LOW-CYCLE AND HIGH-CYCLE FATIGUE

The S-N curve illustrated in Fig. is drawn from 10^3 cycles on log-log graph paper. The complete S-N curve from 100 cycle to 10^8 cycles is shown in Fig. There are two regions of this curve namely, low cycle fatigue and high-cycle fatigue.

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

- Failure of studs on truck wheels, failure of setscrews for locating gears on shafts or failures of short-lived devices such as missiles are the examples of low cycle fatigue.

- The failure of machine components such as springs, ball bearings or gears that are subjected to fluctuating stresses, are the examples of high-cycle fatigue.

- The low-cycle fatigue involves plastic yielding at localized areas of the components. There are some theories of low-cycle fatigue.

- In many applications the designers simply ignore the fatigue effect when the number of stress cycles is less than 1000.
- Such components are designed on the basis of ultimate tensile strength or yield strength with suitable factor of safety.

Components subjected to high-cycle fatigue are designed on the basis of endurance limit stress. S-N curve, Soderberg line, Gerber line or Goodman diagram are used in design

Fatigue Stress Concentration Factor

When a machine member is subjected to cyclic or fatigue loading, the value of fatigue stress concentration factor shall be applied instead of theoretical stress concentration factor. Since the determination of fatigue stress concentration factor is not an easy task, therefore from experimental tests it is defined as Fatigue stress concentration factor

$$K_f = \frac{Endurance\ limit\ without\ Stress\ concentartion}{Endurance\ limit\ with\ Stress\ concentartion}$$

This factor Kf is applicable to actual materials and depends upon the grain size of the material

Notch Sensitivity

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

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

Since σ_0 = Nominal stress as obtained by elementary equations

$\therefore$

$$\text{Actual stress} = k_f \sigma_0$$

$$\text{Theoretical stress} = k_t \sigma_0$$

Increase of actual stress over nominal stress = $(k_f \sigma_0 - \sigma_0)$

Increase of theoretical stress over nominal stress = $(k_t \sigma_0 - \sigma_0)$.

k_f - fatigue stress concentration factor

Notch sensitivity,

$$q = \frac{k_f \sigma_0 - \sigma_0}{k_t \sigma_0 - \sigma_0} = \frac{k_f - 1}{k_t - 1}$$

$$k_f = 1 + q(k_t - 1)$$

(i)When the material has no sensitivity to notches

q = 0 and $K_f = 1$

(ii)When the material is fully sensitive to notches,

q = 1 and $K_f = K_t$

(i) K_t depends on shape, size of discontinuity and type of load condition and its orientation.

(ii) K_t is independent of material behaviour.

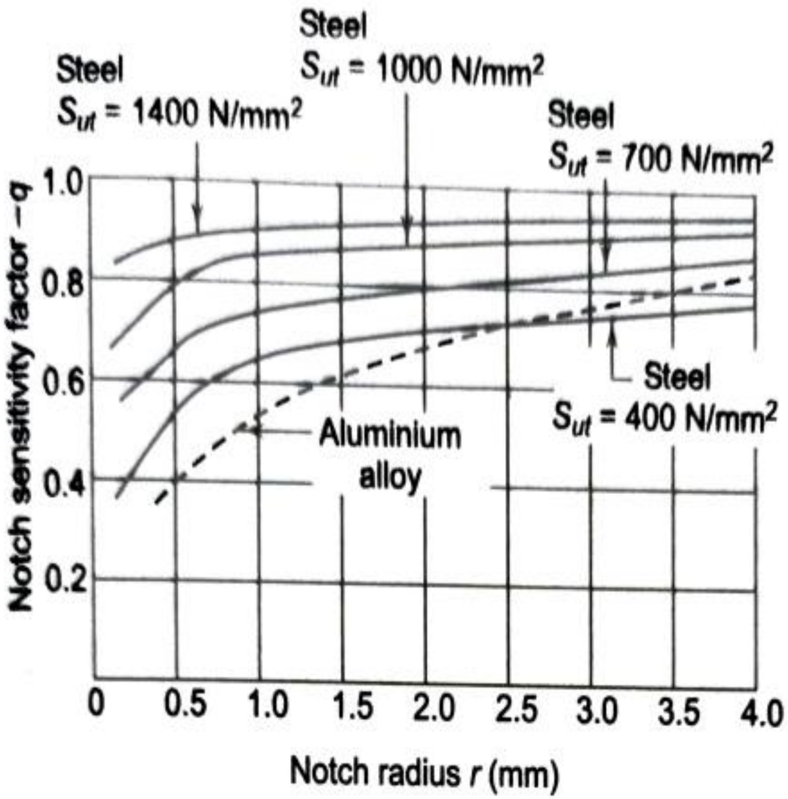
(iii) K_f depends on shape, size of orientation and type of loading condition and material of component.

