Analysis of Cracked Cylindrical Pressure Vessel by using Experimental approach

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Abstract- Fracture Mechanics is a set of theories describing the behavior of solids or structures with geometrical discontinuity. The discontinuity features may be in the form of line discontinuities in two-dimensional media (such as plates & shells) & surface discontinuities in three-dimensional media. One of the important aspects of fracture mechanics is the establishment of a new design philosophy "damage tolerance design methodology". Major advantage of fracture mechanics is fracture parameter stress intensity factor. Stress Intensity Factor (SIF) is essential Linear Elastic Fracture Mechanics (LEFM) parameters for structural integrity assessment of structures containing cracks and singular stress fields. SIF gives a measure of the intensity of the stress field in the crack tip regionbyusingFiniteElementAnalysis, Numericalmethod, Leastsquaremethod,RepresentativeVolumeElementmethod,StrainGaugemethod,TwoParameterfracturemetd. In this paper review is taken for different methods for determining stress intensity factor for cracked cylindrical pressure vessel. In my present work the problem of calculation of the stress intensity factors (SIF) for surface cracks located in the stress concentration areas of a pressure vessel is considered.

Keywords – Cracked Cylinder Pressure Vessel, Fracture Mechanics, Stress Intensity Factor, Strain Gauge, Surface Crack

I. INTRODUCTION

Fracture mechanics can be divided into linear elastic fracture mechanics (LEFM) & elasto-plastic fracture mechanics (EPFM). LEFM gives excellent results for brittle-elastic materials like high-strength steel, glass, ice concrete & so on, however, EPFM gives excellent results for ductile materials like low carbon materials like steel, stainless steel, certain aluminum alloys & polymers, plasticity will always precede fracture. Also it may be noted that, when the load is low enough, linear fracture mechanics provides a good approximation to the physical reality. Usually fractures are dangerous and costly with respect to structural failure mode. Notable examples include collapse of aero-structures, automobile chassis, railway bridges, pressure vessel, ships and pipeline explosions.

The term "fracture mechanics" refers to a vital specialization within solid mechanics in which the presence of a crack is assumed, and quantifies relations between the crack length, the material's inherent resistance to crack growth, and the stress at which the crack propagates at high speed to cause structural failure.

Fracture mechanics is the name coined for the study which combines the mechanics of cracked bodies and mechanical properties. As indicated by its name, fracture mechanics deals with fracture phenomenon and events. The establishment of fracture mechanics is closely related to some well knows disaster in recent history .The failure occurs primarily because of the change from riveted to welded construction and the major factor was the combination of poor weld properties with stress concentrations and poor choice of brittle materials in the construction.

A major achievement in the theoretical foundation of LEFM was the introduction of the stress intensity factor (SIF) as a parameter for the intensity of stresses close to the crack tip and related to the energy release rate. Stress intensity factors are a measure of the change in stress within the vicinity of the crack tip. Therefore, it is important to know the crack direction and when the crack stops propagating. The stress intensity factor is compared with the critical stress intensity factor K_{IC} (material fracture toughness value) to determine whether or not the crack will propagate.

I. 1Objective of Presented Paper

Basically the objective of presented paper is following-

1. To study major causes of failures of pressure vessel.

2. To analyze the cracked pressure vessel for various crack dimensions and for various materials for calculation of stress intensity factor.
3. To analyze the cracked pressure vessel for various materials of pressure vessel for calculation of stress intensity factor.

The cracked cylindrical pressure vessel subjected to surface crack considered for present work.
In Presented paper the experimental method implemented for solving the problem concern with the surface crack. The Cracked Cylindrical Pressure Vessel material selected for carry out the Experimental work are commonly used
1. Stainless Steel
2. Aluminium
3. Brass
4. Mild Steel
5. Copper

I. 2 Problem Definition

In the present paper the problem related to cracked cylindrical pressure vessel is considered for calculating SIF.
A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure.
The failure of pressure vessel are due to different causes are as follows-
1. Failure due to cracking, explosion ruptures, creep and stress rupture.
2. Overtempture,overpressure corrosion, Stress corrosion cracking
3. Faulty inspection, damage during shipment and store
4. Improper material used in processing
5. Discontinuities, faulty welding, stress raisers, Caustic embrittlement, Erosion

The rest of the paper is organized as follows. Proposed embedding and extraction algorithms are explained in section II. Experimental results are presented in section III. Concluding remarks are given in section IV.

