Calibration of Strain Gauges

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Abstract

This experiment teaches force measuring using a stain gauge. By applying known loads and moments to the balancing structure, the four-component strain gauge is calibrated in order to get the 16 calibration constants (Kij).

Nomenclature

F_1	Force that affects the strain gauge 1 and 3, N
M_1	Moment corresponding to F1, N-m
F_2	Force that affects the strain gauge 2 and 4, N
M_2	Moment corresponding to F2, N-m
K_{ji}	The coefficient of calibration constant matrix

1 Introduction

Electrical devices called strain gauges are quite tiny and delicate. They are frequently used to assess strain or tension within other sensors. They measure electrical resistance that changes in relation to variations in strain. Strain is the material's displacement or distortion as a result of applied stress. Stress is the force exerted on a material divided by the cross-sectional area of the substance. We are intended to concentrate stress through beam components that house strain gauges. Strain gauges turn the applied force, pressure, torque, etc. into a measurable electrical signal. Strain is caused by force, and the strain gauge measures it by detecting a change in electrical resistance. Following that, data acquisition is used to acquire the voltage measurement.

There are several uses for strain gauges. To quantify any strain and stress that occurs during flight in various locations of an aircraft, strain gauges are glued to load-bearing components. Additionally, they are utilized in safety and maintenance applications as well as load cells and pressure transducers. But calibrating the measurement using known variables is a crucial stage in the design and development of any sensor.

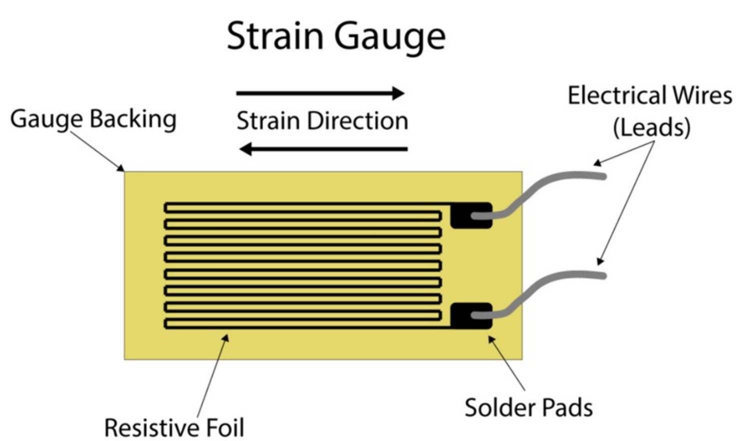
2 Experimental setup

The main equipment required for performing this experiment are as follows:

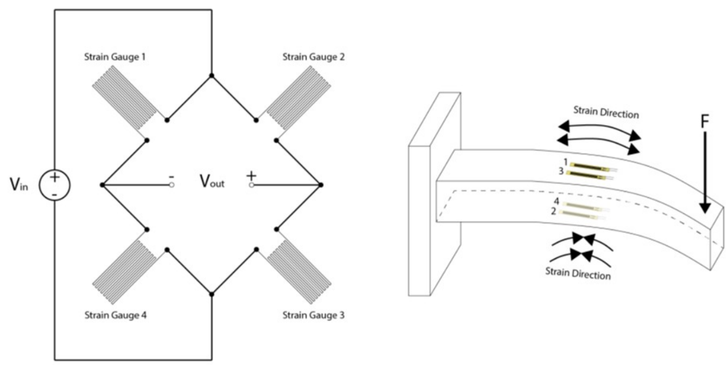
- Strain Gauge Balance
- DC Lab bench power supply-Strain gauge being active device requires external power supply during operation.
- Digital storage oscilloscope (DSO)- To display the output voltage reading from strain gauges
- Masses- 50g, 100g, 200g, 300g, 500g, 750g, 1kg

