4.4 SPRING:

Springs are the elastic bodies which absorb energy due to resilience. The absorbed energy may be released as and when required. A spring which is cable of absorbing the greatest amount energy for the given stress, without getting permanently distorted, is known as the best spring. The two important types of springs are:

1. Laminated or leaf spring and
2. Helical spring

4.4.1 CLASSIFICATION OF SPRINGS:

Based on the shape behavior obtained by some applied force, springs are classified into the following ways:

SPRINGS

HELICAL SPRINGS

LEAF SPRINGS

1. SPIRAL SPRINGS
2. TORSION SPRING

TENSION HELICAL SPRING

COMPRESSION HELICAL SPRING

I. HELICAL SPRINGS:

DEFINITON:

It is made of wire coiled in the form of helix.

CROSS-SECTION:

Circular, square or rectangular

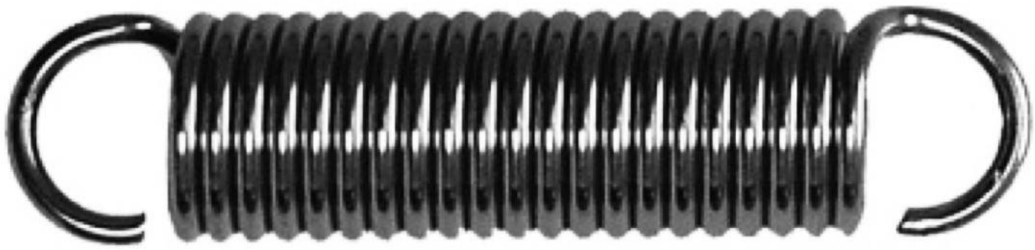
CLASSIFICATION:

1) Open coil springs (or) Compression helical springs
2) Closed coil springs (or) Tension helical springs

1) HELICAL TENSION SPRINGS:

CHARACTERISTICS:

- Figure1 shows a helical tension spring. It has some means of transferring the load from the support to the body by means of some arrangement.
- It stretches apart to create load.
- The gap between the successive coils is small.
- The wire is coiled in a sequence that the turn is at right angles to the axis of the spring.
- The spring is loaded along the axis.
- By applying load the spring elongates in action as it mainly depends upon the end hooks



APPLICATIONS:

1) Garage door assemblies
2) Vise-grip pilers
3) carburetors

2) HELICAL COMPRESSION SPRINGS:

CHARACTERISTICS:

- The gap between the successive coils is larger.
- It is made of round wire and wrapped in cylindrical shape with a constant pitch between the coils.
- By applying the load the spring contracts in action.
- There are mainly four forms of compression springs as shown in figure..

They are as follows:

1) Plain end
2) Plain and ground end

3) Squared end
4) Squared and ground end

Among the four types, the plain end type is less expensive to manufacture. It tends to bow sideways when applying a compressive load.

APPLICATIONS:

1) Ball point pens
2) Pogo sticks
3) Valve assemblies in engines

3) TORSION SPRINGS:

CHARACTERISTICS:

- It is also a form of helical spring, but it rotates about an axis to create load.
- It releases the load in an arc around the axis as shown in figure4.
- Mainly used for torque transmission
- The ends of the spring are attached to other application objects, so that if the object rotates around the center of the spring, it tends to push the spring to retrieve its normal position.

APPLICATIONS:

- Mouse tracks
- Rocker switches
- Door hinges
- Clipboards Automobile starters **4) SPIRAL SPRINGS:**

CHARACTERISTICS:

- It is made of a band of steel wrapped around itself a number of times to create a geometric shape as shown in figure5.
- Its inner end is attached to an arbor and outer end is attached to a retaining drum.
- It has a few rotations and also contains a thicker band of steel.
- It releases power when it unwinds.

APPLICATIONS:

- Alarm timepiece
- Watch
- Automotive seat recliners **II. LEAF SPRING:**

DEFINITION:

A Leaf spring is a simple form of spring commonly used in the suspension vehicles.

