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# A Review On Analysis Of Fracturetoughness Parameters And Crack Growth Initiation Of Pressure Vessel & Piping Materials

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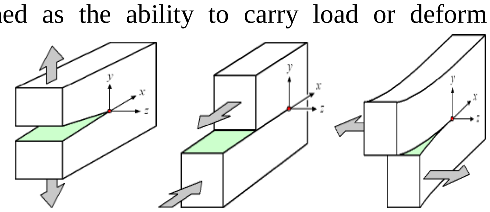
**Abstract-There are many components of mechanical machines, industrial process plants and household appliances that fail through overloading improper utilities. Tradition failure criteria cannot adequately explained many structural failures that occur at stress level consider lower than the ultimate strength of the material e.g. bridges, tanks, pipes, weapons, ships, railways and aerospace structures.Some of these failures occur due to deficiency of constructions, but many due to material deficiencies in the form of pre-existing flaws that initiates cracks and thus caused fracture. This paper summarizes the overview of several important fracture toughness parameters like critical stress intensity factor, J-Integral & Crack tip opening displacement (CTOD).**

**Key words-**critical stress intensity factor, j-integral, Crack-tip opening displacement, critical length of the crack.



## 1.INTRODUCTION

Fracture Toughness Parameters are concern in the field of fracture mechanics.Fracture mechanics is based on the implicit assumption that there exists a crack in a work component. The crack is artificially prepared in different shapes i.e. a hole, a notch, a slot, a re-entrant corner etc. The crack may exist within a component due to manufacturing defect like slag inclusion, cracks in a weldment or heat affected zones due to uneven cooling and presence of foreign particles. A dangerous crack may be nucleated and grown during the service of the component (fatigue generated cracks, nucleation of notches due to environmental dissolution). Fracture mechanics is with the question, a known is crack likely to grow under a certain given loading condition. Initially, the fluctuating load nucleates a crack, which than grows slowly and finally the crack growth rate per cycle picks up speed. Thereafter comes the stage when the crack length is long enough to be considered critical for a catastrophic fracture failure.A segment of crack front can be divided into three basic modes shown in Fig.1.1



I-Opening Mode, II-Sliding Mode, III-Tearing Mode

**Fracture Design Consideration[1]:**the development of fracture mechanics shows that there are three primary factors that can control the brittle fracture:

Material toughness ($K_c$, $K_{Ic}$):Material toughness can be defined as the ability to carry load or deform plastically in the presence of a notch and can be described as critical stress intensity factor under conditions of plane stress($K_c$) or plane strain ($K_{Ic}$) for slow loading and linear-elastic behaviour.

Crack size (a):Brittle fracture initiate from discontinuities of various kinds. Complex welded structures are not fabricated without discontinuities.

Stress level (σ):Tensile stresses (nominal, residual or both) are necessary for brittle fractures to occur.

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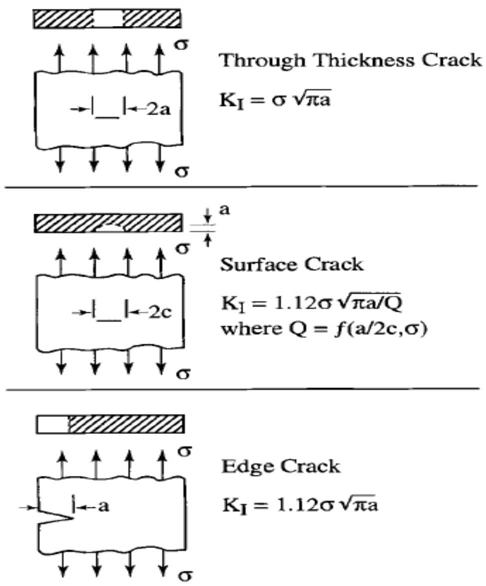



Fig.1.2 $K_I$ values for various crack geometries

## 2.LITERATURE REVIEW

Evans et al. [2] described a method of testing cylinder wall material based on the compact tension specimen design. The test differs from the test using the well-known C-shape specimen because fracture propagating in the direction of the cylinder axis is simulated in the new test as shown in fig.2.1. Fracture of the specimen simulates crack extension along the axis of the cylinder driven, for example, by the hoop stress in a pressure vessel wall.

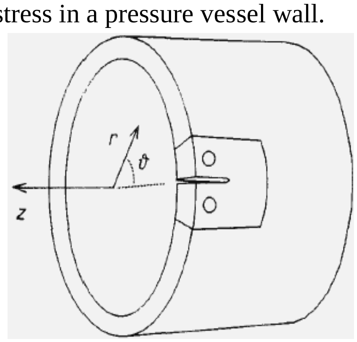



Fig 2.1 Specimen taken from a cylinder wall.

Some examples of tests on specimens taken from an aluminium alloy cylinder were given. The authors have tested a number of specimens taken from the walls of aluminium alloy cylinders (158 mm internal diameter, 8 mm wall thickness).

