Machine Design-I

(Session-2018-19)

Numericals on Fluctuating Stresses

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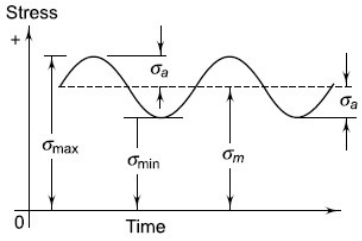
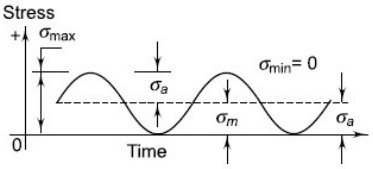
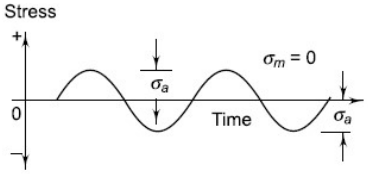
Numericals Continued on Fluctuating Stresses



(a) Fluctuating stresses

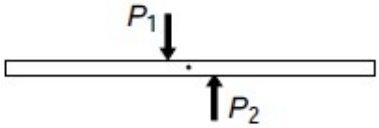


(b) Repeated stresses

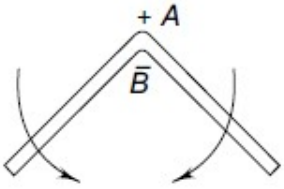


(c) Reversed stresses

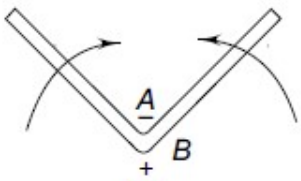
Example



(a)

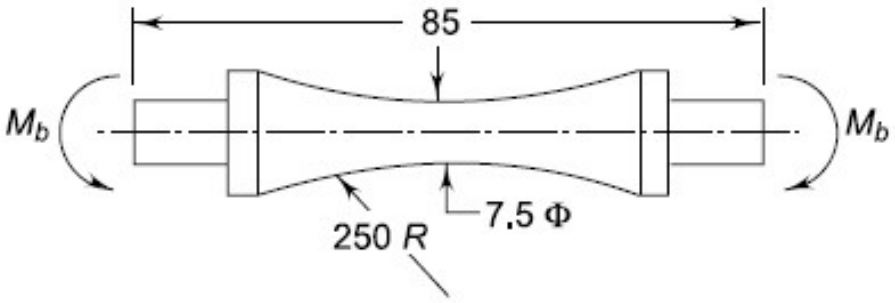


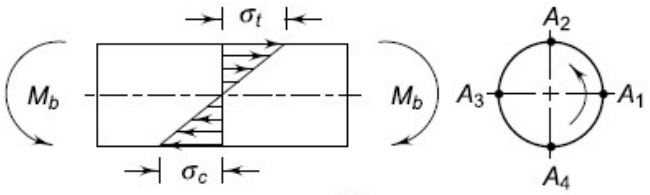
(b)



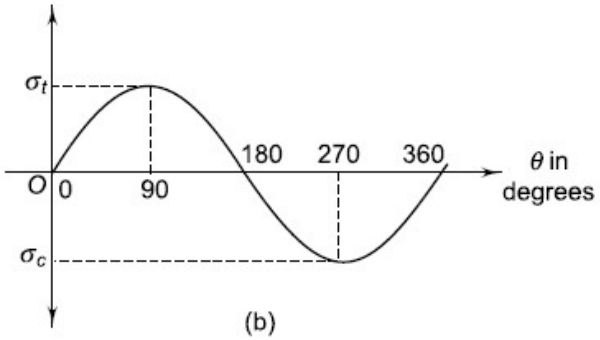
(c)

