Mechanics of Materials: MM-L

Open Ended Lab

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Objective:

To find the stiffness of different extension springs and compare them with theoretical values.

Apparatus:

1. Extension Springs (AISI 304, 1082 Steel)
2. Hangers
3. Weights
4. Ruler

Theory:

Stiffness is the measure of an object's resistance to deformation when a force is applied. In the context of springs, it is quantified by the spring constant (), which determines how much a spring stretches or compresses under a given force. A higher stiffness means less deformation, while lower stiffness results in more deformation.

$$Stiffness = \frac{W}{\Delta} = \frac{d^4 G}{8ND^3}$$

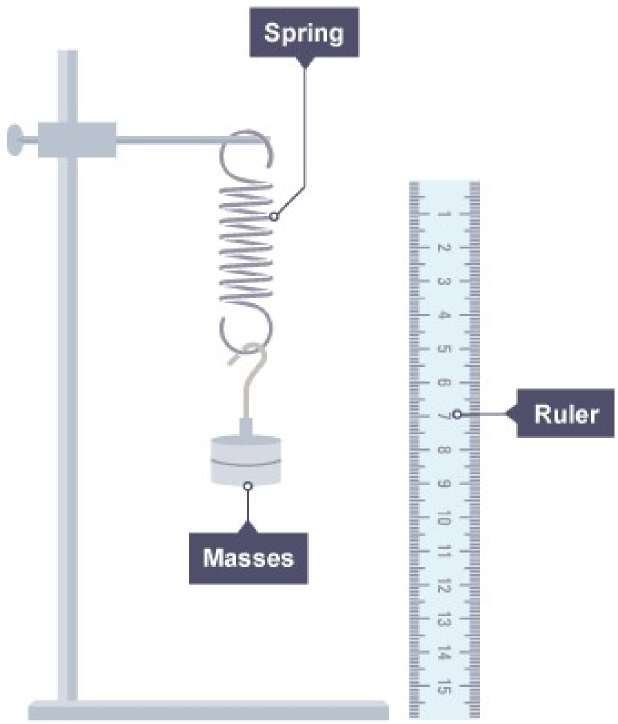
Hooke's Law states that the force required to stretch or compress a spring is directly proportional to its displacement from the equilibrium position. Mathematically, it is expressed as, where is the force, is the spring constant, and is the displacement. This law holds true as long as the elastic limit of the material is not exceeded. It describes the linear relationship between force and extension or compression in a spring.

Modulus of rigidity is defined as the ratio of shear stress to the shear strain in the elastic region of the material.

$$Modulus\ of\ Rigidity = G = \frac{Shear\ Stress}{Shear\ Strain}$$

In this experiment, we will test two extension springs made from different materials: **AISI 304** is **stainless steel** which is non-magnetic, corrosion-resistant, and more expensive, offering superior durability. In contrast, **1082 Steel** is **Carbon Steel** which is magnetic, has higher stiffness, but is more prone to corrosion. These material differences affect the spring's mechanical properties, such as stiffness. The experiment aims to compare the performance of both springs, emphasizing how material composition influences stiffness.

Diagram:



Procedure:

1. Set up the stand to provide a stable structure for hanging the extension spring.
2. Hang the extension spring on the stand as shown in the diagram.
3. Attach the hanger to the extension spring.
4. Gradually add weights to the hanger one by one and measure and record the deflection after each addition.
5. After all the weights have been added, remove them one by one and measure and record the deflection after each removal.
6. Repeat the entire procedure for the second spring.

Observations and Calculations:

- **AISI 304 (Stainless Steel)**

Wire Diameter (d) = 1.63 mm

Spring O/D = 24.1 mm

Spring Length (l) = 125 mm

Number of active Turns (N) = 73

Modulus of rigidity (G) = 77,000 N/mm^2

$$Stiffness = \frac{W}{\Delta} = \frac{d^4 G}{8ND^3}$$

Where d = wire diameter

N = Number of turns

D = mean diameter of spring coil (O/D – d)

