MEE-S307
Design Of Machine Elements

Design of Springs

Er. Yastuti Rao Gautam
Asst. Prof.
Mech. Engg. Dept.
U.I.E.T. Kanpur
C.S.J.M.U. Kanpur

Definition of spring

- A spring is an elastic object used to store mechanical energy. Springs are elastic bodies (generally metal) that can be twisted, pulled, or stretched by some force. They can return to their original shape when the force is released. In other words it is also termed as a resilient member.
- A spring is a flexible element used to exert a force or a torque and, at the same time, to store energy.
- The force can be a linear push or pull, or it can be radial, acting similarly to a rubber band around

a roll of drawings.

Objectives of Spring

1. **Absorbing , cushioning, or controlling of energy due to shock and vibration.**

Car springs or railway buffers . To control energy, springs-supports and vibration dampers.

2. Control of motion

- Maintaining contact between two elements (cam and its follower) In a cam and a follower arrangement, widely used in numerous applications, a spring maintains contact between the two elements. It primarily controls the motion.

- Creation of the necessary pressure in a friction device (a brake or a clutch)

A person driving a car uses a brake or a clutch for controlling the car motion. A spring system keep the brake in disengaged position until applied to stop the car. The clutch has also got a spring system (single springs or multiple springs) which engages and disengages the engine with the transmission system.

- Restoration of a machine part to its normal position when the applied force is withdrawn (a governor or valve)

3. Measuring forces

Spring balances, gages

4. Storing of energy

In clocks or starters

The clock has spiral type of spring which is wound to coil and then the stored energy helps gradual recoil of the spring when in operation. Nowadays we do not find much use of the winding clocks.

spring materials

Hard-drawn wire

This is cold drawn, cheapest spring steel. Normally used for low stress and static load. The material is not suitable at subzero temperatures or at temperatures above 1200C.

Oil-tempered wire

It is a cold drawn, quenched, tempered, and general purpose spring steel. It is not suitable for fatigue or sudden loads, at subzero temperatures and at temperatures above 1800C.

Chrome Vanadium

This alloy spring steel is used for high stress conditions and at high temperature up to 2200C. It is good for fatigue resistance and long endurance for shock and impact loads.

Chrome Silicon:

This material can be used for highly stressed springs. It offers excellent service for long life, shock loading and for temperature up to 2500C.

Music wire

This spring material is most widely used for small springs. It is the toughest and has highest tensile strength and can withstand repeated loading at high stresses. It cannot be used at subzero temperatures or at temperatures above 1200^0 C.

Stainless steel:

Widely used alloy spring materials.

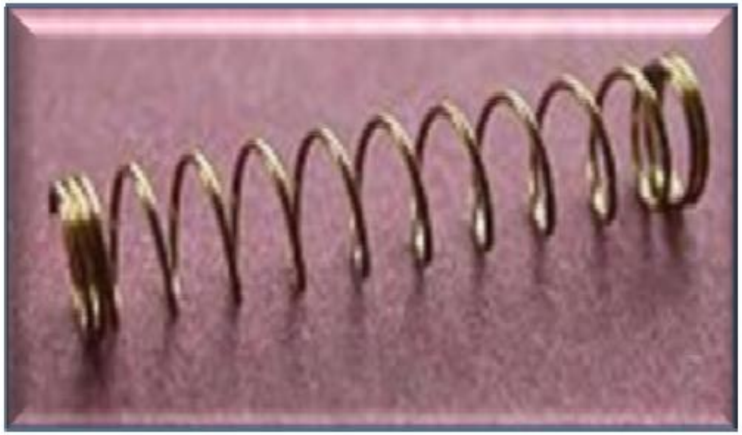
Phosphor Bronze / Spring Brass:

It has good corrosion resistance and electrical conductivity. it is commonly used for contacts in electrical switches. Spring brass can be used at subzero temperatures