II. Modes of Fracture

Three Modes of Cracking-
Mode I -opening mode
Mode II -in-plane shearing/sliding mode
Mode III -out-of-plane shearing/tearing mode

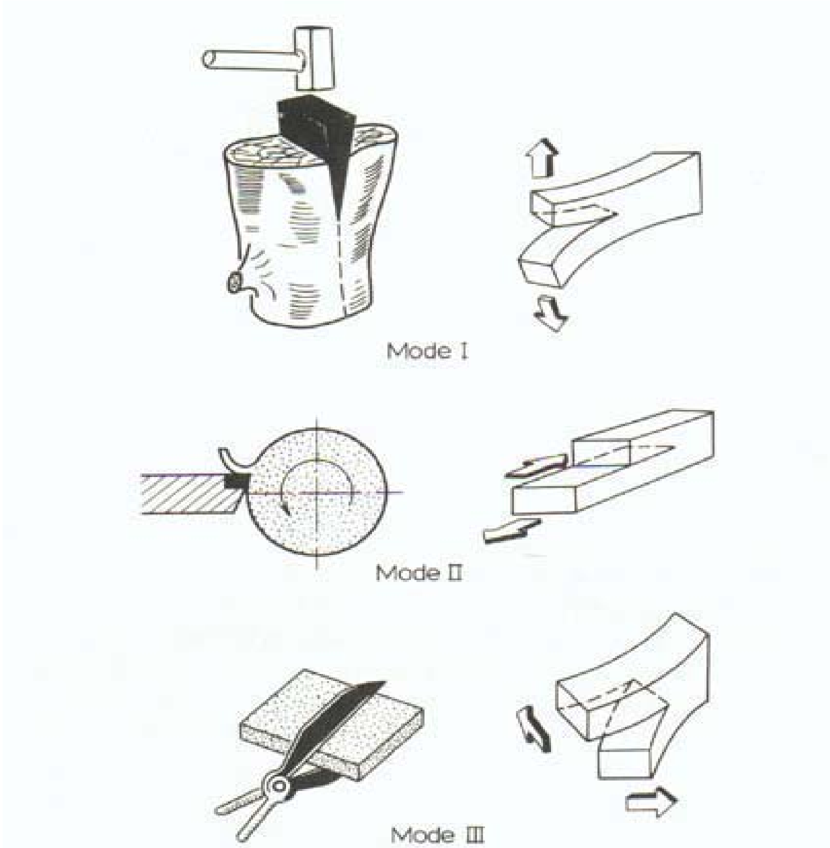

Fig.1 Modes of fracture

In the mode I or opening mode, the body is loaded under tensile forces, such that the crack surfaces are pulled apart in the opposite direction. The deformations are then symmetric with respect to the planes perpendicular to the y axis and the z axis.

In the mode II or sliding mode, the body is loaded under shear forces applied parallel to the cracked surfaces, which slide over each other in the direction of applied forces. The deformations are then symmetric with respect to the plane perpendicular to the z axis and skew symmetric with respect to the plane perpendicular to the y axis.

Finally, in the mode III or tearing mode, the body is loaded under shear forces parallel to the crack front and the crack surfaces slide over each other in the z direction. The deformations are then skew-symmetric with respect to the plane perpendicular to the z and the y axis.

III. Experiment and Result

A. Method to Solve Problem

Methods for solving the problem related to cracked cylindrical pressure vessel –

1. Experimental Method
2. FEM Method
3. Analytical Method

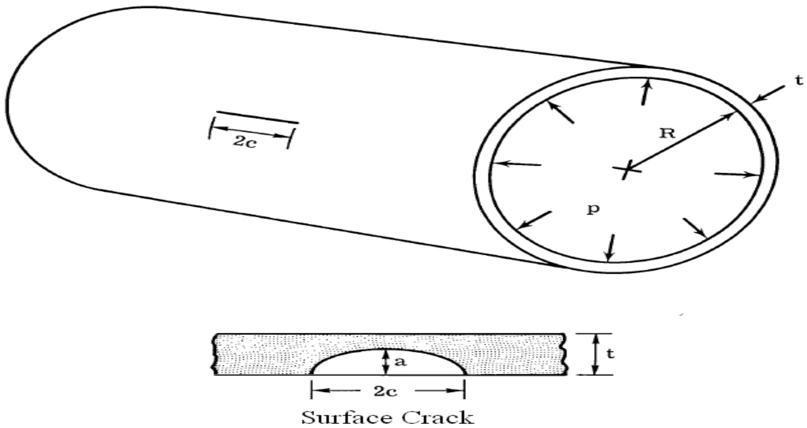

Fig. 2:-Surface cracked in pressurized cylinder

a=Initial depth of surface crack, mm
c=Initial length of surface, mm
R=Internal radius of cylindrical pressure vessel, mm
p=Initial pressure, Pa
t=Shell thickness, mm

The Following Table Showing Theoretically and Experimentally Determined Boundary-Correction Factors for Surface Cracks in Pressurized Cylinders Made Of a Brittle Epoxy.

