Indian Institute Of Technology Kanpur

AE 351A

Experiments in Aerospace Engineering 2020-21

Semester II

Beam Deflection and Strains

Submitted By:

Ankit Lakhiwal

180102

(ankitl@iitk.ac.in)

Department of Aerospace Engineering

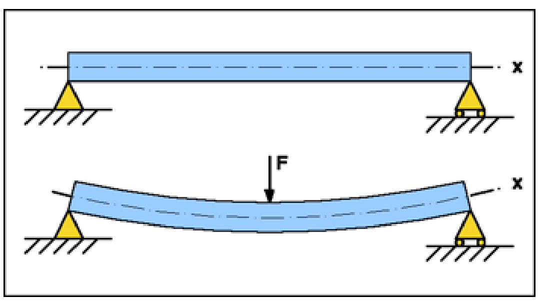
February 12, 2021

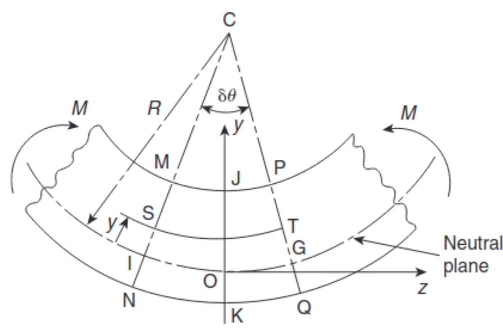
1 Objective

1. Experimentally measure the strain and deflection in a beam subjected to transverse loading.
2. Determine the strain and the deflection variation along the beam using Euler-Bernoulli beam theory and compare the results with experimental measurements.

2 Introduction and Theory

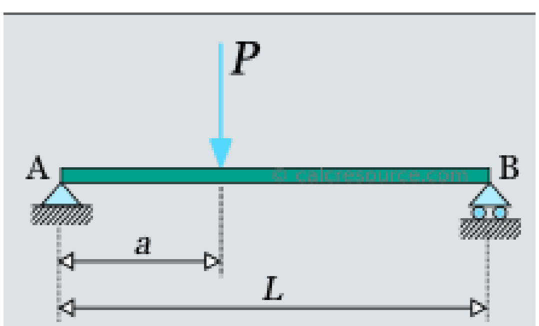
A beam is a structural element that primarily resists loads applied laterally to the beam's axis. Its mode of deflection is primarily by bending. The loads applied to the beam result in reaction forces at the beam's support points. The total effect of all the forces acting on the beam is to produce shear forces and bending moments within the beam, that in turn induce internal stresses, strains and deflections of the beam.





Euler-Bernoulli Beam Theory provides a means of calculating the load-carrying and deflection characteristics of beams.

Simply supported beam with point force at a random position



$$R_A = \frac{Pb}{L}$$

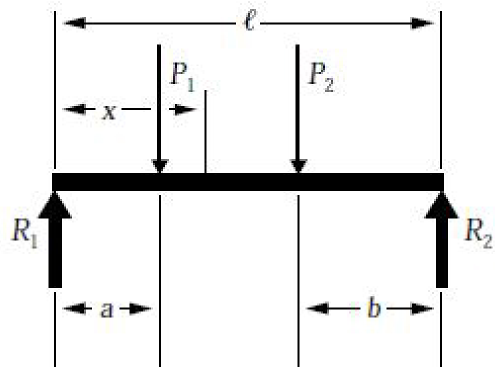
$$R_B = \frac{Pa}{L}$$

Bending moment at x:

$$M(x) = \frac{Pbx}{L} \quad ,x <= a$$

$$M(x) = \frac{Pa(L-x)}{L}) \quad ,x > a$$

Simply supported beam with point force at two random position



$$R_1 = \frac{P_1(l-a) + P_2 b}{l}$$

$$R_2 = \frac{P_1 a + P_2(l-b)}{l}$$

$$M(x) = R_1 x \quad ,x < a$$

$$M(x) = R_1 x - P_1(x-a) \quad ,a < x < l-b$$

$$M(x) = R_2(l-x) \quad ,x > l-b$$

3 Equipment's

- Aluminium alloy 6063 series beam
- Dial gage
- Strain gage
- Weights(1kg)
- Computer setup

