INSTITUTE OF DISTANCE LEARNING

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

ME 355
STRENGTH OF MATERIALS II

UNIT 5

By Dr. P.Y. Andoh

EMAIL// 020 096 0067

Introduction

- ***STRESSES AND DEFLECTION OF SPRINGS***

DEFLECTION OF BEAMS

Learning Objectives

After reading this unit you should be able to:

1. Derive the bending stress in semi- and quarter-elliptic leaf spring type
2. Derive the deflection in semi- and quarter-elliptic leaf spring type
3. Derive the equations used to compute the stresses under axial loading and axial torque in helical springs
4. Estimate the diameters of the coils and wire of a helical spring
5. Compute the strain energy and stresses in flat spiral springs

INTRODUCTION

- A spring is a device, in which the material is arranged in such a way that it can undergo a considerable change, without getting permanently distorted.

- A spring is used to absorb energy due to resilience, which may be restored as and when required.

Stiffness of a Spring

- The load required to produce a unit deflection in a spring is called spring stiffness or *stiffness of a spring.*

Types of Springs

I. Bending spring

II. Torsion spring

Forms of Springs

I. Carriage springs or leaf springs

   a. semi-elliptical types (*i.e.,* simply supported at its ends subjected to central load) and

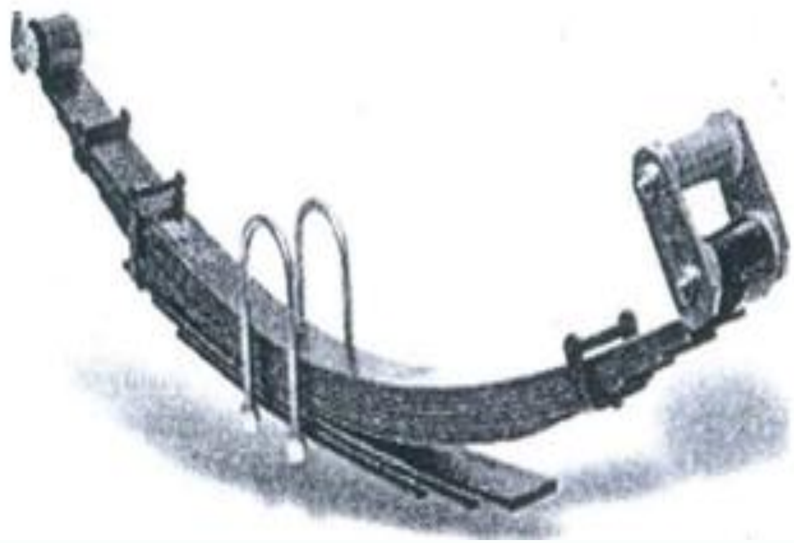
   b. quarter-elliptical (*i.e.,* cantilever) types

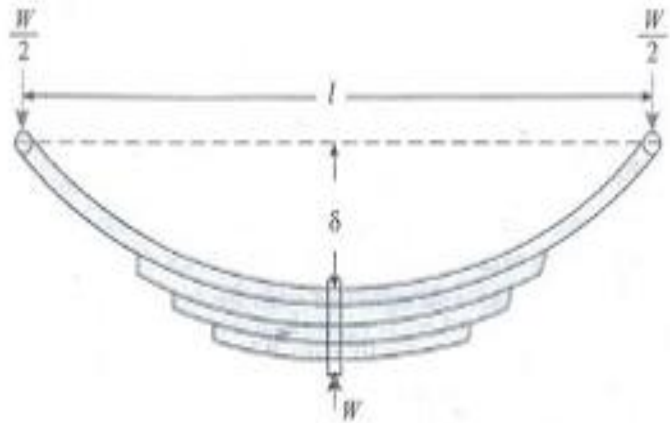
II. Helical springs

   a. Closely-coiled helical springs and

   b. Open-coiled helical springs

Semi-elliptical Type Leaf Springs





- Let

l	Span of the spring,
t	Thickness of plates,
b	Width of the plates,
n	Number of plates,
W	Load acting on the spring
σ	Maximum bending stress developed in the plates,
δ	Original deflection of the top spring and
R	Radius of the spring

