International Journal of Technology and Engineering Sciences (IJTES)

www.mapscipub.com

Volume 03 || Issue 01 || January 2023 || pp. 24-30 E-ISSN: 2583-1925

Analysis of The Crack in The Thick Pressure Vessel

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Abstract In several sectors, crack propagation behaviour is a serious problem. pipes, pressure vessels, gas turbines, and aerospace constructions. In this study, pressure vessel cracks have undergone a thorough investigation. A component or structure is not automatically deemed dangerous and hence unreliable just because it has a crack in it. It is important to understand how long an initial fracture of a specific size would take to expand to a critical size at which the component or structure would become hazardous and fail, whether under cyclic or continuous loads. Additionally, one should be able to calculate the residual service life of a component under typical service loading conditions by understanding how a fracture develops and how quickly it spreads. This aspect motivates us to employ the numerical approach. To forecast the spread of 3D cracks. The current study looked into an elliptical fracture in a pressure vessel by measuring the Stress Intensity Factor (SIF) of cracks for model-I surface displacement in three dimensions. In this study, the SIF of an axial fracture onto the inner surface of a cylinder was computed using a semi-parametric method in ANSYS software. The results were then compared to those obtained by other researchers using various analytical techniques. An FEA simulation in ANSYS was used to perform this evaluation in this case.

Key Words: Pressure Vessel, Stress Intensity Factor**,** Crack propagation, ANSYS, Finite Element Method

1. INTRODUCTION

In the industrial, cylindrical structures are frequently employed (Gas and oil pipelines, pressure vessels, piping, etc.). These cylindrical structures frequently operate under harsh conditions, including thermal shock, high internal pressure, and high or low working temperatures.

A cylindrical pressure vessel is a container that holds a liquid, vapour, or gas at a different pressure other than atmospheric pressure at the same elevation.

According to the principle of thick and thin cylinders, the most hazardous longitudinal cracks are those that are found on the internal face of the cylinder. Pressure vessels and pipes can occasionally acquire semi-elliptical surface cracks while being used or produced. Crack flaws are important in these applications, thus subsequent fracture and fatigue analysis of such cracks is of major practical importance and necessitates the measurement of stress intensity variables.

To obtain the safe design conditions SIF calculations should be considered. Although several stress intensity factor handbooks have been published, the available solutions of stress intensity factors for pressure vessels are not always adequate for particular engineering applications.
Stress Intensity Factor (SIF) of a crack may be efficiently determined by 'Weight Function' method. But it pertains of complicated calculations and when there are many types of cracks to be studied on different types of bodies this method becomes cumbersome. Calculation of SIF of a three dimensional crack using Finite Element Method (FEM) may replace 'Weight Function' method due to its less functional complicacy. To determine SIF of a three dimensional crack using FEM, any FEM tool like ANSYS/NASTRAN/ABACUS etc. may be used. In this thesis ANSYS has been used and whole the analysis process in ANSYS has been done semi-parametrically. But before the discussion on the process adopted in ANSYS it is necessary to discuss about stress in a cylinder.

Thin walled pressure vessels are the most categorized. A thin walled pressure vessel is any cylinder [shell] for which the ratio of the thickness to the diameter is 10% or less. Another way of saying this is a pressure vessel is thinned walled if the diameter is 10 times or more the thickness. Also, Kumar et al. [19] optimized the pressure vessel using CFD analysis

2. RESEARCH METHODOLOGY

2.1. Stress in a thin cylinder

$\frac{t}{d} < 0.1$	1.1

Consider a cylindrical pressure vessel

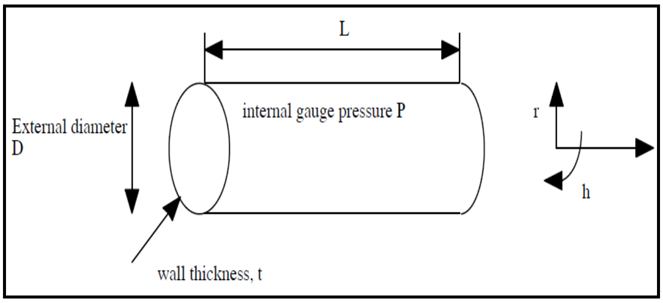

Fig.1: Schematic Diagram of a Cylinder.

