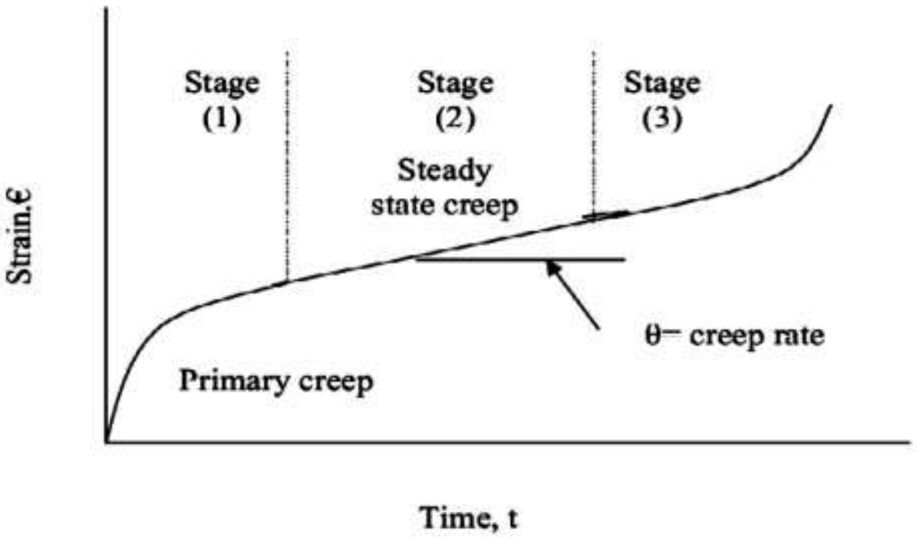
Creep testing and creep curves:

Creep tests require careful temperature control. Typically, a specimen is loaded in tension or compression usually at constant load, inside a furnace which is maintained at a constant temperature. The tension is measured as a function of time. Fig. below shows a typical set of results from such a test. Metals polymers, and ceramic, all show creep curves of this general shape.



Creep occurs in three stages:

Stage 1 – Primary creep stage

Consist of a short part during which strain increases rapidly

Stage 2 – Secondary creep stage

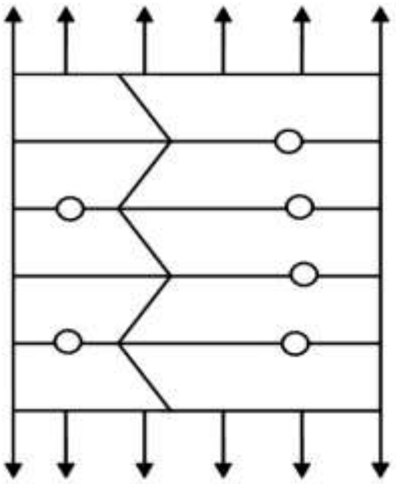
Consist of a long period where the rate is much slower and constant

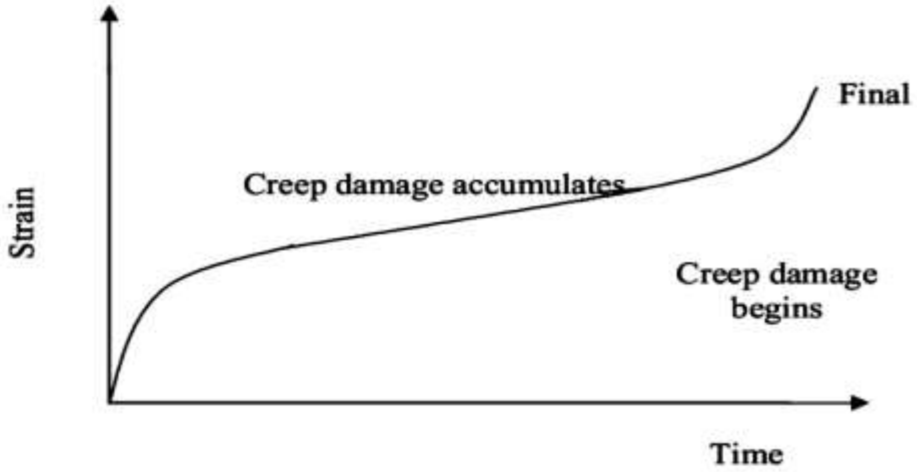
Stage 3 – Tertiary creep stage

At this stage the creep rate increases and the material fractures.