The bending moment, at the centre of the span due to this load

$$M = \frac{Wl}{4} \ldots (i)$$

Moment resisted by one plate

$$M_i = \frac{\sigma . I}{y} == \frac{\sigma . bt^2}{6}$$

The total moment resisted by n plates,

$$M = M_i . n = \frac{n\sigma bt^2}{6} \ldots (ii)$$

- Equating (i) and (ii),

$$\frac{Wl}{4} = \frac{n\sigma bt^2}{6}$$

$$\Rightarrow \sigma = \frac{3Wl}{2nbt^2}$$

- From the geometry, the central deflection,

$$\delta = \frac{l^2}{8R} \ldots (iii)$$

For a bending beam,

$$\frac{\sigma}{y} = \frac{E}{R}$$

$$\Rightarrow R = \frac{E.y}{\sigma} = \frac{Et}{2\sigma}$$

Substituting this value of *R* in equation *(iii),*

$$\delta == \frac{\sigma l^2}{4Et}$$

Substituting the value of σ in the above equation

$$\delta = \left(\frac{3Wl}{2nbt^2}\right)\left(\frac{l^2}{4Et}\right) = \frac{3Wl^3}{8Enbt^3}$$

Example 5-1:

A laminated spring 1 m long is made up of plates each 50 mm wide and 10 mm thick. If the bending stress in the plates is limited to 100 MPa, how many plates are required to enable the spring to carry a central point load of 2 kN. If modulus of elasticity for the spring material is 200 GPa, what is the deflection under the load?

Solution

Given: Length (l) = 1 m= 1 x 10^3 mm; Width (b) =50 mm; Thickness (t) = 10 mm Bending stress (σ_b) = 100 MPa = 100 N/mm^2; Central point load (W) = 2 kN = 2 x 10^3 N and modulus of elasticity (E) = 200 GPa = 200 x 10^3 N/mm^2

No. of plates required in the spring

$$100 = \frac{3Wl}{2nbt^2} = \frac{3(2000)(1000)}{2n(50)(10)^2} = \frac{600}{n}$$

$$\Rightarrow n = \frac{600}{100} = 6$$

Deflection under the load

$$\delta = \frac{3Wl^3}{8Enbt^3}$$

$$= \frac{3(2000)(1000)^3}{8(200x10^3)(6)(50)(10)^3} = 12.5\ mm$$

Example 5-2:

A leaf spring is to be made of seven steel plates 65 mm wide and 6.5 mm thick. Calculate the length of the spring, so that it may carry a central load of 2.75 kN, the bending stress being limited to 160 MPa. Also calculate the deflection at the centre of the spring. Take E for the spring material as 200 GPa.

Solution

Given: No. of plates (n) = 7; Width (b) = 65 mm; Thickness (t) = 6.5 mm; Central load (W) = 2.75 kN = 2.75 x 10^3 N; Maximum bending stress (σ_b) = 160 MPa = 160 N/mm2 and modulus of elasticity for the spring material (E) = 200 GPa = 200 x 10^3 N/mm^2

Length of the spring

$$160 = \frac{3Wl}{2nbt^2} = \frac{3(2750)l}{2(7)(65)(6.5)^2} = 0.215l$$

$$\Rightarrow l = \frac{160}{0.215} = 744.2\ mm$$

Deflection at the centre of the spring

$$\delta = \frac{3Wl^3}{8Enbt^3}$$

$$= \frac{3(2750)(744.2)^3}{8(200x10^3)(7)(65)(6.5)^3} = 17\ mm$$

Example 5-3:

A leaf spring 750 mm long is required to carry a central point load of 8 kN. If the central deflection is not to exceed 20 mm and the bending stress is *not greater than 200 MPa, determine the thickness, width and number of plates. Also, compute the radius, to which the plates should be curved. Assume width of the plate equal to 12 times its thickness and E equal to 200 GPa*

Solution

Given: Length *(l)* = 750 mm; Point load *(W) = 8 kN =8 x* 10^3 N; Central deflection (δ) = 20 mm; Bending stress (σ_b) = 200 MPa == 200 *N/mm²;* Width of plates *(b)* = 12t (where *t* is the thickness of the plates) and modulus of elasticity *(E)* = 200 GPa = 200 x 10^3 N/mm²

Thickness of the plates

$$20 = \frac{\sigma l^2}{4Et} = \frac{(200)(750)^2}{4(200x10^3)t} = \frac{140.6}{t} \Rightarrow t = \frac{140.6}{20} = 7.0\ mm$$