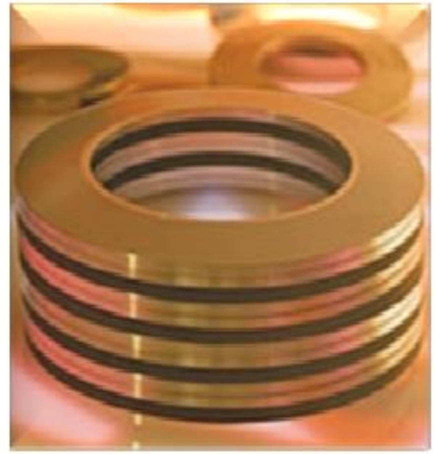
Types of springs

uses	Types of springs
Push	Helical compression spring, Belleville spring, Torsion spring, force acting at the end of torque arm. flat spring, such as a cantilever spring or leaf spring
Pull	Helical extension spring, Torsion spring, force acting at the end of torque arm. Flat spring, such as a cantilever spring or leaf spring, Draw bar spring (special case of the compression spring) constant – force spring.
Radial torque	Garter spring, elastomeric band, spring clamp, Torsion spring, Power spring

Push Types Springs



Helical compression spring



Belleville spring

Torsion spring

Flat spring

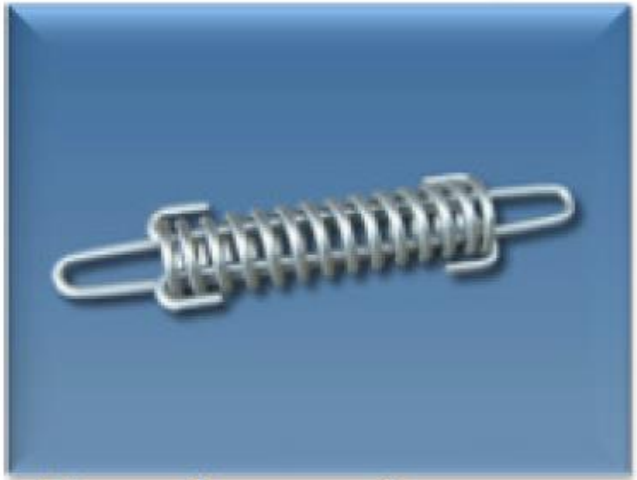
leaf spring

Pull Types Springs

Helical extension spring

Torsion spring

Flat spring`

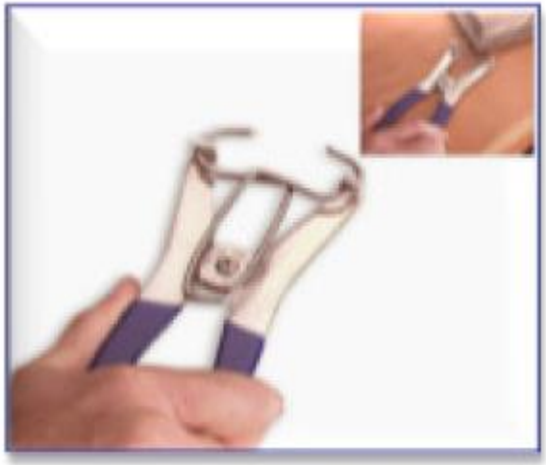


Draw bar spring

constant – force spring

Radial torque types springs

Garter spring



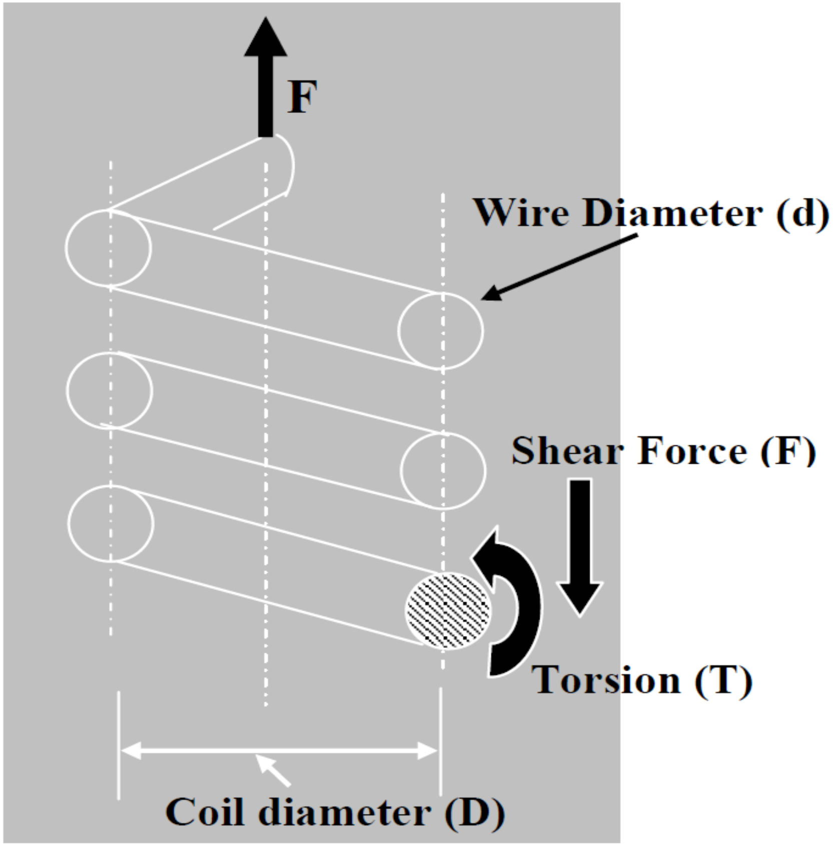
