frontal crash was modeled as a static structural analysis. The frame sufficiently protects the driver, with a safety factor of 2.

- Used push plate to model crashing surface (e.g. wall, toe-box).
- Suspension modeled as a longitudinal spring where all suspension–frame connections are rigidly, remotely attached.
- Applied load estimated as a 5G deceleration during a crash for a 300 kg (661 lbs) vehicle.
- Converged at 2.5 mm mesh refinement.
- The max. von Mises stress was 334 MPa.
- The max. displacement was 8.5 mm.

Manufacturing Jigs



Cutting and welding jigs were developed using affordable materials such as 3D printing PLA, laser cut OBS, 2x4s, and 80/20 aluminum extrusions to aid in manufacturing the roll-cage.

- The cutting jig aids in making welding copes with difficult angles.
- The welding jig aids in manufacturing by removing human alignment error and reducing heat-related deformation.

Conclusion

Our objectives, other than manufacturing, were achieved.

- Welding quality testing ensured that the welding techniques used on the roll-cage will offer sufficient strength
- The FEA ensured that the roll-cage will offer safety to the driver, where a safety factor of 2 is predicted during frontal impact.
- Manufacturing jigs were designed and built to ease the future coping cuts and welding of the roll-cage.

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Future Work

The roll-cage still needs to be manufactured; including coping cuts, tube bending, and welding. Future work will be taken over by the Power-Train and Auxiliary teams, which will add their subsystems as well as suspension from this year's team.

- The completed vehicle will participate in the SAE Baja competition in May 2025.
- Join the U of U SAE Baja Club to participate!