Width of plate

$$b = 12t = 12(7) = 84.0\ mm$$

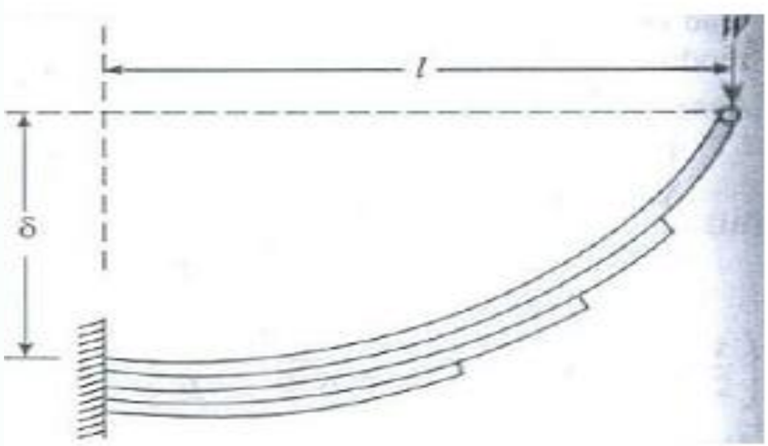
Number of plates

$$200 = \frac{3Wl}{2nbt^2} = \frac{3(8000)(750)}{2n(84)(7)^2} = \frac{2187}{n} \Rightarrow n = \frac{2187}{200} = 10.9 \approx 11$$

The radius of plates

$$R = \frac{Et}{2\sigma} = \frac{(200x10^3)(7)}{2(200)} = 3500\,mm$$

Quarter-Elliptical Type Leaf Springs



Quarter-elliptical spring

Let

	l	Length of the spring,
	t	Thickness of the plates,
	b	Width of the plates,
	n	Number of plates,
	W	Load acting at the free end of the spring
	δ	Original deflection of the spring.

Bending moment at the fixed end of the leaf

$$M = Wl$$

Moment resisted by one plate

$$M_i = \frac{\sigma . I}{y} == \frac{\sigma . b t^2}{6}$$

The total moment resisted by n plates,

$$M = M_i.n = \frac{n\sigma bt^2}{6} \ldots(ii)$$

Equating (i) and (ii)

$$Wl = \frac{n\sigma bt^2}{6}$$

$$\Rightarrow \sigma = \frac{6Wl}{nbt^2}$$

From the geometry

$$\delta = \frac{l^2}{2R} \ldots(iii)$$

But

$$R == \frac{Et}{2\sigma}$$

Therefore

$$\delta = \frac{l^2}{2\left(Et/2\sigma\right)} = \frac{\sigma l^2}{Et}$$

Hence

$$\delta = \frac{\sigma l^2}{Et} == \frac{6Wl^3}{Enbt^3}$$

Example 5-4:

A quarter-elliptic leaf spring 800 mm long is subjected to a point load of 10 kN. If the bending stress and deflection is not to exceed 320 MPa and 80 mm respectively, find the suitable size and number of plates required by taking the width as 8 times the thickness. Take E as 200 GPa.

Solution

Given: Length (l) = 800 mm; Point load (W) = 10 kN = 10×10^3 N; Bending stress (σ_b) = 320 MPa = 320 N/mm^2; Deflection (δ) = 80 mm; Plate width b = 8t (where t is the thickness of the plates) and modulus of elasticity (E) = 200 GPa = 200×10^3 N/mm^2

Thickness of the plates

Let t Thickness of plates in mm, and

N Number of the plates

bending stress $$320 = \frac{6Wl}{nbt^2} = \frac{6(10x10^3)(800)}{nbt^2} = \frac{48x10^6}{nbt^2} \ldots(i)$$

For deflection

$$80 = \frac{6Wl^3}{Enbt^3} = \frac{6\left(10x10^3\right)\left(800\right)^3}{\left(2x10^3\right)nbt^3} = \frac{153.6x10^6}{nbt^3} \ldots(ii)$$

Dividing equation (ii) by (i),

$$\frac{80}{320} = \left[\frac{153.6x10^6}{nbt^3}\right]\left[\frac{nbt^2}{48x10^6}\right] = \frac{3.2}{t} \Rightarrow t = \frac{3.2(320)}{80} = 13\,mm$$

