Indian Institute of Technology Gandhinagar

Design and Fabrication of Laminated Leaf Spring

ME 352 : Mechanical Engineering Lab 2

Lab Report - Experiment 7

Group - 8

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Under The Guidance Of

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OBJECTIVE

To design and fabricate a laminated leaf spring of specified stiffness.

ABSTRACT

A laminated leaf spring of specified stiffness is a type of suspension system used in vehicles designed to provide a specific level of stiffness and support. We created a single, robust, and flexible unit using thin layers of mild steel strips bonded together. The number and thickness of the layers used in the spring construction are carefully selected to achieve the desired stiffness and load-carrying capacity.

The leaf springs are very popular for heavy-duty applications due to their durability, simplicity, and accessibility. It absorbs and stores potential energy through deflection during load application by utilizing shock and vibration. The spring's leaves flex and absorb shock when the vehicle travels over bumps or rough terrain, giving the passengers a more comfortable ride and preventing damage to the vehicle.

EXPERIMENTAL DESIGN AND FABRICATION DETAILS:

We used 3 strips of mild steel with lengths 55.2 cm, 38.2 cm, and 19.1 cm each, with each having width of 2 cm and a thickness of 2.2 mm. We joined them together through clamps. The entire setup was placed on a wooden base, and the sensor was attached to the midpoint to measure the displacement.

