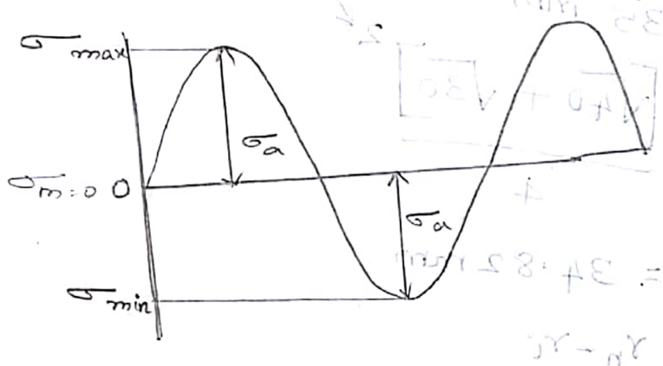
Variable Stresses.

The load in which the magnitude and direction changes with respect to time
(eg) Axle Shaft, Crank shaft, Connecting rod, Springs, Pinion Teeth etc.

Types

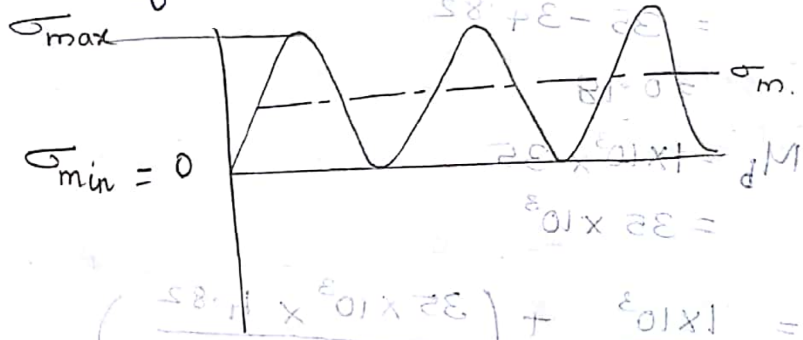
Reversed or Cyclic Stress

The stress that varies from one value of tensile to the same value of compression.

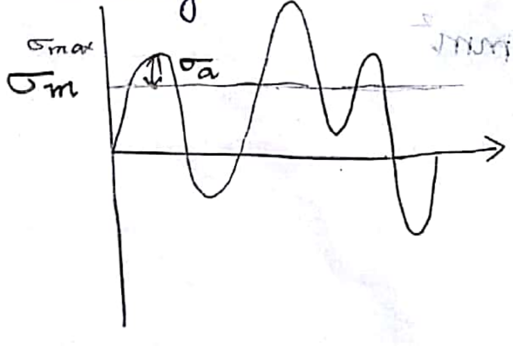


Repeated Stress :-

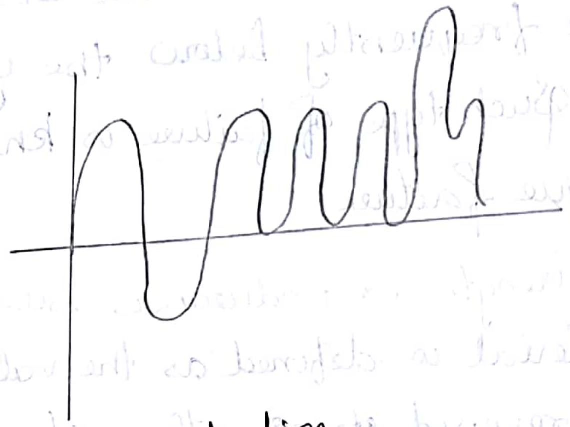
The stress which varies from zero to maximum value of same nature



Fluctuating Stress



Alternative stress.



Stress Concentration

Stress Concentration Factor:-

Whenever sudden change in cross section the maximum stress will induce. The ratio of Maximum stress to the normal stress is called as stress concentration factor.

$$(K_t) = \frac{\sigma_{max}}{\sigma_o}$$

Variable Loading (Fatigue stress)

Method to avoid stress Concentration

Avoid sharp edges.

Fatigue Failure

The load which varies in magnitude or direction with respect to time is known as fatigue or fluctuating or alternative load.