Width of plates

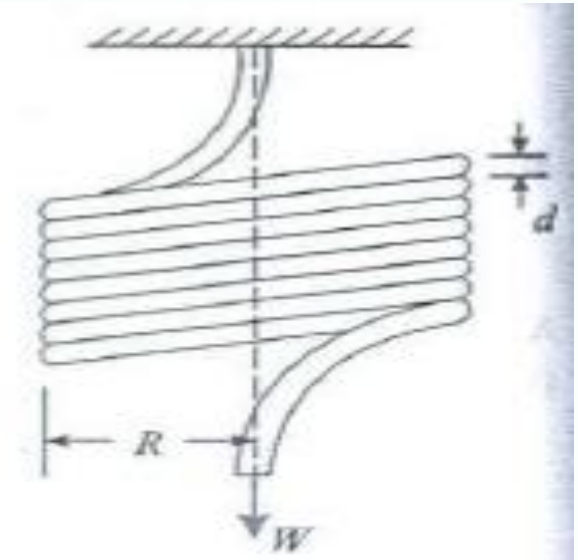
$$b = 8t = 8(13) = 104\,mm$$

N*umber of plates required*

$$320 = \frac{48x10^6}{nbt^2} \Rightarrow n = \frac{48x10^6}{(320)(104)(13)} = 8.5 \approx 9$$

Closely-coiled Helical Springs

A Closely-coiled Helical Spring Subjected to an Axial Load



Let

d	Diameter of the spring wire,
R	Mean radius of the spring coil
n	No. of turns of coils,
C	Modulus of rigidity for the spring material,
W	Axial load on the spring
τ	Maximum shear stress induced in the wire due to twisting,
θ	Angle of twist in the spring wire
δ	Deflection of the spring, as a result of axial load

Twisting moment

$$T = WR \ldots (i)$$

$$T = \frac{\pi}{16} . \tau . d^3 \ldots (ii)$$

Equating (i) and (ii)

$$W.R = \frac{\pi}{16} . \tau . d^3$$

From geometry $l = 2\pi R.n$

Torsion of circular shafts

$$\frac{T}{J} = \frac{C.\theta}{l}$$

This implies

$$\theta = \frac{Tl}{JC} = \frac{WR.2\pi Rn}{\frac{\pi}{32} x d^4 C} = \frac{64WR^2 n}{Cd^4}$$

Deflection of the spring

$$\delta = R\theta = \frac{64WR^3 n}{Cd^4}$$

Energy stored in the spring

$$U = \tfrac{1}{2} W\delta$$

Stiffness of the spring

$$s = \frac{W}{\delta} = \frac{Cd^4}{64R^3 n}$$

Example 5-5:

A close-coiled helical spring is required to carry a load of 150 N. if the mean coil diameter is to be 8 times that of the wire, calculate these diameters. Take maximum shear stress as 100 MPa.

Solution

Given: Load (W) = 150 N; Diameter of coil (D) = 8d (where d is the diameter of the wire) or radius (R)= 4 d and maximum shear stress (τ) = 100 MPa = 100 N/mm^2

We know that relation for the twisting moment, $W.R = \frac{\pi}{16}.\tau.d^3$

This implies, $150x.4d = \frac{\pi}{16}.x100x.d^3 \quad \therefore d^2 = \frac{150x4x16}{100\pi} = 30.6$

Hence, $d = \sqrt{30.6} = 5.53 \approx 6\ mm$

and $D = 8d = 8(6) = 48\ mm$

Example 5-6:

A closely. coiled helical spring of round steel wire 5 mm in diameter having 12 complete coils of 50 mm mean diameter is subjected to an axial load of 100 N. Find the deflection of the spring and the maximum shearing stress in the material. Modulus of rigidity (G) = 80 GPa

Solution

Given: Diameter of spring wire (d) = 5 mm; No. of coils (n) = 12; Diameter of spring (D) = 50 mm or radius (R) = 25 mm; Axial load (W) = 100 N and Modulus of rigidity (G) = 80 GPa = 80 x 10^3 N/mm^2

Deflection of the spring

$$\delta = \frac{64WR^3n}{Cd^4} = \frac{64(100)(25)^3(12)}{(80x10^3)(5)^4} = 24\ mm$$

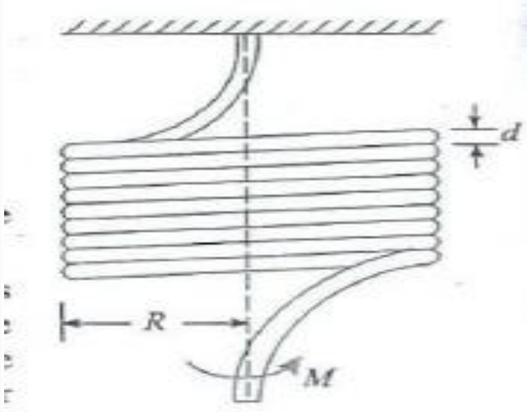
Maximum shearing stress in the material

$$W.R = \frac{\pi}{16}.\tau.d^3$$

$$100x.25 = \frac{\pi}{16}.x\tau x.(5)^3$$

$$\therefore \tau = \frac{2500}{24.54} = 101.9\ N/mm^2$$

A Closely-coiled Helical Spring Subjected to an Axial Twist



Let	*d*	Diameter of the spring wire,
	R	Mean radius of the spring coil,
	n	No. of turns of coils,
	e	Modulus of rigidity for the spring material
	M	Moment or axial twist applied on the spring.

