MEE-S307
Design Of Machine Elements

Design of Springs

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Strength of Spring Materials

- With small wire diameters, strength is a function of diameter.
- A graph of tensile strength vs. wire diameter is almost a straight line on log-log scale.
- The equation of this line is
- $S_{ut} = \frac{A}{d^m}$
- where *A* is the intercept and *m* is the slope.
- Values of *A* and *m* for common spring steels are given in

Design of Helical Springs for Variable Load

- The helical springs subjected to fatigue loading are designed by using the **Soderberg line method**.

- The spring materials are usually tested for torsional endurance strength under a repeated stress that varies from zero to a maximum.

- Since the springs are ordinarily loaded in one direction only (the load in springs is never reversed in nature), therefore a modified Soderberg diagram is used for springs.

P_{max} and P_{min} in load cycle .

Spring subjected to an external fluctuating load .

$$P_m = \frac{1}{2}(P_{max} + P_{min})$$

$$P_a = \frac{1}{2}(P_{max} - P_{min})$$

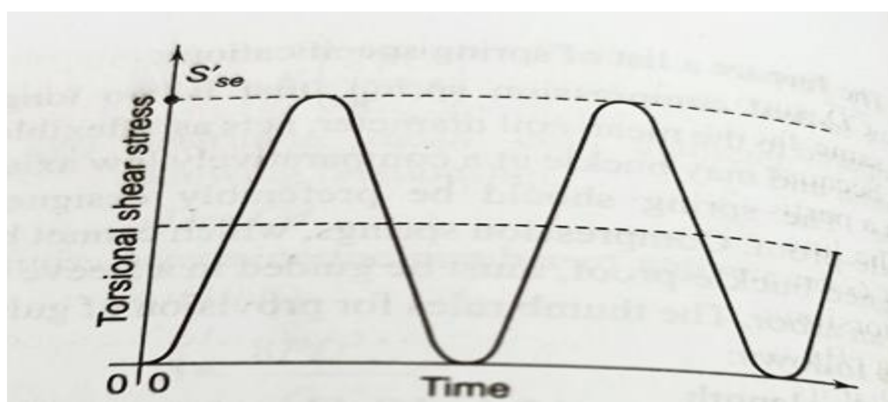
$$\tau_m = K_s \frac{8 P_m D}{\pi d^3}$$ where $$K_s = (1 + \frac{0.5}{C})$$

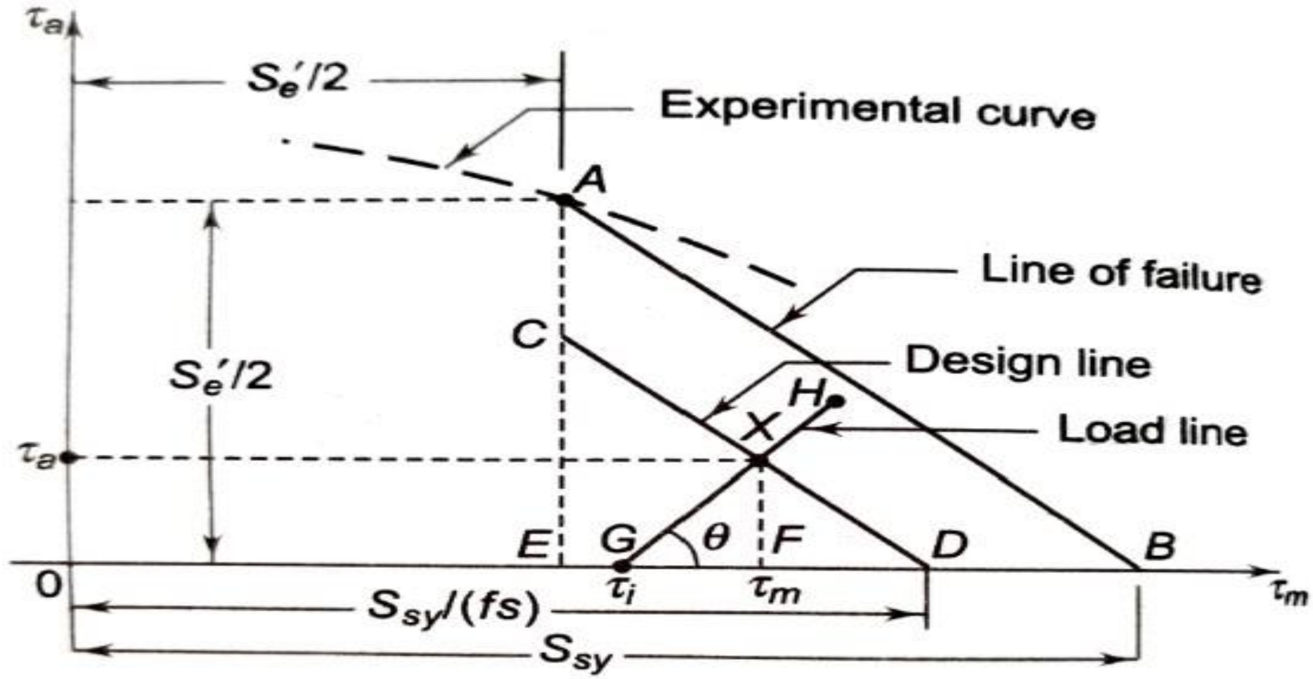
(K_s Stress correction factor for direct shear stress and it is applicable to mean stress only)