4 Procedure and Measurement

1. Mounted the beam with simply supported boundary conditions.
2. Measured the beam dimensions and the location of strain gages with respect to the supports.
3. Applied a concentrated load.
4. Recorded all dial gage readings and the strain values using strain indicator equipment.
5. Theoretically calculated strains at each of the strain gage locations using Euler-Bernoulli beam theory and compared the results with experimentally measured strain values. Generated graphs that show both experimental measurements and theoretical predictions. Calculated the percent errors and explained possible reasons for the discrepancies.
6. Performed the analysis steps mentioned above in 5 for the beam deflection.
7. Removed all dial gages. Simulated symmetric four point bend condition by applying two concentrated loads of the same magnitude symmetrically with respect to the supports. Tabulated strain data recorded using strain indicator equipment and repeated the analysis steps mentioned in 5.

Least Count of the dial gauge	0.01mm
No. of divisions in one round	100div
Beam span length (L)	865mm
Beam cross-section height (d)	12mm
Beam cross-section width (b)	25mm
E of the beam	70GPa
Pan-1 position(from assumed x=0 position)	270mm
Pan-2 position(from assumed x=0 position)	575mm

Table 1: Initial measurement

5 Results and Discussion

5.1 Sample Calculation

- Neutral axis distance from surface $y = \frac{d}{2} = 6mm$
- Moment of inertia $I = \frac{bd^3}{12} = 3600mm^4$
- C = $\frac{y}{EI} = 2.3809 * 10^{-8} perN - mm$

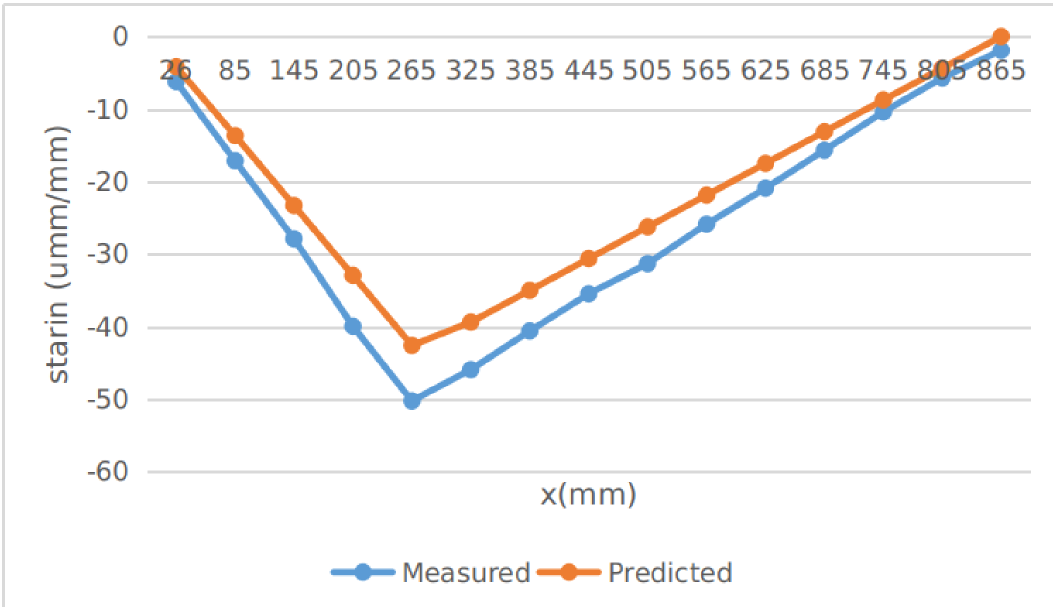
- for Case 1
  load 1kg position a = 270mm
  at $x = 265mm, x < a$
  $M(x) = \frac{1*9.81*265}{865} = 1788.1985N.mm$
  at $x = 685mm, x > a$
  $M(x) = \frac{1*9.81*270*(865-685)}{865} = 551.1745N.mm$
- for Case 2
  load 1kg at two position a = 270mm and b = 575mm
  at $x = 265mm, x < a$
  $M(x) = \frac{1*9.81*(865-270+575)*265}{865} = 2659.7575N.mm$
  at $x = 445mm, b > x > a$
  $M(x) = \frac{1*9.81*(865-270+575)*445}{865} - 1*9.81*(445-270) = 2749.635N.mm$
  at $x = 685mm, x > b$
  $M(x) = \frac{1*9.81*(865+270-575)*(865-685)}{865} = 1724.97225N.mm$
- Case 3 is similar to Case 1 with different load position a = 575mm.