3 Theory

The strain gauge has to be coupled to an electrical circuit that can precisely react to the minuscule resistance variations brought on by strain. In a Wheatstone bridge circuit, several strain gauges can be utilized to track minute variations in electrical resistance. When a force is applied to a body, the amount of deformation depends on the amount of force used. The linked strain gauges are once more compressed or stretched as a result of this deformation, changing their electrical resistance and hence changing the voltage. An excitation voltage is



delivered across the circuit in a Wheatstone bridge arrangement, and the output voltage is measured at two points in the center of the bridge. The Wheatstone bridge is balanced and has zero output voltage when there is no load on the load cell. The output voltage changes as a result of the bridge being knocked out of balance. As the resistance change is minute, hence signal amplification is frequently required to accurately identify changes. The strain signal changes are strengthened by the amplification process, but extra undesired noise is also picked up in the signal as a side effect. Signal conditioning removes the extra noise to provide accurate and comprehensible data. Calibration: The strain at



the various positions on the balancing structure is represented by the voltages V1, V2, V3, and V4 from these strain gauges. Forces and moments around the loading point M affect these voltages. Assuming a linear relationship , the dependence can be expressed as

$$\Delta V_1 = K_{11}F_1 + K_{12}M_1 + K_{13}F_2 + K_{14}M_2 \tag{1}$$

$$\Delta V_2 = K_{21}F_1 + K_{22}M_1 + K_{23}F_2 + K_{24}M_2 \tag{2}$$

$$\Delta V_3 = K_{31}F_1 + K_{32}M_1 + K_{33}F_2 + K_{34}M_2 \tag{3}$$

$$\Delta V_4 = K_{41}F_1 + K_{42}M_1 + K_{43}F_2 + K_{44}M_2 \tag{4}$$

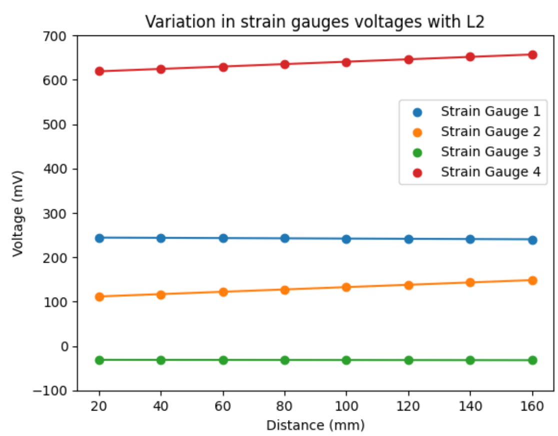
We apply the known transverse loads (both perpendicular to the axis of the beam) at the known position on the balancing structure in order to get the calibration constant Kij. We then changed the force first while maintaining the moment constant and then varied the moment while maintaining the force constant.

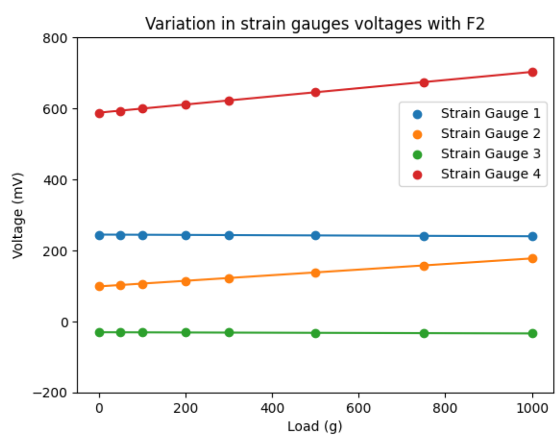
4 Procedure

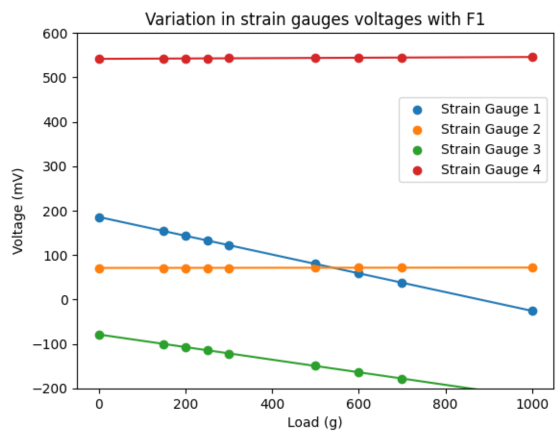
- Establish the set up.
- The cantilever beam is loaded with empty pan at the reference section and corresponding voltage is recorded using DSO.
- The cantilever beam is loaded with different loads (50g, 100g, 200g, 300g, 500g, 750g, 1kg) at same location (120mm).