The variable stress induced in the component are known as fluctuating load.

The mechanical component subjected to fluctuating load, it fail at stress considerably below the ultimate strength and quite frequently below the yield strength. Such type of failure is known as fatigue failure

Fatigue Strength or Endurance Strength of a material is defined as the value of completely reversed stress, the standard test specimen can withstand without failure for a given number of cycles

Endurance limit or Fatigue limit :-

It is defined as maximum value of completely reversed test the standard test specimen can withstand without failure to an infinite number of cycles.

Sn curve used to find the endurance limit

σ_1 - endurance limit

Soderberg Relationship

$$\frac{\sigma_m}{\sigma_y} + \frac{\sigma_a}{\sigma_e} = 1/n$$

Goodman

$$\frac{\sigma_m}{\sigma_u} + \frac{\sigma_a}{\sigma_e} = 1/n.$$

Gerber

$$\left(\frac{\sigma_m}{\sigma_u}\right)^2 n + \frac{\sigma_a}{\sigma_e} = 1/n$$

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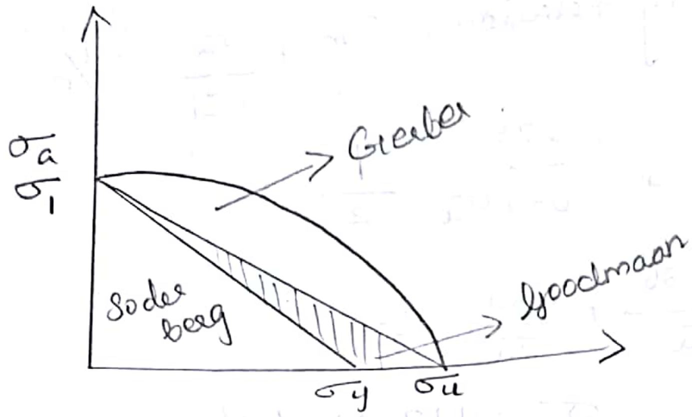
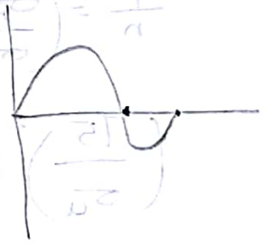


Most preferable Goodmaan

1. Machine component is subjected to fluctuating stress which have fluctuating between 300 MN/m² and −150 MN/m². Determine the value of maximum ultimate strength according to Gerber relationship, Goodmaan relationship, Soderberg relationship. Take $\sigma_y = 0.55$ ultimate strength. $\sigma_{-1} = 0.5\,\sigma_u$

FOS = 2.

Given :-



$\sigma_{max} = 300\ MN/m^2$

$\sigma_{min} = -150\ MN/m^2$

$\sigma_y = 0.55\,\sigma_u$

$\sigma_{-1} = 0.5\,\sigma_u$

$n = 2$.

Soln :-

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$= \frac{300 - 150}{2} = 75\ MN/m^2.$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{300 + 150}{2}$$

$$= 225\ MN/m^2.$$

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Soderberg Relation. $\frac{\sigma_m}{\sigma_y} + \frac{\sigma_a}{\sigma_{-1}} = 1/n$.

$$\frac{75}{0.55\,\sigma_u} + \frac{225}{0.5\,\sigma_u} = \frac{1}{2}.$$

$$\frac{136.36}{\sigma_u} + \frac{450}{\sigma_u} = \frac{1}{2}.$$

$$\sigma_u = 1172 \text{ MN/m}^2.$$

Goodmann Relation

$$\frac{\sigma_m}{\sigma_u} + \frac{\sigma_a}{\sigma_{-1}} = 1/n.$$

$$\frac{75}{\sigma_u} + \frac{225}{0.5\,\sigma_u} = \frac{1}{2}.$$

$$\sigma_u = 1050 \text{ MN/m}^2$$

Gerber Relationship

$$\frac{1}{n} = \left(\frac{\sigma_m}{\sigma_u}\right)^2 n + \frac{\sigma_a}{\sigma_{-1}}$$

$$\left(\frac{75}{\sigma_u}\right)^2 \times 2 + \frac{225}{0.5\,\sigma_u} = \frac{1}{2}.$$

