Team 3: Wind Tunnel Force Sensor

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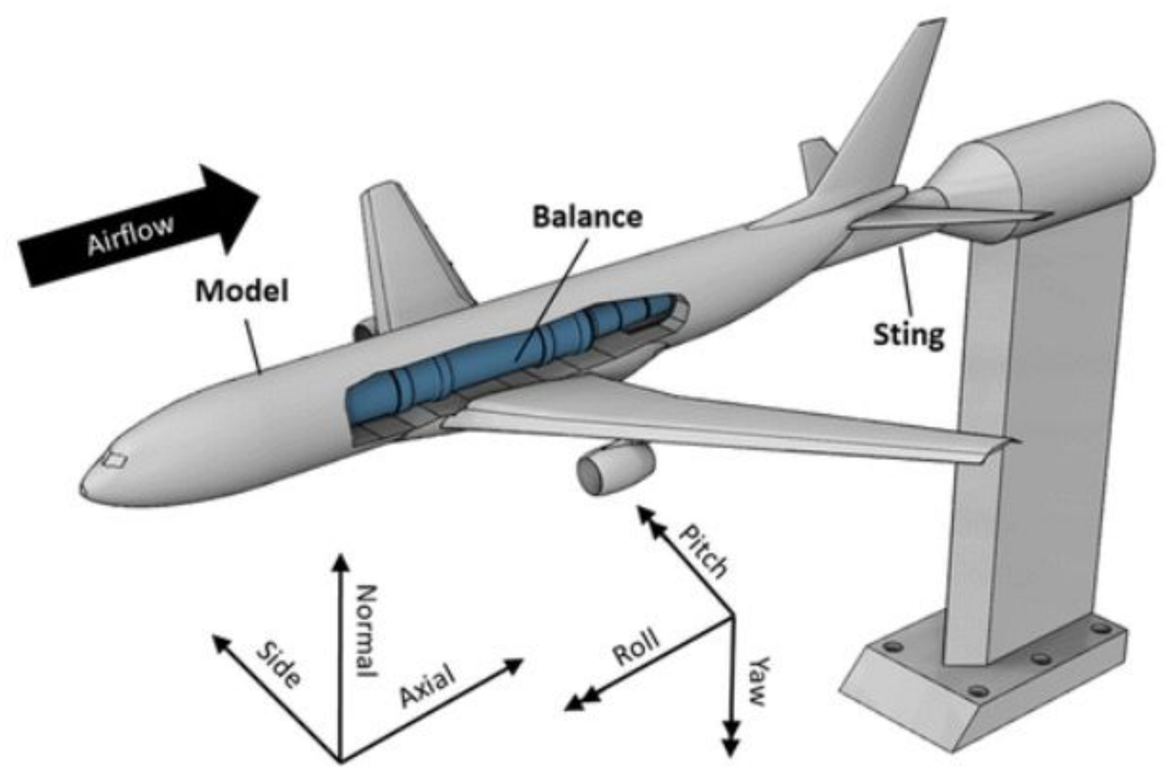
Executive Summary

The objective of our project is to design and prove the functionality of a 6 axis wind tunnel force sensor. The sensor is designed with cost and manufacturing in mind first, as the goal is to replace the $10,000 force sensor previously used in the lab with a sensor that is roughly $200.

Our prospective design utilizes strain gauges in a wheatstone bridge configuration to transduce forces coming into an elastic element. From the strain gauges, we will record data into a micro controller and produce readings in real time. From our research and experimentation, our design has the capabilities of being successful and reaching our sponsors goal.



Load Cell

- Custom-designed load cell utilizing strain gauges attached to an aluminum box.
- Engineered to measure forces and torques in the x, y, and z dimensions.
- Aluminum construction paired with sensitive strain gauges ensures precise readings.
- Calibration with known weights guarantees measurement accuracy.
- Calibration establishes a solid baseline for interpreting testing signals.
- Ensures data integrity and validates theoretical design models.

