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# FEM Analysis of a Different Partial Inner Crack Angle on to an Inner Surface of Axisymmetric Pressure Vessel to Find Stress Intensity Factor

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**ABSTRACT:** In present work a curved cracking, a pressing factor vessel has been examined by assessing Stress Intensity Factor (SIF) of cracks for mode-I surface displacing 3-Dimensionally.

This assessment has been done here by a FEA reproduction in ANSYS 18.0. In any case, ANSYS simply gives modified agreeing ability to two-dimensional issues. It can't clearly make break parts for three-dimensional models. At the break tip region we make the quarter-point segment genuinely to show the right characteristic of the weights near the break tip, thusly making the computation for three-dimensional break issue possible. Likewise, mesh200 segment can be used to work the locale with two dimensional lone parts, and subsequently clear this district through certain sort out structure to set up 3-dimensional break segments. Finally, three static and dynamic break models are given to exhibit the precision and limit of these procedures. The precision of these methods is assured differentiated. These two strategies were not hard to manage and expand the limit of ANSYS in figuring three-dimensional SIF.

In this work a semi-parametric methodology has been taken on in ANSYS 18.0 programming to handle SIF of an axial crack onto the internal surface of a chamber and the results have been checked with the results controlled by various experts using particular consistent strategy. Next a context oriented examination has been performed to show the sufficiency of ANSYS programming in dissecting different breaks at different circumstance in a thing with no issue.

**KEYWORDS:** Fracture Mechanics, Elliptical crack, Displacement Correlation Technique, Stress Intensity Factor.

## I. INTRODUCTION

- *Basics of crack mechanics*

Cracks mechanics are the stressed with the beginning and transmission of breaks in materials and designs. In various cases, the breakdown of show-stoppers because of crack can be hopeless. For example the development of breaks in pressure vessels because of break transmission can cause a deadly blast. When planning mechanical constructions, break mechanics examination are expected to keep away from crack disappointments.

The most common cases of crack surface displacements are to be called as a mixed mode obtained by overlaying these 3 basic modes. The break surfaces which are calm limits near the break tip, emphatically affect the pressure circulation close by the break. More far off limits and outer stacking primarily impact the power of the pressure field at the break tip. Flexible pressure investigation of breaks prompts the idea of stress force factor K, which is utilized to characterize the versatile pressure field around the break tip.

As verified over, the development of break surfaces can be separated into three kinds, with relating pressure fields. In this way, three pressure force factors KI, KII and KIII are utilized to recognize the pressure fields for these 3 modes. The elements of stress power factor K are  $[\text{stress}] \times (\text{length})^{1/2}$ .

The factor K be controlled by on the components of the example and the stacking condition.

- *Calculation of SIF using ANSYS 18.0*

Crack Mechanics provides a theoretical circumstantial for materials and structures containing cracks and flaws, and the stress intensity factor (SIF) is an important parameter in crack analysis. SIF plays a dominant role because it indicates the singular intensity of the linear elastic crack field (strain and strain).

Due to the importance of SIF, its solutions have received a lot of attention since the dawn of fracture mechanics. Exact solutions to these problems are limited to a few special configurations; for example elliptical cracks embedded in very large bodies, we can look it up in SIF manuals. For unpredictable configurations, such as the intersection of a region crack with a free surface, a surface current are called, where exact solutions are both challenging to obtain and generally unobtainable. In adding to the difficulty of the problem, there is the unsuccessful fact that such a surface defect is the most collective defect in many engineering structures.

- *Singular elements generation using mesh 200 element*

MESH 200 component is a "Mesh in particular" component and contributes nothing to the arrangement. With this component, we can easily produce 3-dimensional break components. To produce 3-dimensional break components, first the region network is produced with network 200 component, by utilizing the KSCON order to make two-dimensional single region components with 8 hubs at the break tip, then, at that point the volume cross section can be created by means of VDRAG, VROTAT, VOFFST and VEXT orders and so forth through a specific co-ordinate framework dependent on the space lattice. For complex designs, the model can be appropriated into many parts. These parts can be secured together or utilizing a stuck contact charts. The one containing break utilizes mesh 200 components to produce single components and the others can have the option to work generously. It makes tackling 3-dimensional breaking issues without any problem.

