Vibration-Isolated Manual Wheelchair

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Introduction and Problem

Standard wheelchairs transmit vibration directly from the wheels through the frame to the user, leading to discomfort, fatigue, and long-term health risks such as low-back pain and disc degeneration. The design replaces the rigid rear axle connection with a composite leaf-spring suspension system, reducing vibration while maintaining comparable weight and maneuverability to a standard wheelchair.

Testing Methods

We performed dynamic vibration testing by:

- Placing accelerometers on the footrest, axle, and seat to measure baseline vibration over various surfaces
  - Tests were conducted on both standard wheelchair and vibration-isolated prototype to compare vibration transmission
- Three-point bend tests on single leaf-spring composites to measure flexural strength, stiffness, yield stress, and elongation
- Properties applied to Finite Element Analysis (FEA) model to enable accurate simulation of the rear-axle assembly under load and vibration

Design Specifications

Customer Priority	Metric	Target Value	Achieved Value
1	Vibration reduction at footrest	>0.3* (m/s^2)	5.66 (m/s^2)
2	Spring constant(k)	57,795 (N/m)	52,970 (N/m)
3	Weight	>30 lbs	30 lbs
4	Adjustability	+/- 2 in	>2 in

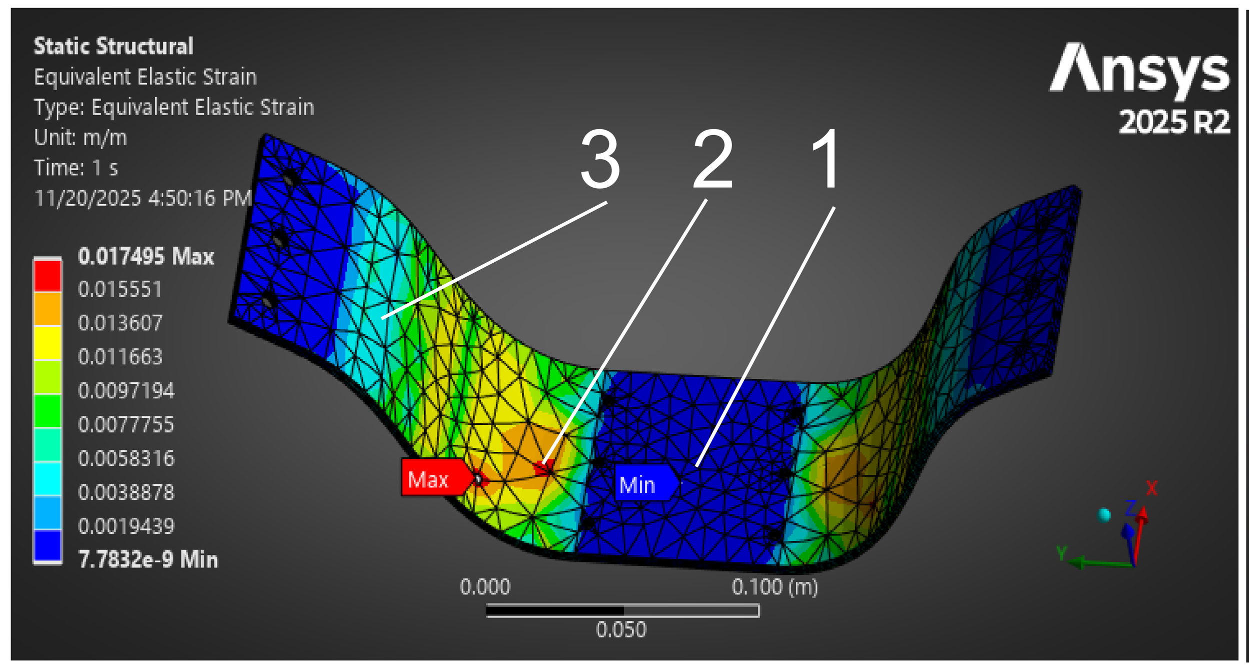
Design Overview

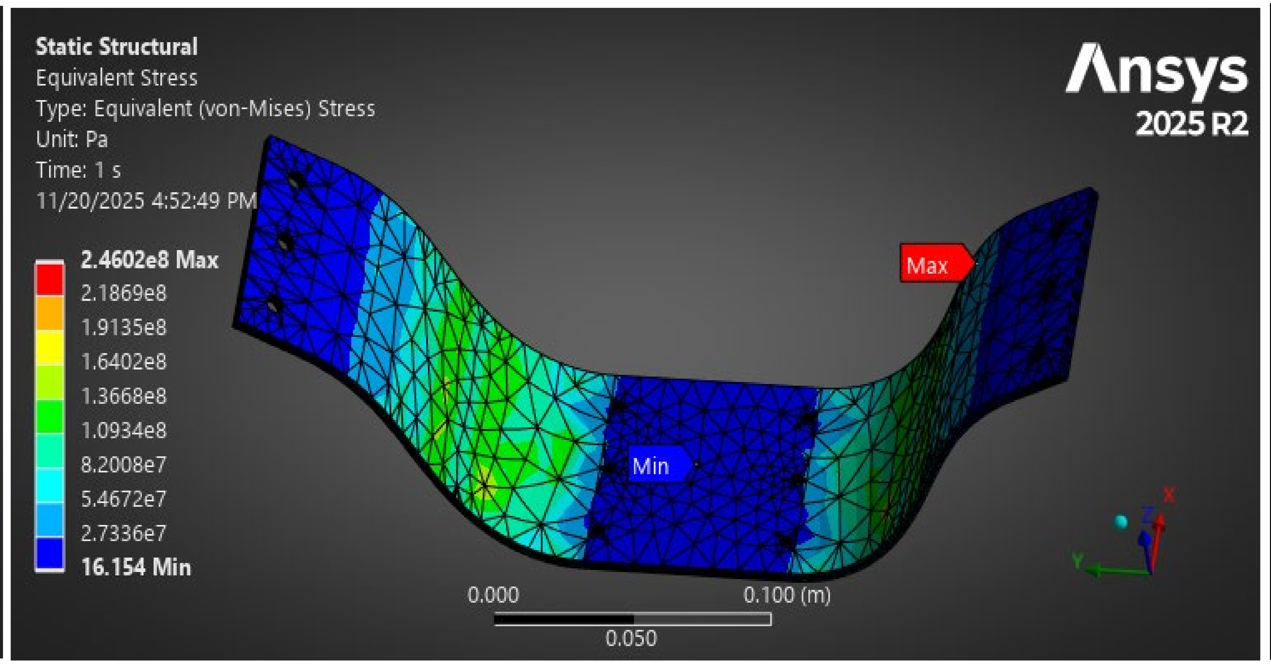
The design uses lightweight components for comfort, strength, and stiffness:

- Carbon-fiber footplate and seat
- Machined 7075 Aluminum frame and bearing housings
- A single front caster improves maneuverability and avoids steering conflict on uneven surfaces
- Two hybrid composite leaf springs mounted to bearing housings to provide rear suspension
  - Layering pair carbon's strength with the damping and flexibility of glass fiber for an optimal balance of stability, durability, and vibration isolation

Finite Element Analysis

FEA was conducted to predict stress and strain distributions, deformation, and overall durability of the rear suspension and full wheelchair assembly. The analysis used experimentally derived material properties from our composite bend tests to simulate realistic loading conditions. We then conducted strain gage tests at the indicated points on the leaf spring, which confirmed our FEA analysis.

