AE351 Experiments in Aerospace Engineering

Experiment-S3

Beam Deflection and Strains

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170382 | B9

OBJECTIVE

The objective of this experiment is to experimentally measure the strain and deflection in a beam subjected to transverse loading. Determine the strain and the deflection variation along the beam using Euler-Bernoulli beam theory and compare the results with experimental measurements.

INTRODUCTION & THEORY

The experiment consists of a simply supported Beam of rectangular cross section subjected to a concentrated load. The load is applied by hanging dead weight at the specified location of the beam. A total of 15 strain gauges are present. The strain gauge locations from the neutral axis (y) are constant. Therefore, from Euler-Bernoulli beam theory the theoretical strain distribution on the top of the beam can be given by,

$$\varepsilon_x(x) = M(x)\left[\frac{y}{EI}\right] = C_2\ M(x)$$

where $C_2 = y/EI$ is a constant that can be calculated.

$I = b*d^3/12$

$M = Px/2$ (for $x<L/2$)

$M = P(L-x)/2$ (for $x>L/2$)

EQUIPMENT USED

- A beam of rectangular cross section with carefully mounted (15) strain gages on its top
- Strain indicator (with Wheatstone bridge circuits) to record strain gauge data
- Weights
- Vernier Calipers and Measuring scale
- Deflection dial gages to measure beam deflection

PROCEDURE & MEASUREMENTS

1. Mount the beam with simply supported boundary conditions. Measure beam dimensions and the location of strain gages with respect to the supports. Apply a concentrated load as specified by your lab instructor. Record all dial gage readings and the strain values using strain indicator equipment and tabulate your data.
2. Theoretically calculate strains at each of the strain gage locations using Euler-Bernoulli beam theory and compare your results with experimentally measured strain values. Generate graphs that show both your experimental measurements (as data points) and theoretical predictions (as solid lines/curves). Calculate the percent errors and discuss possible reasons for the discrepancies.
3. Repeat with two concentrated loads

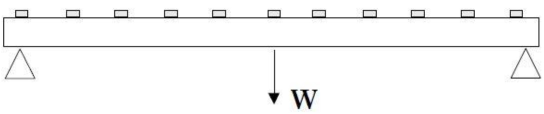
RESULTS & DISCUSSION

- Initial Observations
  - Length (L) = 884mm
  - Breadth (B) = 25 mm
  - Height (H) = 11 mm
  - E (for Al) = 69 GPa