CHARACTERISTICS:

- Figure shows a leaf spring.Sometimes it is also called as a semi-elliptical spring, as it takes the form of a slender arc shaped length of spring steel of rectangular cross section.
- The center of the arc provides the location for the axle,while the tie holes are provided at either end for attaching to the vehicle body.
- Heavy vehicles,leaves are stacked one upon the other to ensure rigidity and strenth.
- It provides dampness and springing function.
- It can be attached directly to the frame at the both ends or attached directly to one end,usually at the front,with the other end attched through a shackle a short swinging arm.

- The shackle takes up the tendency of the leaf spring to elongate when it gets compressed and by which the spring becomes softer.
- Thus depending upon the load bearing capacity of the vehicle the leaf spring is designed with graduated and Ungraduated leaves as shown in figure Because of the difference in the leaf length,different stress will be there at each leaf.To compensate the stress level,prestressing is to be done.Prestressing is achieved by bending the leaves to different radius of curvature before they are assembled with the center clip.
- The radius of curvature decreases with shorter leaves.
- The extra intail gap found between the extra full length leaf and graduated length leaf is called as nip.Such prestressing achieved by a difference in the radius of curvature is known as nipping.

APPLICATIONS:

Mainly in automobiles suspension systems.

ADVANTAGES:

- It can carry lateral loads.
- It provides braking torque.
- It takes driving torque and withstand the shocks provided by the vehicles.

SPRING MATERIALS:

The mainly used material for manufacturing the springs are as follows:

1. Hard drawn high carbon steel.
2. Oil tempered high carbon steel.
3. Stainless steel
4. Copper or nickel based alloys.
5. Phosphor bronze.
6. Iconel.
7. Monel
8. Titanium.
9. Chrome vanadium.
10. Chrome silicon.

Depending upon the strength of the material, the material is Selected for the design of the spring.

4.4.3 NOMENCLATURE OF SPRING:

The below figure shows the momenclature of the spring under loading conditions.

Active Coils: Those coils which are free to deflect under load.

Angular relationship of ends: The relative position of the plane of the hooks or loops of extension spring to each other.

Buckling: Bowing or lateral deflection of compression springs when compressed, related to the slenderness ration (L/D).

Closed ends: Ends of compression springs where the pitch of the end coils is reduced so that the end coils touch.

Closed and ground ends: As with closed ends, except that the end is ground to provide a flat plane.

Close-wound: Coiled with adjacent coils touching.

Deflection: Motion of the spring ends or arms under the application or removal of an external load.

Elastic limit: Maximum stress to which a material may be subjected without permanent set.

Endurance limit: Maximum stress at which any given material may operate indefinitely without failure for a given minimum stress.

Free angle: Angle between the arms of a torsion spring when the spring is not loaded.

Free length: The overall length of a spring in the unloaded position.

Frequency (natural): The lowest inherent rate of free vibration of a spring itself (usually in cycles per second) with ends restrained.

Hysteresis: The mechanical energy loss that always occurs under cyclical loading and unloading of a spring, proportional to the are between the loading and unloading loaddeflection curves within the elastic range of a spring.

Initial tension: The force that tends to keep the coils of an extension spring closed and which must be overcome before the coil starts to open.

Loops: Coil-like wire shapes at the ends of extension springs that provide for attachment and force application.

Mean coil diameter: Outside wire diameter minus one wire diameter.

Modulus in shear or torsion: Coefficient of stiffness for extension and compression springs.

Modulus in tension or bending: Coefficient of stiffness used for torsion and flat springs.

(Young's modulus).

