Indian Institute of Technology Gandhinagar

Design and Fabrication of Laminated Leaf Spring

ME 352 Experiment Report

EXPERIMENT 7

Group 6

Kamal Vaishnav	20110089
Hrishikesh CP	20110078
Kareena Beniwal	20110095
Harshil Safi	20110073

Under the guidance of

Prof. Jayaprakash KR

Objective

The objective of this experiment is to design and fabricate a laminated leaf spring of specific stiffness. The final product will be tested for its load-bearing capabilities, deflection characteristics, and durability under various conditions. The results of the experiment will be used to develop recommendations for the design and fabrication of laminated leaf springs in a wide range of applications.

Introduction

Leaf springs are a type of suspension system found in vehicles such as cars, trucks, and trailers. They are made up of a number of thin metal plates (called leaves) that are stacked together and attached to the vehicle's frame and axle. As the vehicle moves, the leaves flex and bend, providing suspension and absorbing shock. Leaf springs have been used in vehicles for many years and are still used in some heavy-duty applications today.

Mathematical Analysis

1. Derivation of stiffness for cantilever leaf spring

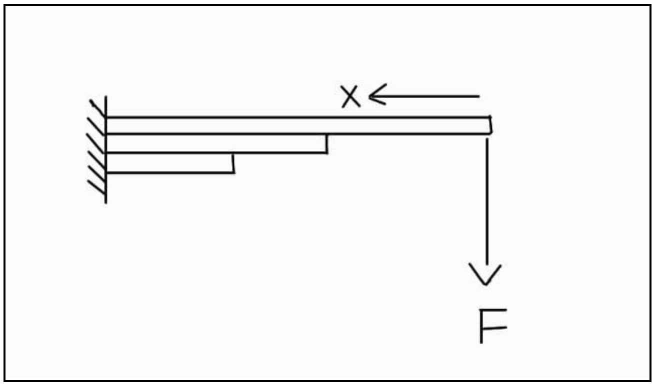
Consider a leaf spring in the shape of a rectangular plate. The plate is supported at one end and is free at the other end. When a force is applied to the free end, the plate will bend and experience a deformation.

The stiffness of the spring can be calculated using Hooke's Law, which states that the force (F) applied to an object is proportional to its deformation (x). In other words:

$$F = kx$$

where k is the spring constant, also known as the stiffness of the spring.

For a cantilever leaf spring, the deformation (x) is the displacement of the free end of the spring. The force (F) is the load applied to the free end of the spring.



Moment about the free end will be:

$$M = FL$$

We have flexural formula:

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

Where, I : moment of inertia of the beam
y : distance from neutral axis of beam
M : moment applied

Consider individual leaf:

$y = \frac{t}{2}$ (to get maximum stress)
Where, t : thickness of single plate

Therefore,

$$M = \frac{\sigma b t^3}{\frac{t}{2} 12} = \frac{\sigma b t^2}{6}$$

For n number of plates:

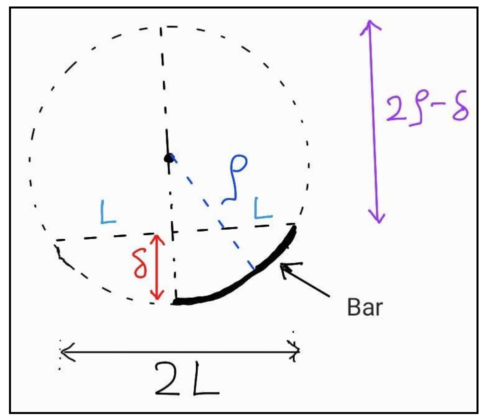
$$M = n\frac{\sigma b t^2}{6}$$

Hence,

$$M = n\frac{\sigma b t^2}{6} = FL$$

Resulting stress therefore would be:

$$\sigma = \frac{6FL}{nbt^2} \quad (1)$$



From the geometry and radius of curvature of the bar:

$$L * L = (2\rho - \delta) * \delta$$

(using property of a chord of a circle)

which gives:

$$\delta = \frac{L^2}{2\rho} \quad (2)$$

Using relation between radius of curvature and stress:

$$\sigma = \frac{Ey}{\rho}$$

$$\Rightarrow \frac{1}{\rho} = \frac{\sigma}{Ey} \quad (3)$$

Substituting (3) in (2):

$$\delta = \frac{L^2\sigma}{2\,Ey} \quad (4)$$

Substituting (1) in (4):