5.2 Data Presentation

Strain gage Readings

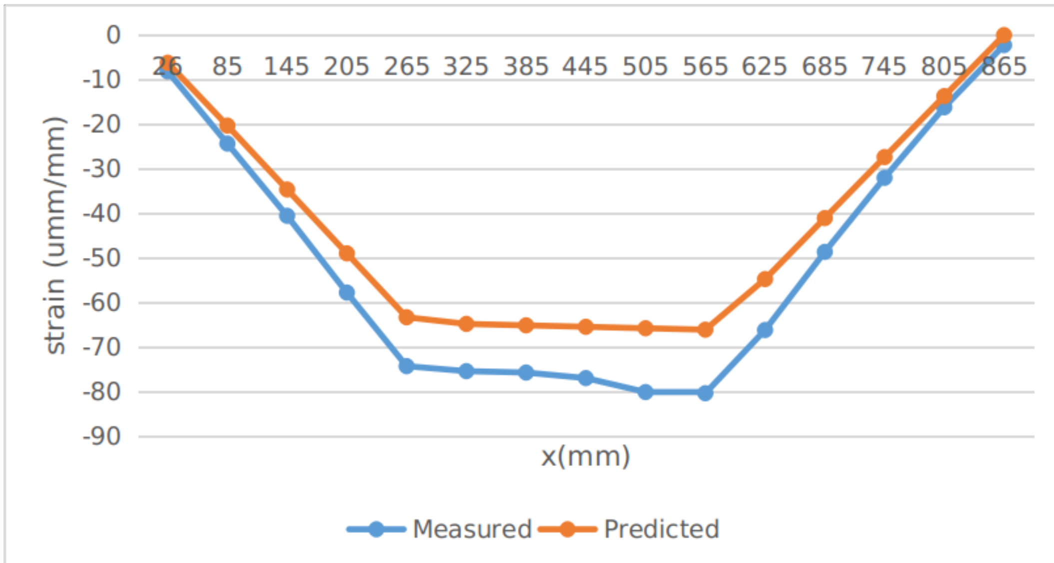
Case 1: 1kg in Pan1 and No weight in Pan2

Pan 1 (1kg) load and Pan2 no load					
SG No.	position(x) (mm)	M(x)(Nmm)	Readings(umm/mm) Measured	Predicted	Error(%)
1	26	175.445896	-6.2404842	-4.17719	33.06302519
2	85	573.5731214	-17.132253	-13.65620	20.28951214
3	145	978.4482659	-27.88941	-23.29587	16.47053572
4	205	1383.32341	-39.9428823	-32.93555	17.543389
5	265	1788.198555	-50.2287377	-42.57522	15.23732958
6	325	1653.523699	-45.9132942	-39.36875	14.25414698
7	385	1469.798844	-40.5957683	-34.99444	13.79781159
8	445	1286.073988	-35.4617918	-30.62014	13.65316292
9	505	1102.349133	-31.3017337	-26.24583	16.15215068
10	565	918.6242775	-25.8556194	-21.87153	15.40900613
11	625	734.899422	-20.9079855	-17.49722	16.31321756
12	685	551.1745665	-15.6737955	-13.12292	16.27480878
13	745	367.449711	-10.4002196	-8.74861	15.88052459
14	805	183.7248555	-5.7131479	-4.37431	23.43441548
15	865	0	-1.9110928	0.00000	100