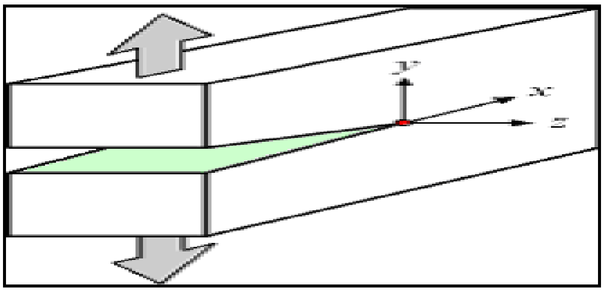

Fig 2: Mode-I of crack surface displacement

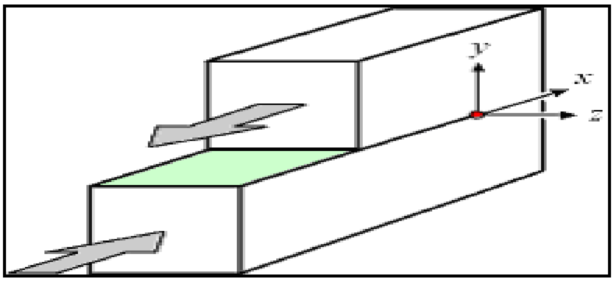

Fig 3: Mode-II of crack surface displacement

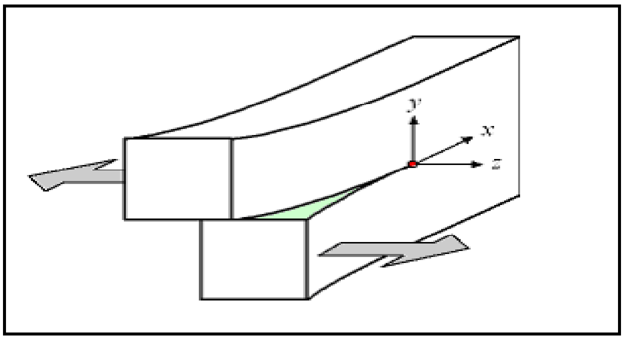

Fig 4: Mode-III of crack surface displacement

2.2. Stress in a thick cylinder

A thick walled pressure vessel is any cylinder [shell] for which the ratio of thickness to the inside diameter is 10% or more.

$$\frac{t}{d} \geq 0.1 \qquad 1.2$$

Using a theory of elasticity derivation, the stresses for internal pressure (p) on a thick-walled cylinder are:

$$\sigma_A = \frac{pR_i^2}{R_o^2 - R_i^2} \text{ Axial stress} \qquad 1.3$$

$$\sigma_C = \frac{pR_i^2\left(1+\frac{R_o^2}{R^2}\right)}{R_o^2 - R_i^2} \quad \text{Circumferential stress} \qquad 1.4$$

$$\sigma_R = \frac{pR_i^2\left(1-\frac{R_o^2}{R^2}\right)}{R_o^2 - R_i^2} \text{ Radial stress} \qquad 1.5$$

Where (R_i) = internal radius,

(R_o)= external radius

3.MODELLING ANALYSIS

3.1. Basics of Fracture Mechanics

These basic modes of crack surface displacements are Mode-I, the opening mode Fig 2, Mode-II the (edge) sliding mode Fig 3, Mode-III, the tearing mode Fig 4.

This study has looked at an axial semi-elliptical crack on a cylinder's inner surface.

In order to prevent free surface effects, it is assumed in the models that L >> 2c. Cylinders with an R/t of 5 to 20 are taken into account in this study. As pipelines, hydraulic cylinders, structural components, etc., these cylinders are frequently employed. As pipelines, hydraulic cylinders, structural components, etc., these cylinders are frequently employed.

L	= Cylinder Length (m).
Ro	= Cylinder Outer radius (m).
Ri	= Cylinder Inner radius (m).
R	= radial distance of a point on the crack front (mm).
a	= Minor axis of semi-elliptical crack (mm)
c	= Major axis of semi-elliptical crack (mm).