$$\tau_a = K_c K_s \frac{8P_a D}{\pi d^3} = K\frac{8P_a D}{\pi d^3}$$

A helical spring never subjected to completely reversed load Changing in magnitude from tension to compression and passing through zero with respect to time .

- Helical spring completely subjected to purely compressive force .
- Extension spring completely subjected to purely tension force
- In general spring wire is subjected to pulsating shear stress which is vary from zero to S'_{se} (endurance limit in shear stress)





Fatigue Diagram for Spring Design

- Point A indicate the Failure point of spring wire in fatigue .
- Point B indicate the failure under static condition when the $\tau_m$reaches the torsional shear strength (S_{sy})
- AB line called line of failure
- Any point on line CD such as "X" represent a stress situation with same FoS
- Line CD called design line because it is used to fined out the permissible stress with particular FoS.
- Line GH load line.

$$\frac{\tau_a}{\frac{S_{sy}}{FoS} - \tau_m} = \frac{\frac{1}{2} S'_{se}}{S'_{sy} - \frac{1}{2} S'_{se}}$$

Used when Helical Springs subjected to Variable Load .

Surge in Spring

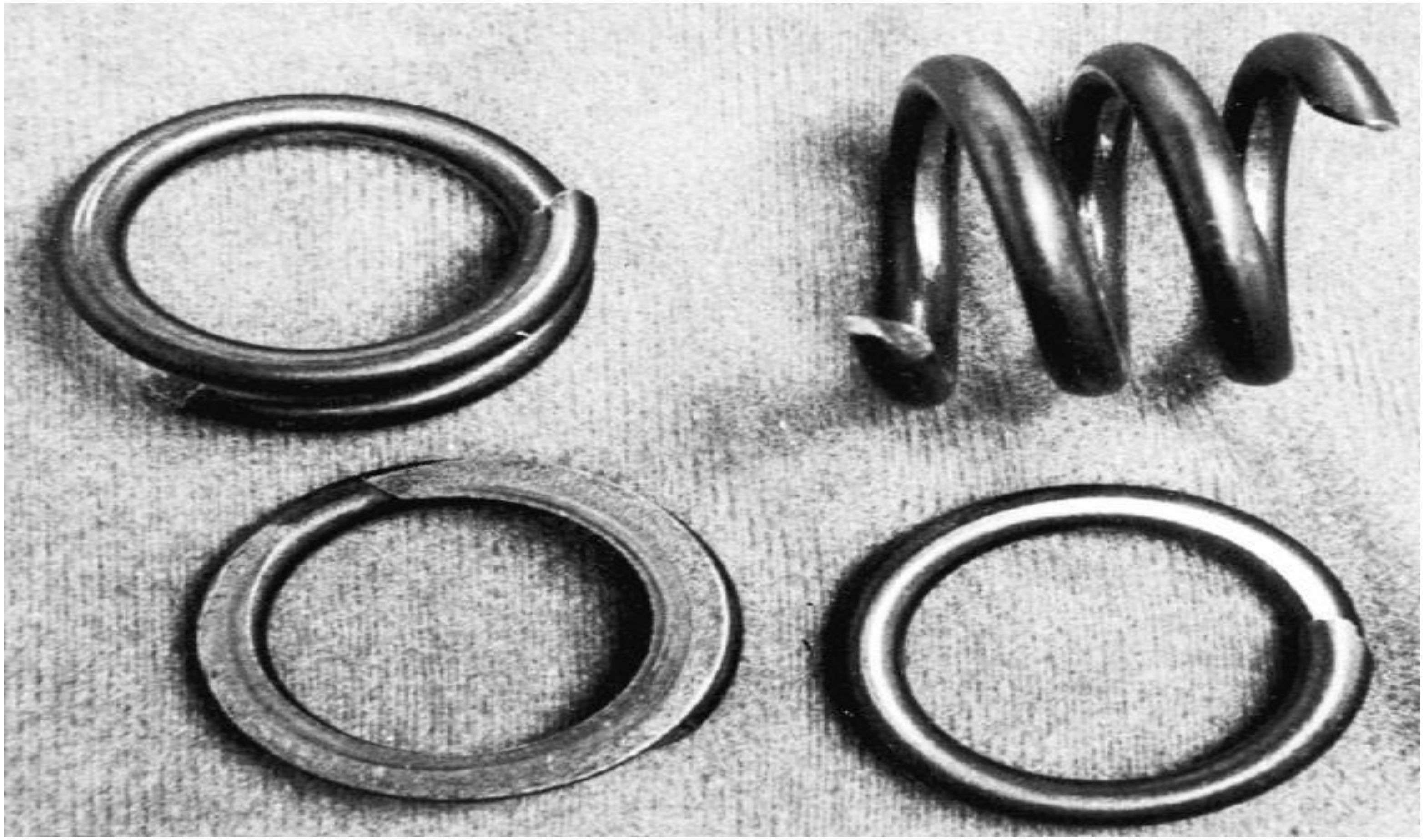
- Natural frequency of vibration of spring coincides with the frequency of external periodic force, resonance occurs
- Spring is subjected to a wave of successive compressions that travels from one end to other and back which is termed as surge
- Load is transmitted by transferring compression to adjacent coils
- If the onward and backward travel time coincides with exiting frequency, resonance occurs
- Natural frequency of helical compression springs (between two parallel plates)

