Validation of Suspension Component Stresses on the Cal Poly Pomona Baja Car Using Strain Gages

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Baja SAE is a collegiate design series where student teams design and build a single seat, enclosed off-road vehicle. Each year a new vehicle is designed with attempts to improve the capabilities of the vehicle at a minimal cost, and race the vehicle against other student teams from around the world.

Company/Institute: Cal Poly Pomona, Baja SAE (Society of Automotive Engineers)

Industry/Application Area: Stress Measurement (Automotive/Suspension**)**

Product Used:

- Stacked Rosette (0,45,90): C2A-06-062WW-350
- Rosette (0,45,90): CEA-06-120CZ-120
- Linear Gages: CEA-06-240UZ-120
- M-Bond 200 Adhesive Kit

The Challenge

As stated in the 2016 Collegiate Design Series Baja SAE Rules, “all vehicles must use the same 10 Horsepower Briggs and Stratton Engine.” This limitation means the suspension system design must be as strong and as light as possible, and balance the strength of a component against added weight. The vehicle’s performance must consider and address:

- Unexpected loading conditions due to rough or irregular terrain
- Unsprung mass, which can affect steering, traction, and driver comfort during acceleration, deceleration and cornering
- Ride comfort due to vibration in the chassis

One goal of our suspension is to assure durability under normal driving conditions, which means we must assess the obstacles and tracks that are encountered in our competitions, excluding vehicle-to-vehicle collisions. After the manufacturing of the vehicle is complete, testing is performed to validate the design assumptions. It’s challenging to validate the loading conditions the suspension components experience during operation. Attempting to simulate loading conditions onto the components cannot be done without making assumptions. The lower A-arms and trailing arms experience some of the most complicated loading situations and due to the tubular designs, finding an accurate means of measurement is difficult.

The Solution

Strain gages provide a solution for testing suspension components in dynamic conditions. They allow for non-destructive, direct measurements of our critical components without interfering with normal driving conditions. By conducting tests that closely resemble conditions experienced during our competitions, we are able to confirm that our assumptions for expected loads are close to what we actually encounter.

Points of interest for adhering strain gages to the suspension components were selected based on Finite Element Analysis.

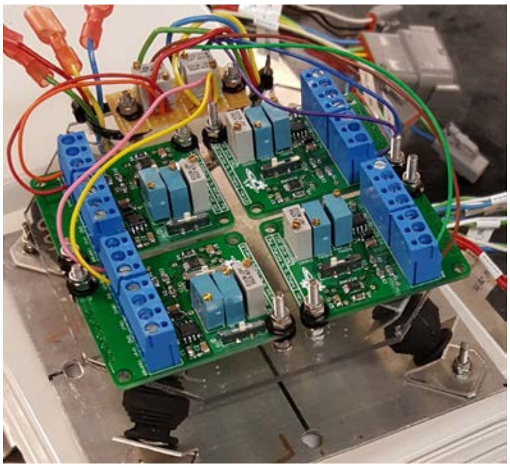


Figure 1: Student made amplifiers on suspended mounting for shock absorption and vibrations.

In our scenario, the pre-wired 350 ohm stacked rosette (C2A-06-062WW-350) provided a solution to recording stresses of our lower A-arms and trailing arm, as the tubular geometry of these critical members made finding the principal stresses complicated. The equations used for calculating stresses from measured strain assume a small differential area, and using a small stacked rosette decreases any errors this assumption would create for a small tubular surface. Using a higher resistance of 350 ohm allowed for greater excitation without introducing greater error due to temperature. This rosette also made installation easier by not having to deal with the difficulty of soldering small leads to the tiny solder pads of each gage. For the upper A-arm and upright, the 120 ohm rosette (CEA-06-120CZ-120) were sufficient for measurement along the flat faces of the surface. Lastly, all the suspension links were best measured by the 120 ohm linear gages (CEA-06-240UZ-120) as they only experienced tension and compression.