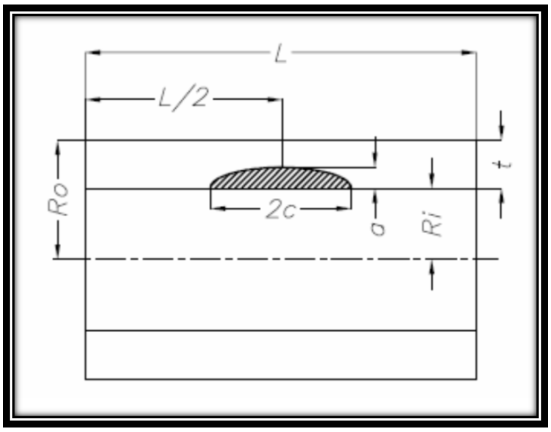

Fig 5: Axial inner semi-elliptical crack

Figure 6 depicts a model of a cylinder where the mesh area is swept along the fracture front, and Figure 7 displays the mesh tubular volume.

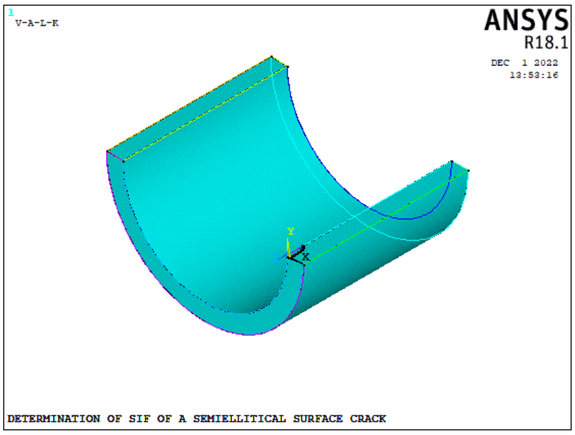

Fig 6: Model of the cylinder.

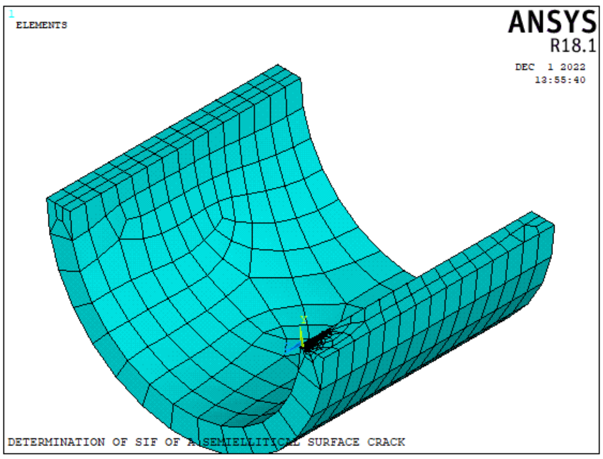

Fig 7: General view of crack model after meshing.

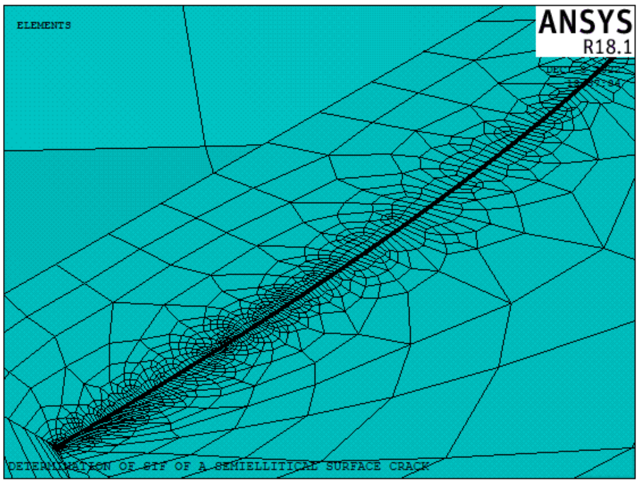

Fig 8: Meshing around the crack front.

