JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

DESIGN OF MACHINE ELEMENTS – II {6ME4-04}

UNIT – I

CO 1 :- To determine the finite and Infinite life of Mechanical Components due to fluctuating loads.

Contents :- Fatigue Considerations in Design : Variable load, loading pattern, endurance stresses, Influence of size, surface finish, notch sensitivity and stress concentration.

Goodman line, Soderberg line, Design of machine members subjected to combined, steady and alternating stresses.

Design for finite life, Design of shafts under Variable stresses, Bolts subjected to variable stresses.

Unit - 1

DME - II

Design against Fluctuating load

Syllabus :- Fatigue Considerations in Design : Variable load, loading pattern, endurance stresses, Influence of size, surface finish, notch sensitivity and stress concentration.

Goodman line, soderberg line, Design of machine members subjected to combined, steady and alternating stresses.

Design for finite life, design of shafts under variable stresses, bolts subjected to variable stresses.

Completely reversed or cyclic stresses :- The stresses which vary from one value of compressive to same value of tensile or vice versa are known as completely reversed or cyclic stresses.

fluctuating stresses :- The stresses which vary from a minimum value to a maximum value of the same nature, (i.e tensile or compressive) are called fluctuating stresses.

Repeated stresses :- The stresses which vary from zero to a certain maximum value are called repeated stresses.

Alternating stresses :- The stresses which vary from a minimum value to a maximum value of the opposite nature (i.e from a certain minimum compressive to a certain maximum tensile or from a minimum tensile to a maximum compressive) are called alternating stresses.

Stress Concentration :- Stress Concentration is defined as the localization of high stresses due to the irregularities present in the component and abrupt changes of the cross-section.

In order to consider the effect of the stress concentration and find out localized stresses, a factor called 'stress concentration factor' is used. It is denoted by K_t and defined as,

$$K_t = \frac{\text{Highest value of actual stress near discontinuity}}{\text{Nominal stress obtained by elementary equations for minimum cross-section}}$$

$$K_t = \frac{\sigma_{max}}{\sigma_0} = \frac{\tau_{max}}{\tau_0}$$

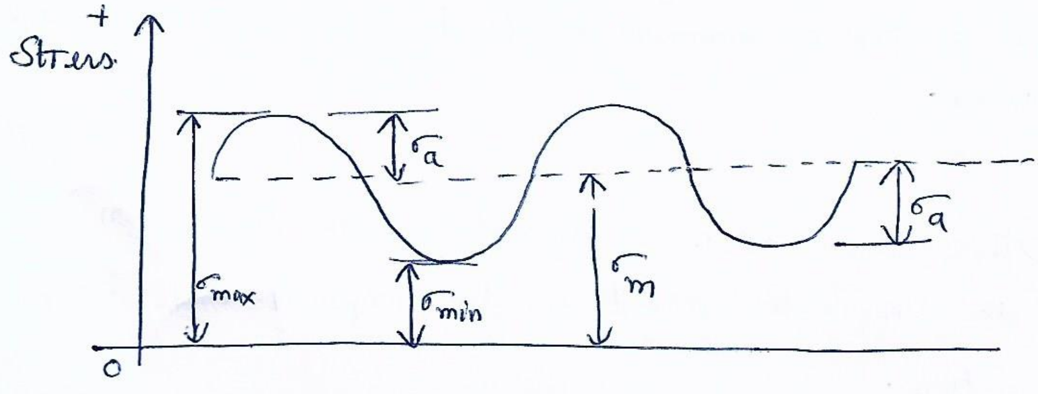
The causes of stress concentration are as follows :-

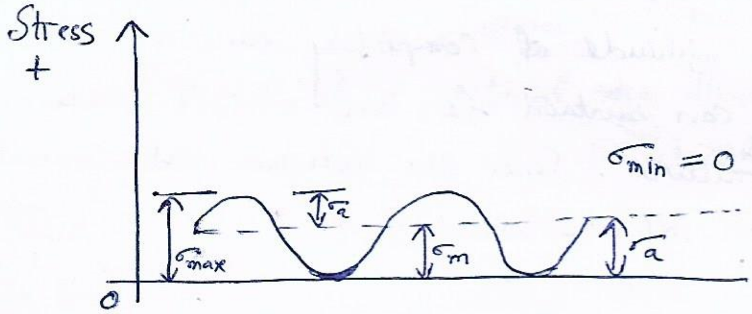
(i) Variation in properties of materials
(ii) Load application
(iii) Abrupt changes in section
(iv) Discontinuities in the component.
(v) Machining scratches.