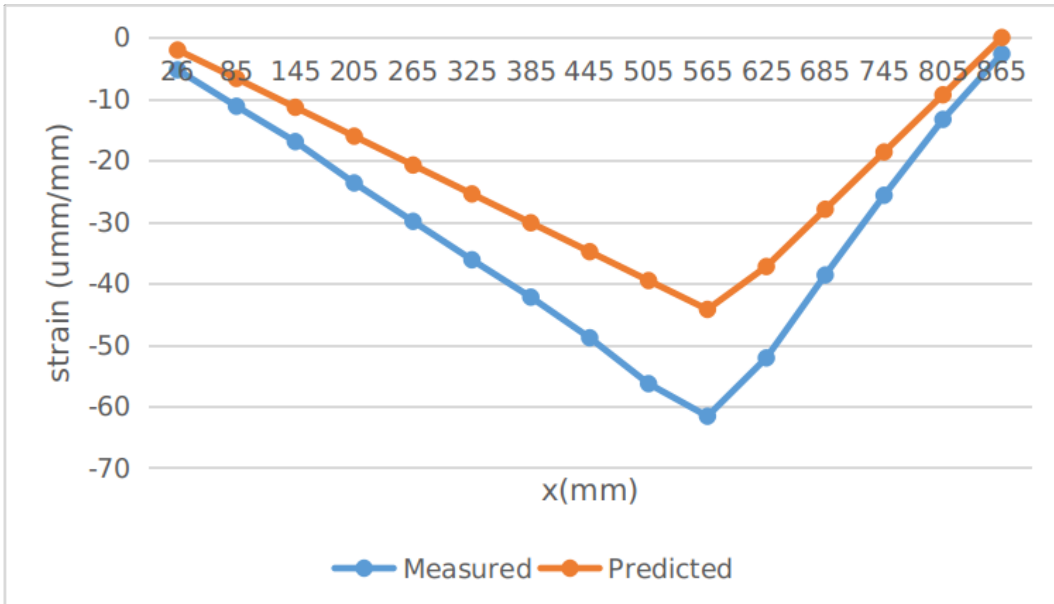
Case 2: 1kg in Pan1 and 1kg in Pan2

SG No.	position(x) (mm)	M(x)(Nmm)	Pan1 1kg load and Pan2 1kg load — Readings(umm/mm) Measured	Predicted	Error(%)
1	26	260.957341	-8.1342173	-6.21313	23.61731801
2	85	853.1297688	-24.3465482	-20.31217	16.57065101
3	145	1455.339017	-40.56093755	-34.65017	14.57256968
4	205	2057.548266	-57.78494215	-48.98817	15.22330067
5	265	2659.757514	-74.2941824	-63.32617	14.76295369
6	325	2722.416763	-75.41916395	-64.81802	14.05629907
7	385	2736.026012	-75.7341069	-65.14204	13.9858566
8	445	2749.63526	-76.97573355	-65.46607	14.95233252
9	505	2763.244509	-80.11006035	-65.79009	17.87537268
10	565	2776.853757	-80.3743283	-66.11411	17.74225365
11	625	2299.963006	-66.19042595	-54.75982	17.2692751
12	685	1724.972254	-48.6537329	-41.06986	15.58743398
13	745	1149.981503	-32.02986065	-27.37991	14.51755004
14	805	574.9907514	-16.2006845	-13.68995	15.49767665
15	865	0	-2.2529271	0.00000	100