TABLE 1: INPUT PARAMETERS FOR THE ANALYSIS

Parameter	Value
Inner pressure of magnitude (P)	10 Mpa
Radial distance from the point on crack front (R)	50 mm
Radial distance from crack front to cylinder thickness ratio (R/t)	5, 10 and 20 (3 Values)
Half crack length in minor axis to cylinder thickness ratio (a/t)	0.2, 0.4 and 0.6 (3 Values)
Ratio of Half-length of crack (in minor axis) to Half -length crack (in major axis) (a/c)	0.2, 0.4 and 0.8 (3 Values)

4.RESULT AND DISCUSSION

Now graphs (9) have been plotted between KI* values and different (a/t) values, the present ANSYS results have been compared with the Nabavi's [4] work, we can see from the Fig. that it follows the same trend and show the minimum deviation of 0.86 % and maximum deviation of 12.26 % with the results reported in the literature [4].

Several graphs produced from Nabavi's [4] work and the current study (obtained from ANSYS) are shown in the figures below for various values of the (a/c) ratio.

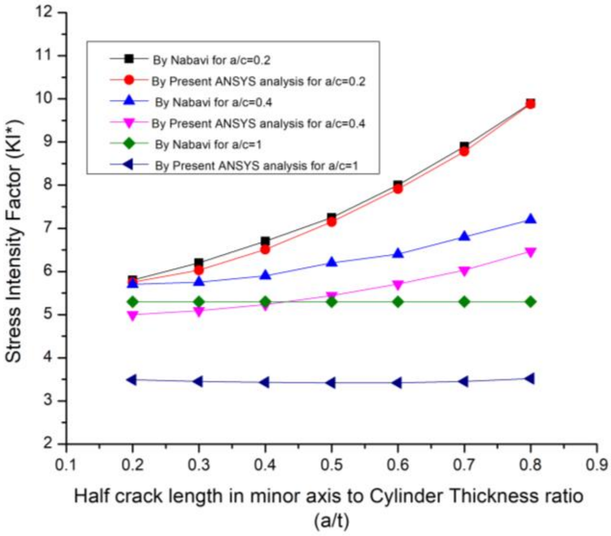

Fig 9: Comparison of results of (a/t) with (KI*) with Nabavi [4]

Fig. 10 to 12 shows the variation of (KI*) for different values of Crack Front Angle (Φ) from 0° - 90º, into these figures R/t = 5 has been taken fixed while the values of (a/t) is vary 0.2 to 0.6. We can conclude from these Fig. that while increasing the value of (a/t) the (KI*) increases.

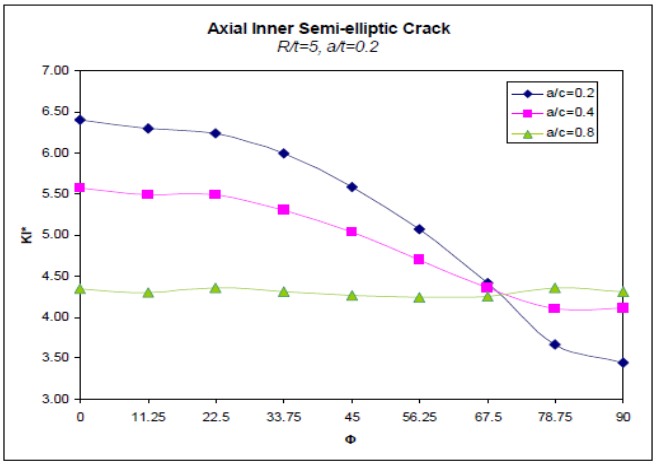

Fig 10: Variation of (KI*) for different values of Crack Front Angle (Φ), Type-1, as (R/t) = 5 and (a/t) = 0.2.