Length of the spring,

$$l = 2\pi R n = 2\pi R' n' \ldots (i)$$

Therefore,

$$\frac{1}{R} = \frac{2\pi n}{l} \qquad \frac{1}{R'} = \frac{2\pi n'}{l}$$

$$\frac{M}{I} = E \; x \; Change \quad of \;\; curvature$$

$$= E\left(\frac{1}{R'} - \frac{1}{R}\right) = E\left[\frac{2\pi n'}{l} - \frac{2\pi n}{l}\right]$$

$$= \frac{2\pi E}{l}(n' - n)$$

Therefore

$$2\pi(n' - n) = \frac{Ml}{EI} \ldots (ii)$$

The total angle of bend

$$\phi = 2\pi(n' - n) = \frac{Ml}{EI}$$

$$\frac{d\phi}{dl} = \frac{M}{EI}$$

The energy stored in the spring,

$$U = \tfrac{1}{2} M.\phi$$

Example 5-7

A closely-coiled helical spring is made lip of 10 nun diameter steel wire having 10 coils with 80 mm mean diameter. If the spring is subjected 10 an axial twist of 10 kNmm, determine the bending stress and increase ill the number of turns. Take E as 200 GPa

Solution

Given: Diameter of spring wire (d) = 10 mm; No. of coils (n) = 10; Diameter of coil (D) = 80 mm or radius (R) = 40 mm; Axial twist (M) = 10 kN -mm = 10 x 10^3 N-mm and Modulus of elasticity (E) = 200 GPa = 200 x 10^3 N/mm^2

Moment of inertia

$$I = \frac{\pi}{64} x d^4 = \frac{\pi}{64} x (10)^4 = 490.9\ mm^4$$

Bending stress in file wire

$$\sigma = \frac{M}{I}.y = \frac{\left(10x10^3\right)}{490.9}x(5) = 101.9\ N/mm^2$$

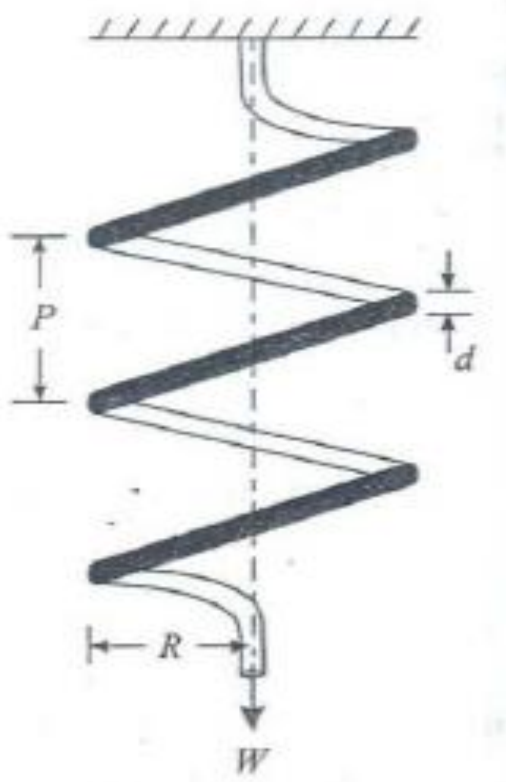
Increase in the number of turns

$$l = 2\pi Rn = 2\pi x40x10 = 800\pi\ mm$$

$$\left(n' - n\right) = \frac{Ml}{EI}x\frac{1}{2\pi} = \frac{\left(10x10^3\right)\left(800\pi\right)}{\left(200x10^3\right)\left(490.9\right)}x\frac{1}{2\pi} = 0.04mm$$

Open-coiled Helical Springs

Let



d	Diameter of the spring wire,
R	Mean radius of the spring coil,
P	Pitch of the spring coils,
n	No. of turns of coils,
C	Modulus of rigidity for the spring materials
W	Axial load on the spring,
τ	Maximum shear stress induced in the spring wire due to loading,
σ_b	Bending stress induced in the spring wire due to bending,
δ	Deflection of the spring as a result of axial load and
α	Angle of helix.

