FRACTURE TOUGHNESS TESTS OF CERAMICS

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

- **Crack formation**
- **Crack propagation**

There are two fracture mechanisms: ductile fracture and brittle fracture.

Ceramic materials have extremely low ductility, therefore they failure by brittle mechanism.

- **Brittle fracture**
- **Fracture Toughness**
- **Flexure Test**
- **Indentation Fracture Test**

Brittle fracture

Brittle fracture is characterized by very low Plastic deformation and low energy absorption prior to breaking.
A crack, formed as a result of the brittle fracture, propagates fast and without increase of the stress applied to the material.

The brittle crack is perpendicular to the stress direction.

There are two possible mechanisms of the brittle fracture: **transcrystalline (transgranular, cleavage)** or **intercrystalline (intergranular).**
Cleavage cracks pass along crystallographic planes through the grains.
Intercrystalline fracture occurs through the grain boundaries, embrittled by segregated impurities, second phase inclusions and other defects.
The brittle fractures usually possess bright granular appearance.

Fracture Toughness

Fracture Toughness is ability of material to resist fracture when a crack is present.
The general factors, affecting the fracture toughness of a material are: temperature, strain rate, presence of structure defects and presence of stress concentration (**notch**) on the specimen surface.
Stress-intensity Factor (K) is a quantitative parameter of fracture toughness determining a maximum value of stress which may be applied to a specimen containing a crack (notch) of a certain length.

Depending on the direction of the specimen loading and the specimen thickness, four types of stress-intensity factors are used: **K_C**, **K_{IC}**, **K_{IIC}**, **K_{IIIC}**.
K_C– stress-intensity factor of a specimen, thickness of which is less than a critical value.
K_C depends on the specimen thickness. This condition is called **plane stress**.
K_{IC},K_{IIC}, K_{IIIC}– stress-intensity factors, relating to the specimens, thickness of which is above the critical value therefore the values of **K_{IC}, K_{IIC}, K_{IIIC}** do not depend on the specimen thickness. This condition is called **plane strain**.
K_{IIC} and **K_{IIIC}** – stress-intensity factors relating to the fracture modes in which the loading direction is parallel to the crack plane. These factors are rarely used for metallic materials and are not used for ceramics;
K_{IC} – plane strain stress-intensity factor relating to the fracture modes in which the loading direction is normal to the crack plane. This factor is widely used for
both metallic and ceramic materials.
K_{IC} is used for estimation critical stress applied to a specimen with a given crack length:
$\sigma_C \leq K_{IC} /(Y(\pi a)^{1/2})$
Where

K_{IC} – stress-intensity factor, measured in MPa*m½;
σ_C– the critical stress applied to the specimen;
a – the crack length for edge crack or half crack length for internal crack;
Y – geometry factor.
Two test methods are used for measuring fracture toughness parameter (stress-intensity factor) of ceramic materials: Flexure Test and Indentation Fracture Test.

Flexure Test

The test method is similar to that which is used for measuring Flexural Strength, however notched specimens are used.

Indentation Fracture Test

Vickers Hardness Method is used for this test.
Polished surface of a ceramic sample is indented by Vickers Indenter, resulting in formation of four cracks emanating from the indent corners.
The cracks length is inversely proportion to the material toughness; therefore **K_{IC}** may be estimated by measuring the cracks length.

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