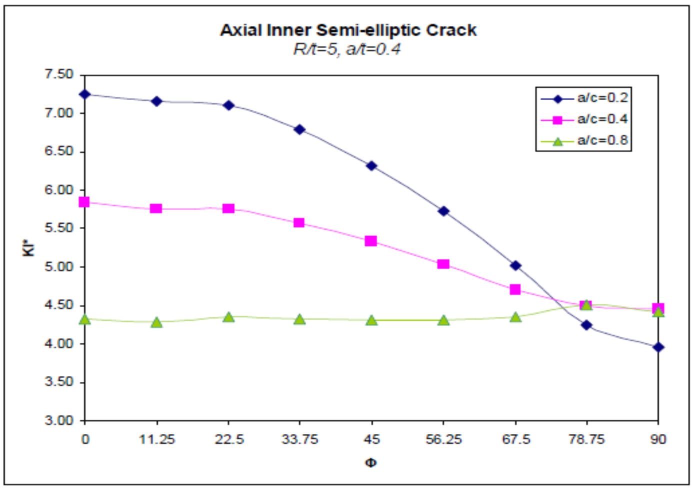

Fig 11: Variation of (KI*) for different values of Crack Front Angle (Φ), Type-1 as (R/t) =5 and (a/t) = 0.4.

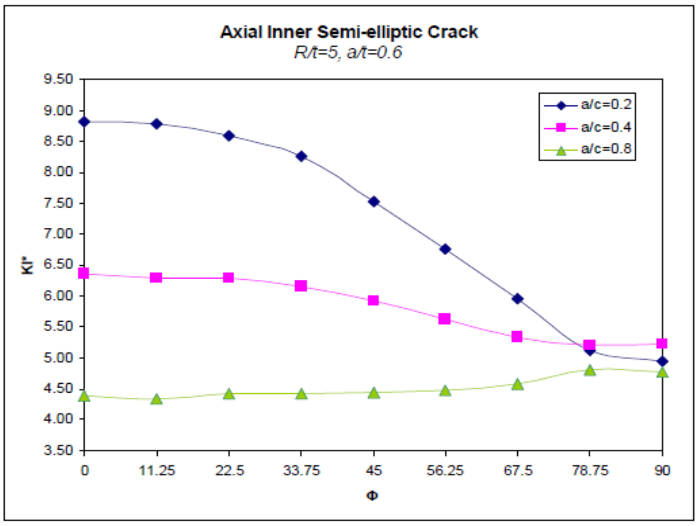

Fig 12: Variation of (KI*) for different values of Crack Front Angle (Φ), Type-1 as (R/t) =5 and (a/t) = 0.6.

Fig. 13 to 15 shows the variation of (KI*) for different values of Crack Front Angle (Φ) from 0° - 90º, into these figures R/t = 10 has been taken fixed while the values of (a/t) is vary 0.2 to 0.6.

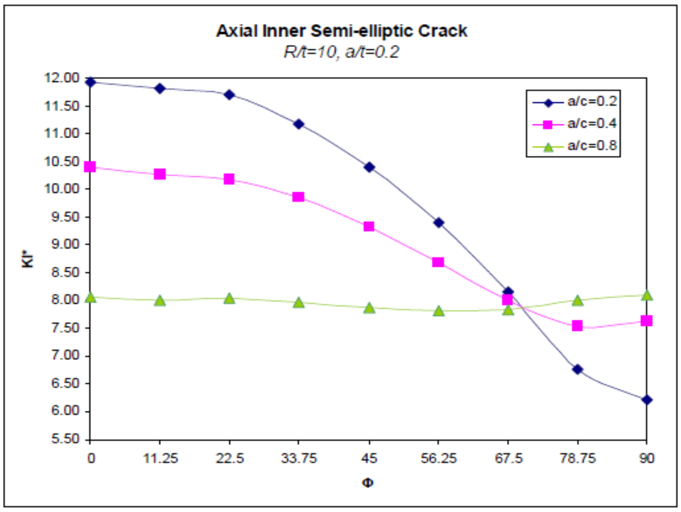

Fig 13: Variation of (KI*) for different values of Crack Front Angle (Φ), Type-1 as (R/t) =10 and (a/t) = 0.2.