## II. DESCRIPTION OF THE PROBLEM

In the literature, stress intensity factor solutions are obtained by different researchers for cylindrical structures. Some of them considered internal cracks and the others outer cracks. Some of them considered axial cracks and the others circumferential cracks.

In this study, different locations of semi-elliptical cracks in a cylinder are considered. Stress intensity factors of inner surface and embedded cracks are calculated for both axial and circumferential cracks. During the calculations, material of the cylinder is assumed to be homogeneous isotropic.

Three dimensional Finite Element Analysis (FEM) is performed by using ANSYS 12.0. To facilitate modeling for end-users, APDL codes are developed for each crack case. By using these codes, an end-user can easily model a cracked cylinder and obtain SIFs just by providing certain input values in the ANSYS environment. After solving the problem by FEM, that is, obtaining the displacement field around the crack front; SIFs are calculated by using Displacement Correlation Technique (DCT).

A number of sample results and comparisons with the existing results in the literature are provided.

## III. FORMULATION OF THE PROBLEM

- *Geometry of the Problem*

Two cases of semi-elliptic cracks are examined in this study. Elliptic and semi-elliptic shapes are frequently used in the literature since good approximations to actual crack shapes can be obtained by varying  $a/c$  ratios. First one is axial crack and other one is circumferential crack.

In the models, it is assumed that  $L \gg 2c$  to avoid free surface effects.

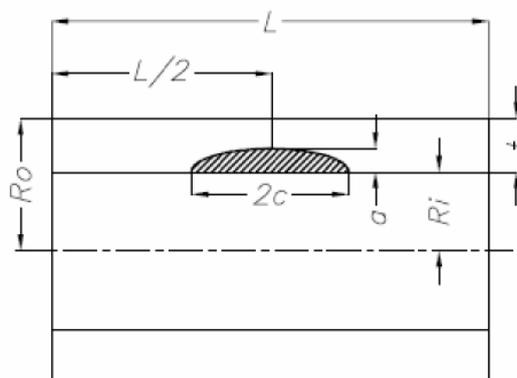


Fig 1: Axial inner semi-elliptic crack.

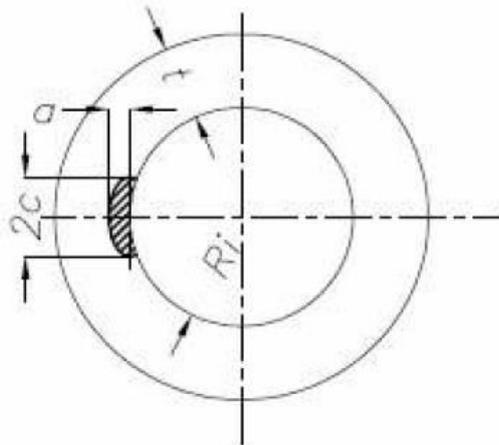


Fig 2:Circumferential inner semi-elliptic crack.

In this thesis cylinders with  $5 \leq \frac{R}{t} \leq 20$  are considered.

- *Three Dimensional Crack Modeling*

Finite Element analysis program ANSYS 11.0 is used for modeling. There are two ways to communicate with ANSYS program. One of them is using the ANSYS menu system, called the Graphical User Interface (GUI) and the other way is using ANSYS commands. For the second way, either command window or APDL codes can be used. APDL codes are text documents which ANSYS commands can be written in it. From GUI, by following the instructions <File-Read input from>, APDL codes can be used. By the help of APDL codes, model can be changed easily. In this thesis, ANSYS Parametric Design Language (APDL) subroutines are used. Also there are some ways to interface with the GUI while using APDL. One of them is the \*ASK command. By using this command, running APDL code stops to get an input from the user. In this study, \*ASK command is used to get the inputs; a, c, t and R. Therefore cylinder and crack can be modeled according to different dimensions.

In this thesis, modeling of three dimensional cracks in ANSYS have been done using ‘Bottom up modeling’ method and ‘Top down modeling’ method together.

