Load Cell Design Using COMSOL Multiphysics

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Abstract

Introduction:

Load cells are commonly used force transducers that convert an applied mechanical load into a voltage. Load cells typically comprise spring elements that are designed to deform with load, semiconductor strain gages that vary their resistance with deformation (strain) of the spring element, and a Wheatstone bridge circuit that produces voltage proportional to strain. One popular spring element design is the binocular configuration, which is a beam with two holes and a web of beam material removed, as shown in Figure 1. The complexity of the "binocular" section of this beam prevents prediction of strain via simple hand calculation, hence a COMSOL model was used to guide load cell design.

COMSOL Multiphysics Model:

A 3D Solid Mechanics model was built, with geometry drawn in SolidWorks (Figure 1) and imported using the COMSOL CAD Import Module. The spring element was modeled as homogeneous, linearly elastic 6061 aluminum. The left hand end of this beam was defined as a fixed constraint boundary. Loads were applied to the right hand side of the beam as a point load in the y direction. A fine physics-controlled mesh was generated (Figure 2) and a stationary analysis was performed, using default solver settings. Model geometry parameters were varied until the sum of strains in all four high strain regions (defined below) provided several hundred micro-strain (1e-6) over the desired load range of 0-2.5kg.

Model Verification:

The load cell design was fabricated from 6061 aluminum bar stock and strain gages were mounted at the four high stress regions. Strain gages were general purpose Vishay Micro-Measurements CEA-13-240UZ-120 and installed using standard techniques. Gages were wired with 27 AWG polyurethane insulated solid copper wire and gage lead wires were of uniform length to prevent unwanted lead resistance differences. The four gages were wired as a full active bridge using four conductor shielded cable and a Vishay P3 Strain Indicator and Recorder.

Results:

Figure 3 shows bending strain arising from an applied load of 900g. The highly scaled deformation

image shows the four high strain regions at the top and bottom regions of the bored holes of the spring element. Starting from the upper left and moving clockwise, there is tension T1, compression C1, tension T2 and compression C2. These strains were combined to add in a full bridge configuration, and so the absolute values of strains T1, C1, T2 and C2 were added to predict total transducer strain. COMSOL model strain predictions were within +/-0.5% of measured strain for loads ranging from 500-2500g. Overall measured strain of the transducer was very linear, as desired (Figure 4).

Conclusion:

Load cell design is challenging due to the complex geometry of spring elements. COMSOL solid models are useful for predicting strain in these designs, for locating strain gage mounting positions and especially for optimizing maximum strain for the desired load range. Model predictions were validated by measurements with the completed load cell, and agreed within 0.5%. The resulting load cell was strongly linear, with correlation coefficient r2=0.9999.

Reference

Khan, A. S. and X. Wang. Strain Measurements and Stress Analysis. Prentice Hall, NJ (2001).

Hannah, R.L. and S. E. Reed. Strain Gage Users' Handbook. Springer, NY (1992).

Vishay Micro-Measurements "Model P3 Strain Indicator And Recorder" Instruction Manual.4, Measurements Group, Raleigh, NC (2005).

Figures used in the abstract

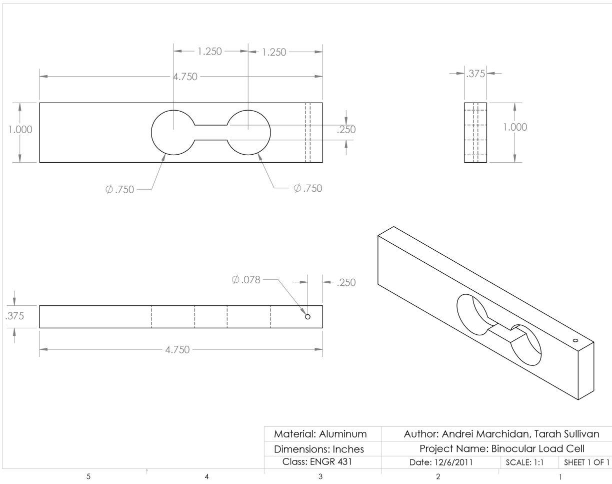

Figure 1: Load cell geometry imported from SolidWorks.

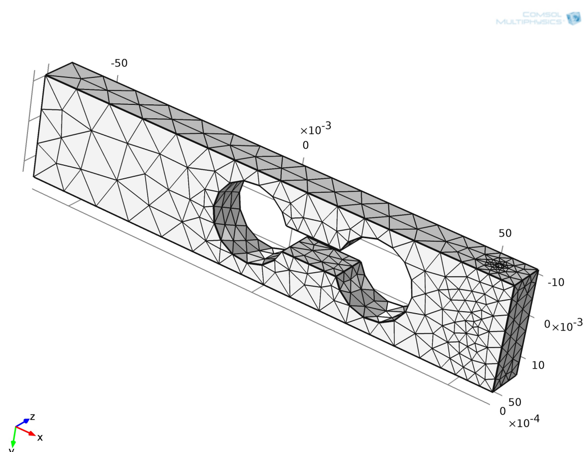

Figure 2: COMSOL fine mesh of load cell spring element.

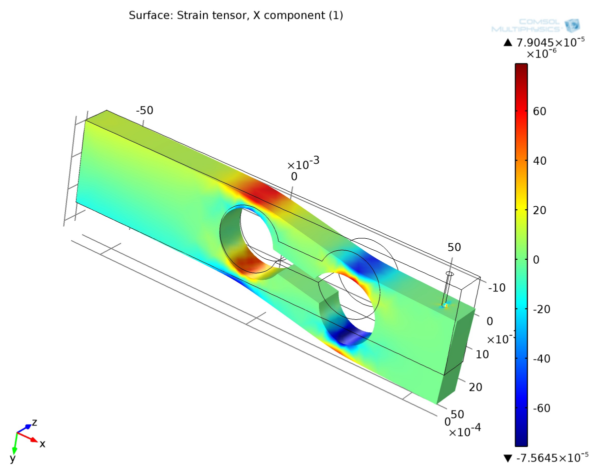

Figure 3: Bending strain of load cell loaded with 900g. Exaggerated deformation shows high tensile and compressive strain regions.

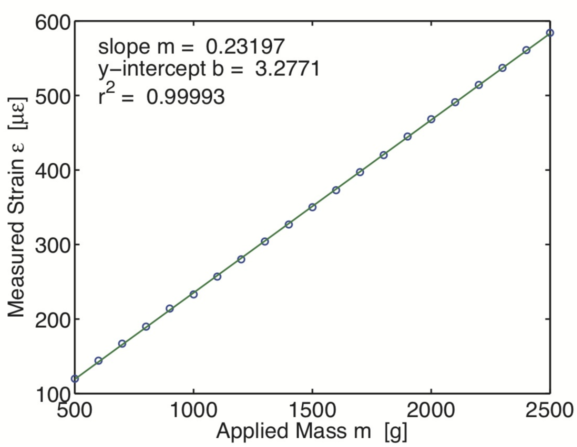

Figure 4: Measured total strain (full bridge) of completed transducer for load range 0-2.5kg, showing high degree of linearity.