Fracture mechanism analysis of two wheeler rear wheel

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ABSTRACT- **In this paper we will study fracture mechanics and clearly distinguishing between crack and fracture, types of fracture etc. Here we take into study, an incidence of fracture that occurred in the rear wheel of Karizma bike and analyzing the effect of dynamic fracture in that incidence and influence of fatigue on it. Discussion of preventive measures to be taken to avoid the fracture is also discussed.**
The failure often occurred under conditions of low stress (several ships failed suddenly while in the harbor) which made them seemingly inexplicable. As a result extensive investigations were initiated in many countries and especially in USA. Due to this low stress fracture in high strength material induced the development of Fracture Mechanics.

Keywords: **Cracks, fracture, failure, Toughness, Plasticity**

I. INTRODUCTION:

Through the ages the application of materials in engineering design has posed difficult problems to mankind. In the Stone Age, the problem was mainly in shaping of the material. In the previous days of the Bronze Age and the Iron Age the difficulties were both in production and shaping. For many centuries metal working was laborious and extremely costly. Estimates goes that the equipment price of a knight and horse in the 13^{th} century of a centurion tank in Second World War.

With the improving skill of metal working, applications of metal in structures increased progressively. Then it was experienced that structure built of these materials did not always behave satisfactorily and unexpected failures occurred. The vastly increased use of metals in the 19^{th} century caused number of accidents and casualties to reach unknown levels. Some of these accidents were due to poor design, but it has been seen that material deficiencies in the form of pre-existing flows could initiate Cracks and Fractures**.**

Fracture is the separation, or fragmentation of a solid body into two or more parts under the action of stress.

1.1 Process of Fracture

(1) Crack Initiation
(2) Crack Propagation.

1.2 Example of fracture under complex conditions:

1) Fracture due to torsion
2) Fatigue
3) Creep
4) Low temperature brittle fracture
5) Temperature embrittlement

1.3 What is crack?

Partial breaking of a material is called crack. Initiation of a crack begins due to repeated cyclic loading which causes localized changes in the structure of the material further leading to fracture.

Fig 1.3.1 Crack Propagation in Material

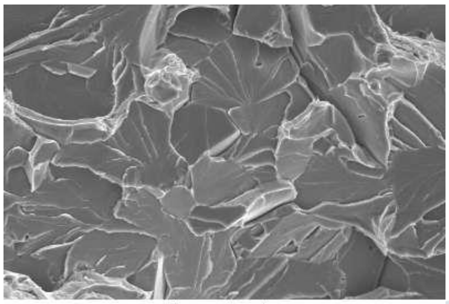
II .TYPES OF FRACTURE:

Fractures can be mainly classified into two types they are as below:

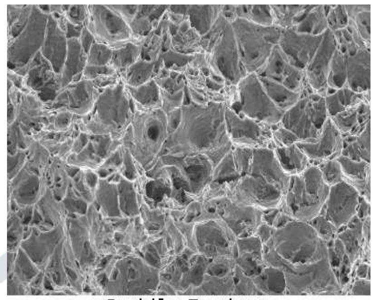
1. Ductile fracture
2. Cleavage fracture

2.1 Cleavage Fracture:

Cleavage fracture is the most brittle form of fracture that can occur in crystalline materials. Brittle cleavage fractures in ships, bridges and tanks have made it a notorious type of failure. Cleavage Fracture is encountered in cases like low temperatures and high strain rates.



Cleavage Fracture



Ductile Fracture

Cleavage Fracture of metals occurs by direct separation along crystallographic planes due to simple breaking of atomic bonds. Its main characteristics are that it occurs with a particular crystallographic plane.

Brittle fracture is characterized by rapid rate of crack propagation .No gross deformation is present but very less micro deformation is present at the fracture surface.Brittle fracture is avoided at all costs because it occurs without warning and produces disastrous consequences.

2.2 Ductile Fracture:

Fracture occurring under the single application of continuously increasing load can be either brittle cleavage fracture or fracture associated with plastic deformation, which is essentially ductile the most familiar type of fractures by overload in tension, which produces the classic cup and cone fracture.
Ductile fracture is characterized by appreciable plastic deformation prior to and during the propagation of crack. Amount of gross deformation is present at fracture surface.

Ductile fracture gives warning before they fracture as compared to brittle fracture.