Reduction of stress Concentration :-

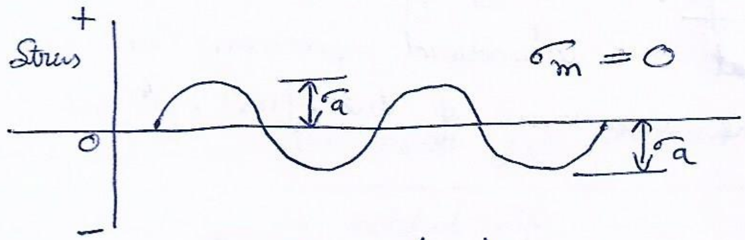
(i) Additional notches and holes in tension members.
(ii) Providing fillet radius, undercutting and notch for member in bending
(iii) Drilling Additional holes for shaft.
(iv) Providing undercut and reducing the shank diameter and making it equal to the core diameter of the thread in threaded members

Types of cyclic stresses :-





(b) Repeated Stresses.



(C) Reversed stresses.

$$\sigma_m = \frac{1}{2}(\sigma_{max} + \sigma_{min})$$

$$\sigma_a = \frac{1}{2}(\sigma_{max} - \sigma_{min})$$

Fatigue failure :- Fatigue failure is defined as the time delayed fracture under cyclic loadings. Examples of parts in which fatigue failures are common are transmission shafts, connecting rods, gears, vehicle suspension springs and ball bearings.

Difference b/w static failure and fatigue failure :-

In case of failure under static load, there is plastic deformation prior to failure, which gives warning well in advance.

On the other hand, fatigue cracks are not visible till they reach the surface of the component and by that time the failure has already taken place. The fatigue failure is sudden and total.

Endurance limit :- The fatigue or endurance limit of a material is defined as the maximum amplitude of completely reversed stress that the standard specimen can sustain for an unlimited number of cycles without fatigue failure. Since the fatigue test cannot be conducted for unlimited or infinite number of cycles, 10^6 cycles is considered as a sufficient number of cycles to define the endurance limit.

fatigue life :- The fatigue life is defined as the number of stress cycles that the standard specimen can complete during the test before the appearance of the first fatigue crack.

