LECTURE

Fracture

- Brittle Fracture
- Ductile Fracture
- Fatigue Fracture
- Creep Fracture

Fracture

Fracture is the separation of a specimen info two or more parts by an applied stress.

Fracture takes place in two stages:
(i) initial formation of crack and
(ii) spreading of crack.

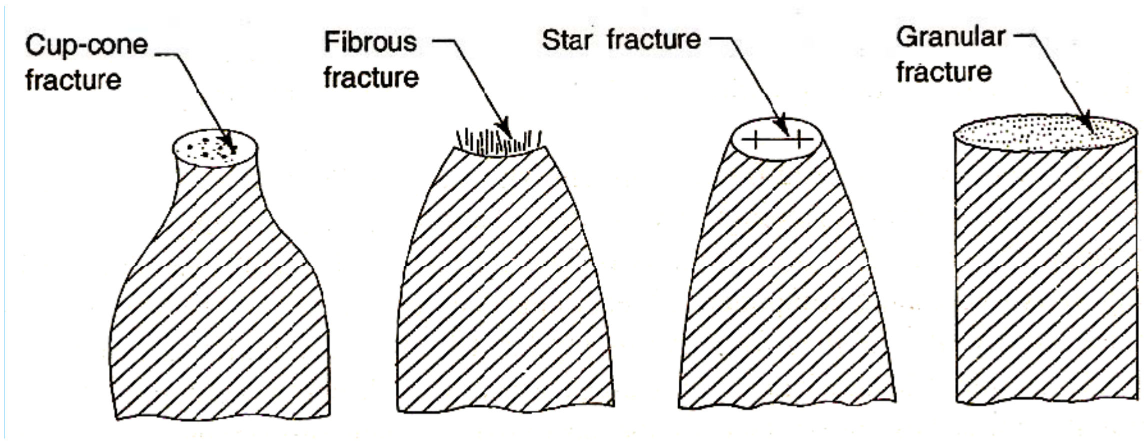
- Depend upon the type of materials, the applied load, state of stress and temperature metals have different types of fracture.

Types of fracture

- Brittle Fracture
- Ductile Fracture
- Fatigue Fracture
- Creep Fracture

Fracture

- Fracture is usually undesirable in engineering applications.
- Flaws such as surface cracks lower the stress for brittle fracture where as line defects are responsible for initiating ductile fractures.
- Different types of fracture



Brittle Fracture

- Brittle fracture is the failure of a material with minimum of plastic deformation. If the broken pieces of a brittle fracture are fitted together, the original shape & dimensions of the specimen are restored.
- Brittle fracture is defined as fracture which occurs at or below the elastic limit of a material.

The brittle fracture increases with

- Increasing strain rate
- Decreasing temperature
- Stress concentration conditions produced by a notch.

Salient Features of Brittle Fracture

- Brittle fracture occurs when a small crackle in materials grows. Growth continues until fracture occurs.
- The atoms at the surfaces do not have as many neighbors as those in the interior of a solid and therefore they form fever bonds. That implies, surface atoms are at a higher energy than a plane of interior atom. As a result of Brittle fracture destroying the inter atomic bonds by normal stresses.
- In metals brittle fracture is characterized by rate of crack propagation with minimum energy of absorption.
- In brittle fracture, adjacent parts of the metal are separated by stresses normal to the fracture surface.
- Brittle fracture occurs along characteristics crystallographic planes called as cleavage planes. The fracture is termed as cleavage fracture.
- Brittle fracture does not produce plastic deformation, so that it requires less energy than a ductile failure.

Mechanism of Brittle Fracture

- The mechanism of Brittle fracture is explained by Griffith theory.
- Griffith postulated that in a brittle material there are always presence of micro cracks which act to concentrated the stress at their tips.
- The crack could come from a number of source, e.g. as a collection of dislocations, as flow occurred during solidification or a surface scratch.
- In order to explain the mechanism of ideal brittle fracture, let us consider the stress distribution in a specimen under constant velocity in the vicinity of crack.
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Mechanism of Brittle Fracture

- When a longitudinal tensile stress is applied, the crack tends to increase its length causes an increase in surface area of a crack.
- The surface energy of the specimen is increased.
- There is also compensation release of energy. This means, an increase in crack length causes the release of elastic energy .
- "Griffith state that when the elastic energy released by extending a crack equal to the surface energy required for crack extension" then the crack will grow.