$$\delta = \frac{6FL^3}{nEbt^3}$$

Since

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

Therefore

$$\boxed{k = \frac{nEbt^3}{6L^3}}$$

Given:

k = 4000 $\pm$ 200 N/m

E (of mild steel) = 210 GPa

take n = 3

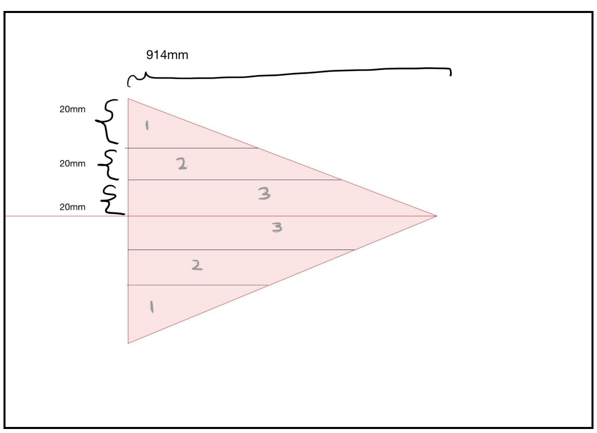
take t = 0.9 cm = 0.009

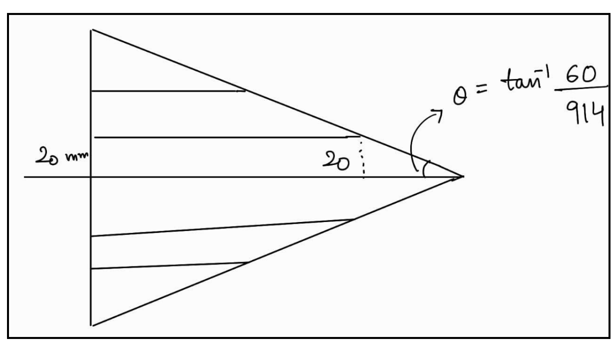
take b = 4 cm = 0.04

$$\Rightarrow L = \left(\frac{3\ X\ 210\ X\ 10^9 X\ 0.04\ X 0.009^3}{6\ X\ 4000}\right)^{\frac{1}{3}}$$

$$\Rightarrow L = 914\ mm$$

Hence the length of the main leaf is 914 mm, and the length of the other leaves can be calculated by following geometrical analysis:





Using geometry we get the other two lengths as 609 mm and 304 mm.

While for ***ease in fabrication tapered faces were replaced with flat ones***.