Specimen for Fatigue Test





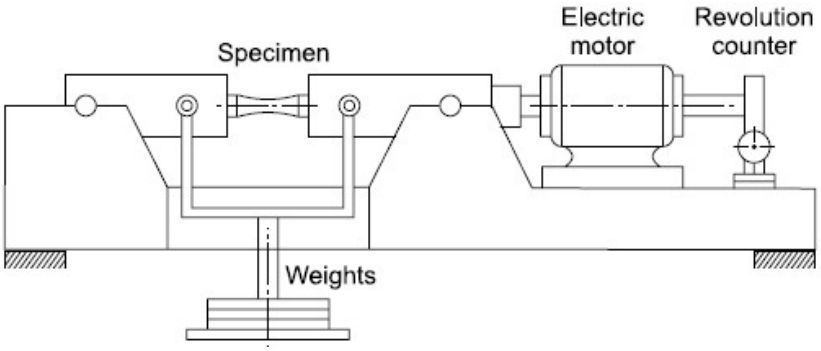
(a)



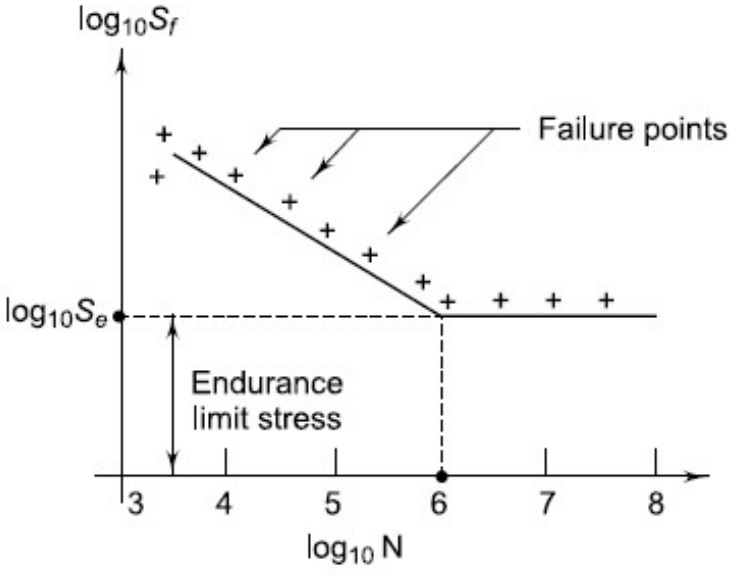
(b)

Rotating Beam Subjected to Bending Moment: (a) Beam, (b) Stress Cycle at Point A

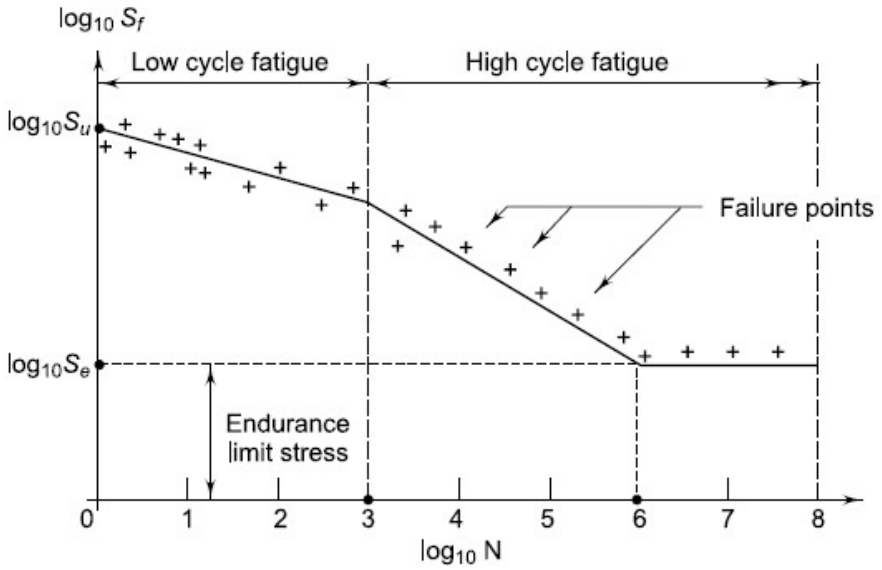
Rotating Beam fatigue testing Machine



S-N Curve for Steels



Low Cycle and High Cycle Fatigue



Fatigue Stress Concentration Factor

$$K_f = \frac{\text{Endurance limit of the notch free specimen}}{\text{Endurance limit of the notched specimen}}$$