MESH200, SOLID95 and SOLD 90 are used as element types for meshing.

MESH200; is a facet type meshing which means the element is subdivided into smaller portions called facets. Facets are piecewise linear surface approximations of the actual element face. MESH200 is a mesh-only element, contributing nothing to the solution. This element is used for the successive steps of meshing. More information can be found in [14].

For axial inner semi-elliptic crack, ten keypoints are generated for modelling half of the crack. Crack front is divided into eight equal parts by keypoints 1-9. 9th keypoint is at 90° and 10th keypoint is at 100°. 10th keypoint will be no more needed when cylinder is created and will be deleted.

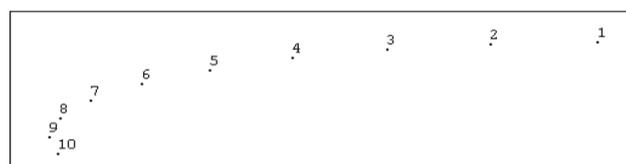


Fig 3:Keypoints on the crack front.

A semi-circular area is created at Keypoint 1 perpendicular to the plane on which keypoints are created. This area is created to form the tubular volume around crack front in the following steps.

Then, lines are created between these keypoints following an elliptical path.

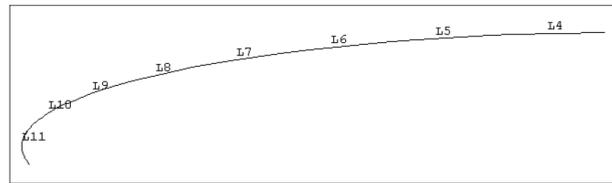


Fig 4: Lines on the crack front.

Area created at Keypoint 1 is dragged along the lines to form a tubular volume around crack front.

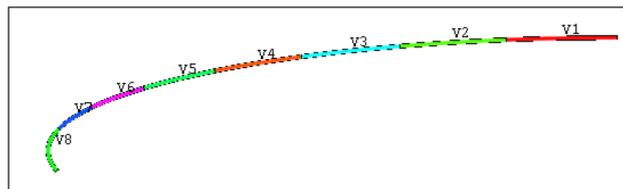


Fig 5: Volumes around crack front.

Cylinder is generated including the crack. Cylinder is divided into sub volumes. These volumes will be meshed by different element sizes in the following steps. The smallest volume around crack will be the finest mesh. The volumes around this small volume will be less fine. Finally, rest of the cylinder will have coarse mesh. Quarter of the cylinder is generated and symmetry boundary conditions are used at the bottom and side areas.

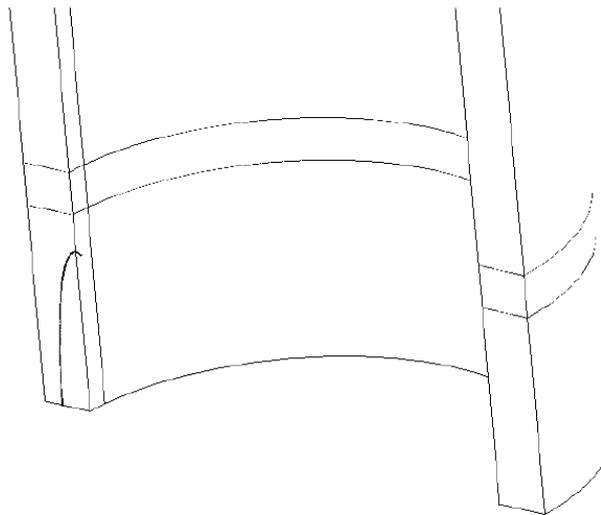


Fig 6: Cylindrical structure.

As can be seen in Figure 6 there is a part of tubular volume getting out from the inner surface of the cylinder. After overlapping volumes the excess part of this volume will be deleted. After deleting excess volume, the structure below is ready to be meshed.