Low cycle and High-cycle fatigue :-

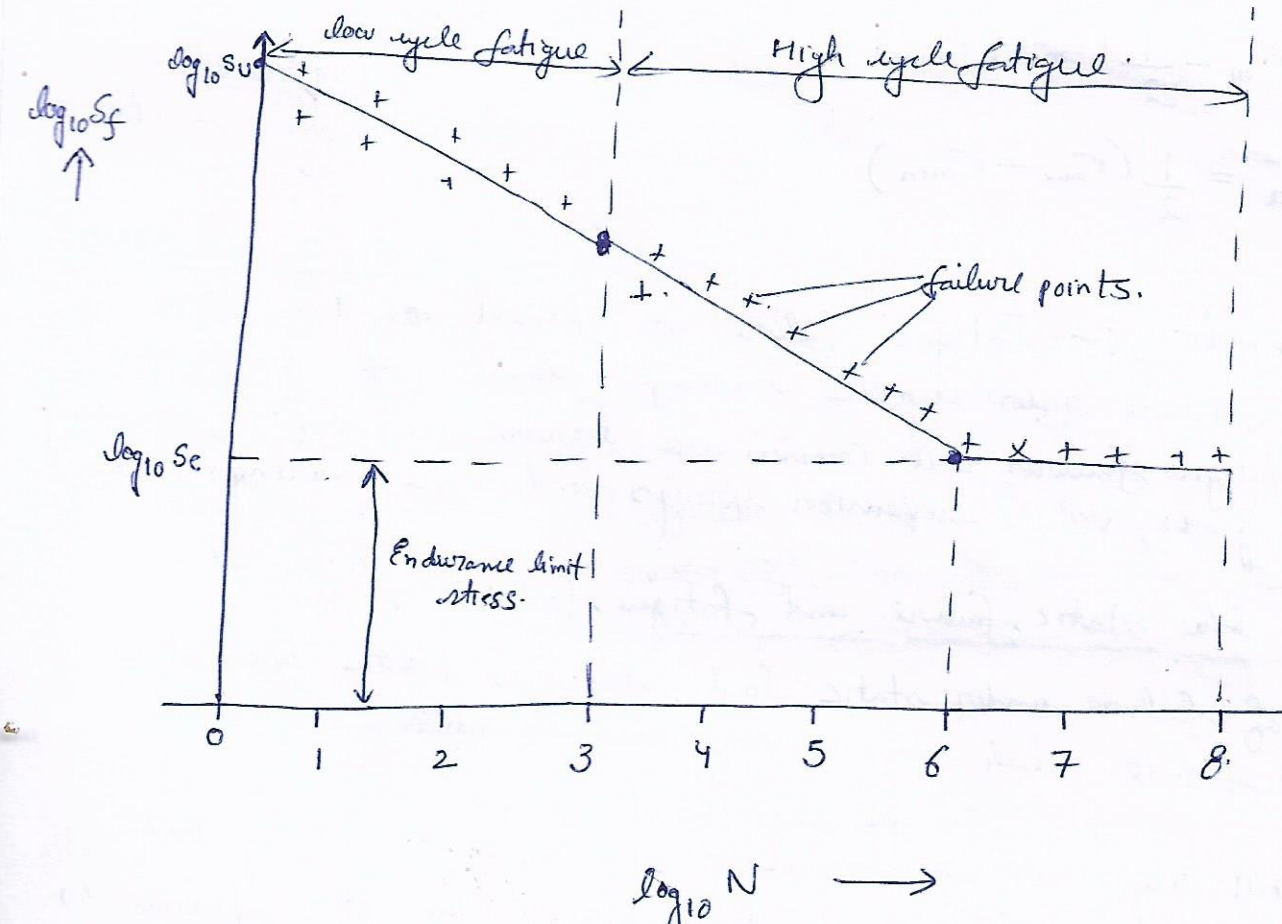


fig. Low and High cycle fatigue.

* Any fatigue failure when the number of stress cycles are less than 1000, is called low cycle fatigue. Any fatigue failure when the number of stress cycles are more than 1000, is called high cycle fatigue.

Notch Sensitivity :- It is observed that the actual reduction in the endurance limit of a material due to stress concentration is less than the amount indicated by the theoretical stress concentration factor K_t. Therefore, two seperate notations – K_t and K_f are used for stress concentration factors. K_t is the theoretical stress concentration factor, which is applicable to ideal materials that are homogenous, isotropic and elastic.

K_f is the fatigue stress concentration factor, which is defined as follows :-

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

↳ This factor is applicable to actual materials and depend upon the grain size of the materials.

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 :-

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

$$q = \frac{(K_f \sigma_0 - \sigma_0)}{(K_t \sigma_0 - \sigma_0)} \Rightarrow q = \frac{K_f - 1}{K_t - 1}.$$

$$\hookrightarrow K_f = 1 + q(K_t - 1).$$

when $q = 0 \Rightarrow K_f = 1$

when $q = 1 \Rightarrow K_f = K_t$

Endurance limit Estimation :-

S_e' = Endurance limit stress of a rotating beam specimen subjected to reversed bending stress (N/mm²).

S_e = Endurance limit stress of a particular mechanical component subjected to reversed bending stress (N/mm²).

There is an approximate relationship between the endurance limit and the ultimate tensile strength (S_{ut}) of the material.

For steels :- $S_e' = 0.5\ S_{ut}$

For cast Iron & cast steel ⇒ $S_e' = 0.4\ S_{ut}$

For wrought aluminium alloys ⇒ $S_e' = 0.4\ S_{ut}$

For Cast aluminium alloys ⇒ $S_e' = 0.3\ S_{ut}$

Relationship b/w S_e' and S_e :-

$$S_e = K_a \times K_b \times K_c \times K_d \times S_e'$$

$\left\{ K_d = \frac{1}{K_f} \right\}$.