Bending moment

Causes twisting of coils $T = WR\cos\alpha$

Causes bending of coils $M = WR\sin\alpha$

Length of the spring wire

$$l = 2\pi Rn\sec\alpha ...(i)$$

Twisting moment

$$WR\cos\alpha = \frac{\pi}{16} x\tau xd^3 ...(ii)$$

Bending stress

$$\sigma_b = \frac{M}{I}.y = \frac{WR\sin\alpha.\frac{d}{2}}{\frac{\pi}{64}xd^4}$$

$$= \frac{32WR\sin\alpha}{\pi d^3} ...(iii)$$

Angle of twist

$$\theta = \frac{Tl}{JC} = \frac{WR\cos\alpha.l}{JC}$$

Angle of bend due to bending moment

$$\phi = \frac{Ml}{EI} = \frac{WR\sin\alpha.l}{EI}$$

The work done by the load in deflecting the spring, is equal to the stress energy of the spring.

Therefore,

$$\tfrac{1}{2}W\delta = \tfrac{1}{2}T\theta + \tfrac{1}{2}M\phi \Rightarrow W.\delta = T\theta + M\phi$$

Hence,

$$\delta = WR^2 l = \frac{1}{W}\left[\frac{\cos^2\alpha}{JC} + \frac{\sin^2\alpha}{EI}\right]$$

Or

$$\delta = \frac{T\theta + M\phi}{W}$$

$$= \frac{1}{W}\left\{\left[(WR\cos\alpha)\left(\frac{WR\cos\alpha.l}{JC}\right)\right] + \left[(WR\sin\alpha)\left(\frac{WR\sin\alpha.l}{EI}\right)\right]\right\}$$

- Now substituting the values of $l = 2\pi Rn\sec\alpha$, $J = \frac{\pi}{32}(d)^4$

And $I = \frac{\pi}{64}(d)^4$ in the above equation

$$\delta = WR^2 x 2\pi nR\sec\alpha = \left[\frac{\cos^2\alpha}{\frac{\pi}{32}d^4C} + \frac{\sin^2\alpha}{\frac{\pi}{64}d^4E}\right]$$

$$= \frac{64WR^3 n\sec\alpha}{d^4}\left[\frac{\cos^2\alpha}{C} + \frac{\sin^2\alpha}{E}\right]$$

- NOTE: If we substitute $\alpha = 0$ in the above equation, it gives deflection of a closed coiled spring

Example 5-8:

An open coil helical spring made up of 10 nun diameter wire and of mean diameter of 100 mm has 12 coils and angle of helix being 15°. Determine the axial deflection and the intensities of bending and shear stresses under an axial load of 500 N. Take C as 80 GPa and E as 200 GPa.

Solution

Given: Diameter of wire (d) = 10 mm; Mean diameter of spring (D) = 100 mm or radius (R) == 50 mm; No. of coils (n) = 12; Angle of helix (α) = 15^o; Load (W) = 500 N; Modulus of rigidity (C) = 80 GPa = 80 x 10^3 N/mm^2 and modulus of elasticity (E) = 200 GPa = 200 x 10^3 N/mm^2

Deflection of the spring

$$\delta == \frac{64x500x(59)^3 x12\sec 15^o}{(10)^4}\left[\frac{\cos^2 15^o}{80x10^3}+\frac{\sin^2 15^o}{200x10^3}\right]=61.3\,mm$$