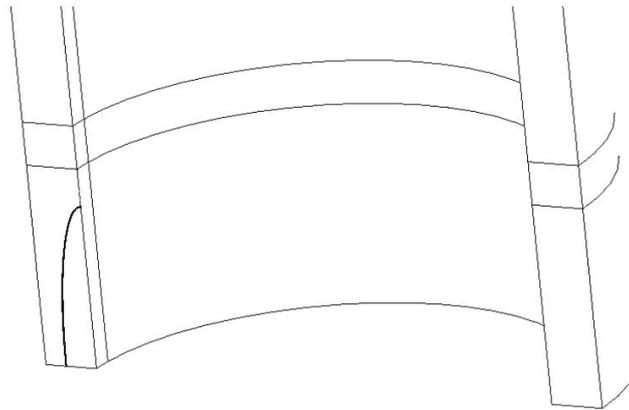


Fig 7:Crack and Cylinder.

KSCON command is used to mesh the area at the bottom of the tubular volume around crack front. KSCON specifies a keypoint about which an area mesh will be skewed. This command defines a concentration keypoint about which an area mesh will be skewed. It is useful for modeling stress concentrations and crack tips. During meshing, elements are initially generated circumferentially about, and radially away, from the keypoint. Lines attached to the keypoint are given appropriate divisions and spacing ratios. Only one concentration keypoint per unmeshed area is allowed. The KSCON command does not support 3-D modeling. Therefore area is meshed with this command and then volumes around crack front are swept.

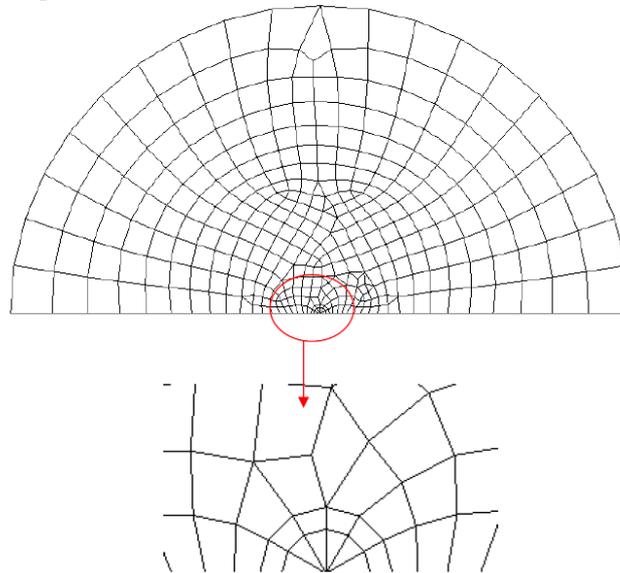


Fig 8:Singular elements.

Singular elements around crack front can be seen in Figure 2.17. Radius of the singular elements (first row) is taken as 0.001mm. It is usually taken as  $a/1000$  in the other thesis studies [12], [13].

In this thesis study, working with different dimensions with one APDL code is important, so radius of singular elements is taken to be constant. Therefore after meshing, number of elements in the tubular volume for different dimensions remains constant. When calculating stress intensity factors, number of nodes at the point where SIFs are calculated will be used. Keeping the number of elements constant, makes it possible to calculate SIFs along the crack front with APDL code.

After meshing the semicircular area it is swept along the crack front. Meshed tubular volume can be seen in figure 9 below.

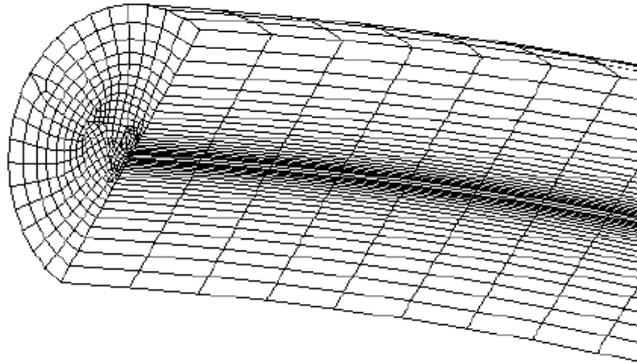


Fig 9: Meshing around crack front.

After meshing the volume around the crack front, other volumes are meshed with different element sizes as seen in Figure 10.

