Case Studies

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Validation of UW ECOCAR 3

Student Designed Structures

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Strain gages from Micro-Measurements® were used by the University of Washington ECOCAR 3 team to validate the design of the front electronics shelf and generator structure mount in the car. The gages allowed the team to develop a framework for validation of future ECOCAR structures. Knowing the bounds of maximum stress experienced in the harshest of driving conditions will allow the team to further load these structures. From seeing how well the FEA results correlate with the measured stress in the car the addition of components will not require further structure reinforcement. FEA and experimental mechanics can work as a team! This will allow UW ECOCAR to save considerable amounts of design and manufacturing time.

Company/Institute: University of Washington EcoCAR 3,
University of Washington, Seattle

Industry/Application Area: Automotive Hybrid Vehicles, Structural Validation

Product Used:

- Rectangular Rosette Strain Gages, C2A-13-031WW-350
- BAK-200 Basic Application Kit

The Challenge

The 2017-2018 UW ECOCAR mechanical team at the University of Washington is focused on the verification and improvement components installed in the car from the previous three years. Verifying the stresses experienced in the front electronics shelf, invertor mounts, and generator structure mount will allow us to add further components to these structures without significant structural changes to the engine bay. In the fourth year of the competition the team is focused on refinement, and validating the current structure will allow us to move forward in installing the last components without major structural changes. The car must not exceed a 1.5 safety factored yielding stress of 184 MPa for any 6061-T6 aluminum structure under a theoretical 20g loading. The gages will allow us to determine if our assembled structures can realistically handle this load once we extrapolate from the experienced accelerations and strains.

The Solution

Computer models are useful tools for predicting structural performance, but they only tell part of the story. Strain gage testing is performed to correlate the actual response of the part to test inputs with the generated computer model. Many uncontrollable realities can affect the FEA model, including complex structural design (not easily modeled), insufficient FEA mesh density, unknown or unaccounted for residual stresses in the part (often caused by the manufacturing and/or assembly processes), errors in material constants, unexpected interactions from other assemblies, and uncertainty in the applied loads (inaccurate boundary conditions). Perhaps one of the best questions to ask concerning strictly analytical design (no experimental verification) is: Would you want to ride on a car that had no design requirements verified by physical measurement (only computer-generated data was used to qualify the plane)?

The rectangular rosettes provided by Micro-Measurements® were bonded to the three structures near welds with predicted high stress points from the FEA results under 20g loading. Passing this 20g loading is an important ECOCAR competition requirement to ensure driver safety. Using the rectangular rosettes allowed the team to determine the principal strains under four loading conditions. For each structure the team performed axial acceleration and braking while collecting strain and acceleration data. A similar procedure was followed while maintaining speed and taking several sharp turns to simulate pure transverse acceleration. In the following figure you can see measured data with little noise and distinct patterns. The first large peak of negative strain is braking, and the sinusoidal behavior observed in the end was from hard banking turns. From this point the team used the corresponding accelerometer data to extrapolate out from the principal strains experienced to theoretical 20g loadings. This extrapolation allowed the team to validate the design of the front shelf and generator mounting structure.