Fabrication

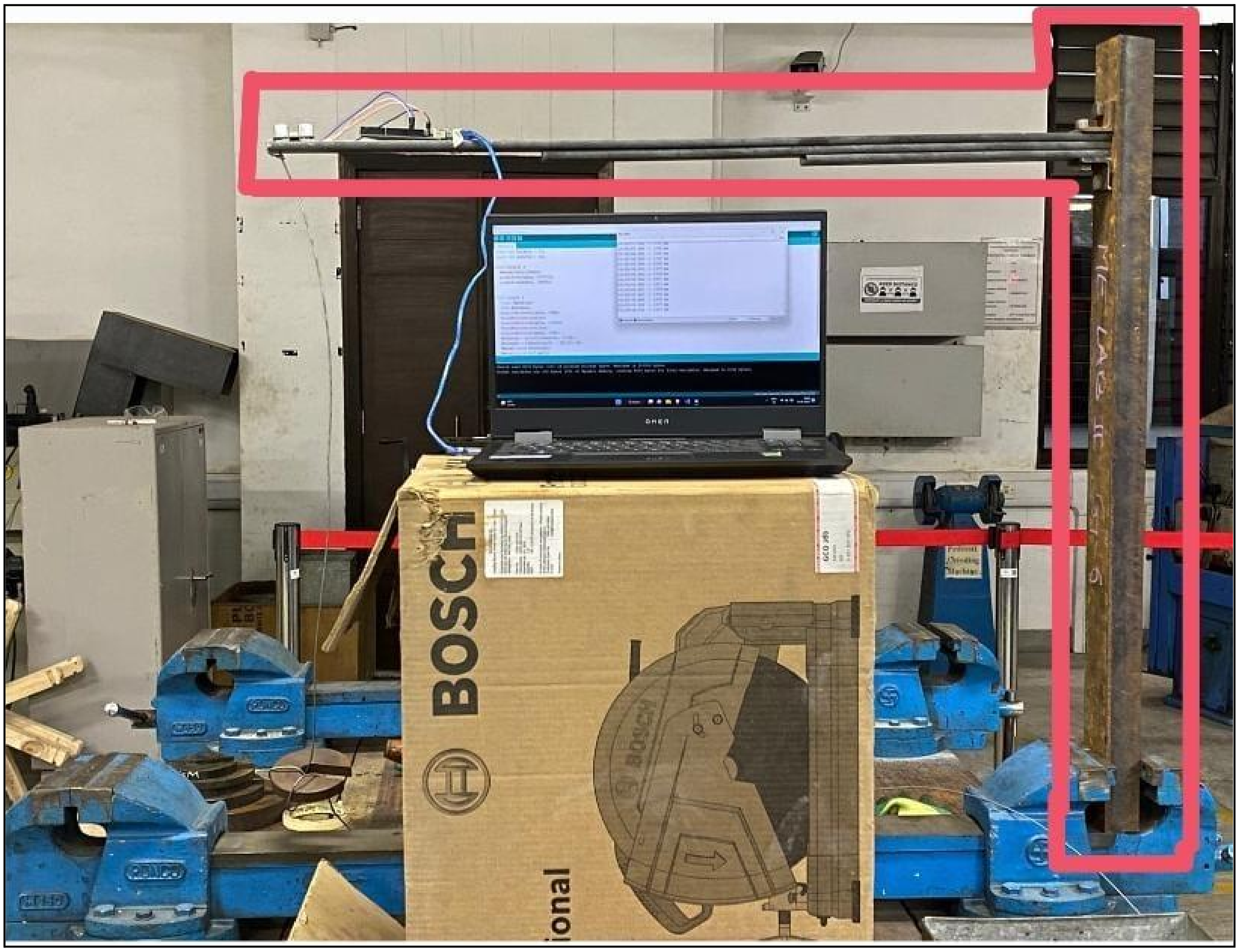


Fig: The set up

In the course of our experiment, the appropriate material for the leaf spring was determined by evaluating its yield strength. The selected material, mild steel, was ordered and cut to the appropriate dimensions for the fabrication of the leaves. The leaves were then clamped together using a nut and bolt, and mounted on a C-channel with holes drilled in the appropriate locations. To maintain stability and secure positioning, L-shape clamps were utilized and connected to the leaves using nuts and bolts. The C-channel was held in place using a table vice, and an ultrasonic sensor was attached to the end of the leaf to measure deflection, in conjunction with weights.

Fig. Support Design

Procedure

The free end of the cantilever leaf spring was loaded with varying loads and the deflection in the beam was measured using an ultrasonic sensor, connected with the arduino and the data was recorded. The least count for the ultrasonic sensor is taken to be 2mm.

We got following values:

Trial no	Load (N)	positon	Spring constant (N/m)	Error (in k)	Deflection(mm)
0		1376			
1	5	1377	5000	10000	
2	10	1379	3333	805	2
3	15	1382	2500	802	3
4	20	1383	2857	615	1
5	25	1384	3125	601	1
6	30	1386	3000	512	2
7	35	1387	3182	416	1
8	40	1388	3333	412	1
9	45	1390	3214	410	2
10	50	1391	3333	399	1
11	55	1392	3438	350	1
12	60	1393	3529	343	1
13	65	1394	3611	340	1
14	70	1395	3684	339	1
15	75	1397	3571	335	2
16	80	1398	3636	331	1
17	85	1400	3542	295	2
18	90	1401	3600	288	1
19	95	1402	3654	281	1

Hence average value of k comes out to be 3767 unit with an average error of 430 unit, therefore

$$k = 3767 + 430 = 4197 \text{ N/m}$$

Thus the objective has been achieved.