$$\frac{11250}{\sigma_u^2} + \frac{450}{\sigma_u} = \frac{1}{2}.$$

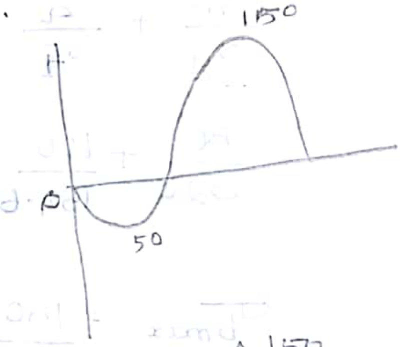
$$2(11250 + 450\,\sigma_u) = \sigma_u^2$$

$$22500 + 900\,\sigma_u = \sigma_u^2.$$

$$\sigma_u^2 - 900\,\sigma_u - 22500 = 0.$$

$$\sigma_u = 924 \text{ MN/m}^2$$

2. A cantilever beam of circular cross section is subjected to cyclic load (bending moment) varies from −50 N to 150 N. Determine the diameter of rod by i) Goodmann relationship ii) Soderberg relationship. Use the following data. Ultimate strength = 550 MPas Yield strength = 320 MPas Endurance limit = 275 MPas. Size correction factor = 0.85. Surface correction factor = 0.9 Theoretical stress Concentration = 1.4. Notch sensitivity factor = 0.9. Factor of safety = 2.



Soln :-

$\sigma_u = 550$ MPas.

$\sigma_y = 320$ MPas.

$\sigma_{-1}' = 275$ MPas.

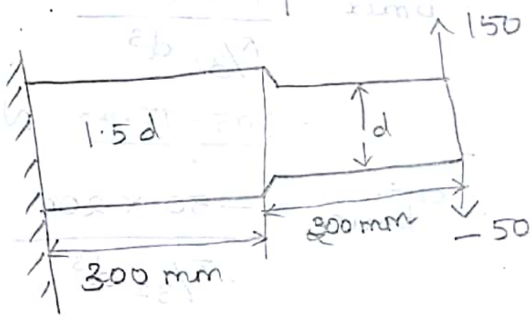
$K_{sz} = 0.85$

$K_{SF} = 0.9$

$K_t = 1.4$

$q = 0.9.$

$n = 2$



$$\sigma_{-1} = \frac{\sigma_{-1}' \times K_L \times K_R \times K_{sz} \times K_{SF} \times K_t}{K_f.}$$

$$K_f = 1 + q(K_t - 1)$$

$$= 1 + 0.9(1.4 - 1)$$

$$= 1.36$$

$$\sigma_{-1} = \frac{275 \times 1 \times 1 \times 0.85 \times 0.9}{1.36}.$$

$$= 154.68 \text{ MPa}$$

$$\sigma_m = \frac{150-50}{2}$$

$$= 50 \text{ MPas}$$

$$\sigma_a = \frac{150+50}{2}$$

$$= 100 \text{ MPas.}$$

Soderberg

$$\frac{\sigma_m}{\sigma_y} + \frac{\sigma_a}{\sigma_f} = \frac{1}{n}.$$

$$\frac{50}{320} + \frac{100}{154.68}$$

$$\sigma_{bmax} = \frac{150 \times 200}{\pi/32\, d^3}$$

$$= \frac{305577.45}{d^3} \text{ N/mm}^2$$

$$\sigma_{bmin} = \frac{-50 \times 200}{\pi/32\, d^3}.$$

$$= \frac{-101859.16}{d^3} \text{ N/mm}^2.$$

$$\sigma_{mean} = \frac{\sigma_{bmax} + \sigma_{bmin}}{2} = \frac{101859.14}{d^3}$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}.$$

$$\sigma_a = \frac{203718.325}{d^3} \text{ N/mm}^2$$

Soderberg Relationship.