2.3 Dynamic Fracture:

Fig 2.3.1 Fracture observed in the rear wheel of Karizma bike

We have seen cases in which fracture has occurred in static condition after prolonged loading conditions and stress. But here is another case where in the fracture has occurred in the dynamic state or in simple words the fracture has occurred during motion.

A bike which looks as if its normal but just view the crack in the rear wheel, its due to Dynamic Fracture which has occurred when the bike was in motion. Now let’s analyses how it has actually happened?

Here instability occurs due to crack extension, the elastic energy release rate remains larger than the crack resistance “R”. The surplus of released energy (G-R) can be converted into kinetic energy .The kinetic energy is associated with rapid movement of the material at each side of the crack path, during the passage of a high velocity crack the difference between “G” and “R” determines how much energy can become available as kinetic energy and consequently it governs the speed at which the crack will propagate through the material.

Both G and R represent the energies associated with crack extension. The crack resistance is the function of the plastic behavior of the material at the crack tip and of its fracture characteristics. The yield stress increases and the fracture strain decreases at higher strain rates at the tip of crack moving at high velocity the strain rates are very high, and it must be expected that the material behaves in a more brittle manner the higher crack speed. Fractures are analyzed using the latest scanning electron microscopy (SEM) and other metal testing techniques.

Analysis:

- It is fatigue loading problem.
- Fatigue loading is given by the equation.

  $F=mr\omega^2$

  Where,

  m=lumped mass of wheel body at crack.

  r=radius of crack location.

ω=angular acceleration of the wheel.

In this location there is tensile load acting on crack.

Fig.2.3.2 crack due to tensile load

In this location there is compressive load acting on crack

Fig2.3.3 Crack Due to Compressive Load

In this location branching has happened along wheel rotation.
Fig.2.3.4 crack along wheel rotation

III. PREVENTION:

- ➢ Fractures can be prevented by proper quality control techniques and suitable design.
- ➢ Methods like Non- Destructive testing and X –ray analysis can prevent fracture.
- ➢ Excessive loading should be avoided and if possible repeated cyclic loadings should be minimized.
- ➢ Manufacturing defects like blow holes should be avoided and suitable manufacturing process should be adopted.
- ➢ Research and Development will further provide scope in prevention of fracture.

IV. DEFECTS:

Structural materials have inner defects such as cracks, which are extreme stress Concentrators.
There are technological defects shown in diagrams A and B below, which are cracks that grew under exploitation into fatigue cracks, thermal impact cracking. Improper exploitation such as scratching produces such defects. Leaking occurs through the cracks, allowing detection of defects before catastrophic failure occurs in pressure vessels.
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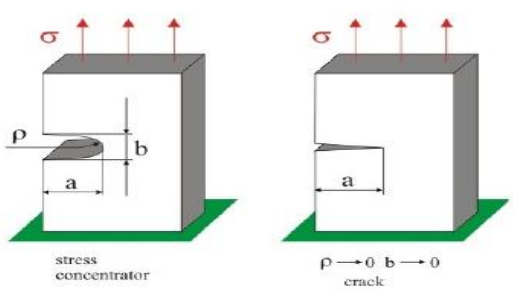

Fig 4.1 crack propagated after application of tensile load

It is possible to approximate the curved front of the defect by an ellipse or circle. A three dimensional singular defect can be replaced by projecting onto a surface perpendicular to the tensile stress. A surface defect is more dangerous than an inner defect of the same size. It is easier to inspect surface defects than inner pores by nondestructive control. A crack is an obstacle in the path of force lines. A concentration of force lines affects the stress pattern in the cross section. According to the solution of the theory of elasticity for an extreme concentrator such as a crack, the maximum stress tends towards infinity. The solutions were obtained for ideal elastic material. Fortunately, the structural materials are not ideally elastic, as there are plastic deformations and microstructural changes in the crack tip.