Table I

a mm	**C mm**	**Experimental F**	**Theoretical F**	**Theoretical F / ExperimentalF**
13.2	**14.6**	**0.959**	**0.932**	**0.97**
12.2	**14.2**	**0.878**	**0.863**	**0.98**
11.1	**14.5**	**0.846**	**0.855**	**1.01**
10.9	**14.5**	**846**	**0.823**	**0.97**
10.5	**15.9**	**0.808**	**0.841**	**1.04**
11.5	**14.4**	**0.831**	**0.839**	**1.01**
10.7	**14.5**	**0.785**	**0.819**	**1.04**
6.9	**9.5**	**0.682**	**0.696**	**1.02**
6.9	**8.3**	**0.708**	**0.689**	**0.97**
7.3	**8.3**	**0.672**	**0.689**	**1.03**
5.4	**8.5**	**0.621**	**0.677**	**1.09**

B. Experimental Set Up
The experimental set up for calculating the stress intensity of cracked cylindrical pressure vessel is as per following-

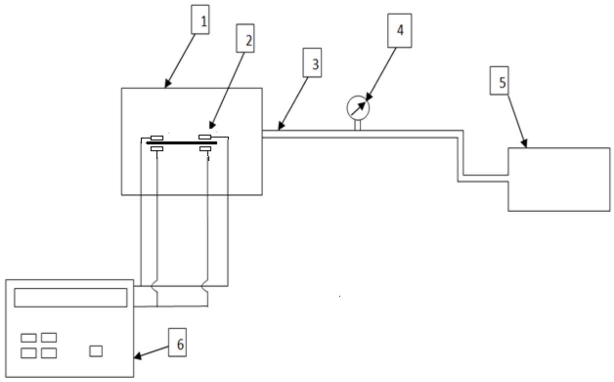

Fig 3. : Schematic Experimental setup

The different components used in experimental set up are as follows-
1. Cracked pressure vessel component
2. Strain Gauges
3. Pipe Carrying Fluid
4. Pressure Gauge
5. Hand Pump
6. Strain value Indicator

4.1. Specification of material
Dia .38 x 50 mm bore x 205 mm length
Maximum pressure – 100 Mpa
Min.pressure – 10 Mpa

Strain gauges are the most widespread device to date in experimental stress analysis. This is due their relatively low cost, on-invasiveness and ease of use in most environments. The fracture mechanics of both stationary and propagating Cracks in homogenous materials or interfaces have been extensively investigated using strain gauges. The accuracy of determination of the stress intensity factors depends on the gauge location and orientation relative to the crack tip.

*C.Calculation of Elastic Stress Intensity Factor by using Empirical Equation***-**

The elastic stress-intensity factors for surface cracks in pressurized cylinders have not been obtained theoretically, but some experimental stress intensity factors have been determined from surface cracks. In this paper an empirical equation giving elastic stress-intensity factors for surface cracks has been developed. Surface Crack in a Thin Pressurized Cylinder, for the internal or external surface crack (axial) in a cylindrical shell subjected to internal pressure (fig.2) the elastic stress-intensity factor at failure is also given by equation

$K_{Ie} = Sn \sqrt{\pi c}\, F$ -- (1)

The equation is valid for mode I crack length where Sn the nominal stress c is the initial crack length (defined in figs. 1) and F is the boundary correction factor. The boundary-correction factor accounts for the influence of various boundaries and crack shape on stress intensity. The following equation give the nominal stress equation and the boundary-correction factor equations for the surface cracked cylindrical pressure vessel is given by

$S_n = pR/t$ ---- -- (2)

$F = a/cQ\ M_e\ fs$ -- (3)

The square-root term converts the through-crack expression to that for a surface crack, M is the combined front-face and back-face correction factor, and f is the shell-curvature correction factor for a surface crack.

The elastic shape factor Q

$Q=1+1.47(a/c)^{1.64}$ $a/c<1.0$ ------------- -------------- (4)

$Q=1+1.47(c/a)^{1.64}$ $a/c>1$------------------------------- (5)

The expression for M_e is given by

$M_e = [M_1+(Qc/a-M_1)(a/t)^q]$ --------------------------------(6)

Where q was determined empirically as

$q=2+8(a/c)^3$ -------------------- ---------------------------- (7)

The term M- is the front-face correction, and the a/t term is the back face correction .The expression for M- is given by

M_1=1.13-O.1 (a/c) (0.02<a/c<1.0) --------------- (8)

M_1=c/a (1+o.o3c/a) (a/c>1.0) ------------------- (9)

The shell-curvature correction factor for a surface crack f is given by

$f_s = 1+0.53l_s+1.29l_s^2-0.074l_s^3)^{1/2}$ ----------------------(10)

for 0 <ls<10 10 where ls=c/Rt.a/t Again, Poisson's ratio was assumed to be 1/3. The form of ls was obtained by assuming that the surface crack could be replaced by an "equivalent" through crack of equal area as a/t approaches unity, is approaches .The equation (1) is compared with some experimentally-determined correction factors for a brittle epoxy.

IV. Conclusion

1. When the length of crack is increased then SIF also increases.
2. Strain Gauge gives good results to calculate SIF.

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