For different  $a/c$ ,  $a/t$  and  $R/t$  values, geometry of the crack and cylinder change. In some cases volumes need special effort for meshing. Different element sizes are needed with these cases.

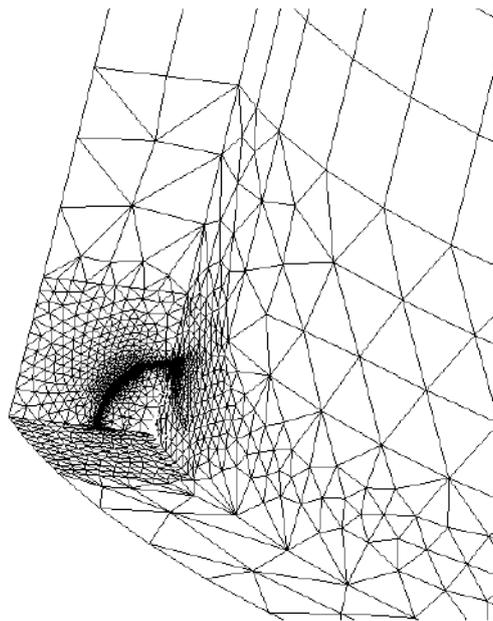


Fig 10: General view of crack model.

Model has two symmetry planes. Planes along longitudinal and circumferential directions are symmetry planes as seen in pink colour in Figure 11 and 12. There is a point to be careful while determining symmetry areas. Crack face area should not be selected as a symmetry area; otherwise crack would not open when the load is applied to the structure.

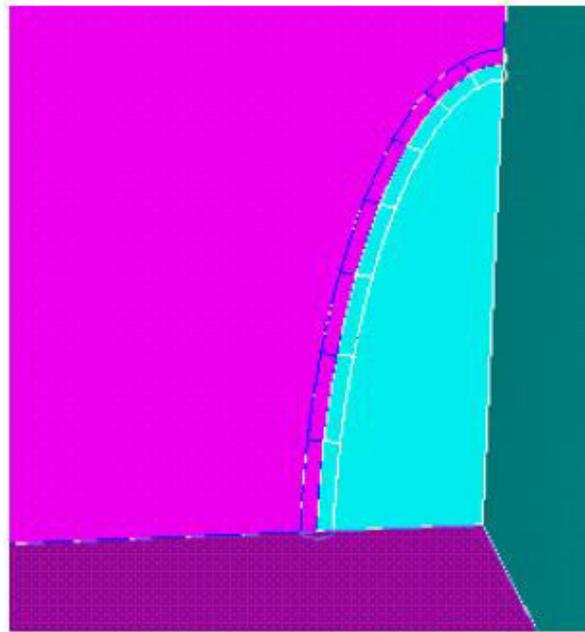


Fig 11: Symmetry areas around crack.

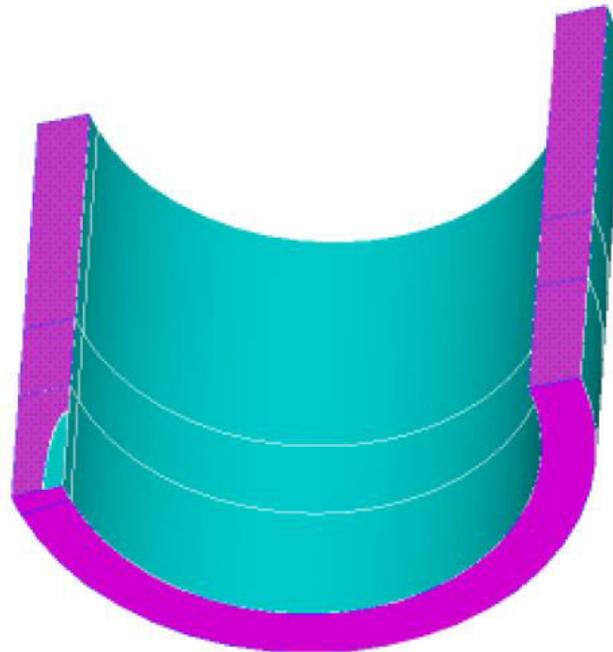


Fig 12: Symmetry areas of the model.