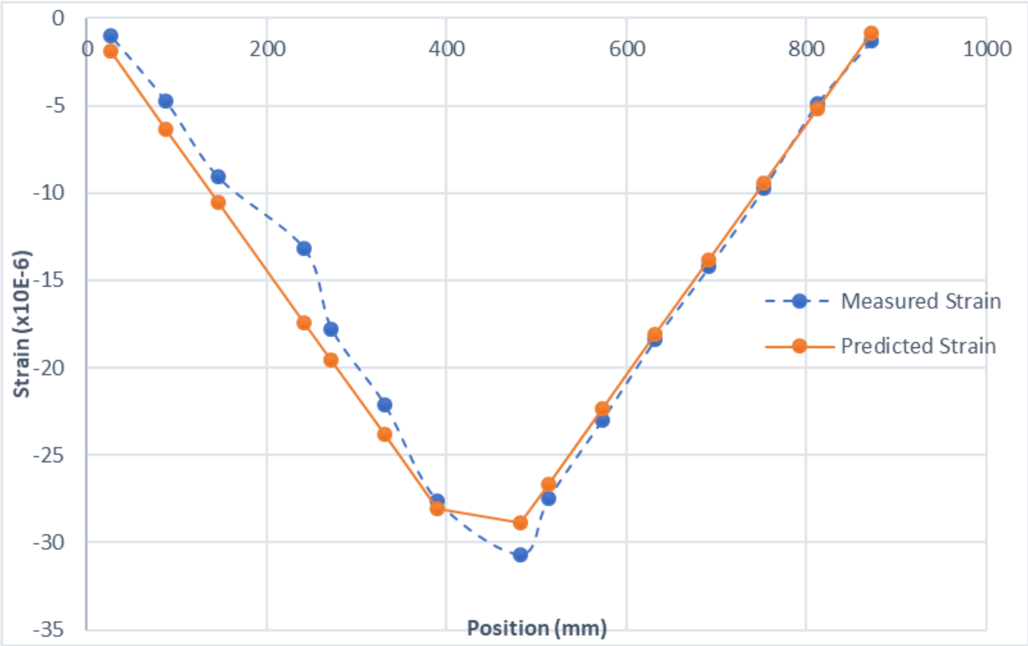
- <u>Dial Gauge Readings</u>

S No.	Position (mm)	Zero Load reading (mm)		Displacement with Load (mm)		
		Start	End	500 gm	1000 gm	500+500 gm
1.	111	0	-0.01	-0.11	-0.23	-0.20
2.	280	0	0	-0.26	-0.53	-0.43
3.	420	0	0.01	-0.32	-0.64	-0.49
4.	614	0	0.01	-0.27	-0.53	-0.42
5.	782	0	0.03	-0.11	-0.23	-0.14

- <u>Case-1 500 gm</u>



Strain Gauge	x (mm)	M (N-m)	ε_x ($\times 10^{-6}$) (Pred.)	ε_x ($\times 10^{-6}$) (Meas.)	Percent Error
1.	872	0.03	-0.86265	-1.3094869	34.12305
2.	812	0.18	-5.1759	-4.8884014	-5.88124
3.	753	0.3275	-9.417263	-9.6958458	2.873224
4.	692	0.48	-13.8024	-14.214137	2.896675
5.	632	0.63	-18.11565	-18.372875	1.400029
6.	573	0.7775	-22.35701	-22.980898	2.714801
7.	513	0.9275	-26.67026	-27.497627	3.008858
8.	482	1.005	-28.89878	-30.670298	5.776022
9.	390	0.975	-28.03613	-27.641815	-1.4265
10.	331	0.8275	-23.79476	-22.100744	-7.66498
11.	272	0.68	-19.5534	-17.769705	-10.0378
12.	242	0.605	-17.39678	-13.203961	-31.7542
13.	146	0.365	-10.49558	-9.0798631	-15.5918
14.	88	0.22	-6.3261	-4.7633161	-32.8087
15.	26	0.065	-1.869075	-0.96432237	-93.8226



- Sample Calculations
  - X<L/2 (x = 26mm)

    M = W/2*0.026=0.065

    ε(predicted)=M*(y)/(E*I)=0.065*(-0.011/2)/191.268)

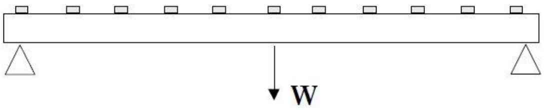
    $= -1.869 \times 10^{-6}$
  - X>L/2 (x = 482mm)