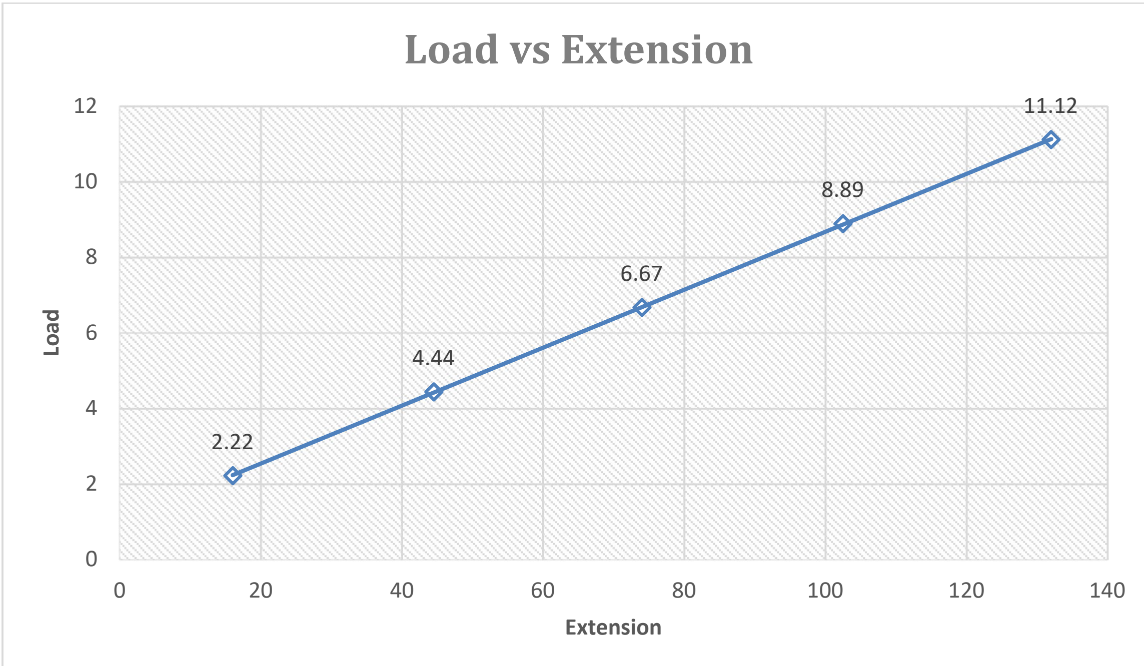
G = Modulus of rigidity

$$Stiffness = \frac{W}{\Delta} = \frac{d^4 G}{8ND^3}$$

$$Stiffness = 0.082038 \frac{N}{mm}$$

No of Obs.	**Load (W) N**	**Deflection (Δ) mm**			**Slope from graph (N/mm)**	**Theoretical Stiffness = $d^4G/8ND^3$ (N/mm)**	**Difference (Th. – Pr.)**	**Percentage Error (%)**
		Loading	Unloading	Mean				(Th. – Pr.)/Th. x 100
1.	2.22	30	2	16	0.13875	0.082038	-0.056712	-69.12894025
2.	4.44	59	30	44.5	0.07825	0.082038	0.003793	4.623467174
3.	6.67	88	60	74	0.07525	0.082038	0.006784	8.269338599
4.	8.89	118	87	102.5	0.07789	0.082038	0.004144	5.051317682
5.	11.12	147	117	132	0.07559	0.082038	0.006445	7.856115459

Graph:



Slope from Graph:

$$Slope = \frac{y_2 - y_1}{x_2 - x_1}$$

$$Slope_1 = 0.13875 \frac{N}{mm}$$

$$Slope_2 = 0.07825 \frac{N}{mm}$$

$$Slope_3 = 0.07525 \frac{N}{mm}$$

$$Slope_4 = 0.07789 \frac{N}{mm}$$

$$Slope_5 = 0.07559 \frac{N}{mm}$$

- **1082 Steel (Carbon Steel)**

Wire Diameter (d) = 1.63 mm

Spring O/D = 23.7 mm

Spring Length (l) = 123 mm

Number of active Turns (N) = 75

Modulus of rigidity (G) = 80,000 N/mm^2

$$Stiffness = \frac{W}{\Delta} = \frac{d^4G}{8ND^3}$$

Where d = wire diameter

N = Number of turns

D = mean diameter of spring coil (O/D – d)