The last thing before solving the problem is applying the loads. If a mechanical load is to be applied, compressive loads should be positive and tensile loads should be negative. In this study internal pressure or axial tension load is applied according to the geometry. Therefore while internal pressure is stated as a positive amount, tensile load is stated as a negative amount.

When the problem is solved, SIFs are calculated using DCT. To achieve this, formulas are written in an APDL code. After solving the problem, ANSYS calculates displacement at each node. Using this displacement values in formulas, SIFs are calculated



Non dimensional SIFs are calculated as follows:

$$KI^* = \frac{KI}{(\sigma \times \sqrt{\pi \times a})}$$

Where  $\sigma$ : Internal pressure or tensile stress

**Loading: Internal Pressure**

Internal pressure is applied to the inner, outer and embedded axial cracks. Internal pressure is applied as 10 MPa in all three cases. Edges of the cylinder are stress free. This type of loading is shown in Figure 13.

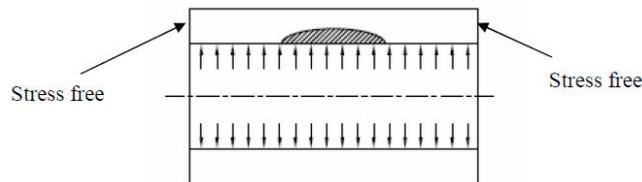


Fig 13: Axial inner semi-elliptical crack.

**Loading: Axial loading (Tension)**

Axial tension loading is applied to the inner, outer and embedded circumferential cracks. Axial stress applied is 10 MPa in all three cases. Crack is located in the symmetry plane. This type of loading is shown in Figure 14.

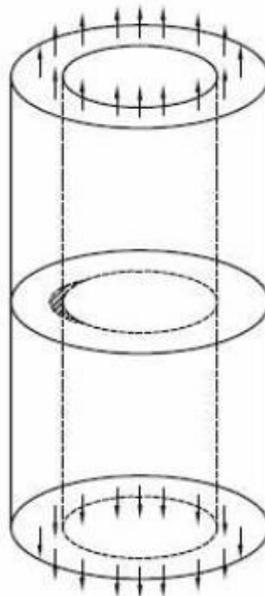


Fig 14: Partial circumferential crack.

**IV. DISPLACEMENT CORRELATION TECHNIQUE**

By solving the problem, displacements of nodes are calculated by ANSYS. Then stress intensity factors are calculated by using displacement correlation technique. This technique has been used earlier in [11], [12], and [13]. Displacements of three nodes are used for this calculation. First one is a point on the crack front. Second and third nodes are the nodes next to the first one. They are on the crack face. The line passes through these three nodes is perpendicular to crack front.

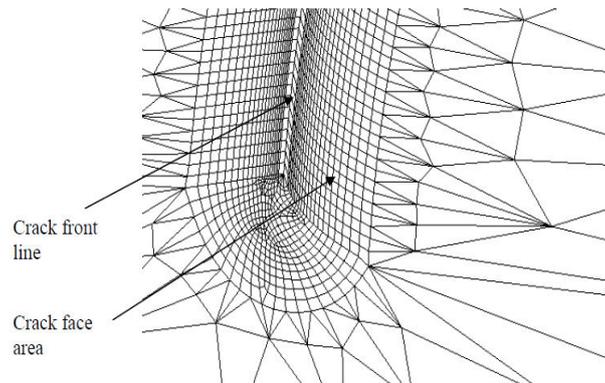


Fig 15: Opened crack view after loading.

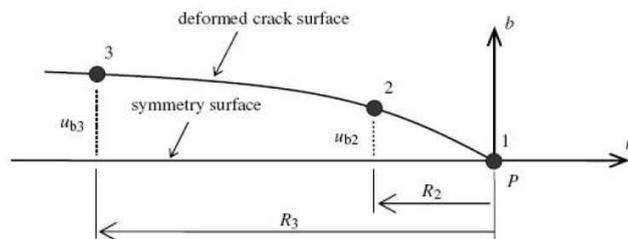


Fig 16: Nodes used in DCT.