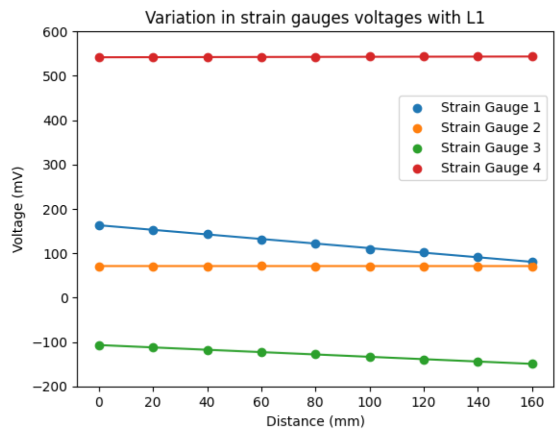
- With loaded configuration, the voltage corresponding to each strain gauge is recorded.
- All the above voltage reading are for zero moment with variable loads.
- Now,to change moment at the constant load. A load of 500g is used at different location from reference section(20mm,40mm,60mm,80mm,100mm,120mm,140mm and 160mm) and voltage is recorded corresponding to all strain gauges.
- As the load is applied in only one direction on beam instead of two. So to apply force in other direction rotate strain gauge by 90 degrees and above steps are repeated.

Results and Discussions









We can get the above graphs on comparing Loads with Voltage and Moment with Voltage. After calibration the constants obtained are.

$$\begin{bmatrix} 2.11237229e-01 & -5.15000000e-01 & -4.69751037e-03 & -2.73809524e-02 \\ 7.79566130e-04 & -4.16666667e-04 & 7.87600277e-02 & 2.63273810e-01 \\ -1.41645906e-01 & -2.65000000e-01 & -3.37067773e-03 & -5.95238095e-03 \\ 4.18474458e-03 & 1.05000000e-02 & 1.14865837e-01 & 2.71130952e-01 \end{bmatrix}$$

Conclusion

Strain Gauges convert force into change in electrical resistance. So, we can observe strain undergone by the beam and voltage of the gauge are proportional .Voltages can be found by preparing a Wheatstone bridge circuit with strain gauges.

Sample Calculation

We need to calibrate the below matrix

$$\begin{bmatrix} E1 \\ E2 \\ E3 \\ E4 \end{bmatrix} = \begin{bmatrix} K11 & K12 & K13 & K14 \\ K21 & K22 & K23 & K24 \\ K31 & K32 & K33 & K34 \\ K41 & K42 & K43 & K44 \end{bmatrix} \begin{bmatrix} F1 \\ L1 \\ F2 \\ L2 \end{bmatrix}$$

Constants can be found by

$k11 = \frac{\partial E1}{\partial F1}, k12 = \frac{\partial E1}{\partial L1}, k13 = \frac{\partial E3}{\partial F2}, k14 = \frac{\partial E4}{\partial L2},$

$k12 = \frac{\partial E2}{\partial F1}, k12 = \frac{\partial E2}{\partial L1}, k23 = \frac{\partial E3}{\partial F2}, k24 = \frac{\partial E4}{\partial L2},$

$k31 = \frac{\partial E1}{\partial F1}, k12 = \frac{\partial E2}{\partial L1}, k33 = \frac{\partial E3}{\partial F2}, k34 = \frac{\partial E4}{\partial L2},$

$k41 = \frac{\partial E1}{\partial F1}, k12 = \frac{\partial E2}{\partial L1}, k43 = \frac{\partial E3}{\partial F2}, k44 = \frac{\partial E4}{\partial L2},$

The slopes of the graphs of voltage vs load or distance (moment) gives us the required constants.

From the graph of voltage vs F1

we get K11 = 0.211 , K21 = 0.00078, K31 = -0.1416 , K41 = 0.004

Error

The following matrix shows error estimated for constants after calibration.

$$\begin{bmatrix} 0.211 \pm 0.0012 & -0.515 \pm 0.012 & -0.0047 \pm 0.00054 & -0.027 \pm 0.0024 \\ 0.00078 \pm 0.00028 & -0.00042 \pm 0.003 & 0.079 \pm 0.00071 & 0.263 \pm 0.0009 \\ -0.1416 \pm 0.0012 & -0.265 \pm 0.0052 & -0.0034 \pm 0.0019 & -0.006 \pm 0.004 \\ 0.004 \pm 0.0012 & 0.01 \pm 0.002 & 0.114 \pm 0.0026 & 0.271 \pm 0.0045 \end{bmatrix}$$