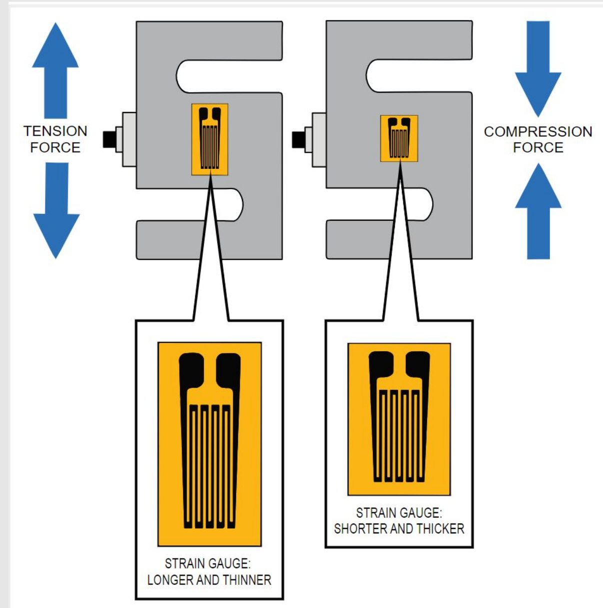


Fig 3: Strain Gauge Illustration
As force acts on load cell, resistance is changed, causing current to change. Current is read and then calibrated to read force output

Finite Element Analyses

FEA can be used to visualize the effect of the bending moment when different forces are applied:

- Case 1: Horizontal Force (N*mm)
- Case 2: Vertical Force (N*mm)
- More cases soon…
  - Multiple forces in different directions

The analysis is crucial for interpreting the data values to be able to display torque as a calculation.

The beams have a large sectional area, which results in bending moment dominating axial/shear forces

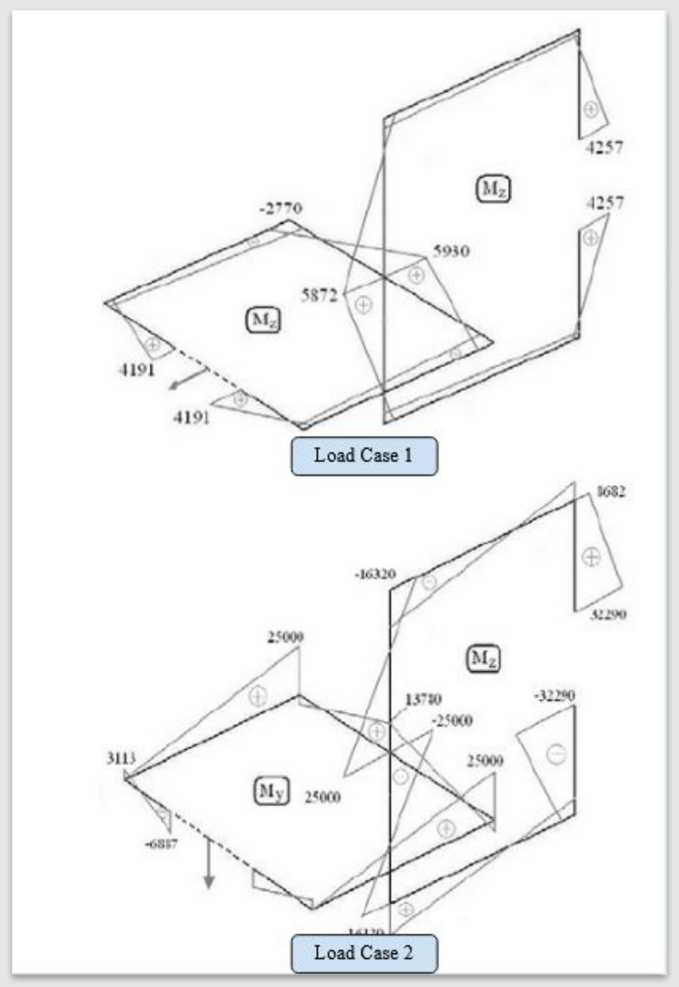


Fig. 1: FEA Load Case Examples

Future Improvements

Enhance Accuracy:

- Investigate advanced materials for the load cell to increase the precision of strain measurements.
- Implement higher-resolution data acquisition systems to capture finer variations in force.