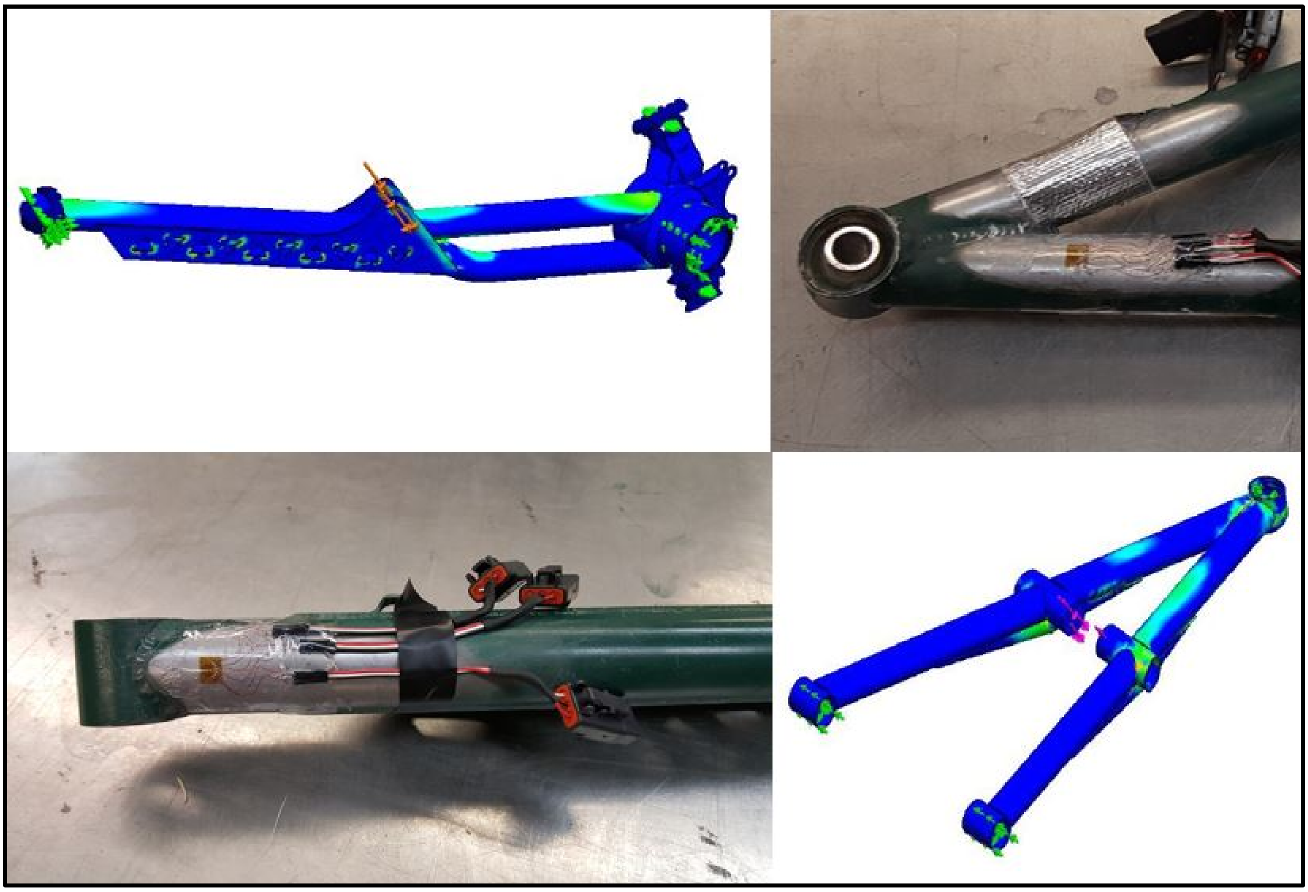
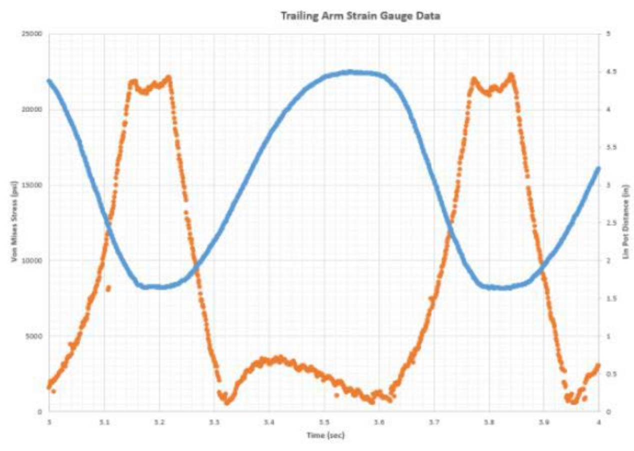