(iv) Notch sensitive index (q) depends on material.

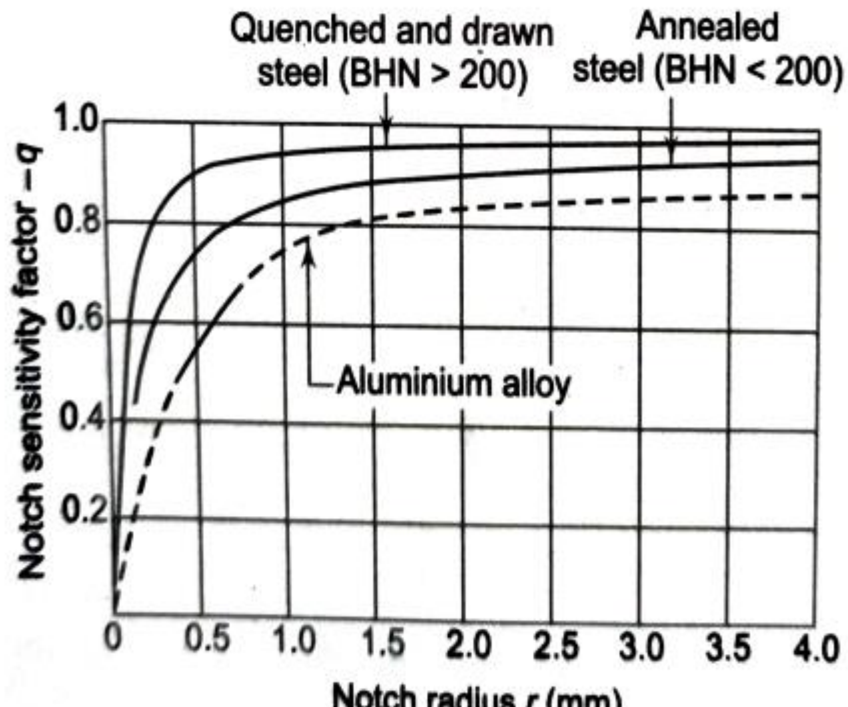
(v) If $q = 0 \Rightarrow K_f = 1 \Rightarrow$ material is insensitive to stress concentration or notch.

(vi) If $q = 1 \Rightarrow K_f = K_t \Rightarrow$ material is highly sensitive to notch.

(vii) For worst design, take $q = 1$.



Notch sensitivity charts (for reversed bending and reversed axial stresses)



Notch sensitivity charts (for reversed torsional shear stresses)

Correction Factors for Specimen's Endurance Limit

$$S_e = k_a\, k_b\, k_c\, k_d\, k_e\, S_e'$$

Where,

- S_e = endurance limit of component
- S_e' = endurance limit experimental(Test Specimen)
- k_a = surface finish factor
- k_b = size factor
- k_c = reliability
- k_d = modified factor to accounts for stress concentration
- k_e = operating T factor