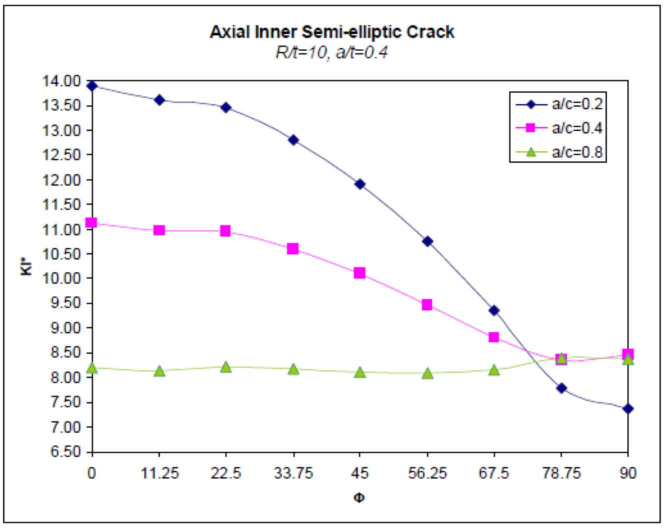

Fig 14: Variation of (KI*) for different values of Crack Front Angle (Φ), Type-1 as (R/t) =10 and (a/t) =0.4.

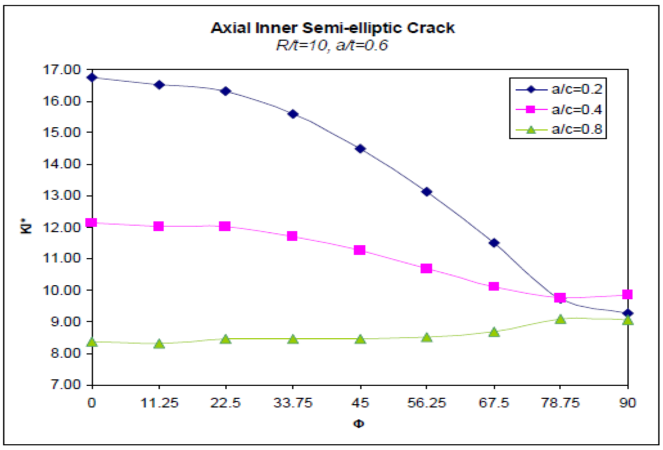

Fig 15: Variation of (KI*) for different values of Crack Front Angle (Φ), Type-1 as (R/t) =10 and (a/t) =0.6.

Fig. 16 to 18 shows the variation of (KI*) for different values of Crack Front Angle (Φ) from 0° - 90°, into these figures R/t = 20 has been taken fixed while the values of (a/t) is vary 0.2 to 0.6.

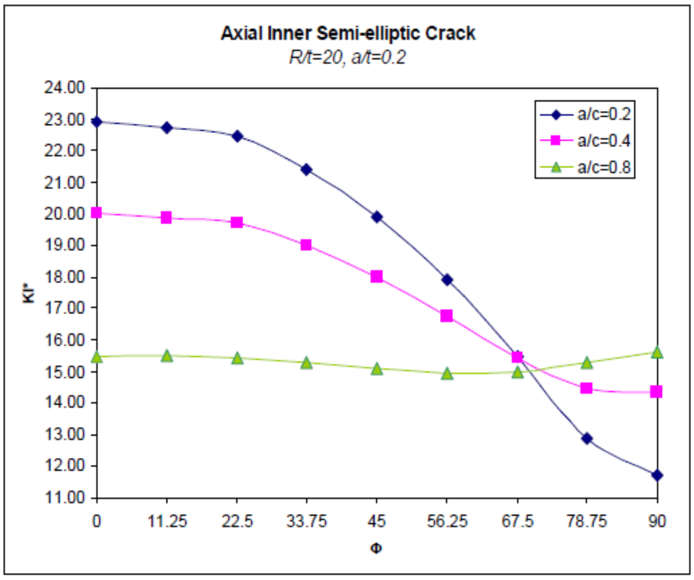

Fig 16: Variation of (KI*) for different values of Crack Front Angle (Φ), Type-1 as (R/t) = 20 and (a/t) = 0.2.