Figure 2: FEA model of trailing arm (top left). Stacked rosette applied to trailing arm (bottom left). Lower A-arm with a stacked rosette applied to each side with one covered by thermal reflecting tape (top right). FEA model of lower A-arm (bottom right).

A team member designed a Wheatstone bridge/amplifier system that fully integrates with our current data logging system. This system allowed for data collection on the testing track. Calibration was done with an Instron tensile tester for the overall system; which included the amplifier and the strain gage used on a test sample made of AISI 4130.

The test conducted simulated obstacles we would encounter, such as a rock garden, steep incline, cornering, hard braking (all wheels locked), and bumps. A linear potentiometer was placed in conjunction with the strain gages as to find the reaction forces from the air shocks.

Figure 3: Rear suspension outfitted with strain gages on linkages, trailing arm and integrated upright. All gages are sealed with RTV and covered with thermal reflecting tape.



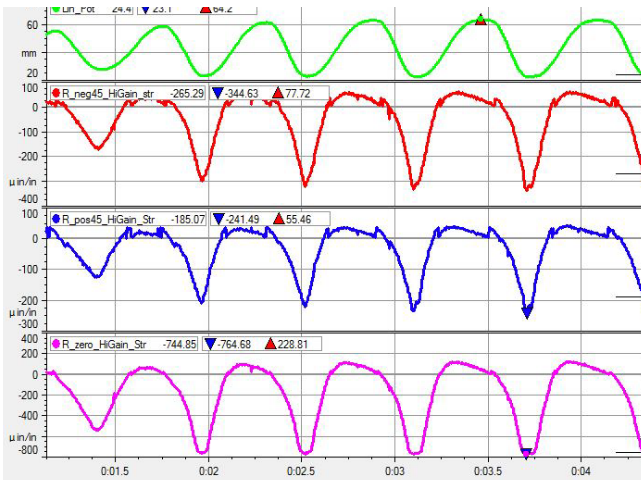


Figure 4: Trailing arm data.
(Blue curve) Linear potentiometer linear displacement of distance versus time [in v. sec]
(Orange curve) Von Misses stress from strain gage rosette versus time [psi v. sec].

Figure 5: Trailing arm data collected from strain gage rosette and linear potentiometer.
Top to bottom:
1) Linear potentiometer displacement versus time [mm v. sec].
2) Strain gage -45° from tube axis [in/in v. sec].
3) Strain gage parallel to tube axis [in/in v. sec].
4) Strain gage 45° from tube axis [in/in v. sec].

The User Explains

Strain gages validated that the true loading conditions were within 2% error of simulated loading conditions, done through FEA. This proves that our factor of safety values are valid assumptions and that our car is capable of handling said loading conditions.

Being able to complete the design cycle is important for any engineering application. Strain gages provided us with a method to directly and nondestructively analyze critical locations on structural components. The simplicity enables greater versatility in application.

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Acknowledgement:

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