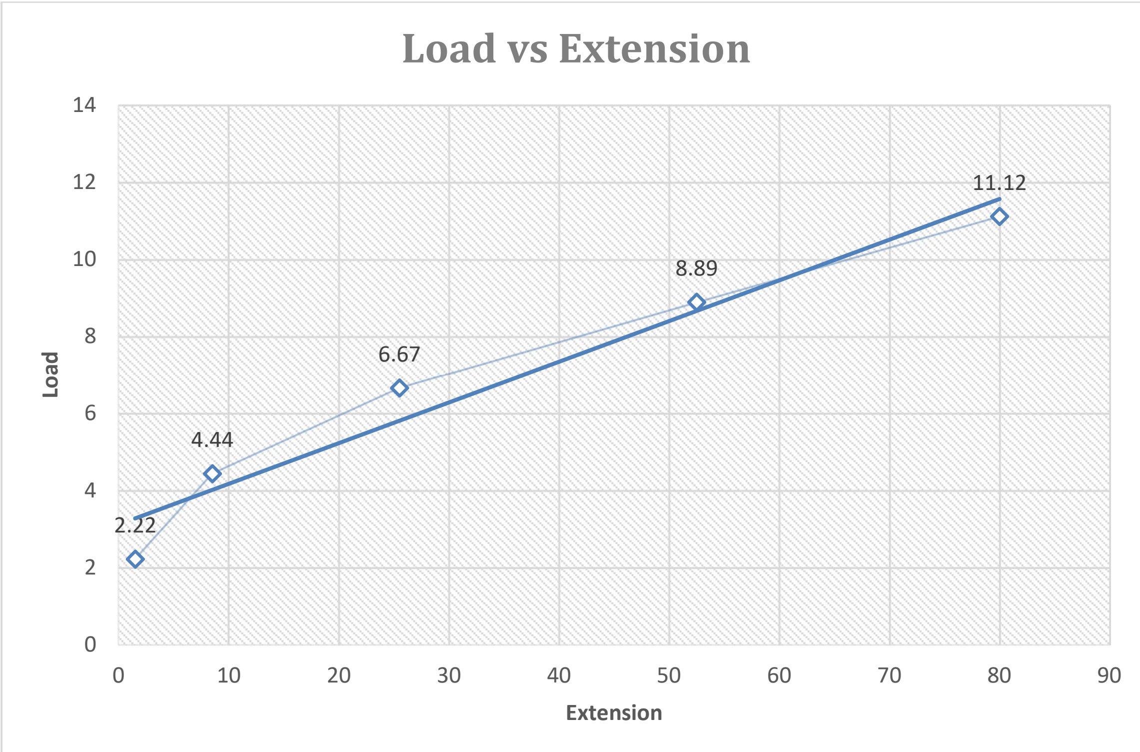
G = Modulus of rigidity

$$Stiffness = \frac{W}{\Delta} = \frac{d^4G}{8ND^3}$$

$$Stiffness = 0.087556 \frac{N}{mm}$$

No of Obs.	**Load (W) N**	**Deflection (Δ) mm**			**Slope from graph (N/mm)**	**Theoretical Stiffness = $d^4G/8ND^3$ (N/mm)**	**Difference (Th. – Pr.)**	**Percentage Error (%)**
		Loading	Unloading	Mean				(Th. – Pr.)/Th. x 100
1.	2.22	3	0	1.5	1.48	0.087556	-1.392445	-94.08412162
2.	4.45	13	4	8.5	0.318571	0.087556	-0.231016	-72.51636771
3.	6.67	38	13	25.5	0.130588	0.087556	-0.043033	-32.95337838
4.	8.89	66	39	52.5	0.082222	0.087556	0.005333	6.485810811
5.	11.12	94	66	80	0.081091	0.087556	0.006464	7.971412556

Graph:



Slope from Graph:

$$Slope = \frac{y_2 - y_1}{x_2 - x_1}$$

$$Slope_1 = 1.48\,\frac{N}{mm}$$

$$Slope_2 = 0.031571\,\frac{N}{mm}$$

$$Slope_3 = 0.130588\,\frac{N}{mm}$$

$$Slope_4 = 0.082222\,\frac{N}{mm}$$

$$Slope_5 = 0.081091\,\frac{N}{mm}$$

Statistical Analysis:

Statistical Analysis of Stiffness for Extension Springs:

1. **Experiment Overview:** The experiment aimed to analyze and compare the stiffness of extension springs made from stainless steel 304 and carbon steel 1082.
2. **Data Collection and Processing:** Multiple readings of force and extension were recorded for both materials to ensure accuracy. Average stiffness was calculated for each material to identify their characteristic mechanical properties.
3. **Results and Comparison**: Carbon steel 1082 showed a higher average stiffness than stainless steel 304. Graphical representation (force vs. extension) confirmed steeper slopes for carbon steel, indicating greater resistance to deformation. Standard deviation analysis validated the consistency of the collected data.
4. **Conclusion:** Carbon steel 1082 is suitable for applications requiring higher force resistance, while stainless steel 304 is better for lighter loads.

The findings highlight the importance of material selection in designing extension springs for specific applications.

Industrial Applications:

Real life applications of stiffness in automotive sector

1. **Suspension Systems**: Stiffness experiments with springs are important for the design of vehicle suspension systems, to ensure optimal shock absorption and stability through proper selection of spring stiffness for different terrains.
2. **Throttle Return Springs:** In automotive throttle mechanisms, stiffness testing of return springs ensures precise control and reliable throttle closure, preventing unintended acceleration.
3. **Clutch Mechanisms:** Manual transmissions rely on the stiffness of springs in the clutch system for smooth operation, balancing ease of pedal engagement with enough force for proper disengagement of the clutch.

Comments:

Through this experiment, we observed and compared the stiffness values of stainless steel 304 and carbon steel 1082. The results revealed that carbon steel 1082 exhibits a higher stiffness than stainless steel 304. This means that under identical conditions, such as the same outer diameter, wire diameter, and spring length, carbon steel 1082 resists deformation more effectively. Consequently, carbon steel 1082 reaches the plastic deformation stage after stainless steel 304.

This finding suggests that carbon steel 1082 is more suitable for applications requiring higher force or load-bearing capacity, whereas stainless steel 304 is better suited for lighter forces due to its lower stiffness. Additionally, the inherent properties of these materials highlight their specific applications in mechanical systems, with carbon steel being preferred for durability and load-intensive purposes, while stainless steel is chosen for environments demanding corrosion resistance and flexibility. This experiment reinforced the importance of material selection in engineering design.