Fatigue Stress Concentration Factor

Notch sensitivity is defined as the susceptibility of a material to succumb to the damaging effects of stress raising notches in fatigue loading. The notch sensitivity factor q is defined as

$$q = \frac{\text{Increase of actual stress over nominal stress}}{\text{Increase of theoretical stress over nominal stress}}$$

Endurance Limit Approximate Estimation

$$S_e = K_a K_b K_c K_d S'_e$$

where,

K_a = surface finish factor
K_b = size factor
K_c = reliability factor
K_d = modifying factor to account for stress concentration.

Surface Finish Factor

Surface finish	*a*	*b*
Ground	1.58	–0.085
Machined or cold-drawn	4.51	–0.265
Hot-rolled	57.7	–0.718
As forged	272	–0.995

Size Factor

Diameter (d) (mm)	K_b
$d \leq 7.5$	1.00
$7.5 < d \leq 50$	0.85
$d > 50$	0.75

Reliability Factor

Reliability R (%)	K_c
50	1.000
90	0.897
95	0.868
99	0.814
99.9	0.753
99.99	0.702
99.999	0.659

Modifying Factor

$$K_d = \frac{1}{K_f}$$

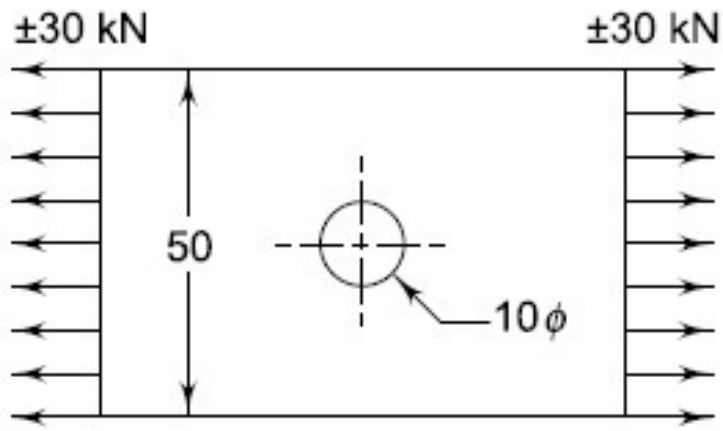
Axial Loading

$$(S_e)_a = 0.8\, S_e$$

Infinite Life Problems

Example 5.3 *A plate made of steel 20C8 (S_{ut} = 440 N/mm^2) in hot rolled and normalised condition is shown in Fig. 5.28. It is subjected to a completely reversed axial load of 30 kN. The notch sensitivity factor q can be taken as 0.8 and the expected reliability is 90%. The size factor is 0.85. The factor of safety is 2. Determine the plate thickness for infinite life.*

Ans : t = 36.84 mm



Finite Life Problems

Example 5.6 *A rotating bar made of steel 45C8 (S_{ut} = 630 N/mm^2) is subjected to a completely reversed bending stress. The corrected endurance limit of the bar is 315 N/mm^2. Calculate the fatigue strength of the bar for a life of 90,000 cycles.*

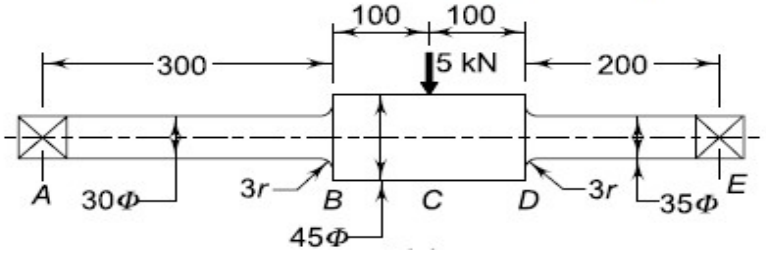
Ans : $S'_f = 386.63$ N/mm^2

Finite Life Problem for Practice

Example 5.7 *A forged steel bar, 50 mm in diameter, is subjected to a reversed bending stress of 250 N/mm^2. The bar is made of steel 40C8 (S_{ut} = 600 N/mm^2). Calculate the life of the bar for a reliability of 90%.*