spring clamp

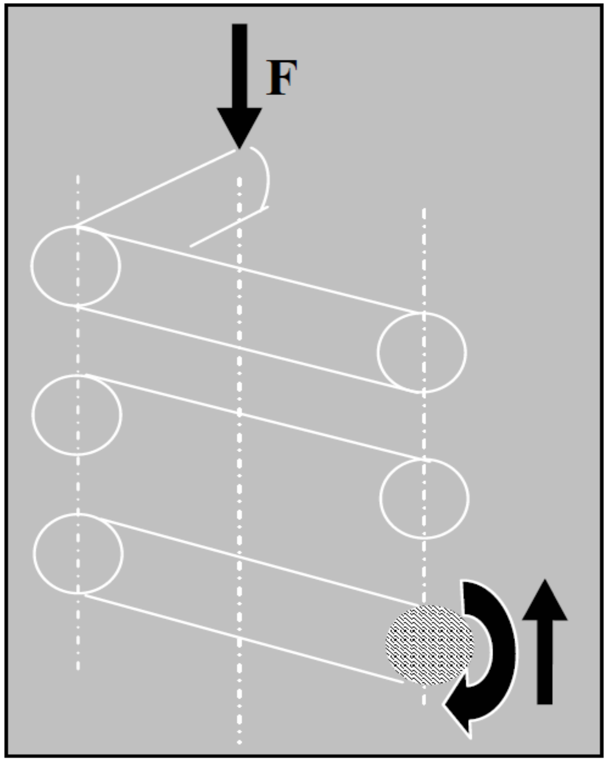
Torsion spring

Power spring

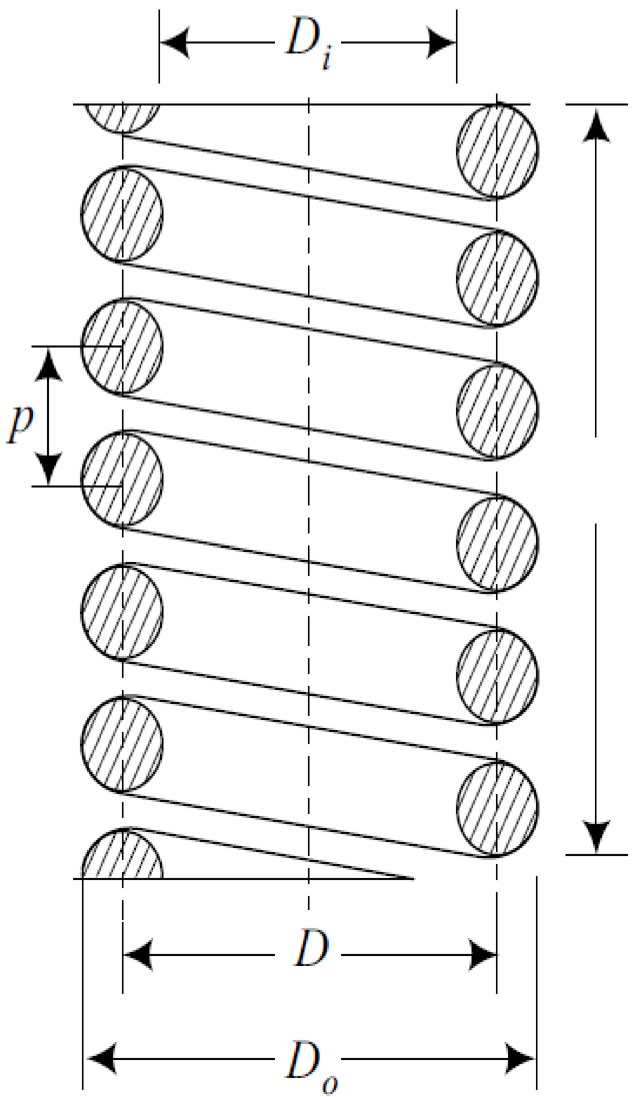
Helical spring

It is made of wire coiled in the form of helix having circular, square or rectangular cross





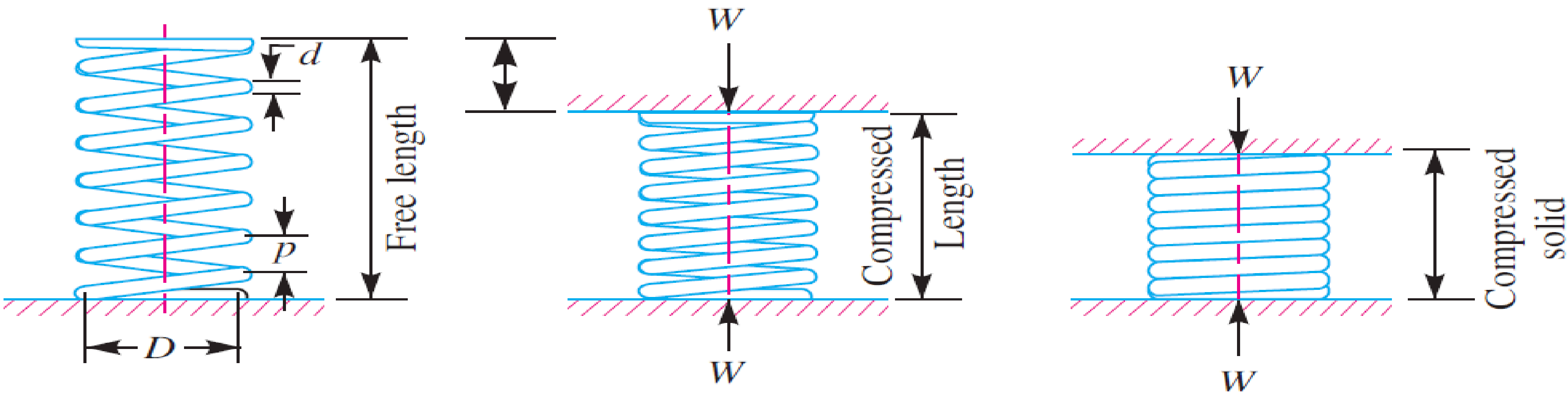
Terms used in Compression Springs



$$R = \text{Mean radius, mm}$$
$$D_i = \text{inside diameter of coil, mm} = D - d$$
$$D_o = \text{outside diameter of coil, mm} = D + d$$
$$C = \text{spring index} = D/d.$$