Mechanism of Brittle Fracture

$$\sigma = \sqrt{\frac{2\gamma E}{\pi e}}$$

Where,

- e is half of the crack length,
- γ is the true surface energy
- E is the Young's modulus.
- the stress is inversely proportional to the square root of the crack length. Hence the tensile strength of a completely brittle material is determined by the length of the largest crack existing before loading.
- For ductile materials there is always some plastic deformation before fracture. This involves an additional energy term γp. Therefore the fracture strength is given by

$$\sigma = \left[\sqrt{\frac{2E\gamma}{\pi e}}\right]^{\frac{1}{2}}$$

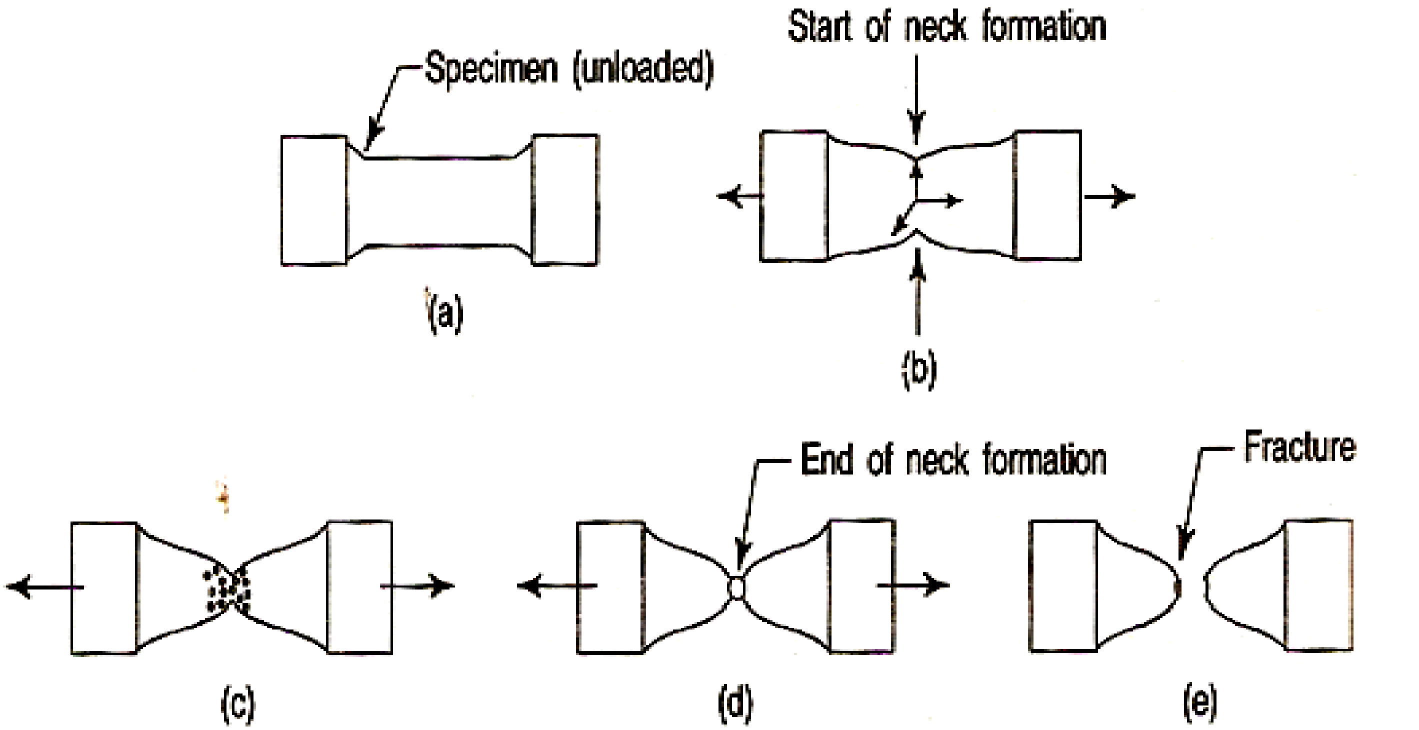
Ductile Fracture

- Ductile fracture is defined as the fracture which takes place by a slow propagation of crack with considerable amount of plastic deformation.

There are three successive events involved in a ductile fracture.

- The specimen begins necking and minute cavities form in the necked region. This is the region in which the plastic deformation is concentrated. It indicates that the formation of cavities is closely linked to plastic deformation.
- It has been observed that during the formation of neck small micro cracks are formed at the centre of the specimen due to the combination of dislocations.
- Finally these cracks grow out ward to the surface of the specimen in a direction 45° to the tensile axis resulting in a cup-end-cone-type fracture 0