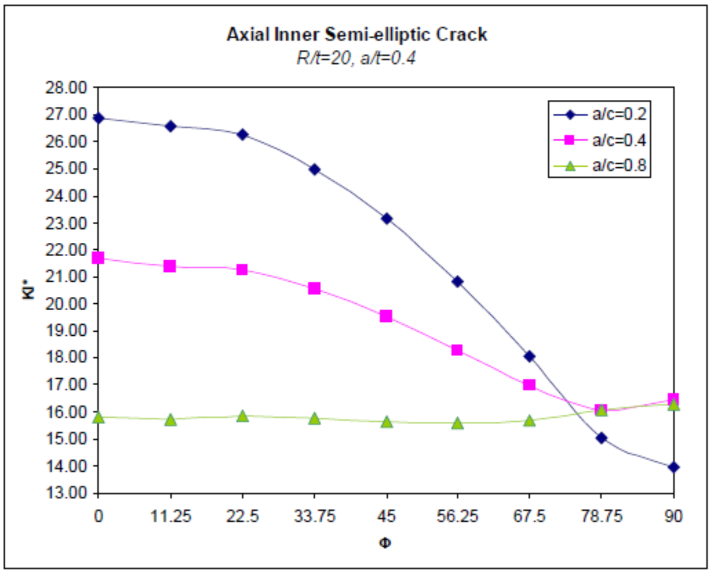

Fig 17: Variation of (KI*) for different values of Crack Front Angle (Φ), Type-1 as (R/t) =20 and (a/t) =0.4.

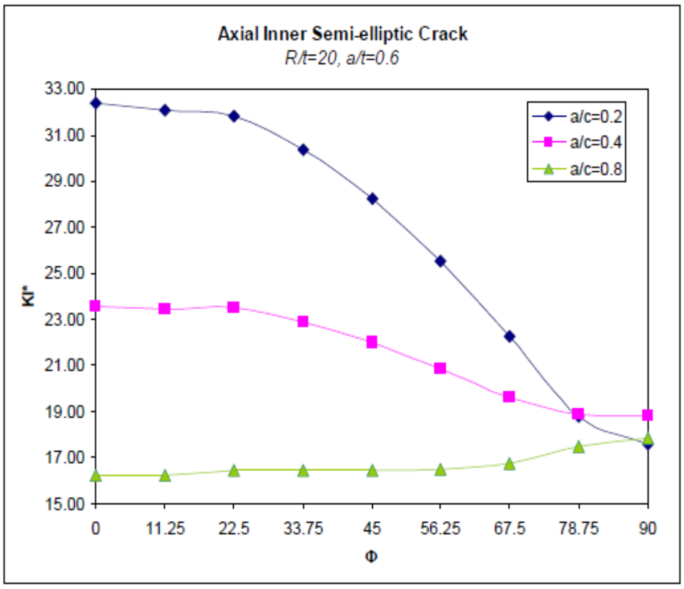

Fig 18: Variation of (KI*) for different values of Crack Front Angle (Φ), Type-1 as (R/t) = 20 and (a/t) = 0.6.

Fig. 19 to 21 shows the variation of (KI*) at the deepest point for various values of (a/t) which varies from 0.2 – 0.6, into these figures R/t have been varies from R/t = 5 to 20 while the (Φ) has been taken as fixed parameter.

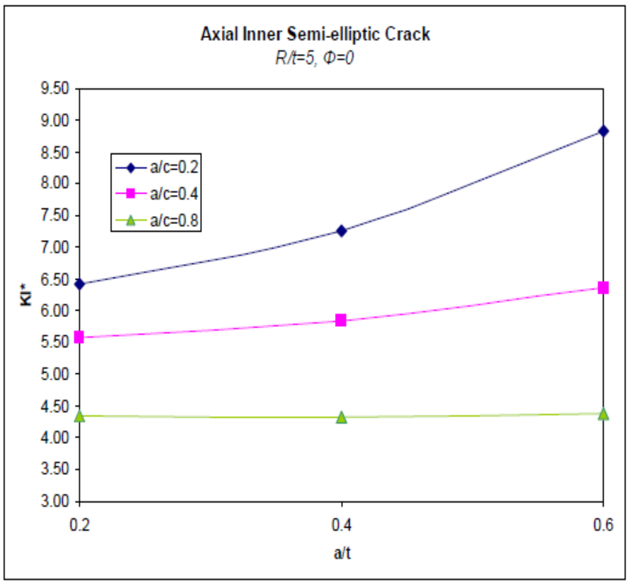

Fig 19: Variation of the (KI*) at the deepest point for several values of (a/t) for the fixed value of (R/t) = 5 and (Φ) = 0.