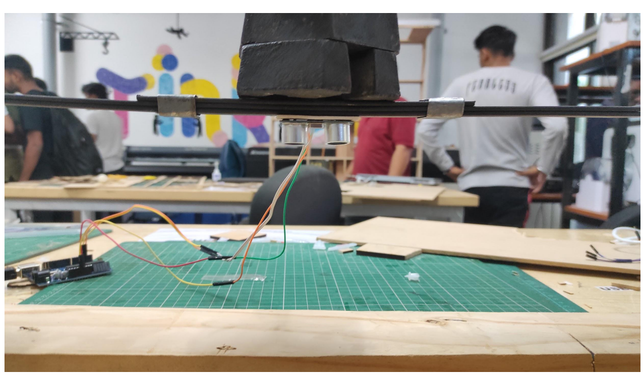

Figure 1 : Sensor to measure the change in height at midpoint

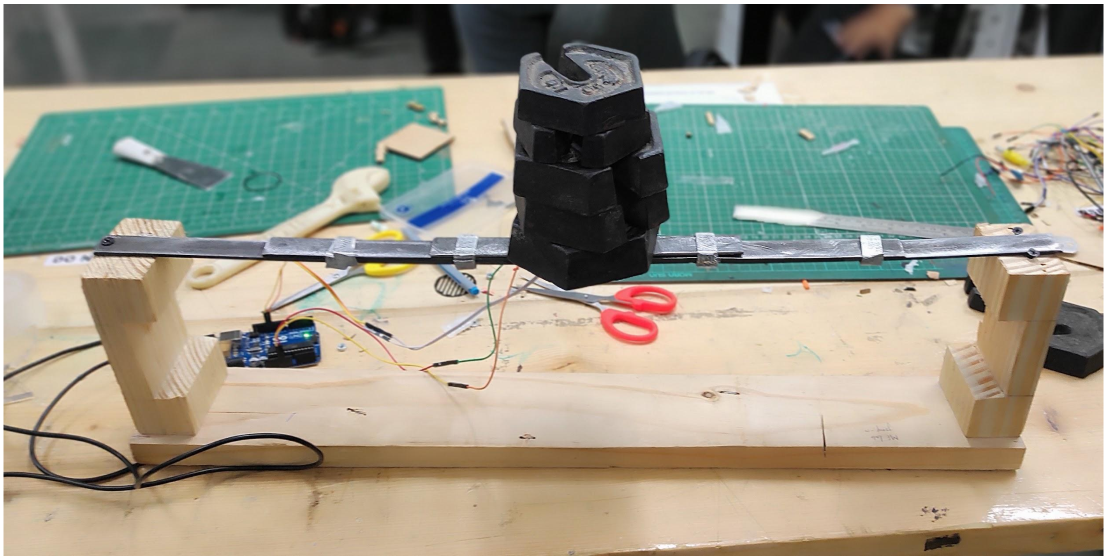

Figure 2 : Final experimental setup

MATHEMATICAL MODELLING

Nomenclature

$l\ =\ length\ of\ plate$

$b\ =\ width\ of\ plate$

$t\ =\ thickness\ of\ plate$

$n\ =\ number\ of\ plate$

$w\ =\ load\ applied\ on\ leaf\ spring$

$k\ =\ stiffness\ constant\ for\ leaf\ spring$

$\delta_{max}\ =\ maximum\ deflection\ in\ spring$

$\sigma_{max}\ =\ maximum\ bending\ stress\ in\ plate$

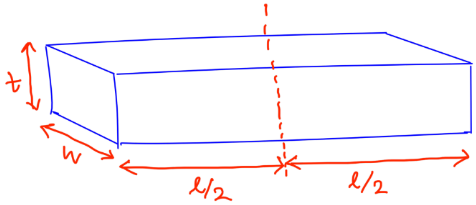

Figure 3: Dimensions of the leaf(beam)

Bending equation for the beam shown in fig(3) can be written as:

$$\sigma = \frac{My}{I} \tag{1}$$

$where\ M = bending\ moment$

$y = distance\ of\ the\ point\ from\ the\ neutral\ axis$

$I = moment\ of\ inertia$

Bending stress can also be written as:

$$\sigma = \frac{Ey}{R} \tag{2}$$

$where\ E = Young's\ modulus\ of\ the\ material\ of\ the\ beam$

$R = radius\ of\ curvature\ of\ the\ beam\ after\ applying\ load$

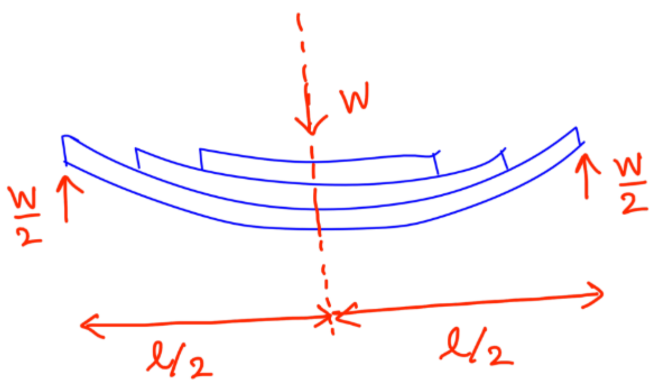

Figure 4: Bending of leaf spring on applying load at midpoint

We can see in fig(4) that load is applied at the middle of the leaf spring, so bending moment can be given as:

$$M = \frac{w}{2} \times \frac{l}{2} = \frac{wl}{4} \tag{3}$$

Moment of inertia(I) for rectangular cross-section can be written as:

$$I = \frac{bt^3}{12}$$

Moment of inertia for n beams can be written as:

$$I = \frac{nbt^3}{12} \tag{4}$$

In eq.(1), M and I are constant for the given system and y can vary from 0 to $\frac{t}{2}$. To get maximum bending stress, putting $y = \frac{t}{2}$ in eq.(1).

Putting value of M and I from eq. (3) and (4) respectively in eq.(1), we get:

$$\sigma_{max} = \frac{\frac{wl}{4} \times \frac{t}{2}}{\frac{nbt^3}{12}} = \frac{3wl}{2nbt^2} \tag{5}$$

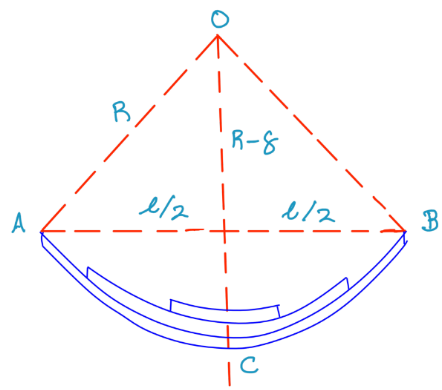

Figure 5: Radius of curvature of beam

In the above fig(5), applying Pythagoras theorem in ΔOAD, we get:

$$(R - \delta)^2 + \left(\frac{l}{2}\right)^2 = R^2$$

$$\Rightarrow \delta^2 - 2\delta R + \frac{l^2}{4} = 0$$

Assuming δ to be very small, i.e., $\delta^2 = 0$

$$\frac{l^2}{4} = 2\delta R$$

$$\Rightarrow \delta = \frac{l^2}{8R} \tag{6}$$

Putting $\sigma = \sigma_{max}$ and $y = y_{max} = \frac{t}{2}$ in eq. (2), we get:

$$\sigma_{max} = \frac{Et}{2R}$$

$$\Rightarrow R = \frac{Et}{2\sigma_{max}} \tag{7}$$

Putting value of R from eq.(7) in eq.(6), we get:

$$\delta_{max} = \frac{l^2}{8\left(\frac{Et}{2\sigma_{max}}\right)}$$

$$\Rightarrow \delta_{max} = \frac{l^2 \sigma_{max}}{4Et} \tag{8}$$

Putting the value of σ_{max} from eq.(5) in eq.(8), we get:

$$\delta_{max} = \frac{l^2}{4Et}\left(\frac{3wl}{2nbt^2}\right)$$

$$\Rightarrow \delta_{max} = \frac{3wl^3}{8nEbt^3} \tag{9}$$

If we consider the system as a spring-mass system then, we have:

$$w = k\delta \tag{10}$$

$$where\ k = stiffness\ constant$$

Putting the value of $\frac{w}{\delta}$ from eq.(9) in eq.(10), we get:

$$k = \frac{w}{\delta}$$

$$\Rightarrow k = \frac{8nEbt^3}{3l^3} \tag{11}$$

Hence, we can write k in terms of length(l), width(w), thickness(t) and load applied(w) on the leaf spring.

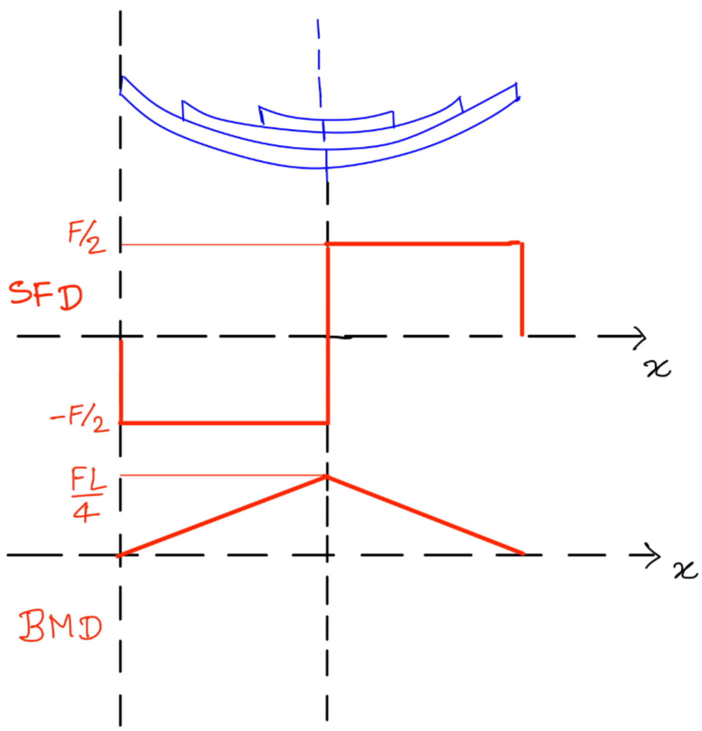

Figure 6: Shear force and bending moment diagram

RESULTS

Mass (gram)	Force (N)	Readings (mm)	Deflection (mm)	K (N/m)
0	0	124.61	0	-
500	4.9	121.81	2.8	1750.2
1000	9.8	119.51	5.1	1921.56
1500	14.7	116.91	7.4	1909.09
2000	19.6	115.11	9.5	2063.15
2500	24.5	112.21	12.4	1975.80
3000	29.5	111.41	13.2	2234.84
3500	34.3	108.01	16.6	2066.26