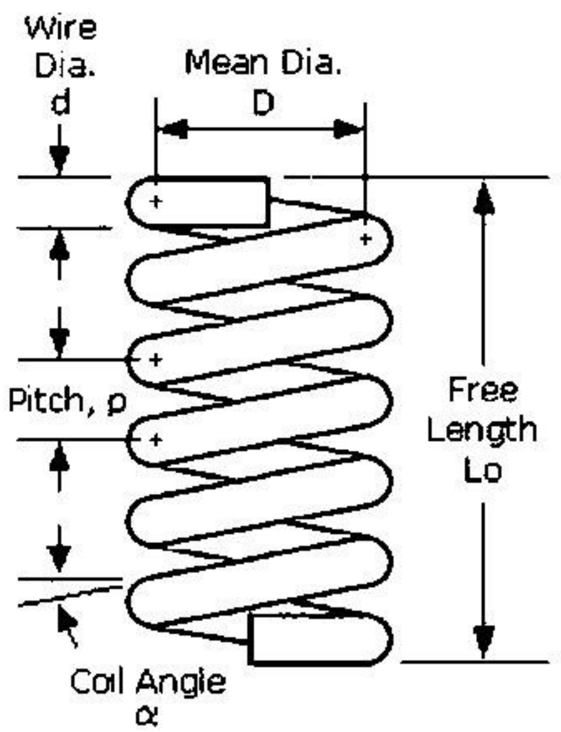
Open ends, not ground: End of a compression spring with a constant pitch for each coil.

Open ends ground: "Opens ends, not ground" followed by an end grinding operation.

Permanent set: A material that is deflected so far that its elastic properties have been exceeded and it does not return to its original condition upon release of load is said to have taken a "permanent set".

Pitch: The distance from center to center of the wire in adjacent active coils.

Spring Rate (or) Stiffness (or) spring constant: Changes in load per unit of deflection, generally given in Kilo Newton per meter. (KN/m).



Remove set: The process of closing to a solid height a compression spring which has been coiled longer than the desired finished length, so as to increase the elastic limit.

Set: Permanent distortion which occurs when a spring is stressed beyond the elastic limit of the material.

Slenderness ratio: Ratio of spring length to mean coil diameter.

Solid height: Length of a compression spring when under sufficient load to bring all coils into contact with adjacent coils.

Spring index: Ratio of mean coil diameter to wire diameter.

Stress range: The difference in operating stresses at minimum and maximum loads.

Squareness of ends: Angular deviation between the axis of a compression spring and a normal to the plane of the other ends.

Squareness under load: As in *squareness of ends*, except with the spring under load.

Torque: A twisting action in torsion springs which tends to produce rotation, equal to the load multiplied by the distance (or moment arm) from the load to the axis of the spring body. Usually expressed in inch-oz, inch-pounds or in foot-pounds.

Total number of coils: Number of active coils plus the coils forming the ends.

Spring index: The ratio between Mean diameter of coil to the diameter of the wire.

Solid length: It is the product of total number of coils and the diameter of the wire when the spring is in the compressed state. It is otherwise called as Solid height also.

4.4.4 SPRINGS IN PARALLEL AND SERIES:

In many situations, the combination of two or more springs either may be connected in series or parallel are required.

4.4.5. SPRINGS IN SERIES:

Two springs of stiffness K_1 and K_2 are connected in series and loaded with W as shown in figure.

In this case, each spring is subjected to the same load applied at the end of one spring. Therefore the load deflection of the assembly is equal to the algebraic sum of the deflection of the two springs.

Total deflection $\frac{W}{K} = \frac{W}{K_1} + \frac{W}{K_2}$

$$\frac{1}{K} = \frac{1}{K_1} + \frac{1}{K_2}$$

Combined stiffness, K = $\frac{K_1 K_2}{K_1 + K_2}$

4.4.6 SPRING IN PARALLEL:

Two springs of stiffness K_1 and K_2 are connected in parallel and loaded with W as shown in figure. Let the load shared by the two springs be W_1 and W_2 therefore the deflection of each spring is same