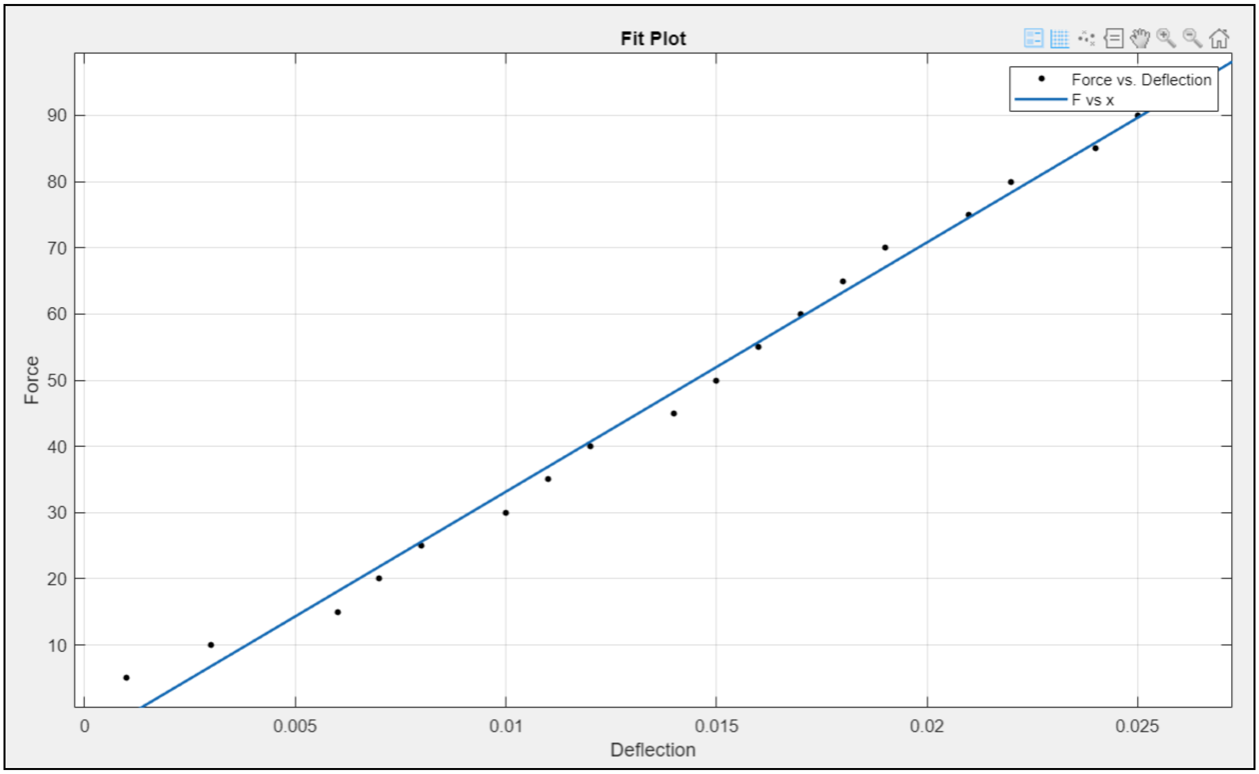


Fig: plot between F and x

Results

Fit name: F vs x

Linear model Poly1:
$f(x) = p1*x + p2$
Coefficients (with 95% confidence bounds):
p1 = 3767 (3602, 3932)
p2 = -4.527 (-7.199, -1.854)

Goodness of fit:
SSE: 103.8
R-square: 0.9927
Adjusted R-square: 0.9923
RMSE: 2.471

k=p1=3767 N/m

Results and Discussions

During the course of the experiment, it was observed that the stiffness value of the spring exhibited variations in relation to the applied load. As a result, the average value of stiffness was utilized in the analysis. Furthermore, a higher deviation in stiffness was observed for initial levels of deflection. Additionally, it was noted that the leaves utilized in the experiment were of a rectangular shape as opposed to the more conventional triangular shape. Furthermore, the clamping at one end resulted in a reduction of the effective length, which may have had an impact on the accuracy of the results. Furthermore, it is possible that errors in the sensor may have also contributed to inaccuracies in the recorded stiffness values.

Scope for Improvement

As we reflect on the progress of our project, we identify several areas for improvement. One such improvement could be the use of triangular shaped leaves to achieve a more accurate and precise determination of the stiffness constant. Additionally, incorporating an additional clamp to bind the leaves together in the middle could enhance the overall stability of the leaf spring. Furthermore, exploring the use of higher grade steel as the material for the leaf spring could potentially reduce variability in the results. To further solidify the findings, repeating experiments under different loadings could verify the invariability of the spring stiffness. The length of the sporting beam could have been a bit shorter so the stiffness of this beam could have been neglected and hence the corresponding deflection of the beam.

Acknowledgements

We would like to express our sincerest gratitude to Mr. Jayprakash KR, Assistant Professor of Mechanical Engineering at IIT Gandhinagar, for his invaluable guidance and support throughout the completion of our experiment on 'Design and Fabrication of Laminated Leaf Spring'. We also extend our appreciation to our TAs NagaVishnu, Vaibhav Tandel, Harsh Gupta, and Ishan for their dedicated support and motivation.

References

https://archive.nptel.ac.in/courses/112/106/112106137/
https://roymech.org/Useful_Tables/Springs/Springs_Leaf.html
Leaf Spring Stiffness (piping-designer.com)