Ans : 23 736.2 cycles

Example 5.8 *A rotating shaft, subjected to a non-rotating force of 5 kN and simply supported between two bearings A and E is shown in Fig. 5.32(a). The shaft is machined from plain carbon steel 30C8 (S_{ut} = 500 N/mm^2) and the expected reliability is 90%. The equivalent notch radius at the fillet section can be taken as 3 mm. What is the life of the shaft?*

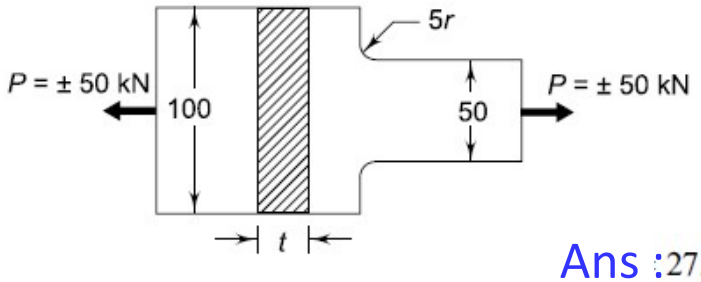


Ans : N = 15958.79 cycles

Example 5.4 *A rod of a linkage mechanism made of steel 40Cr1 (S_{ut} = 550 N/mm^2) is subjected to a completely reversed axial load of 100 kN. The rod is machined on a lathe and the expected reliability is 95%. There is no stress concentration. Determine the diameter of the rod using a factor of safety of 2 for an infinite life condition.*

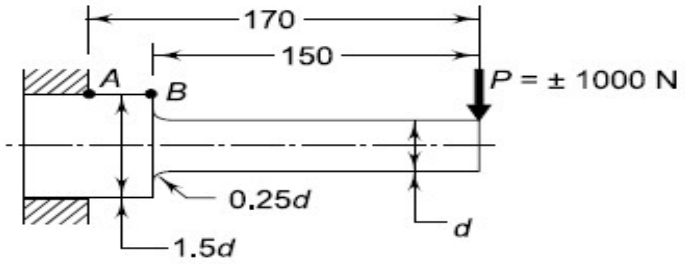
Ans : $d = 44.78$ mm

Example 5.5 *A component machined from a plate made of steel 45C8 (S_{ut} = 630 N/mm^2) is shown in Fig. 5.29. It is subjected to a completely reversed axial force of 50 kN. The expected reliability is 90% and the factor of safety is 2. The size factor is 0.85. Determine the plate thickness t for infinite life, if the notch sensitivity factor is 0.8.*



Ans :27.61mm

Example 5.10 *A cantilever beam made of cold drawn steel 20C8 (S_{ut} = 540 N/mm^2) is subjected to a completely reversed load of 1000 N as shown in Fig. 5.36. The notch sensitivity factor q at the fillet can be taken as 0.85 and the expected reliability is 90%. Determine the diameter d of the beam for a life of 10000 cycles.*



Ans : $d = 17.05$ mm

Cumulative Damage in Fatigue

Example 5.11 *The work cycle of a mechanical component subjected to completely reversed bending stresses consists of the following three elements:*

(i) $\pm 350\ N/mm^2$ *for 85% of time*
(ii) $\pm 400\ N/mm^2$ *for 12% of time*
(iii) $\pm 500\ N/mm^2$ *for 3% of time*

The material for the component is 50C4 (S_{ut} = $660\ N/mm^2$*) and the corrected endurance limit of the component is* $280\ N/mm^2$*. Determine the life of the component.*

Ans : $N = 62\ 723$ cycles