    M = W/2*(0.884-0.482)=1.005

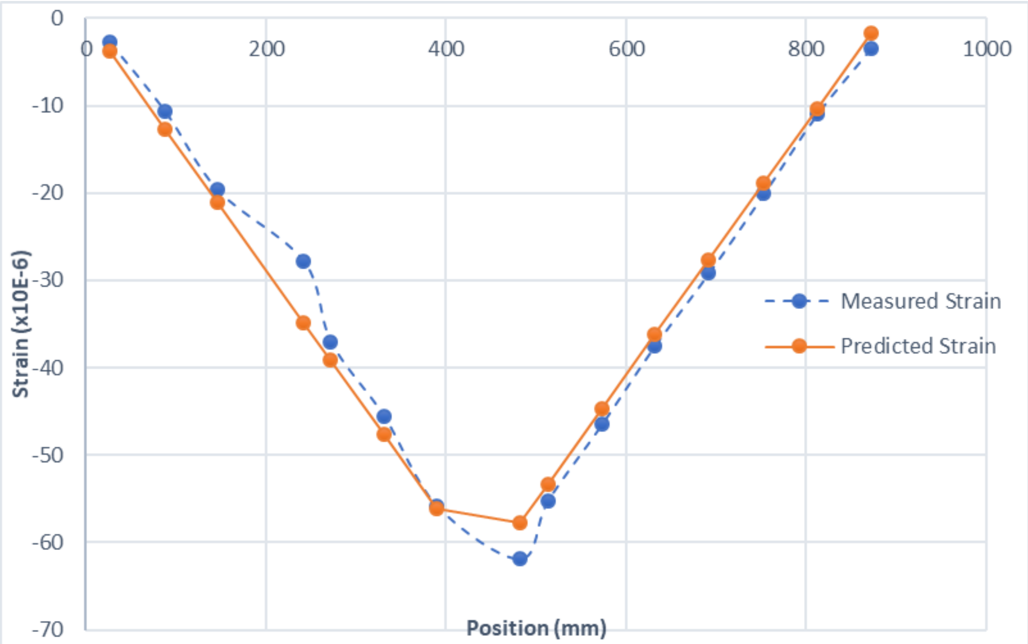
    ε(predicted)=M*(y)/(E*I)=1.005*(-0.011/2)/191.268)

    $= -28.898 \times 10^{-6}$

- <u>Case-2 1000 gm</u>



Strain Gauge	x (mm)	M (N-m)	ε_x ($x10^{-6}$) (Pred.)	ε_x ($x10^{-6}$) (Meas.)	Percent Error
1.	872	0.06	-1.7253	-3.44343716	49.89599287
2.	812	0.36	-10.3518	-10.9954917	5.854142021
3.	753	0.655	-18.834525	-20.0768507	6.187851464
4.	692	0.96	-27.6048	-29.14206874	5.275084462
5.	632	1.26	-36.2313	-37.46577236	3.294933701
6.	573	1.555	-44.714025	-46.46747772	3.773505269
7.	513	1.855	-53.340525	-55.21085132	3.387606377
8.	482	2.01	-57.79755	-61.85382666	6.557842706
9.	390	1.95	-56.07225	-55.82124902	-0.449651315
10.	331	1.655	-47.589525	-45.51083682	-4.567457611
11.	272	1.36	-39.1068	-36.99172902	-5.717686186
12.	242	1.21	-34.79355	-27.78036036	-25.24513559
13.	146	0.73	-20.99115	-19.6020457	-7.086527199
14.	88	0.44	-12.6522	-10.64294862	-18.87870976
15.	26	0.13	-3.73815	-2.6659378	-40.21895034



- Sample Calculations
  - X<L/2 (x = 26mm)

    M = W/2*0.026=0.13

    ε(predicted)=M*(y)/(E*I)=0.13*(-0.011/2)/191.268)

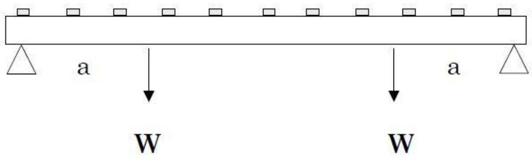
    $= -3.738 \times 10^{-6}$
  - X>L/2 (x = 482mm)