Then SIF is obtained as follows:

$$X = \frac{R_3^{3/2}u_{b2} - R_2^{3/2}u_{b3}}{\sqrt{R_2}\sqrt{R_3}(R_3 - R_2)}$$

$$K_I = \frac{\sqrt{2\pi} \times E}{4(1 - \nu^2)} \cdot X$$

$$K_I = \frac{\sqrt{2\pi} \times E}{4(1 - \nu^2)} \cdot \left[ \frac{R_3^{3/2}u_{b2} - R_2^{3/2}u_{b3}}{\sqrt{R_2}\sqrt{R_3}(R_3 - R_2)} \right]$$

The expressions above are taken from [13]

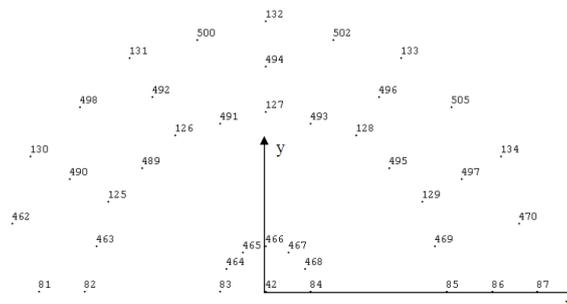


Fig 17: Schematic view of nodes.

To find the SIF along the crack front, a coordinate system is placed at a crack tip node, for example Node 42. X axis should be along the crack face and y axis should be perpendicular to the crack face area. Nodes 42, 84, and 466 should



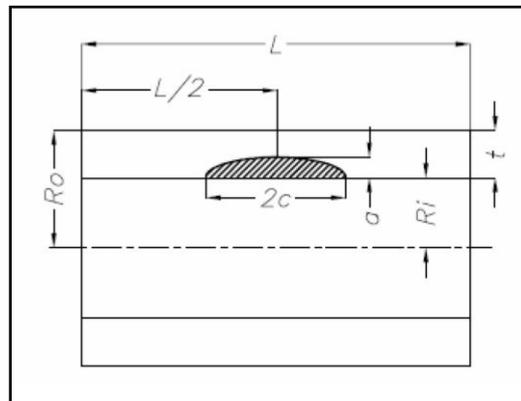
be used to place the coordinate system. These nodes are shown in Figure 2.33. The nodes to be used in SIF calculations are Nodes 42, 84 and 85. 'u<sub>b2</sub>' and 'u<sub>b3</sub>' are calculated by using displacements of these three nodes.

**V. MATHEMATICAL MODEL VERIFICATION**

- *Geometry of the problem*

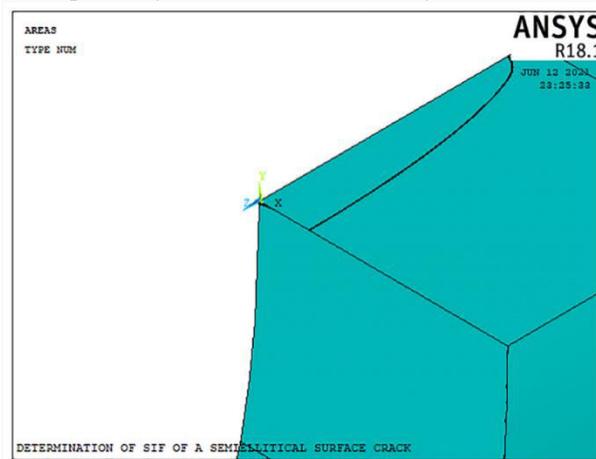
A pivotal semi-curved crack onto the inward surface of a chamber has been analyzed during this investigation. Curved and semi-circular shapes are every now and again use in the writing meanwhile great approximations to genuine crack shapes are regularly gotten by changing a/c proportions. Now the models, it's expected that  $L \gg 2c$  to stay away from free surface impacts.