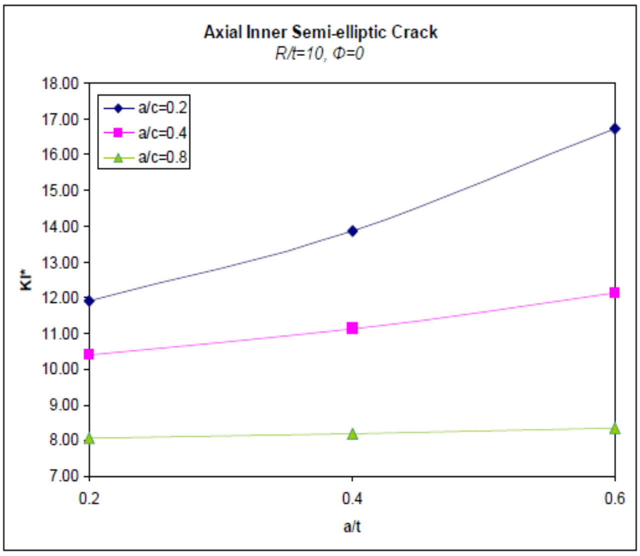

Fig 20: Variation of (KI*) at the deepest point for various values of (a/t) for fixed value of (R/t) =10 and (Φ) = 0

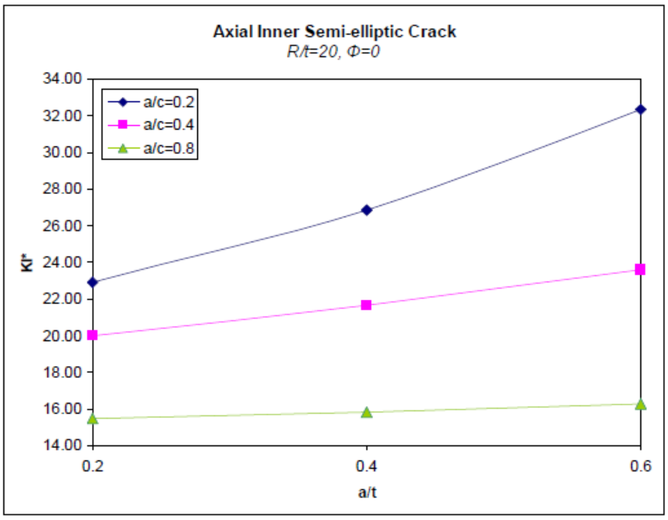

Fig 21: Variation of (KI*) at the deepest point for various values of (a/t) for fixed value of (R/t) = 20 and (Φ) = 0

Kumar et al. [19] optimized the pressure vessel using CFD analysis.

5. CONCLUSIONS

1. It may be deduced that FEA method is sufficient capable to analyse various fractures positioned differently in a body since a semi-parametric method in ANSYS has successfully generated SIF (KI*) and dimensionless SIF (KI*) of an axial crack onto the inner surface of a cylinder.

2. After comparing the data with the conclusions reached analytically by other researchers, a case study was conducted, and findings for various (R/t), (a/c), and (a/t) values were produced.

3.For the mostly cases it was found that analysis with sharp elliptical path (e.g. a/c= 0.2), its meshing has not been performed with a straightforward way because for this special effort is needed for this element sizes are aligned according to the geometry.

4. Model-Stress Intensity Factor (KI) is bigger than Dimensionless Stress Intensity Factor (KI*) at the surface point for the situations (a/c) equal to 0.2 at the deepest point. Its values surpass 0.4 and 0.8.

5.For the value of (a/c) is equal to 0.8, the value of (KI*) along the crack front are found to be nearly constant.

6.The values of KI* increase as the value of (R/t) increases.

7.When the value of (a/c) is equal to 0.2 and 0.4, the (KI*) are found to be increase as the values of (a/t) increases.

8.Nevertheless, when (a/c) is equal to 0.8, KI* does not change so much as a/t increases.

9.From the analysis we found that (a/t) have not affect on the (KI*) when we have taken (a/c) = 0.8.

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