Total load W = $W_1 + W_2$

Common deflection δ = $\frac{W}{K} = \frac{W_1}{K_1} = \frac{W_2}{K_2}$

From that $W_1 = W\frac{K_1}{K}$ and $W_2 = W\frac{K_2}{K}$

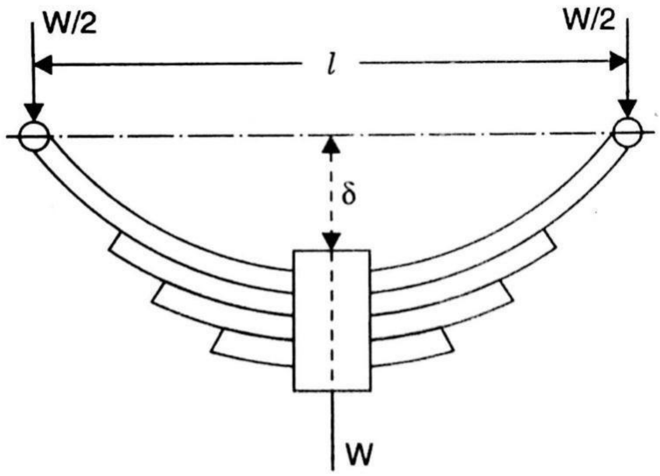
Then total load W = $W\frac{K_1}{K} + W\frac{K_2}{K}$

$$W = \frac{W}{K}(K_1 + K_2)$$

$$K = K_1 + K_2$$

4.4.7 LAMINATED OR LEAF SPRINGS:

The laminated are used to absorb shocks in railway wagons, coaches and road vehicles (such as cars, lorries etc..).



The above shows a laminated spring which consists of a number of parallel strip of a metal having different lengths and same width, placed one over the other. Initially all the plates are bent to the same radius and are free to slide one over the other. Fig. 16.11 shows the initial position of the spring, which is having some central deflection $\boldsymbol{\delta}$.The spring rests on the axis of the vehicle and its top plate is pinned at the ends to the chassis of the vehicle.

When the springs are loaded to the designed load W, all the plates become flat and the central deflection ($\boldsymbol{\delta}$)disappears.

Let b = Width of each plate

n = Number of plates l

= Span of spring

σ= Maximum bending stress developed in the plates

t = Thickness of each plate W =

Point load acting at the centre of the spring and

δ = Original deflection of the spring.

Expression for maximum bending stress developed in the plates. The load W acting at the centre of the lowermost plate, will be shared equally on the two ends of the top plate as shown in Fig.

∴ B.M. at the centre = Load at one end $\times \frac{l}{2}$

$$M = \frac{W}{2} \times \frac{l}{2} = \frac{W.l}{4} \quad .... (1)$$

or The moment of inertia of each plate, $I = \frac{bt^3}{12}$

But the relation among bending stress (σ), bending moment (M) and moment of inertia (I) is given by

$$\frac{M}{I} = \frac{\sigma}{y} \qquad (Here\, y = \frac{t}{2})$$

or
$$M = \frac{\sigma}{y} \times I = \frac{\sigma \times \frac{bt^3}{12}}{\frac{t}{2}} = \frac{\sigma.bt^3}{6} \quad .... (2)$$

∴ Total resisting moment by n plates

$$= n\times M = \frac{n\times\sigma . bt^2}{6}$$

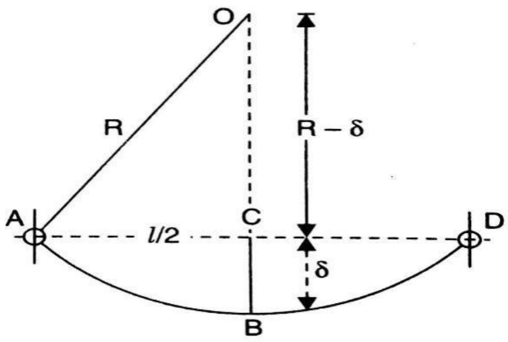
As the maximum B.M due to load is equal to the total resisting moment, therefore equating (1) and (2),

$$\frac{W . l}{4} = \frac{n\sigma . bt^2}{6}$$

$$\sigma = \frac{6W . l}{4 . n . b . t^2} = \frac{3Wl}{2nbt^2} \qquad \text{…. (3)}$$

Equation (3) gives the maximum stress developed in the plate of the spring.