- Bending moment

$$M = WR\sin\alpha = 500x50\sin15^o = 6470 \ N.mm$$

- Moment of inertia

$$I = \frac{\pi}{64}(d)^4 = \frac{\pi}{64}(10)^4 = 490.9 \ mm^4$$

- The bending stress

$$\sigma_b = \frac{M}{I}.y = \frac{6470}{490.9}x5 = 65.9 \ N/mm^2$$

Shear stress induced in the wire

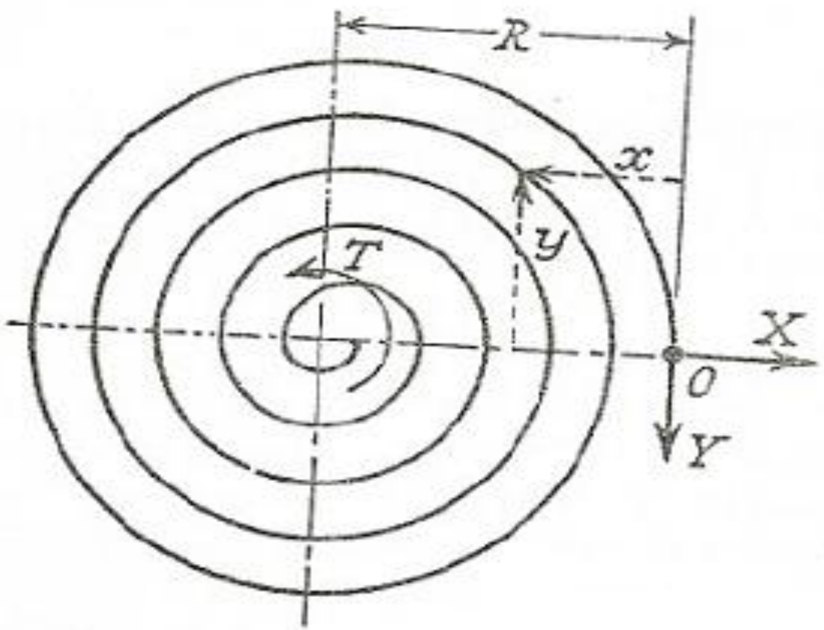
$$T = WR\cos\alpha = 500x50\cos15^o = 24150 \, N.mm$$

- We also know that twisting moment (T),

$$24150 = \frac{\pi}{16}x\tau x d^3 = \frac{\pi}{16}x\tau x(10)^3 = 196.4\tau \Rightarrow \tau = \frac{24150}{196.4} = 123 \ N/mm^2$$

Flat Spiral Springs

Moment $T = YR$



Strain energy

$$\therefore U = \int \frac{(Yx - Xy)^2}{2EI} ds = \int \frac{([T/R]x - Xy)^2}{2EI} ds$$

$$\delta U / \delta X = 0 \text{ giving } X = \left(\frac{T}{R}\right)\left(\frac{\int xyds}{\int y^2 ds}\right) = 0 \text{ by symmetry.}$$

Then $\theta = \dfrac{\delta U}{\delta T} = \dfrac{2T}{R^2}\int \dfrac{x^2 ds}{2EI}$

But $\int x^2 ds = \left(\dfrac{R^2}{4} + R^2\right)l$ approximately treating the spiral as a uniform "disc"

$\therefore\ \theta = 1.25\dfrac{Tl}{EI}$

Strain Energy= $\frac{1}{2}T\theta = 1.25\dfrac{T^2 l}{2EI}$

Maximum bending moment is $Y.2R$ at the left-hand edge which is 2T

Maximum stress $\hat{\sigma} = \dfrac{2T}{Z} = \dfrac{12T}{bt^2}$

where b =width and t =thickness of spring material.

Example 5-9:

A fiat spiral spring is 6 mm wide, 0·25 mm thick, and 2,5 mm long, Assuming the maximum stress of 800 N/mm² to occur at the point of greatest bending moment, calculate the torque, the work stored, and the number of turns to wind up the spring, E =208,000 N/mm².

Solution

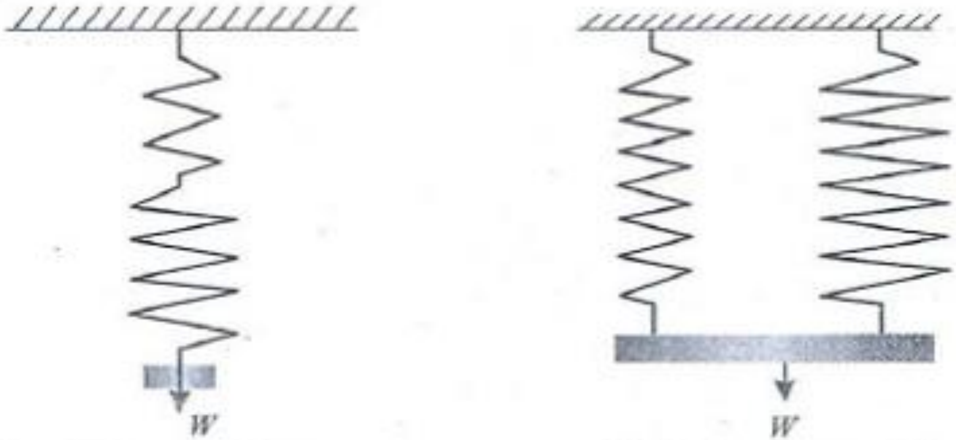
Given: Width of spring (b) = 6 mm; Thickness of spring (t) = 0.25 mm; maximum stress of 800 N/mm² and modulus of elasticity (E) = 208 GPa = 208 x 10³ N/mm²