Creep damage and creep fracture:

During creep, damage, in the form of internal cavities, accumulates. The damage first appears at the start of the tertiary stage of the creep curve reflects this as the holes grows. The section of the sample decreases and (at constant load) the strains goes up and the creep rate goes up even faster than the stress does.





In high temperature design it is important to make sure:

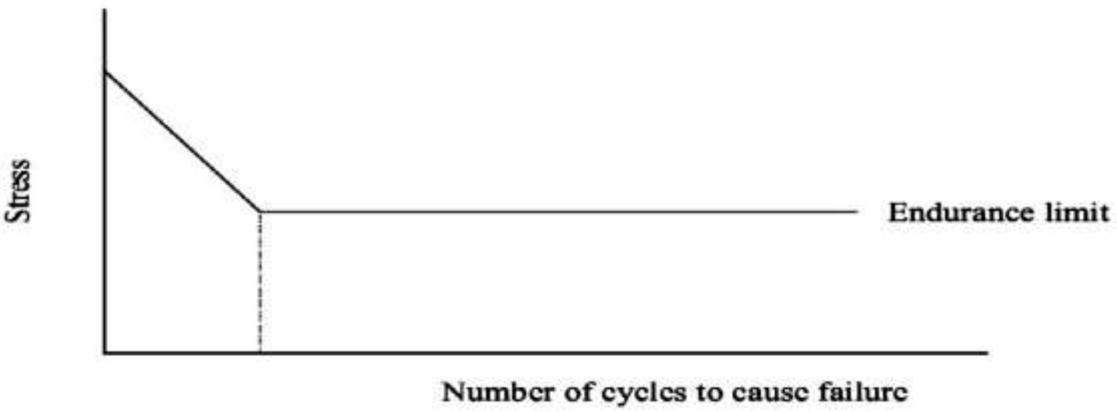
a. That the creep strain during the design life is acceptable.

b. That the creep strain at failure is adequate to cope with the acceptable creep strain.

c. That the time to failure, at the design loads and temperatures is longer (by a suitable factor) than the design life.