$$\frac{1}{n} = \frac{\sigma_m}{\sigma_y} + \frac{\sigma_a}{\sigma_f}$$

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$$\Rightarrow \frac{1}{2} = \frac{\frac{101859.14}{d^3}}{320} + \frac{\frac{203718.325}{d^3}}{154.69}$$

$$\frac{1}{2} = \frac{318.3}{d^3} + \frac{1316.9}{d^3}$$

$$d^3 = 3270.49$$

$$d = 14.84 \text{ mm}$$

$$\frac{1}{n} = \frac{\sigma_m}{\sigma_u} + \frac{\sigma_a}{\sigma_{-1}}$$

$$\frac{1}{2} = \frac{\frac{101858.9}{d^3}}{550} + \frac{\frac{203718.325}{d^3}}{154.69}$$

$$d^3 = 3004.276$$

$$d = 14.42 \text{ mm}$$

1. The shaft subjected to bending moment varies from -200 Nm to 500 Nm and twisting moment varying from 50 Nm to 175 Nm. The material used is $\sigma_u = 600$ MPa, Endurance limit = 300 MPa, Surface finish factor = 0.8, Size correction factor = 0.76, Load factor = 0.897. Stress concentration factor = 1.85. Non sensitive factor = 0.95. Find diameter of shaft by using Vonmise Henze Theory. FOS = 1.5.

$\cancel{\sigma}$. $M_{b_{max}} = 500$ N-m

$M_{b\,min} = -200$ N·m.

$T_{max} = 175$ N·m

$T_{min} = 50$ N·m.

$$\sigma_{b\,max} = \frac{500 \times 10^3}{\pi/32\, d^3}$$

$$= \frac{5.093 \times 10^6}{d^3} \text{ N/mm}^2.$$

$$\sigma_{b\,min} = \frac{-200 \times 10^3}{\pi/32\, d^3}$$

$$= \frac{-2.037 \times 10^6}{d^3} \text{ N/mm}^2.$$

$$\sigma_{-1} = \frac{\sigma_{-1}' \times K_L \times K_K \times K_{sf} \times K_{sz}}{K_F}$$

$$= \frac{300 \times 1 \times 0.897 \times 0.76 \times 0.85}{1 + 0.95(1.85 - 1)}$$

$$= 96.20 \times \cancel{10^6} \text{ MPa}.$$

$$\sigma_{mean} = \frac{\sigma_{max} + \sigma_{min}}{2}$$

Assume $\sigma_y = 400$

$$= \frac{1.528 \times 10^6}{d^3} \text{ N/mm}^2.$$

$$\sigma_{eq} = \sigma_m + \frac{\sigma_a \sigma_y}{\sigma_{-1}}$$

$$= \frac{1.52}{d^3} + \frac{\frac{3.56}{d^3} \times 400}{95.45}$$

$$\sigma_{eq} = \frac{16.43}{d^3} \ N/mm^2.$$

$$\tau_{max} = \frac{16 T_{max}}{\pi d^3}.$$

$$= \frac{16 \times 175 \times 10^3}{\pi d^3}$$

$$= \frac{8.91 \times 10^5}{d^3} \ N/mm^2.$$

$$\tau_{min} = \frac{16 T_{min}}{\pi d^3}$$

$$= \frac{2.54 \times 10^5}{d^3} \ N/mm^2.$$

$$\tau_{mean} = \frac{\tau_{max} - \tau_{min}}{2}$$

$$= \frac{3.18 \times 10^5}{d^3} \ N/mm^2$$

$$\tau_{eq} = \tau_m + \frac{\tau_a \tau_y}{\tau_{-1}}$$

$\tau_1 = \sigma_{-1}$

$\tau_y = 0.6\sigma_y$

$= 400 \times 0.6$

$= 240$

$$= \frac{5.72 \times 10^5}{d^3} + \frac{\frac{3.18 \times 10^5}{d^3} \times \boxed{240}}{95.45}$$

$$= \frac{13.71 \times 10^5}{d^3} \ N/mm^2.$$

$$= \frac{1.371 \times 10^6}{d^3} \ N/mm^2$$

$$\sigma_1 = \frac{1}{2}\left[\sigma_{eq} + \sqrt{(\sigma_{eq})^2 + 4(\tau_{eq})^2}\right]$$

$$\sigma_1 = \frac{1368.0 \times 10^3}{d^3}$$

$$\frac{1368 \times 10^3}{d^3} = 400$$

$$d^3 = 3420.02$$

$$d = 15.067 \text{ mm}$$