Maximum stress, $\hat{\sigma} = \dfrac{12T}{bt^2} \Rightarrow 800 = \dfrac{12T}{6(0.25^2)} \Rightarrow T = 25\ N.mm$

Angle of rotation, $\theta = 1.25\dfrac{(25)(2500)}{(208000)\left[(6)(0.25^2)/12\right]} = 48 rad$

Work stored in spring, $= \frac{1}{2}T\theta = \frac{1}{2}(25)(48) = 600 Nmm$

Springs in Series and Parallel



(a) Springs in series

(b) Springs in parallel

Example 5-10:

Two-close coiled helical springs wound from the same wire, but with different core radii having equal no. of coils are compressed between rigid plates at their ends. Calculate the maximum shear stress induced in each spring, if the wire diameter is 10 mm and the load applied between tile rigid plates is 500 N. The core radii of the springs are 100 mm and 75 mm respectively.

Solution

Given: No. of coils in the outer spring (n_1) = n_2 (where n_2 is the no. of coils in the inner spring); Diameter of spring wire (d) = 10 mm; Load (W) = 500 N; Radius of outer spring (R_1) = 100 mm and radius of inner spring (R_2) = 75 mm

Let τ_1 Shear stress developed in the outer spring.

W_1 Load hared by me outer spring and

T_2, W_2 Corresponding values for the inner spring

We know that deflection of the outer spring,

$$\delta_1 = \frac{64W_1R_1^3n_1}{Cd^4} = \frac{64xW_1(100)^3n_1}{C(10)^4} = \frac{6400W_1n_1}{C} \qquad \text{(i)}$$

Similarly, $$\delta_2 = \frac{64W_2R_2^3n_2}{Cd^4} = \frac{64xW_2(75)^3n_2}{C(10)^4} = \frac{2700W_2n_2}{C} \qquad \text{(ii)}$$

Since the springs are held between two rigid plates, therefore deflections in both the springs must equal and the no. of coils are also equal, i.e. $n_1 = n_2$

Now equating (i) and *(ii)*, $$\frac{6400W_1}{C} = \frac{2700W_2}{C} \Rightarrow W_1 = \frac{27}{64}W_2$$

We also know that $W_1 + W_2 = 500 \Rightarrow \frac{27}{64} W_2 + W_2 = 500 \quad \therefore W_2 = \frac{500x64}{91} = 351.6\ N$

and $W_1 = 500 - W_2 = 500 - 351.6 = 148.4\ N$

We know that relation for torque,

$$W_1 R_1 = \frac{\pi}{16} x \tau_1 x d^3 \Rightarrow \tau_1 = \frac{16 W_1 R_1}{\pi d^3} = \frac{16x148.4x100}{(10)^3 \pi} = 75.6\ N/mm^2$$

Similarly, $W_2 R_2 = \frac{\pi}{16} x \tau_2 x d^3 \Rightarrow \tau_2 = \frac{16 W_1 R_1}{\pi d^3} = \frac{16x351.6x75}{(10)^3 \pi} = 134.4\ N/mm^2$

Sample Questions

Problem 1: *A close-coiled helical spring has mean diameter of 75 mm and spring constant of 80 kN/m and has 8 coils. What is the suitable diameter of the spring wire if maximum shear stress is not to exceed 250 MPa? Modulus of rigidity of the spring wire material is 80 GPa. What is the maximum axial load the spring can carry?*

Problem 6: *A composite spring has two closed-coiled springs connected in series; one spring has 12 coils of a mean diameter of 25 mm and wire diameter 2.5 mm. Find the wire diameter of the other spring if it has 15 coils of mean diameter 40 mm. The stiffness of the composite spring is 1·5 kN/m. Determine the greatest load that can be carried by the composite spring and the corresponding extension if the maximum stress is 250 MNlm²*. C = *80 GNlm²*.

Problem 7: *A helical spring B is placed inside the coils of a second helical spring having the same number of coils and free axial length and of same material. The two springs are compressed by an axial load of 210 N which is shared between them. The mean coil diameters of A and B are 90 mm and 60 mm and the wire diameters are 12 mm and 7 mm respectively. Calculate the load taken and the maximum stress in each spring.*