Zheng et al. (1997) [3] has discussed method of calculating stress intensity factors for cracks subjected to complex stress. The method is based on the use of generalized weight functions. In this paper mode I weight function were derived for the deepest and surface points of an internal, radial-longitudinal, surface, semi-elliptical crack in an open-ended, thick wall cylinder with internal radius to wall thickness ratio Ri/t= 2.0 and the generalized weight function expression for deepest and surface points of the crack were utilized.

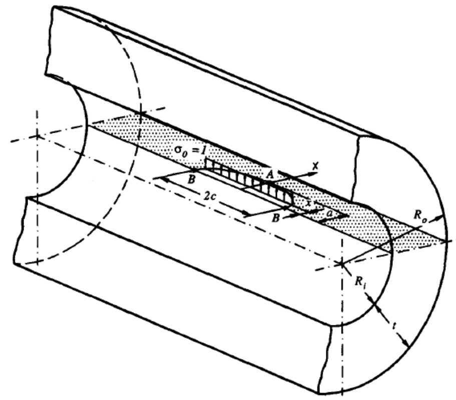
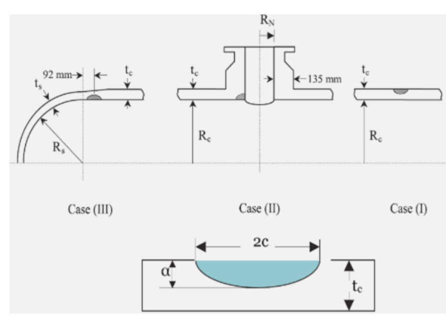



Fig-2.2 Internal, radial-longitudinal, surface, semi-elliptical crack in a cylinder



It has been shown that the weight function enable the determination of stress intensity factor for variety of geometrical and stress field configuration. The crack opening displacement analysis based also on the use of same weight functions revealed that crack in auto-frettaged cylinder (refer Fig. 2.2) may remain partially closed indicating that the usual superposition method might not be valid in some cases.

G.N. Labeas&Diamantoudis [4]have studied the problem of calculation of stress intensity factors(SIF) of semi-elliptical cracks located in the stress concentration areas of a pressure vessel and solved numerically by advanced global-local finite element (FE) analysis. They refer to a single semi-elliptical crack located at three different areas of the pressure vessel as shown in fig.2.3



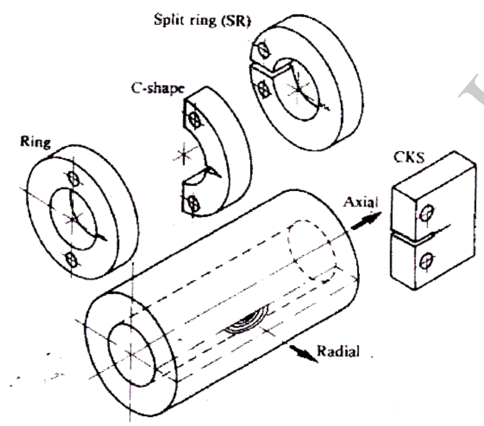

The main conclusions drawn from the study can be summarized as follows:

• SIF results of cracks located in geometrical discontinuity areas of pressure vessels are computed and presented in the work, for various a/c and $a/t_c$ ratios in a form suitable for design purposes.

• The sub-modeling technique is proven to be an accurate and particularly efficient method for the determination of SIF values of semi-elliptical cracks in pressure vessels.

• A crack located at the nozzle–cylinder body intersection, which is the highest stress concentration area of the pressure vessel, is less critical for large a/tc and small a/c ratios, as compared to the same crack located away from this discontinuity area.

Webster et al. [5] (2007) investigated the failure of thick walled tubing subjected to internal pressure. Thick-walled tubing is used for variety of applications in the chemical, nuclear and armaments industries where high internal pressure has to be withstood. If this pressure is cyclic, initiation and propagation of cracks by fatigue may take place with the ultimate risk of failure by fast fracture. Usually fatigue crack in thick walled cylinders initiate at the bore and propagate in a radial plane in the manner




illustrated in Fig. 2.3

Fujczak and Throop[6] investigated experimental strains and load-line deflections of C-shaped fracture-toughness test specimens were reported as functions of load and increasing crack depth (Fig. 2.4). In this study the changes in inner and outer surface strains and the compliance are investigated as functions of increasing crack depth in order to clarify the behaviour of the cracked C-shaped specimen. It is shown that the variation in strain at the outer surface may be used as indicator of fatigue crack growth for evaluating the critical load in fracture toughness tests.

The stresses and load-line deflections are compared with theoretical values calculated for the un-cracked specimens. Their relation to the stress intensity factor of the cracked specimen was examined.