Reduce Size:

- Explore miniaturized designs to achieve a more compact form factor similar to the ATI Nano 17.
- Integrate micro-strain gauges and utilize micro-fabrication techniques.

Ease of Reproduction:

- Standardize components for easier assembly and maintenance.
- Develop a modular design to facilitate mass production and customization.

Fig 4: ATI Industrial Automation F/T Sensor: Nano 17

Cost Reduction:

- Identify cost-effective alternatives to expensive components without compromising quality.
- Optimize the manufacturing process to reduce waste and lower production costs.

Strain Gauge Configuration

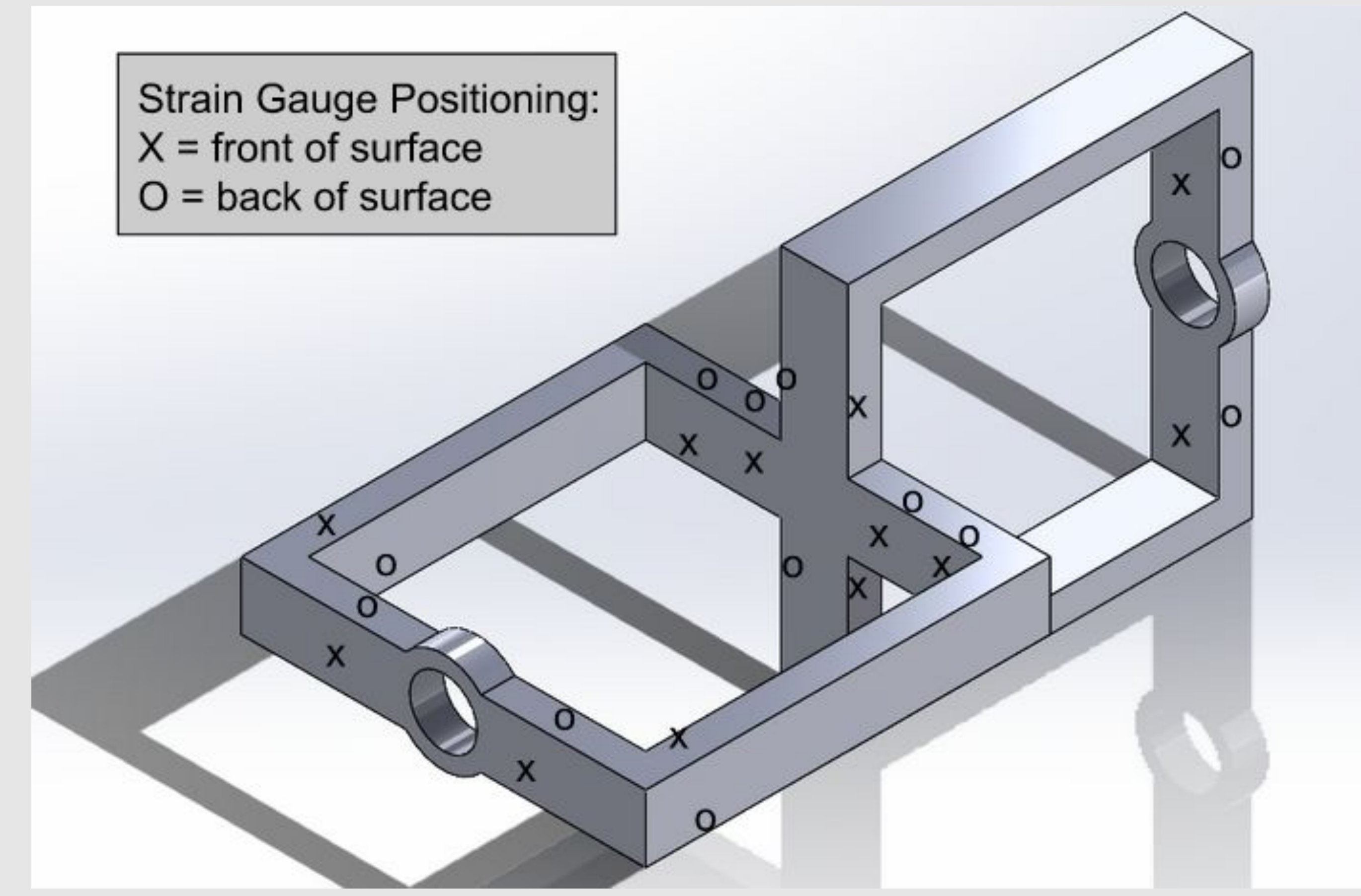
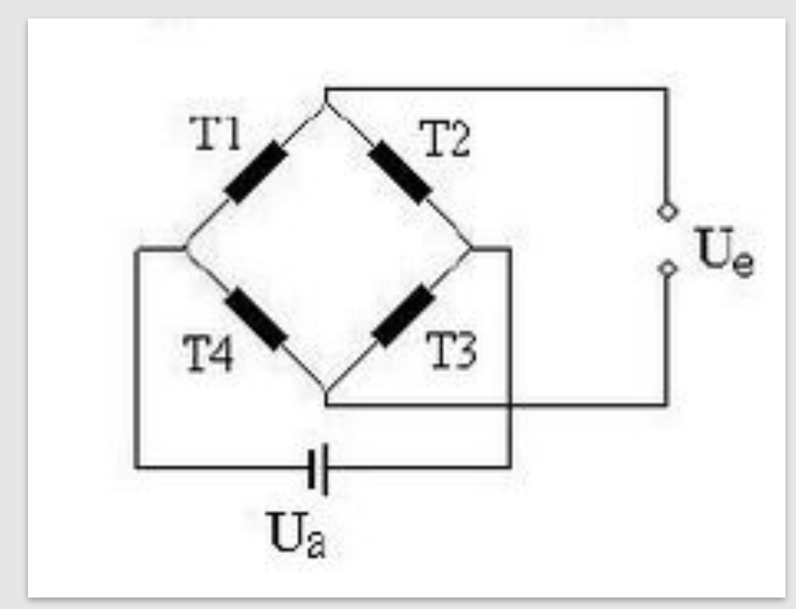