Expression For Central Deflection of The Leaf Spring



Now R = Radius of the plate to which they are bent.

From triangle ACO of Fig. 16.12, we have

$$AO^2 = AC^2 + CO^2$$

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

$$= \frac{l^2}{4} + R^2 + \boldsymbol{\delta}^2 - 2R\,\boldsymbol{\delta}$$

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

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

∴ $$\boldsymbol{\delta} = \frac{l^2}{4\times 2R} = \frac{l^2}{8R} \qquad \text{.... (3)}$$

But the relation between bending stress, modulus of elasticity and radius of curvature (R) is given by $\frac{\sigma}{y} = \frac{E}{R}$

∴ $$R = \frac{E\times y}{\sigma} = \frac{E\times t}{2\sigma}\left(Here y = \frac{t}{2}\right)$$

Substituting this value of R in equation (3), we get

$$\delta = \frac{l^2\times 2\sigma}{8\times E\times t} = \frac{\sigma . l^2}{4Et} \qquad \text{…. (4)}$$

Equation (4) gives the central deflection of the spring.

Problem 4.4.1. A leaf spring carries a central load of 3000 N. The leaf spring is to be made of 10 steel plates 5 cm wide and 6 mm thick. If the bending stress is limited to 150 N/mm^2 determine :

i. Length of the Spring and
ii. Deflection at the centre of the spring. Take $E = 2 \times 10^5$ N/mm^2

Sol. Given

Central load, $W = 3000$ N

No. of plates, $n = 10$

Width of each plate, $b = 5$ cm $= 50$ mm

Thickness, $t = 6$mm

Bending stress, $\sigma = 150$ N/mm^2

Modulus of elasticity, $E = 2 \times 10^5$ N/mm^2.

Let l = Length of spring

δ = Deflection at the centre of spring.

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

$$150 = \frac{3 \times 3000 \times l}{2 \times 10 \times 50 \times 6^2}$$

l

$$= \frac{150 \times 2 \times 10 \times 50 \times 6^2}{3 \times 3000} = \textbf{60 mm.}$$

Using equation (4) for deflection,

$$\delta = \frac{\sigma \,.\, l^2}{4Et} = \frac{150 \times 600^2}{4 \times 2 \times 10^5 \times 6} = \textbf{11.25 mm.}$$

Problem 4.4.2. A laminated spring 1m long is made up of plates each 5 cm wide and 1cm thick.If the bending stress in the plate is limited to 100 N/mm^2, how many plates would be required to enable the spring to carry a central point load of 2 kN . If $E = 2.1 \times 10^5$ N/mm^2, What is the deflection under the load .

Sol. Given :

Length of Spring, $l = 1$ m $= 1000$ mm

Width of each plate, $b = 5$ cm $= 50$ mm

Thickness of each plate, $t = 1$ cm = 10 mm

Bending stress, $\sigma = 100$ N/mm^2

Central load on spring, $W = 2$ kN = 2000 N

Young's modulus, $E = 2.1 \times 10^5$ N/mm^2

Let n = Number of plates and

δ = Deflection under the load.

Using the equation (3),

$$\sigma = \frac{3Wl}{2nbt^2} \text{ or } 100 = \frac{3 \times 2000 \times 1000}{2 \times n \times 50 \times 10^2}$$

or

$$n = \frac{3 \times 2000 \times 1000}{100 \times 2 \times 50 \times 100} = 6. \quad \textbf{Ans.}$$

Deflection under loadUsing equation (4),

$$\delta = \frac{\sigma \cdot l^2}{4Et} = \frac{100 \times 1000^2}{4 \times 2.1 \times 10^5 \times 10} = 11.9 \text{ mm.} \quad \textbf{Ans.}$$