Modifying Factor to Account for Stress Concentration

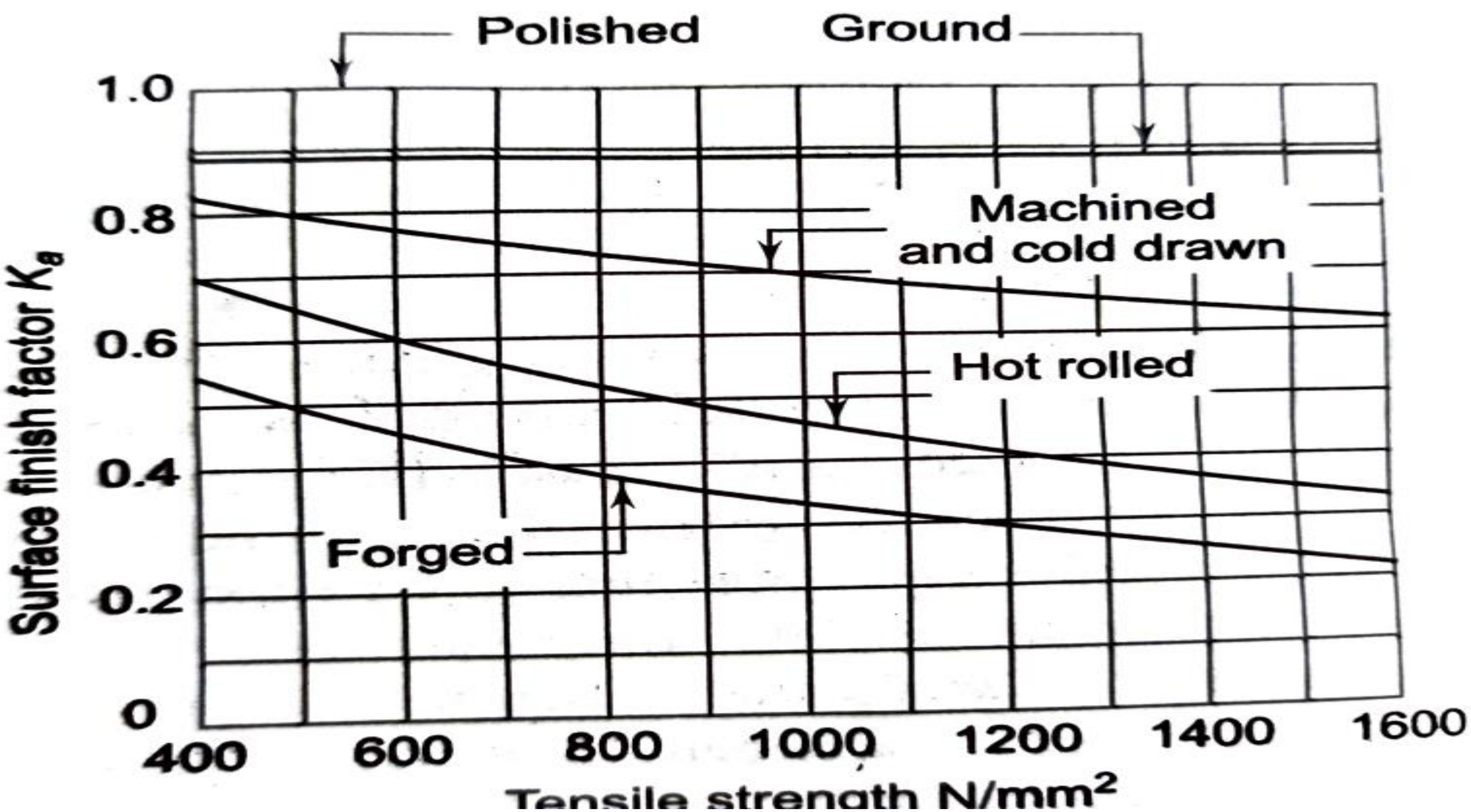
The endurance limit is reduced due to stress concentration. The stress concentration factor used for cyclic loading is less than the theoretical stress concentration factor due to the notch sensitivity of the material. To apply the effect of stress concentration, the designer can either reduce the endurance limit by (K_d) or increase the stress amplitude by (K_f). We will use the first approach. The modifying factor $\boldsymbol{Kd}$ to account for the effect of stress concentration is defined as

K_d = 1/ K_f

The endurance limit ($\boldsymbol{Sse}$) of a component subjected to fluctuating torsional shear stresses bending ($\boldsymbol{Se}$) using theories of failures.

surface finish factor :

The rotating beam test specimen has a polished surface. Most components do not have a polished surface. Scratches and imperfections on the surface act like a stress raisers and reduce the fatigue life of a part. Use either the graph or the equation with the table shown below.



➢Size factor, k_b

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

Shigley and Mischke have suggested an exponential equation for size factor. For bending and torsion, the equation is in the following form,

For $2.79 \text{ mm} \le d < 51 \text{ mm}$

$$K_b = 1.24\, d^{-0.107}$$

For $51 \text{ mm} < d \le 254 \text{ mm}$

$$K_b = 0.859 - 0.000\,873\, d$$

For axial loading,

$$K_b = 1$$