V. STRESSES IN THE CRACK TIP:

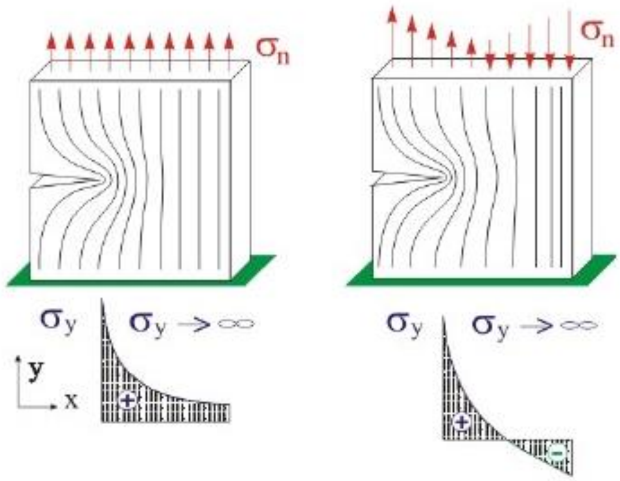

Fig.5.1 stress distribution in the crack tip

The figure below shows the original and deformed state (displacements are magnified) of a plate with a central crack. According to the theory, a sharp crack will transform into an elliptical hole with a shorter length and very small height.
There is a three-component stress field in the crack tip. The plot shows the stress distribution in the center of the specimen with a central crack, only the right part is shown.
In the crack tip there is a small zone where the formula for stress can be simplified. The magnitude rs is the size of the singular zone. Expression is valid for all types of crack in tension with different geometries. The curve lieshigher for larger nominal stress or for a larger crack length, but its form is the same.

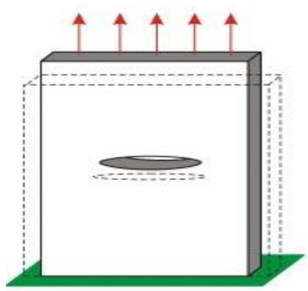

Fig.5.2 Elliptical crack.

VI. TOUGHNESS:

The toughness or resistance to crack growth, of a material is governed by the energy absorbed as the crack moves forward. In an extremely brittle material such as window glass, this energy is primarily just that of rupturing the chemical bonds along the crack plane. But as already mentioned, in tougher materials bond rupture plays a relatively small role in resisting crack growth, with by far the largest part of the fracture energy being associated with plastic flow near the crack tip. A "plastic zone" is present near the crack tip within which the stress

VII. PLASTICITY:

Plastic deformation is unrecovered shear in zones of high stress concentration. The figure shows examples of plastic shear in the crack tip.

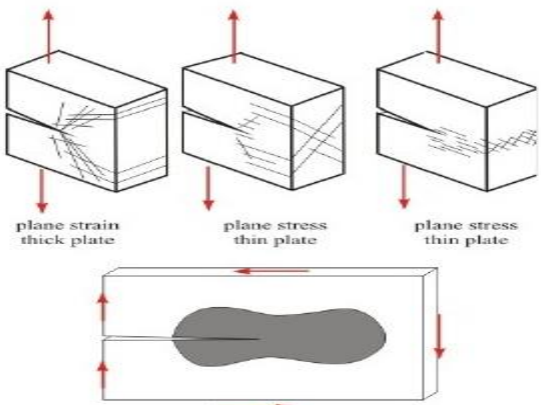

Fig 7.1 various types of cracks

VIII. TEMPERATURE AND DEFORMATION RATE:

There are mainly two kinds of fracture: brittle cleavage and ductile fracture. They demonstrate different values of the crack resistance. A material can have both types if the test temperature varies widely. A decrease in temperature causes dramatic decrease of crack resistance at the transition temperature.

A crack progressing at high speed has no time to realize ductile fracture mode. An initiated crack will release stored energy of deformation and accelerate itself Corrosion cracking tests are conducted on double beam specimens with a wedging bolt. Corrosion causes the material in the crack tip to be brittle. As the crack begins and grows, the force and SIF decreases with increased flexibility of the be

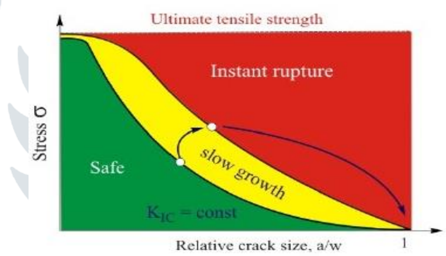

Fig.8.1 stress v/s crack size

IX. SUMMARY:

Fracture is an unpredictable phenomena, the only solution to this is by proper design and using of modern manufacturing techniques. Quality of material plays an important role in robustness of the product. Fractures can be prevented by proper quality control techniques and suitable design. Methods like Non- Destructive testing and X –ray analysis can prevent fracture. Excessive loading should be avoided and if possible repeated cyclic loadings should be minimized. Manufacturing defects like blow holes should be avoided and suitable manufacturing process should be adopted. Research and Development will further provide scope in prevention of fracture.

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