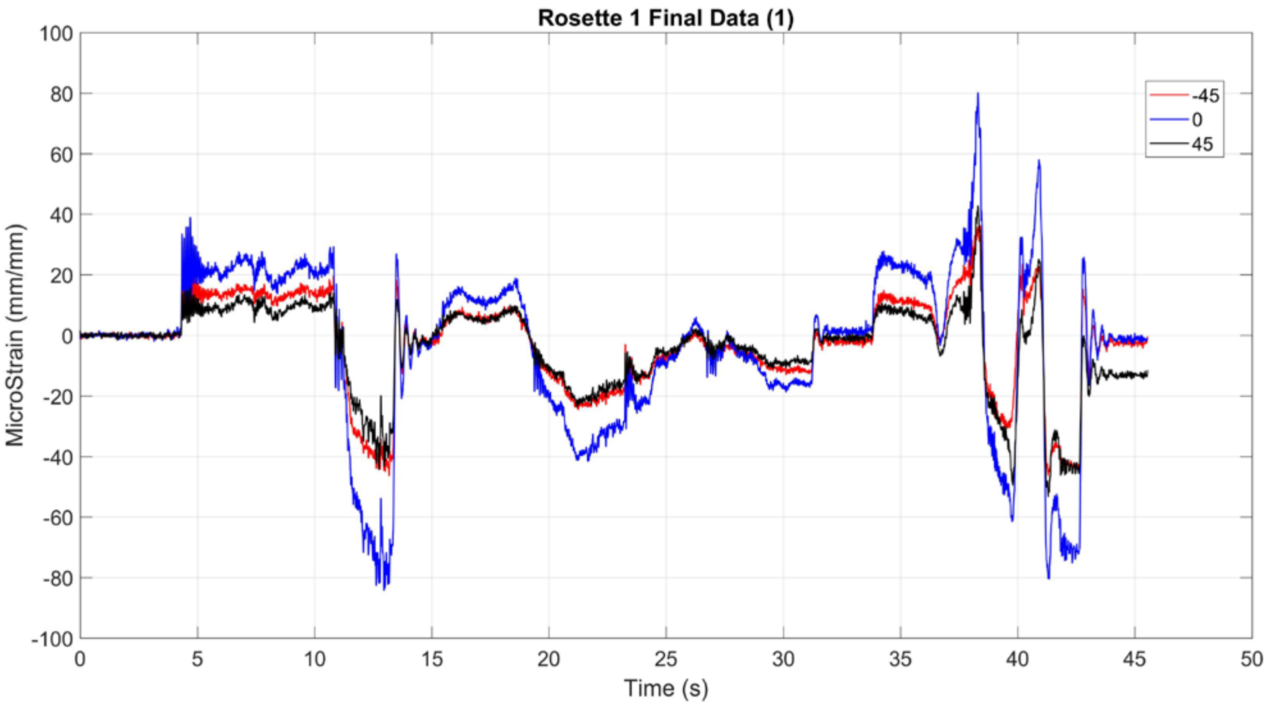

Figure 1: Sample data from one rosette through dynamic testing

A strain gage rosette is, by definition, an arrangement of two or more closely positioned gage grids, separately oriented to measure the normal strains along different directions in the underlying surface of the test part. Rosettes are designed to perform a very practical and important function in experimental stress analysis.

The User Explains

Without the help of Micro-Measurements®, The UW ECOCAR 3 team would not have been able to validate the structures we manufactured. The data we gathered using the strain gage rosettes proved to us that even under 20G loading our components will not fail. This is helpful in two ways. One, at our year 4 competition in May we can present to competition organizers and prove our structures won't fail under vigorous acceleration. Two, if we need to add more components for our ADAS system we have the strength to do so.

Figure 2 above shows example data from a rosette at the highest stress point on the car. We took the average of two tests and then calculated the principle strains based of rosette angle and measured strains at each gauge. We then used constitutive relations for uniaxial loading to calculate the principle stresses. We could then compare these stresses to our FEA.

Rosette 6	Calculated Stress (MPa)	FEA Stress (MPa)	% Error
Accelerating	-6.3649	-45.04	85.8682
Braking	24.0677	43.54	44.7226
Left Turn	58.3023	93.52	37.6578
Right Turn	-89.01	-93.58	4.8834

Figure 2: Average measured stress extrapolated to 20g's compared to FEA at same location

"With Micro-Measurements® strain gauges, we were able to validate the strength of several components on our car. We now can test and accelerate the vehicle vigorously without fear."

Acknowledgement:

UW EcoCAR 3 is a four-year competition sponsored by GM, Department of Energy, and Argonne National Laboratory to convert a 2016 Camaro into an advanced hybrid-electric vehicle. There are 16 schools across the U.S. and Canada all competing in this competition including the University of Washington. Technology developed in this competition will be integrated into future GM vehicles. In the fourth-year of competition the mechanical team must verify all structures implemented into the car. UW was able to validate designs using donated strain rosettes from Micro Measurements.
http://ecocar3.org/washington/about-us/

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