After applying curve fitting, we get the mass vs deflection graph:

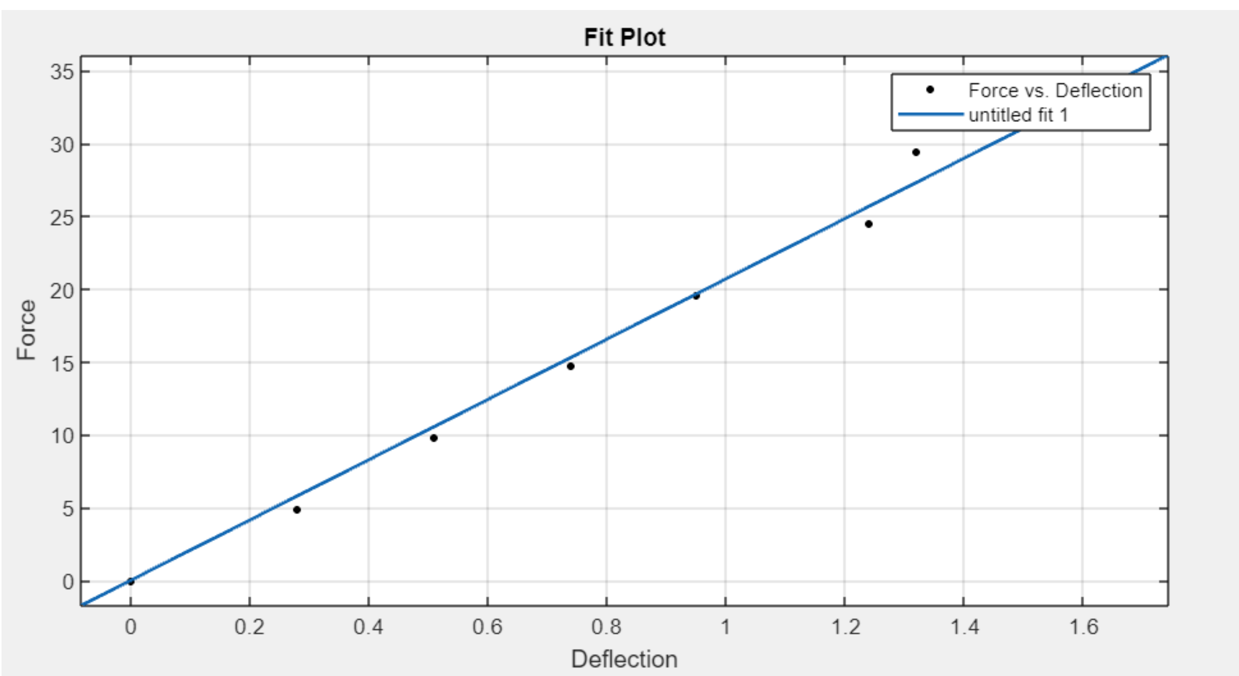

Figure 7 : Experimental mass vs Deflection graph

Custom Curve Fit
f(x) = k*x

Coefficients and 95% Confidence Bounds

	Value	Lower	Upper
k	20.7042	19.8327	21.5757

Goodness of Fit

	Value
SSE	7.4397
R-square	0.9926
DFE	7.0000
Adj R-sq	0.9926
RMSE	1.0309

From the above data, the value of spring constant (‘a’ in the data) obtained is

K = 20.7042 N/cm or 2070.42 N/m

Theoretical value of $k = \frac{8nEbt^3}{3l^3}$.

Putting E = $2 \times 10^5 N/mm$, t = 2.2mm, b = 20mm, l = 552mm and n = 3

Theoretical value of k = 2025.81 N/m

ERRORS

- Imperfect clamping
- Error in displacement calculations

SCOPE OF IMPROVEMENT

- Material variability: The mechanical properties of the materials used to make the laminated leaf spring may vary between different batches or sources.

This can lead to variations in the strength, stiffness, and other properties of the spring.

- Fabrication error: Errors can occur during the fabrication process, such as improper cutting or misalignment of layers. These errors can lead to inconsistencies in the dimensions and mechanical properties of the spring.

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