# MIDHANI MATERIALS

# FRACTURE TOUGHNESS PROPERTIES



MISHRA DHATU NIGAM LTD

(A Govt. of India Enterprise, Ministry of Defence)

# FRACTURE TOUGHNESS PROPERTIES OF MIDHANI MATERIALS.

## Introduction

Fracture is a process of breaking a solid into pieces as a result of stress. There are two principal stages of the fracture process:

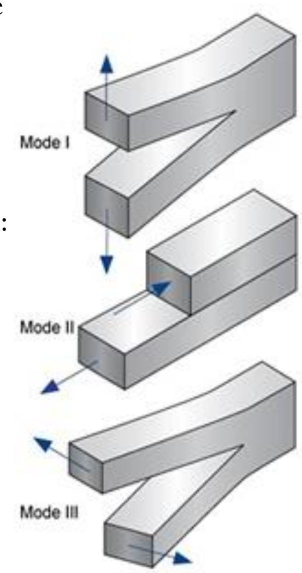
(a) Crack formation
(b) Crack propagation

Toughness is ability of material to resist fracture. The general factors, affecting the toughness of a material are: temperature, strain rate, relationship between the strength and ductility of the material and presence of stress concentration (notch) on the specimen surface

Fracture toughness (KIc) refers to the ability of a material containing a crack to resist fracture. Specifically, fracture toughness testing characterizes resistance to fracture in a neutral environment with a sharp crack, and is one of the most important properties of any material for virtually all design applications. It is a very important material property since the occurrence of flaws is not completely avoidable in the processing, fabrication, or service of a material/component. Flaws may appear as cracks, voids, metallurgical inclusions, weld defects, design discontinuities, or some combination thereof.

It is common practice to assume that a flaw of some chosen size will be present in some number of components and use the linear elastic fracture mechanics (LEFM) approach to design critical components. This approach uses the flaw size and features, component geometry, loading conditions and the material property called fracture toughness to evaluate the ability of a component containing a flaw to resist fracture.

A parameter called the stress-intensity factor (K) is used to determine the fracture toughness of most materials. A Roman numeral subscript indicates the mode of fracture and the three modes of fracture are illustrated in the image to the right. Mode I fracture is the condition in which the crack plane is normal to the direction of largest tensile loading. This is the most commonly encountered mode and, therefore, for the remainder of the material we will consider KI




The stress intensity factor is a function of loading, crack size, and structural geometry. The stress intensity factor may be represented by the following equation:

$$K_I = \sigma\sqrt{\pi a \beta}$$

| | | |
|---|---|---|
| Where: | KI | is the fracture toughness in $MPa\sqrt{m}$ $(psi\sqrt{in})$ |
| | s | is the applied stress in MPa or psi |
| | a | is the crack length in meters or inches |
| | B | is a crack length and component geometry factor that is different for each specimen and is dimensionless. |

**Plane Strain** - a condition of a body in which the displacements of all points in the body are parallel to a given plane, and the values of theses displacements do not depend on the distance perpendicular to the plane .

Most popular test performed in the Fracture Lab is the KIC Test per ASTM E399. Pre-cracking is an essential part of Fracture Toughness testing. The pre-crack is the creation of a simulated “flaw” that aids in the testing of fractured specimens. The actual crack, which initiates at the tip of a machined notch, is typically measured automatically using compliance techniques.

This test method covers the determination of the plane-strain fracture toughness (KIc) of metallic materials by increasing-force tests of fatigue pre-cracked specimens. Force versus crack-mouth opening displacement (CMOD) is recorded either autographically or digitally. The force at a 5 % secant offset from the initial slope (corresponding to about 2.0 % apparent crack extension) is established by a specified deviation from the linear portion of the record. The value of KIc is calculated from this force using equations that have been established by elastic stress analysis of the specimen configurations specified in this test method. The validity of the KIc value determined by this test method depends upon the establishment of a sharp-crack condition at the tip of the fatigue crack in a specimen having a size adequate to ensure predominantly linear-elastic, plane-strain conditions. To establish the suitable crack-tip condition, the stress-intensity factor level at which specimen fatigue pre-cracking is conducted is limited to a relatively low value.

When performing a fracture toughness test, the most common test specimen is compact tension (CT) specimens. An accurate determination of the plane-strain fracture toughness requires a specimen whose thickness exceeds some critical thickness (B). Testing has shown that plane-strain conditions generally prevail when:

$$B \geq 2.5\left(\frac{K_{IC}}{\sigma_y}\right)^2$$

Where: B is the minimum thickness that produces a condition where plastic strain energy at the crack tip in minimal

$K_{IC}$ is the fracture toughness of the material

$\sigma_y$ is the yield stress of material

Materials made at MIDHANI having Fracture toughness comparable to international standards.

| Grade Name | 0.2% Proof Stress( Mpa) | Fracture toughness $K_{IC}$ (MPa√m ) |
|---|---|---|
| MDN 250 | 1652-1689 | 82 -100 |
| MDN 350 | 2200-2300 | 38-40 |
| DMR 1700 | 1550 | 80 |
| Titan 31A | 830 | 50 |
| Titan 33A | 900 | 60 |

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