$$\omega = \frac{1}{2}\sqrt{\frac{k}{m}}$$

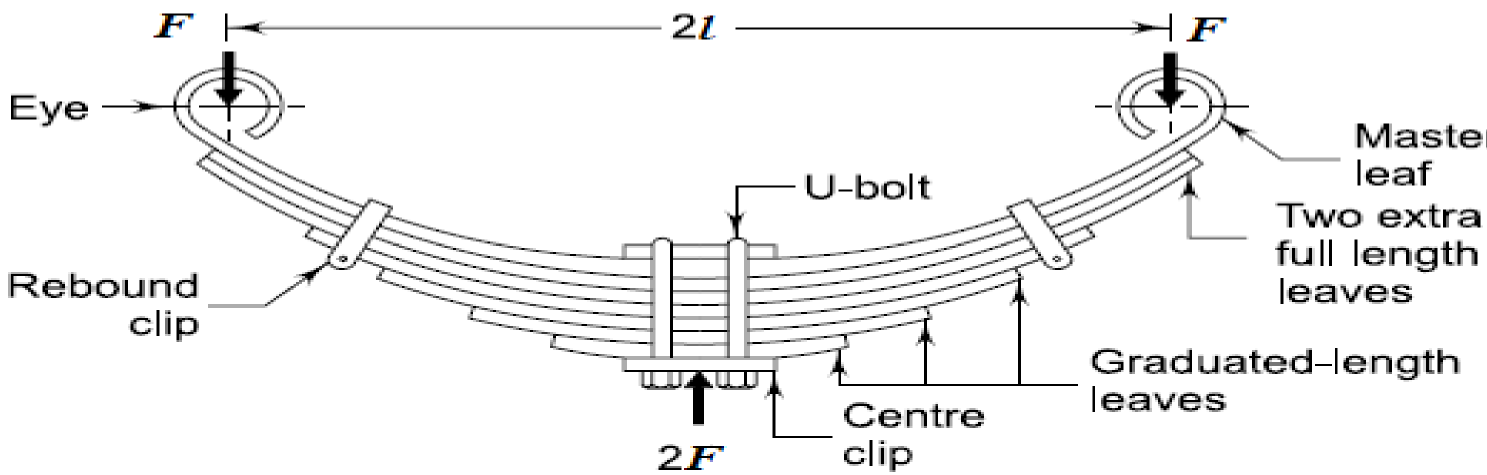
m = mass of spring (kg) (m= Alρ)

k = stiffness of spring (N/m)

Catastrophic failure may occur, as shown in this valve-spring from an over-revved engine.