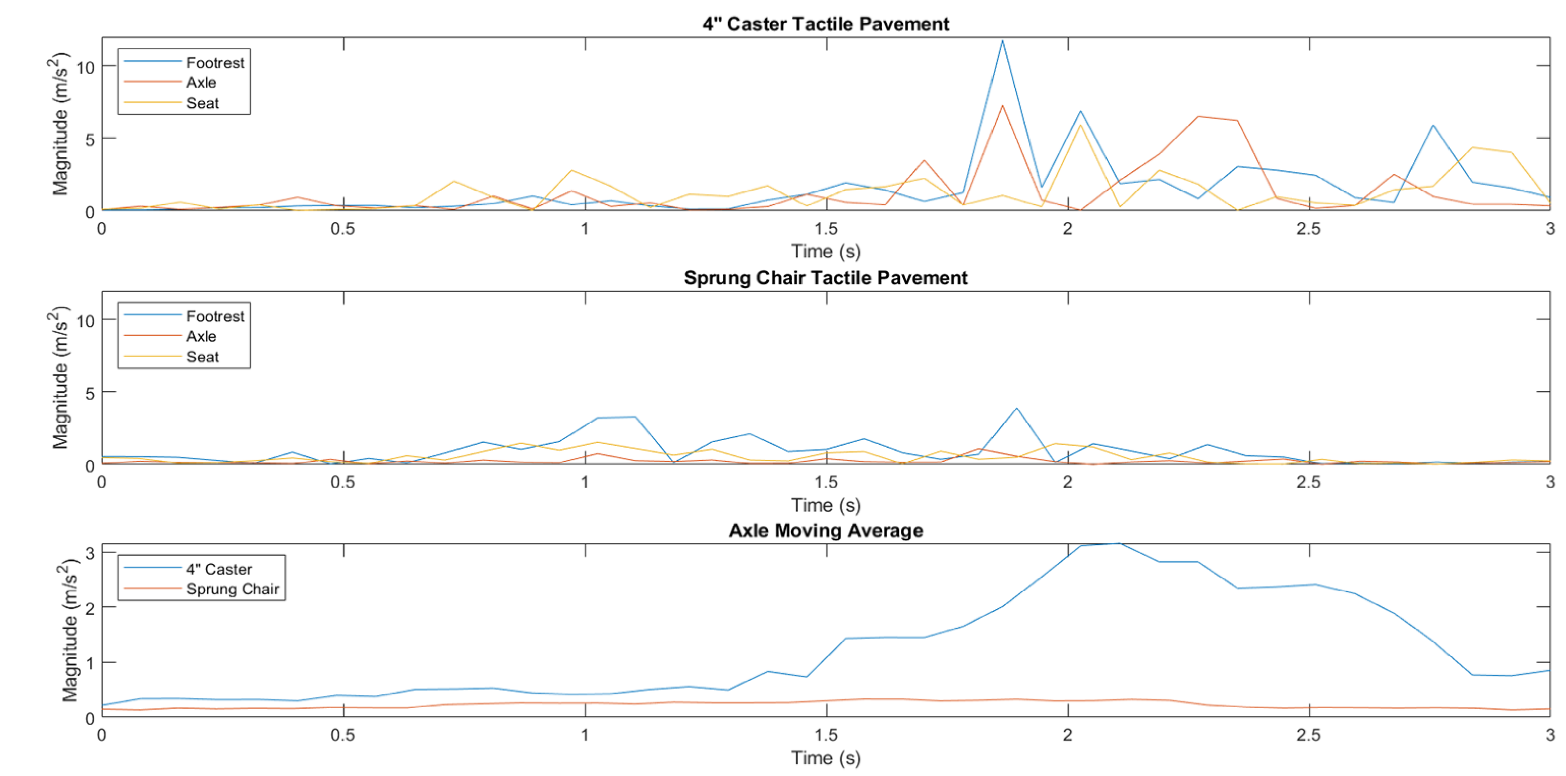




Posture	Strain Gage **1**	Strain Gage **2**	Strain Gage **3**
Seated	-444 µε	-3146 µε	1873 µε
Lean Right	-506 µε	-1693 µε	1098 µε
Lean Left	-328 µε	-4139 µε	2404 µε
Lean Forward	-348 µε	-2565 µε	1511 µε
Lean Backward	-471 µε	-3631 µε	2086 µε

Results

Testing data showed an average **48% reduction** of vibration-induced acceleration throughout the wheelchair compared to a standard model, confirming improved ride comfort. FEA and physical strain gauge testing accurately predicted the location and magnitude of peak strain, validating the model's reliability. The prototype met camber and deflection targets, ensuring proper alignment and stiffness under load. FEA also confirmed that each leaf-spring could **support up to 1000 lbs** before failure, providing a strong margin of safety.



	Baseline Control Peak Magnitudes			Vibration-Isolated Wheelchair Peak Magnitude		
Locations	**Parking lot asphalt**	**Metal Tread Plate**	**Tactile Pavement**	**Parking lot asphalt**	**Metal Tread Plate**	**Tactile Pavement**
Footrest	21.19	18.36	11.78	11.21	10.62	3.91
Axle	16.62	12.75	7.29	6.45	6.03	1.08
Seat Back	48.57	17.28	5.94	7.08	11.18	1.53

Conclusion

- Physical testing and simulation validated the vibration isolated wheelchair design.
- The hybrid leaf spring suspension effectively reduced transmitted vibrations by 48% while meeting strength and load requirements.

The prototype performed well under load and offered a smoother ride. With its lightweight, manufacturable design, the concept shows strong potential for further funding and commercial development.

Acknowledgments

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