Ductile Fracture



various stages in ductile fracture

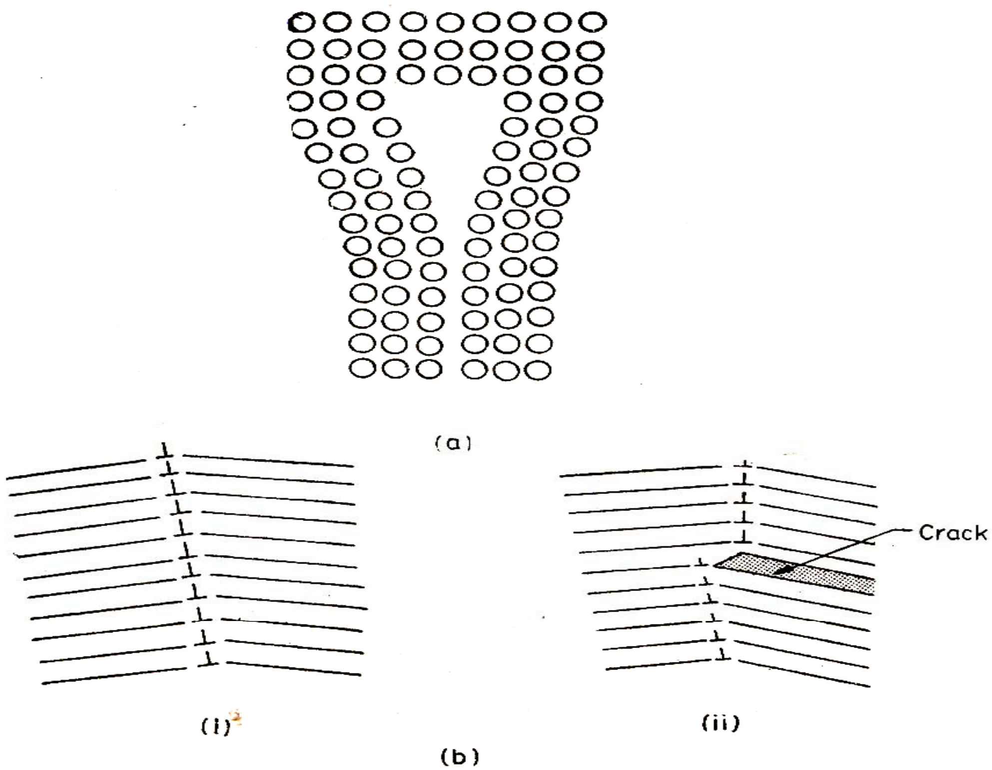
Ductile Fracture

- An important characteristic of ductile fracture is that it occurs through a slow tearing of the metal with the expenditure of considerable energy.
- The fracture of ductile materials can also explained in terms of work-hardening coupled with crack-nucleation and growth.
- The initial cavities are often observed to form at foreign inclusions where gliding dislocations can pile up and produce sufficient stress to form a void or micro-crack.
- Consider a specimen subjected to slow increasing tensile load. When the elastic limit is exceeded, the material beings to work harden.
- Increasing the load, increasing the permanent elongation and simultaneously decrease the cross sectional area.
- The decrease in area leads to the formation of a neck in the specimen, as illustrated earlier.

Ductile Fracture

- The neck region has a high dislocation density and the material is subjected to a complex stress.
- The dislocations are separated from each other because of the repulsive inter atomic forces.
- As the resolved shear stress on the slip plane increase, the dislocation comes closed together.
- The crack forms due to high shear stress and the presence of low angle grain boundaries.
- Once a crack is formed, it can grow or elongated by means of dislocations which slip.
- Crack propagation is along the slip plane for this mechanism.
- Once crack grows at the expense of others and finally cracks growth results in failure.

Ductile Fracture



a) crack nucleation at a slip-plane obstacle
b) Crack nucleation at low-angle grain boundaries

Comparison between Brittle and Ductile fracture

Ductile fracture	Brittle fracture
• Material fractures after plastic deformation and slow propagation of crack	• Material fractures with very little or no plastic deformation.
• Surface obtained at the fracture is dull or fibrous in appearance	• Surface obtained at the fracture is shining and crystalling appearance
• It occurs when the material is in plastic condition.	• It occurs when the material is in elastic condition.
• It is characterized by the formation of cup and cone	• It is characterized by separation of normal to tensile stress.
• The tendency of ductile fracture is increased by dislocations and other defects in metals.	• The tendency brittle fracture is increased by decreasing temperature, and increasing strain rate.
• There is reduction in cross – sectional area of the specimen	• There is no change in the cross – sectional area.

Fatigue Fracture

- Fatigue fracture is defined as the fracture which takes place under repeatedly applied stresses.
- It will occur at stresses well before the tensile strength of the materials.
- The tendency of fatigue fracture increases with the increase in temperature and higher rate of straining.
- The fatigue fracture takes place due to the micro cracks at the surface of the materials.
- It results in, to and fro motion of dislocations near the surface.
- The micro cracks act as the points of stress concentration.
- For every cycle of stress application the excessive stress helps to propagate the crack.
- In ductile materials, the crack grows slowly and the fracture takes place rapidly.
- But in brittle materials, the crack grows to a critical size and propagates rapidly through the material.

Creep Fracture

- Creep fracture is defined as the fracture which takes place due to creeping of materials under steady loading.
- It occurs in metals like iron, copper & nickel at high temperatures. The tendency of creep fracture increases with the increase in temperature and higher rate of straining.
- The creep fracture takes place due to shearing of grain boundary at moderate stresses and temperatures and movement of dislocation from one slip to another at higher stresses and temperatures.
- The movement of whole grains relation of each other causes cracks along the grain boundaries, which act as point of high stress concentration.
- When one crack becomes larger it spreads slowly across the member until fracture takes place.
- This type of fracture usually occurs when small stresses are applied for a longer period.
- The creep fracture is affected by grain size, strain hardening, heat treatment and alloying.