Fig. 2: Configuration of elastic element to interpret moments

Above is a figure illustrating the concept for a bracket that translates forces felt by the wind tunnel attachment to multiple sets of strain gauges. The strain gauges will be wired in a full wheatstone bridge. This configuration also chosen as it provides the most accuracy and reduces noises measurements including shear stress.

- the X's denote the strain gauge on the front side
- the O's denote a strain gauge on the opposite side surface



The corresponding signal to a wheatstone bridge:

$$\Delta U_e = (k_t / 4)(\varepsilon_1+\varepsilon_2+\varepsilon_3-\varepsilon_4)U_a$$

- k_t = strain gauge constant
- ε = strain
- T = strain gauge
- U_a = bridge supply voltage

The sensitivity of each bridge can be measured by:

$$S_m = \Delta U_e / U_a$$

References

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[2] D. E. Burns and P. A. Parker, "Additively Manufactured Wind-Tunnel Balance," Journal of Aircraft, pp. 1–6, Apr. 2020, doi: https://doi.org/10.2514/1.c035889.

[3] S. Marin, Sandu Adriana, and Ionaşcu Georgeta, "Design of a compact six-component force and moment sensor for aerodynamic testing," INCAS Buletin, vol. 3, no. 1, pp. 95–100, Mar. 2011, doi: https://doi.org/10.13111/2066-8201.2011.3.1.13.