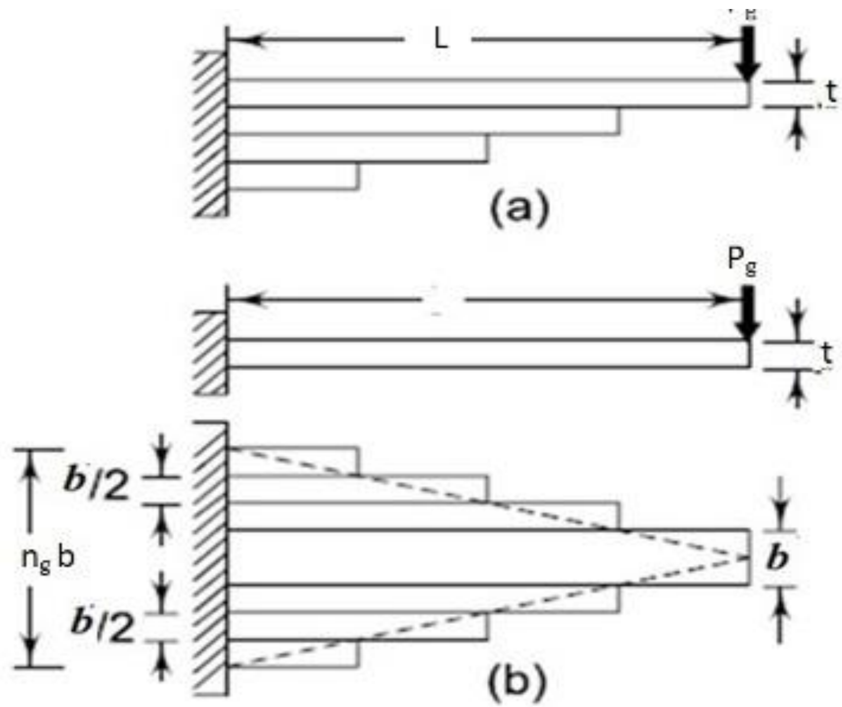


Leaf Spring



- Consists of flat plates/ leaves
- Longest leaf at top is called master leaf
- Bent at the end to form spring eyes
- U bolt and center clip to hold the leaf together
- Master leaf, extra full length leaf, graduated leaf

Leaf Springs: Graduated leaves



Load-Stress equation

$$\sigma_{(b)g} = \frac{6P_gL}{n_gbt^2}$$

Deflation equation

$$\delta_g = \frac{6P_gL}{E\,n_gbt^3}$$

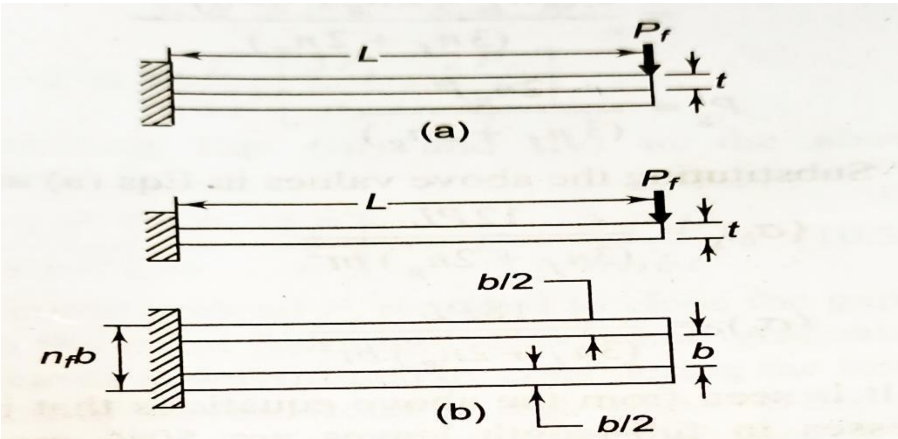
$n_g =$ *no. of graduated length leaves including master leaf*

b = *width of each leaf (mm)*

t = *thickness of each leaf (mm)*

L = *length of cantilever of leaf of the semi elliptic spring (mm)*

Leaf Springs: Extra full length leaves



Load-Stress equation

$$\sigma_{(b)f} = \frac{6P_fL}{n_f b t^2}$$

Deflation equation

$$\delta_f = \frac{4P_fL}{E\,n_f b t^3}$$

$n_f =$ $no. of\ graduated\ length\ extra\ full\ length$ leaves
$b =$ *width of each leaf (mm)*
$t =$ *thickness of each leaf (mm)*
$L =$ *length of cantilever of leaf of the semi elliptic spring (mm)*

Since the deflection of full length leaves is equal to the deflection of graduated length leaves