- K_a → Surface finish factor
- K_b → Size factor
- K_c → Reliability factor
- K_d → Modifying factor to account for stress concentration

The endurance limit (S_{se}) of a component subjected to fluctuating torsional shear stresses is obtained from the endurance limit in reversed bending (S_e) using theories of failures :-

(i) According to the maximum shear-stress theory :-

$$S_{se} = 0.5\ S_e$$

(ii) According to distortion-energy theory :-

$$S_{se} = 0.577\ S_e$$

Endurance limit in axial loading condition :-

Fatigue Design Problems :- There are two types of problems in fatigue design :-

(i) Components subjected to completely reversed stresses.

↓

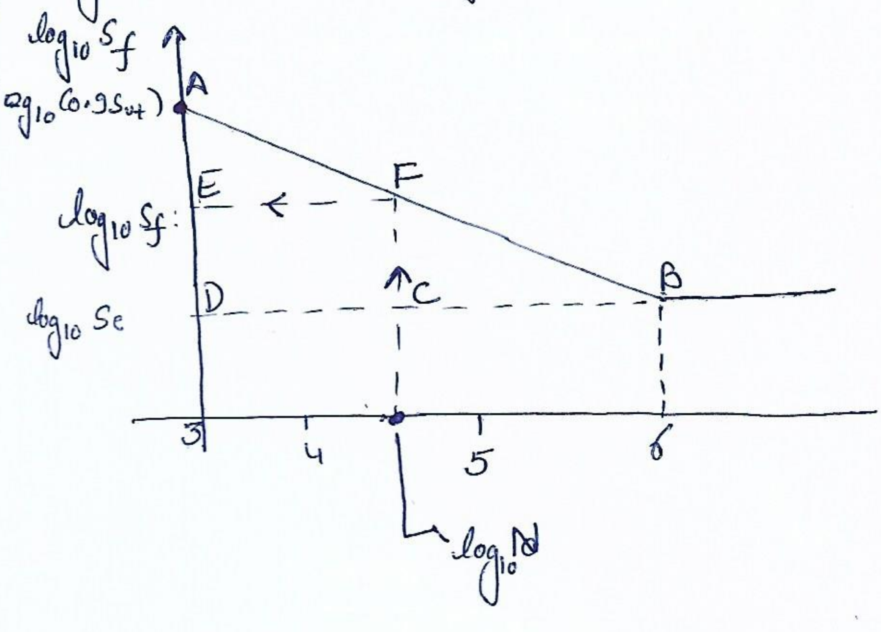
Case I :- When the component is to be designed for infinite life, the endurance limit becomes the criterion of failure. The amplitude stress induced in such components should be lower than the endurance limit in order to withstand the infinite number of cycles. Such components are designed with the help of following equations :-

$$\sigma_a = \frac{S_e}{fs}$$

$$\tau_a = \frac{S_{se}}{fs}$$

where (σ_a) and (τ_a) are stress amplitudes in the component and S_e and S_{se} are corrected endurance limits in reversed bending and torsion respectively.

Case II :- When the component is to be designed for finite life, the S-N curve is used. The curve is valid for steels. It consists of a straight line AB drawn from $(0.9 S_{ut})$ at 10^3 cycles to (S_e) at 10^6 cycles on a log-log paper. The design procedure for such problems is as follows:-



(i) Locate point A with coordinates $[\log_{10} 10^3, \log_{10}(0.9 S_{ut})] \simeq [3, \log_{10}(.9 S_{ut})]$

(ii) Locate point B with coordinates $[\log_{10} 10^6, \log_{10} S_e] \simeq [6, \log_{10}(S_e)]$.

(iii) Join $\overline{AB}$, which is used as a criterion of failure for finite life problems.

(iv) Depending upon the life N of the component, draw a vertical line passing through $\log_{10}(N)$ on the abscissa. This line intersects $\overline{AB}$ at point F.

(v) Draw a line $\overline{FE}$ parallel to the abscissa. The ordinate at point E, i.e $\log_{10}(S_f)$, gives the fatigue strength corresponding to N cycles.

The value of fatigue strength (S_f) obtained by the above procedure is used for the design calculation.