    M = W/2*(0.884-0.482)=2.01

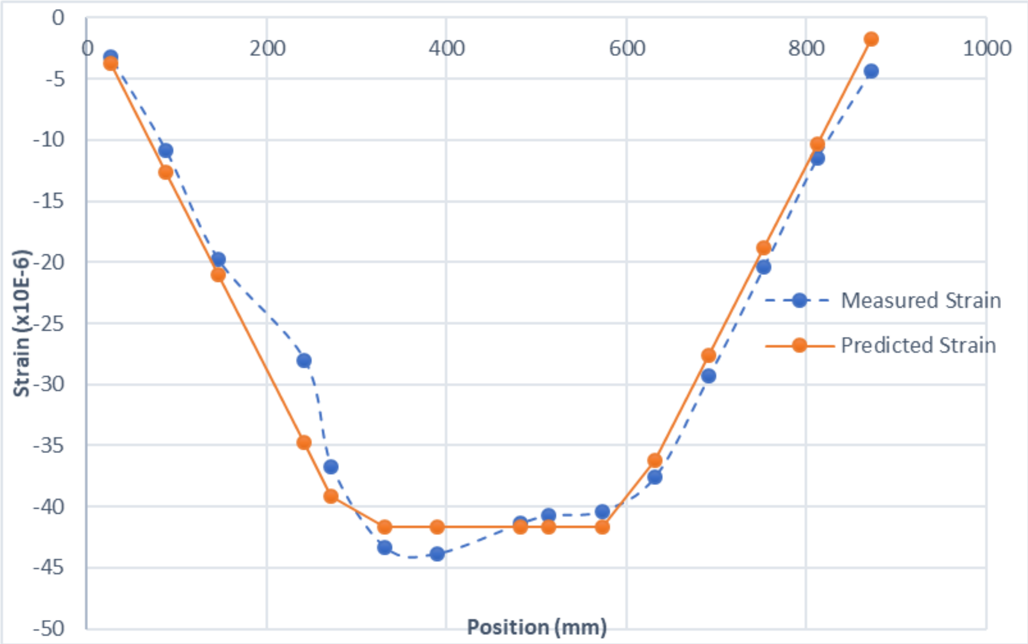
    ε(predicted)=M*(y)/(E*I)=1.005*(-0.011/2)/191.268)

    $= -57.797 \times 10^{-6}$

- <u>Case-3 500 gm + 500 gm a=290mm</u>



Strain Gauge	x (mm)	M (N-m)	ε_x ($\times 10^{-6}$) (Pred.)	ε_x ($\times 10^{-6}$) (Meas.)	Percent Error
1.	872	0.06	-1.7253	-4.35097932	60.34685819
2.	812	0.36	-10.3518	-11.48783648	9.889037696
3.	753	0.655	-18.834525	-20.35476258	7.468707012
4.	692	0.96	-27.6048	-29.30300968	5.79534218
5.	632	1.26	-36.2313	-37.5343252	3.471556217
6.	573	1.45	-41.69475	-40.36341588	-3.298368314
7.	513	1.45	-41.69475	-40.73980948	-2.343998492
8.	482	1.45	-41.69475	-41.37510112	-0.772563381
9.	390	1.45	-41.69475	-43.84090476	4.895324975
10.	331	1.45	-41.69475	-43.30771124	3.724420418
11.	272	1.36	-39.1068	-36.69450694	-6.573989573
12.	242	1.21	-34.79355	-28.00558636	-24.23789151
13.	146	0.73	-20.99115	-19.78131762	-6.116035358
14.	88	0.44	-12.6522	-10.89564328	-16.12164307
15.	26	0.13	-3.73815	-3.18123208	-17.50635936



- Sample Calculations
  - X< a (x = 26mm)

    M = W*0.026=0.13

    ε(predicted)=M*(y)/(E*I)=0.13*(-0.011/2)/191.268

    $= -3.738 \times 10^{-6}$
  - a< X <(L-a) (x = 331mm)

    M = W*a= 5*0.290 = 1.45

    ε(predicted)=M*(y)/(E*I)=1.45*(-0.011/2)/191.268

    $= -41.694 \times 10^{-6}$
  - X>(L-a) (x = 632mm)

    M = W*(L-0.632) = 1.26

    ε(predicted)=M*(y)/(E*I)=1.26*(-0.011/2)/191.268

    $= -36.231 \times 10^{-6}$

RESULT ANALYSIS

- Sources of Error
    - Unstable Strain indicator readings.
    - Incorrect placing of weights (sway of pans or not placing both weights simultaneously).
    - Slippage of Beam.
    - Strain gauge alignment error.
    - Incorrect zeroing and environmental pressure difference.
    - Dial Gauge spring jamming error.
- Precautions
    - Keep the pans steady while placing weights.
    - Precisely measure the distance between dial gauges and strain gauges.
    - Take multiple readings of strain gauge and use the average.
    - Do not move or touch the beam.

CONCLUSION

The experiment was successfully carried out and the values found resembles the true values to acceptable extent.