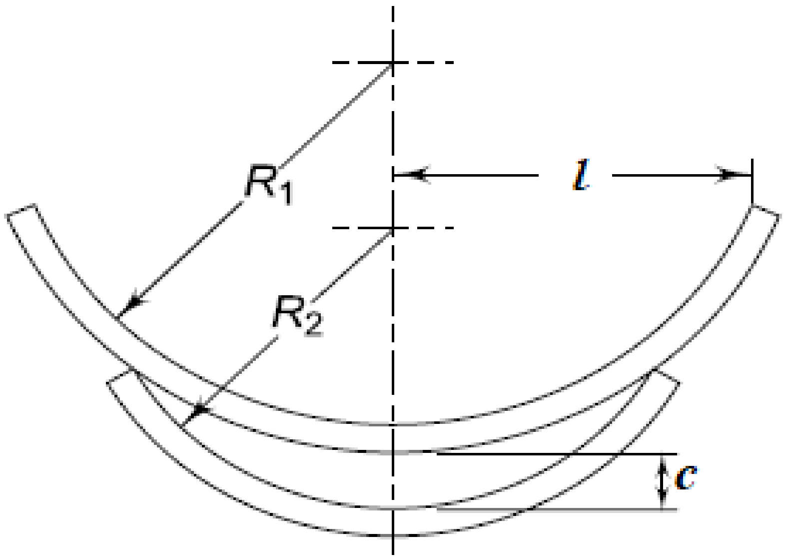
$\delta_f = \delta_g$ and $P_g + P_f$ = P

$$\sigma_{(b)g} = \frac{12PL}{(3\,n_f + 2\,n_g)\,bt^2}$$

$$\sigma_{(b)f} = \frac{18PL}{(3\,n_f + 2\,n_g)\,bt^2}$$

$$\delta = \frac{12PL^3}{(3\,n_f + 2\,n_g)\,Ebt^3}$$

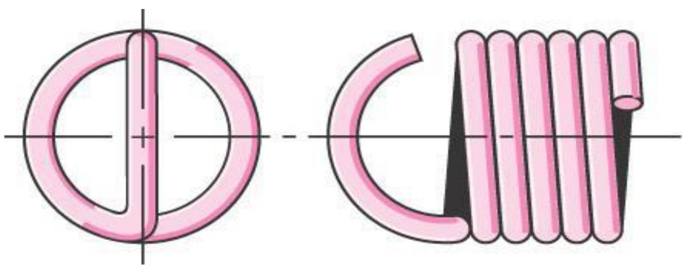
Nipping of leaf springs



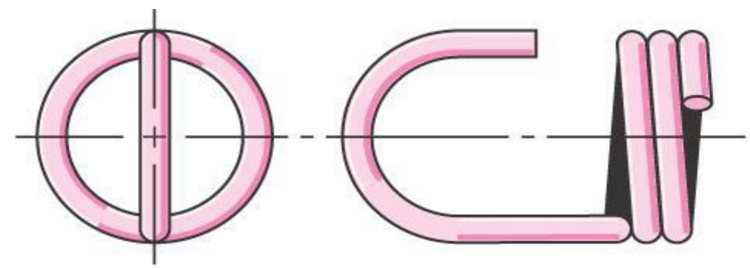
- Pre-stressing by bending leaves to a different radii
- Initial gap between full length leaf and graduated length leaf before the assembly is called nip

Extension Springs

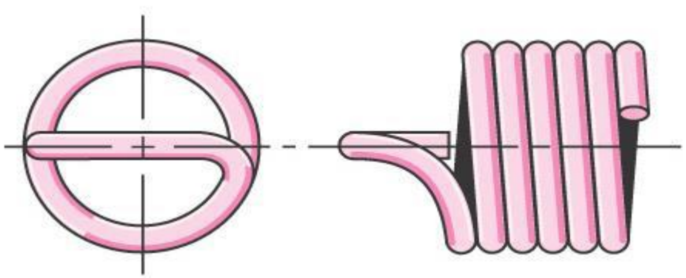
- Extension springs are similar to compression springs within the body of the spring.
- To apply tensile loads, hooks are needed at the ends of the springs.
- Some common hook types:



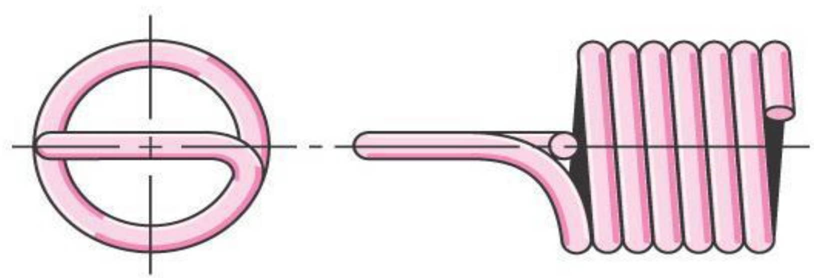
(*a*) Machine half loop–open



(*b*) Raised hook



(*c*) Short twisted loop



(*d*) Full twisted loop