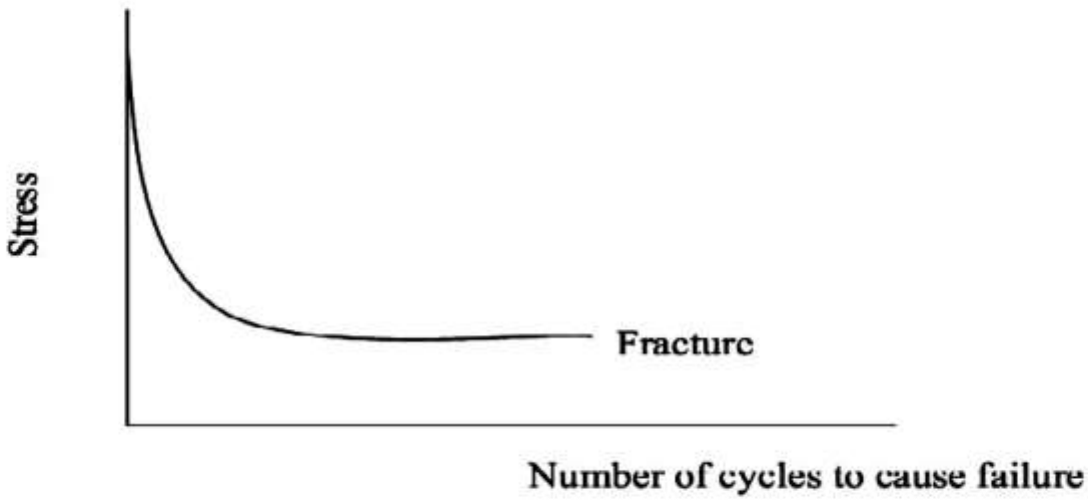
Fatigue strength

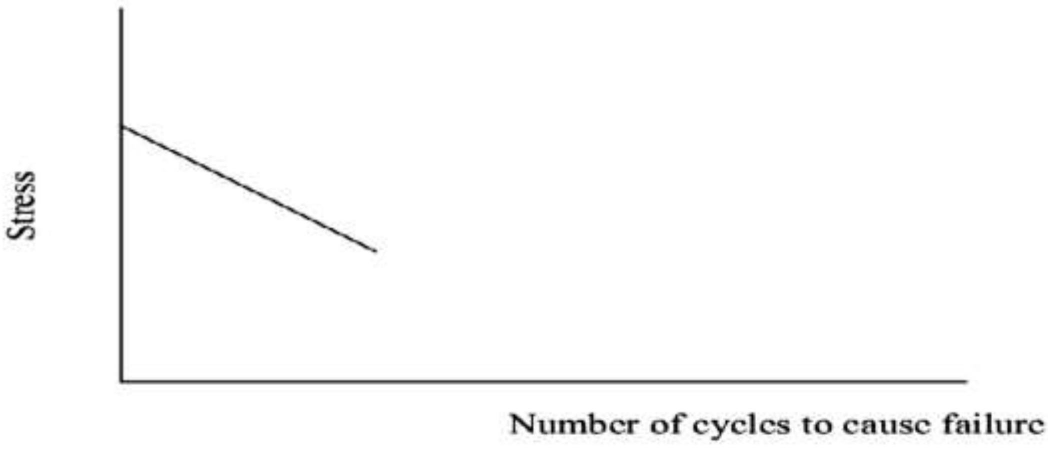
We have considered so far only the strength of material under static loading. In many structures, repeated loading is applied, and when a material fails under a number of repeated loads, each smaller than the ultimate strength, failure in fatigue is said to take place. The results of fatigue test are represented by a relationship between stress and number of cycles to failure.



S-N diagram for ferrous metals

At the beginning the stress decreases as the number of cycles increases. After several million cycles the curve become s horizontal line whose stress value is known as the endurance limit. While almost all ferrous materials exhibit an endurance limit, most nonferrous alloys do not.





S-N diagram for concrete materials

Endurance limit: The stress below which a material can withstand an indefinitely large number of repetitions of stress without failure.

Fatigue strength: The stress which exceeds the endurance limit and at which failure may occur after indefinite number of repeated cycles.

Fatigue failure: Fatigue failure appears to begin with a crack at a point of weakness in the material, with the crack. Progressing long crystal boundaries. During the stress cycle, these small cracks open and close. The cracks cause highest stress at the base of the crack as compared to the stress if there is no crack. Under this repeated concentration of stress, the cracks will gradually extend a cross the section of the member, finally causing complete failure of the member.

Durability: Resistance of a material to deterioration in quality during its period life.

Example:

Problem 1/

A rectangular bar having a cross-section area of 75 mm^2 has a tensile force of 15 KN applied to it .Determine the stress in bar?

Sol. /

Cross-section area A= 75 mm^2 = 75 × 10^{-6} m^2

F = 15 KN = 15 × 10^3

Stress in bar, $\sigma = \frac{F}{A}$ = 15 × 10^3 N / 75 × 10^{-6} m^2 = 0.2 × 10^9 Pa = **200 MPa**

Problem 2/

A bar 1.60 m long contracts axially by 0.1 mm when a compressive load is applied to it. Determine the strain and the percentage strain?

Sol. /

Strain ϵ = contraction / original length = 0.1 mm / 1.60 × 10^3 mm

= 0.1 / 1600 = **0.0000625**

Percentage strain = 0.0000625 / 100 = **0.00625 %**

Problem 3/

A bar tube has an internal diameter of 120 mm and an outside diameter of 150 mm and used to support a load of 5 kN. The tube is 500 mm long before the load is applied .Determine by how much the tube contracts when loaded, taking the modulus of elasticity for bars as 90 GPa.

Sol. /

F = 5 kN = 5000 N

$A = \frac{\pi}{4} \times (D^2 - d^2) = \frac{\pi}{4} (0.150^2 - 0.120^2) = 0.006362\ m^2$

Stress in tube, $\sigma = \frac{F}{A}$ = 5000 N / 0.006362 m^2 = **0.7859 × 10^6 Pa**

Since the modulus of elasticity =

$$E = \text{stress } \sigma / \text{strain } \epsilon$$

Then strain, $\epsilon = \sigma / E = 0.7859 \times 10^6 \text{ Pa} / 90 \times 10^9 \text{ Pa}$

$$= \mathbf{8.732 \times 10^{-6}}$$

Strain ϵ = contraction X / original length L

Thus, contraction $X = \epsilon \times L = 8.732 \times 10^{-6} \times 0.500$

$$= \mathbf{4.37 \times 10^{-6} \text{ m}}$$

H.W/

1. A rectangular bar having a cross-sectional area of 80 mm^2 has a tensile force of 20 kN applied to it. Determine the stress in the bar. [250 MPa]

2. A circular cable has a tensile force of 1 kN applied to it and the force produces a stress of 7.8 MPa in the cable. Calculate the diameter of the cable. [12.78 mm]