Spring index indicates the relative sharpness of curvature
If C low value: Stresses excessive due to curvature effect
If C high: Prone to buckling
C: 6-9 is preferred

- *D* = Mean diameter of the spring coil,
- *d* = Diameter of the spring wire,
- *N* = Number of active coils,
- *G* = Modulus of rigidity for the spring material,
- *F* = Axial load on the spring,
- τ = Maximum shear stress induced in the wire,
- *C* = Spring index = *D*/*d*,
- *p* = Pitch of the coils, and
- δ = Deflection of the spring, as a result of an axial load *F*.



1. ***Solid length*.** When the compression spring is compressed until the coils come in contact with each other, then the spring is said to be ***solid*.** The solid length of a spring is the product of total number of coils and the diameter of the wire.

S.L. = $N_t\ d$ N_t = total no. of coil

2. Free length : The free length of a compression spring, as shown in Fig, is the length of the spring in the free or unloaded condition. It is equal to the solid length plus the maximum deflection or compression of the spring and the clearance between the adjacent coils (when fully compressed).

Free length of the spring,

FL = Compressed length + δ = Solid length + Maximum compression +Clearance

3 . Compressed length: The axial length of the spring which is subjected to maximum compressive force .

4. *Pitch*. The pitch of the coil is defined as the axial distance between adjacent coils in uncompressed state.

p = $\frac{FL}{N_t - 1}$

Stiffness of the spring of Spring rate or spring constant **(k)**: The spring rate is defined as the load required per unit deflection of the spring. Mathematically,

Spring rate, k = F / δ

where W = Load, and

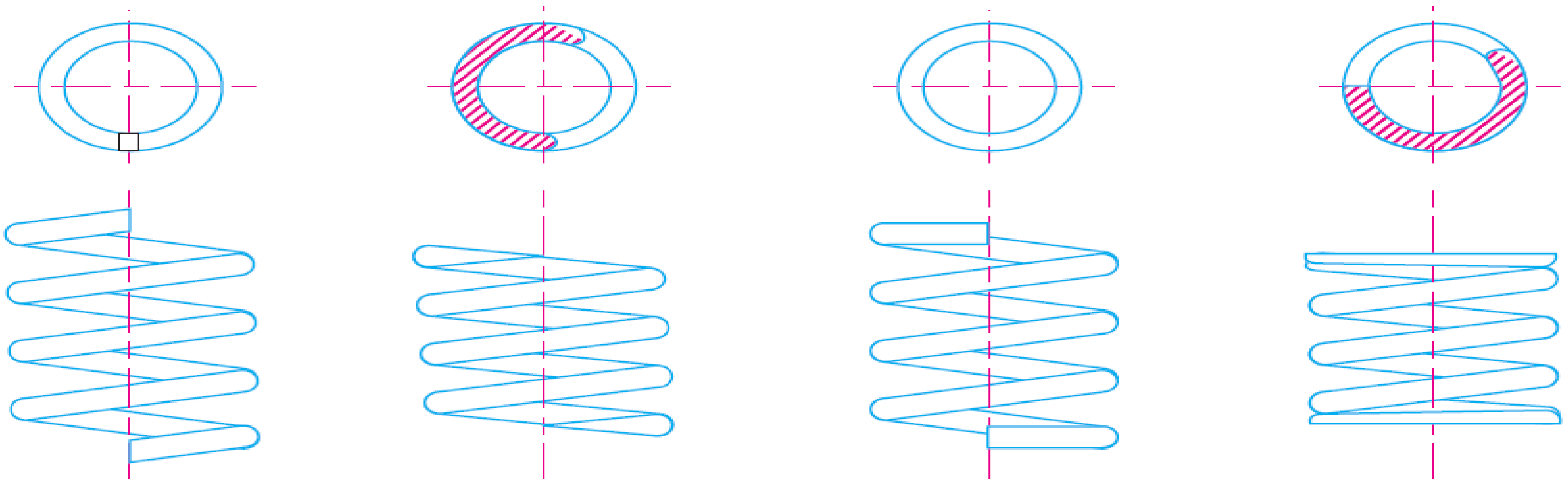
δ = Deflection of the spring.