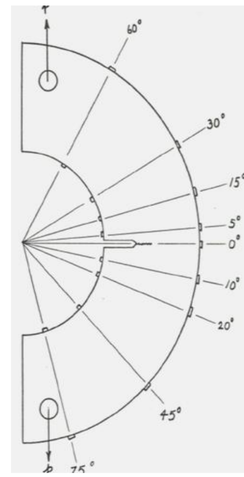
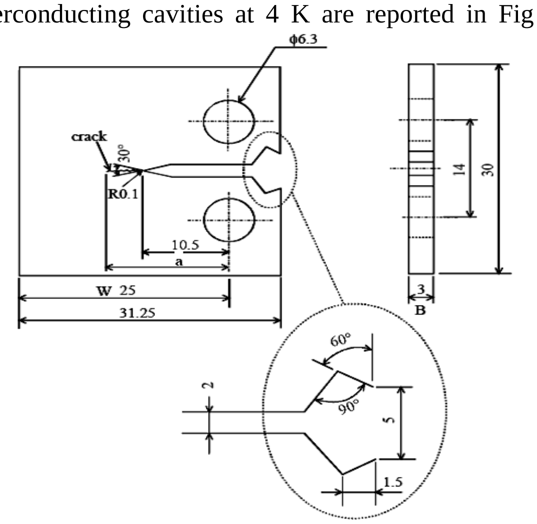



Fig 2.4 Strain gauge positions on C-shaped specimen

The important conclusion of their work was that in the pin-loaded C-shaped specimen the strains on the inner surface are related to crack depth only for very shallow crack depths and the strains on the outer surface directly in front of the crack line, are related to crack depth and may be used as an indicator of crack growth.



Ishio et al. [7] in their paper, the results of fracture toughness and mechanical tests of pure niobium plates (3-mm-thick) and welded joints for superconducting cavities at 4 K are reported in Fig




2.5 Shape of fracture toughness specimen (1/2 CT)

The result shows that fracture toughness ($K_Q$) for bulk Nb at 4 K is 45.5 MPa·m$^{1/2}$and 33.5 MPa·m$^{1/2}$ for weld bead. The fracture of Nb at 4 K initiates the microvoids and micro-cracks and finally these defects cause the cleavage fracture.

Zhu. G.P et al. [8] Crack initiation and stable crack growth under monotonic loading in steels has been studied using an elastic-plastic finite element analysis. The fracture criterion used for crack

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initiation and stable crack growth was the critical strain energy density. In addition the shift core method for the analysis of crack extension was used. In the shift core modeling method, crack advance is simulated by moving the coordinates of the core region which surrounds the crack tip, to obtain the stiffness reduction. The analytically calculated and experimentally measured load for crack initiation and the subsequent stable crack growth agreed well.

Degiorgi V.G et al. [9] have discussed an experimental and computational study of HY-100 steel three-point bend fracture specimens. Two specimens were considered in the experimental portion of the study, differing with respect to thickness and the presence of side grooves. Plane stress and plane strain finite element analyses of the specimens were conducted to assess the relative role of constraint on load vs. crack opening displacement response and crack growth initiation. A critical value of the strain energy density associated with local material fracture was used to predict the onset of crack growth. The experimental responses were bounded by the predicted plane stress and plane strain load vs. crack mouth opening responses. These results also provided an indication of the extent to which the side grooves in the thinner specimen provided more constraint than the thickness of the specimen without side grooves. A comparison with a previous investigation on an HY-100 compact fracture specimen suggests similarities concerning the interaction between material nonlinearity and specimen response nonlinearity.

## CONCLUSIONS

The extensive literature survey carried out during the course of work clearly shows that there is need of study of crack develops in a material used in different application even-though the load applied on that machine components at stress level lower than the ultimate strength of the material. Here it is research need to understand the characteristics of cracks and its developments.

Stress intensity factors are a function of load, crack size and geometry. The critical stress-intensity factor, Kc at which unstable crack growth occurs for conditions of static loading at a particular temperature actually depends on specimen thickness as shown in fig.3.1

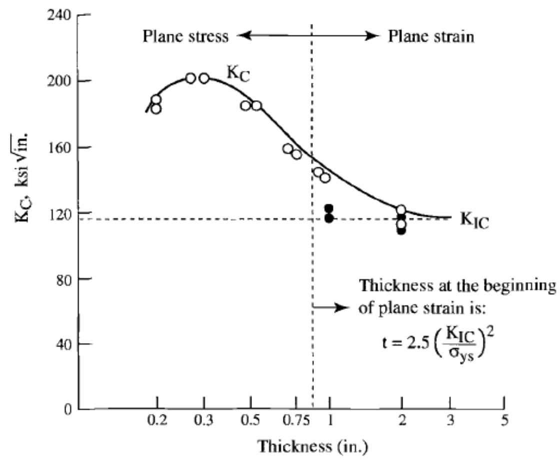


fig.3.1Effect of thickness on Kc behaviour

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