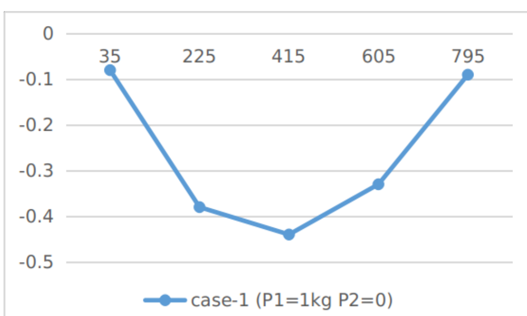
Case 3: No weight in Pan1 and 1kg in Pan2

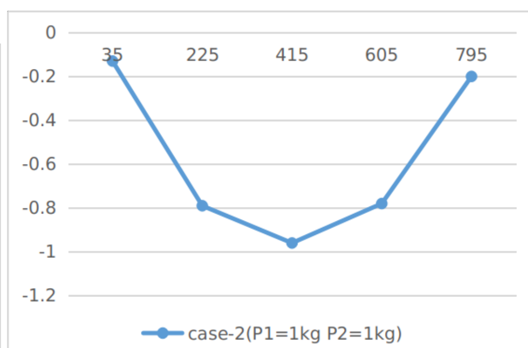
Pan1 0kg load and Pan2 1kg load					
SG No.	position(x) (mm)	M(x)(Nmm)	Readings(umm/mm)		Error(%)
			Measured	Predicted	
1	26	85.51144509	-5.2581246	-2.03594	61.2800732
2	85	279.5566474	-11.1861586	-6.65596	40.49821341
3	145	476.8907514	-16.93612955	-11.35429	32.95816575
4	205	674.2248555	-23.6619249	-16.05262	32.15843744
5	265	871.5589595	-29.9108772	-20.75095	30.62407656
6	325	1068.893064	-36.1662525	-25.44927	29.63253533
7	385	1266.227168	-42.24140595	-30.14760	28.6302102
8	445	1463.561272	-48.8528695	-34.84593	28.67168157
9	505	1660.895376	-56.3217372	-39.54426	29.7886394
10	565	1858.22948	-61.62379185	-44.24259	28.20534999
11	625	1565.063584	-52.1282333	-37.26260	28.51743382
12	685	1173.797688	-38.6457681	-27.94695	27.68432218
13	745	782.5317919	-25.6696015	-18.63130	27.41882092
14	805	391.265896	-13.32244285	-9.31565	30.07551377
15	865	0	2.64988115	0.00000	100

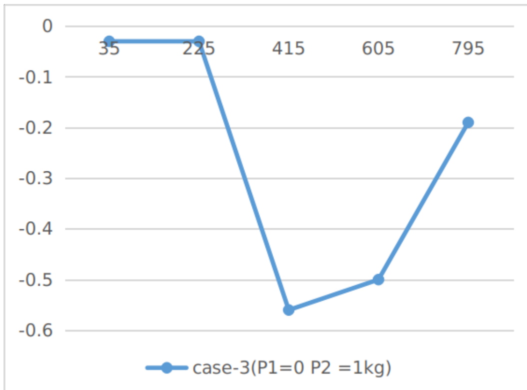


Dial gage Readings

DG No.	Position(mm)	Readings		
		P1 =1kg P2=0	P1=1kg P2=1kg	P1=0 P2=1kg
1	35	-0.08	-0.13	-0.03
2	225	-0.38	-0.79	-0.35
3	415	-0.44	-0.96	-0.56
4	605	-0.33	-0.78	-0.5
5	795	-0.09	-0.2	-0.19







5.3 Discussion and Error Analysis

- Case 1 average % error = 23.18%
- Case 2 average % error = 21.74%
- Case 3 average % error = 37.076%

Source of Error

- Human errors during measuring dial gage reading , dimension of beam etc.
- The value of E can be different for given material.
- Neglecting the weight of could also affect the reading.
- Oscillation of weight in Pan

6 Conclusion

- Strain is maximum at loading position
- Strain is almost constant between two point loads.
- Reducing errors can give better results.