Active (N) and inactive coils: Active coils are the coils in the spring which contribute to spring action, support the external force and deflect under the action of force.

End coils which do not contribute to spring action are called inactive coils.

inactive coils = $N_t - N$ N = No. of active coils

End Connections for Compression Helical Springs

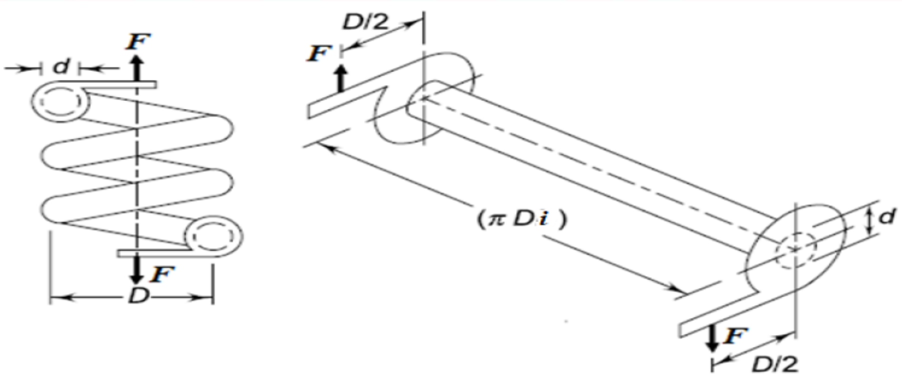


(a) Plain ends. (b) Ground ends. (c) Squared ends. (d) Squared and ground ends.

End Style	No. of Active turns N
Plain ends	N_t
Plain and Ground ends	$N_t - 1/2$
Ground ends	N_t
Squared ends	$N_t - 2$
Squared and ground ends	$N_t - 2$

STRESS AND DEFLECTION EQUATIONS

There are two basic equations for the design of helical springs viz. load-stress equation and load deflection equation.



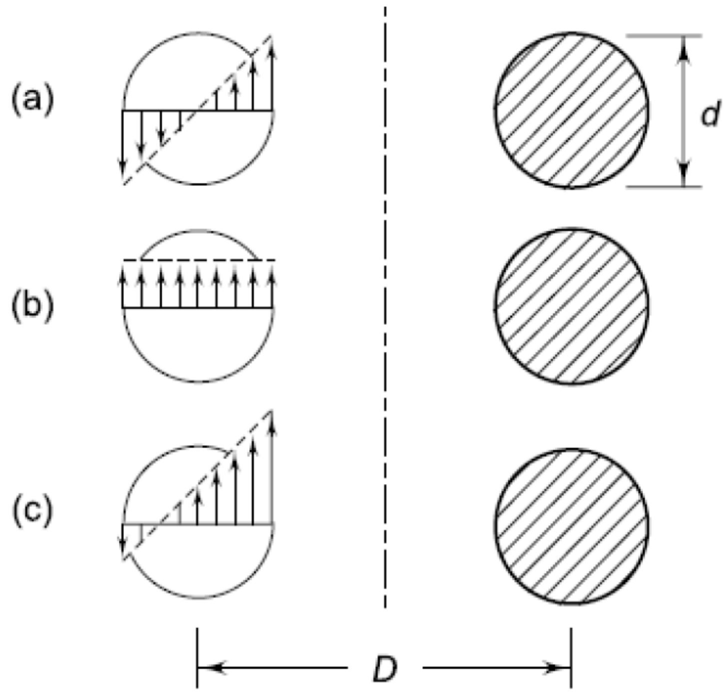
Two basic equations for the design of helical springs

- Load-stress equation
- Load-deflection equation

Dimensions

- The diameter of the bar is equal to the wire diameter of the spring (d)
- The length of the equivalent bar is $(\pi D i)$
- Bar is fitted with bracket of length (D/2)

Stresses in spring wire



Pure torsional stress

Direct shear stress

Combined torsional, direct and curvature shear stress

The force P acting at the end of the bracket induces torsional shear stress in the bar. The torsional

$$M_t = FD/2$$

The torsional shear stress in the bar is given by,

$$\tau_1 = \frac{16M_t}{\pi d^3} = \frac{16 \ FD/2}{\pi d^3}$$

$$\tau_1 = \frac{8FD}{\pi d^3}$$

When the equivalent bar is bent in the form of helical coil, there are additional stresses on account of following two factors:

i) There is a direct or transverse shear stress in the spring wire.

(i) When the bar is bent in the form of coil, the length of the inside fiber is less than the length of outside fiber. This results in stress concentration at the inside fiber of the coil.

the direct shear stress in the bar is given by,

$$\tau_2 = \frac{F}{\frac{\pi}{4}d^2} = \frac{8FD}{\pi d^3}\left(\frac{0.5D}{d}\right)$$

$$\tau = \tau_1 + \tau_2 = \frac{8FD}{\pi d^3}\left(1 + \frac{0.5D}{d}\right)$$

$$K_s = \left(1 + \frac{0.5d}{D}\right)$$

K_s = shear stress correction factor

$$K_s = \left(1 + \frac{0.5}{C}\right)$$

$$\boldsymbol{\tau = K_s \frac{8FD}{\pi d^3}}$$

K_s= factor to account for direct shear stress

K_c = factor to account for stress concentration due to curvature effect

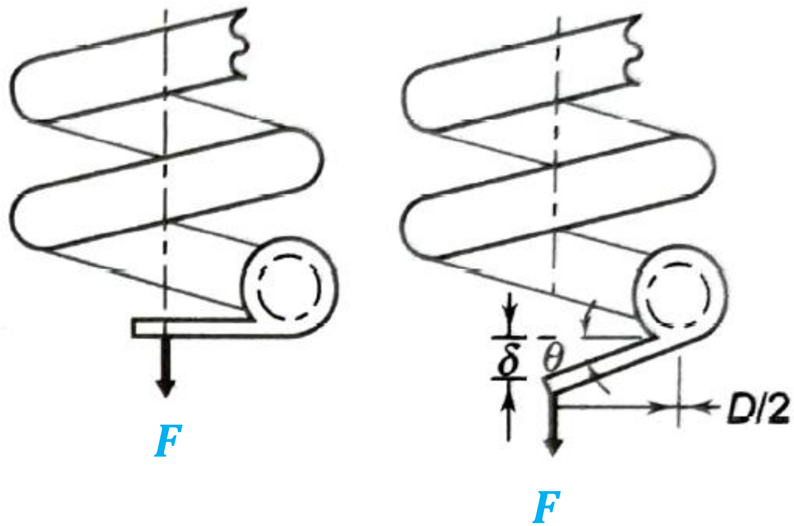
The combined effect of these two factors is given

$K_w = K_s K_c$ where K_w is called stress factor or Wahl factor is given by,

$$K_w = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

In normal applications, the spring is designed by using Wahl factor.
When the spring is subjected to fluctuating stresses, two factors K_s, and K_c are separately used.

Load-Deflection Equation



$$\delta = \frac{8FD^3N}{Gd^4} \qquad k = \frac{Gd^4}{8D^3N}$$

Helical Spring: Design Procedure

- Estimate spring force (F) and required deflection (y), In some cases it will be specified
- Select suitable material, Obtain permissible shear stress, τ=0.5Sut
- Assume spring index value C
- Calculate Wahl factor,
- Determine wire diameter from load-stress equation, d
- Determine coil diameter, D
- Determine number of active coils, by load deflection equation
- Determine total number of coils, it,
- Determine solid length of the spring,
- Find actual deflection, y by load-deflection equation and also free length (Assuming suitable gaps)
- Obtain pitch of the coil, p
- Determine actual spring rate, k