- Here,
- L = Length of the cylinder.
  - Ro = Outer radius of the cylinder.
  - Ri = Inner radius of the cylinder.
  - R = radial distance of a point on the crack front.
  - a = Semi-minor axis of the semi-elliptical crack.
  - c = Semi-major axis of the semi-elliptical crack.



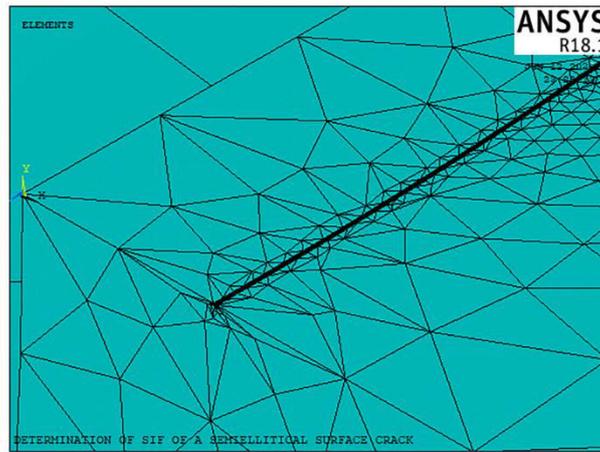
**Figure 4.1: Axial inner semi-elliptical crack**

The abundance volume is erased and presently the construction is ready to be coincided.



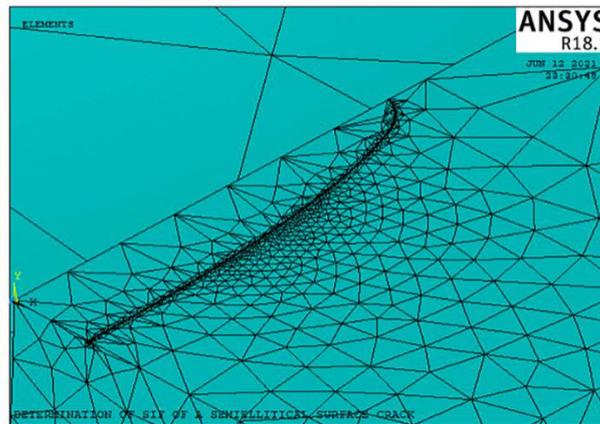
**Figure 4.2: Crack and cylinder**

KSCON request is used to work the world at total lower part of the adjusted volume around break front. KSCON, demonstrates a Key point concerning which a neighborhood cross section would be skewed. This request portrays a degree Key point in regards to which a nearby cross section would be skewed. It is useful for stress obsessions and break tips.



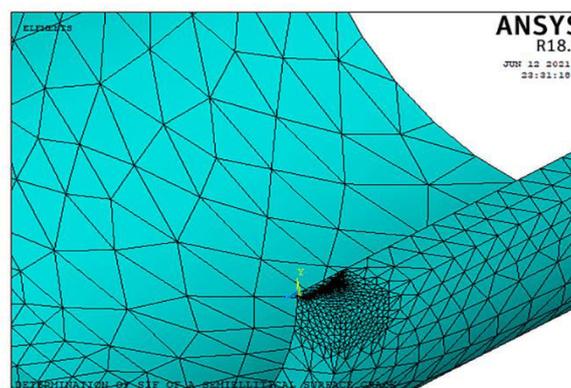
*Figure 4.3: Singular elements*

Solitary components around break front are routinely found in Figure 3. Clear of the specific segments (first line) are taken as 0.001 mm. It's normally taken as  $a/1000$  inside various proposition analyzes. For assorted  $a/c$ ,  $a/t$  and  $R/t$  esteem, math of the break and chamber change. Once in a while volumes need excellent effort for grid. Unmistakable segment sizes are needed with Meshing around the crack front, these case showed in Figure 4.4.



*Figure 4.4: Meshing around the crack front*

Wedge-formed symmetrical of two balance plane along longitudinal and circumferential bearings are evenness planes as found in pink shading Figure 4.5 and 4.6. There's some degree to be careful while deciding evenness regions. Break face region shouldn't be chosen as a balance region. In any case air out wouldn't once the load is applied to the design.



*Figure 4.5: General view of crack model*

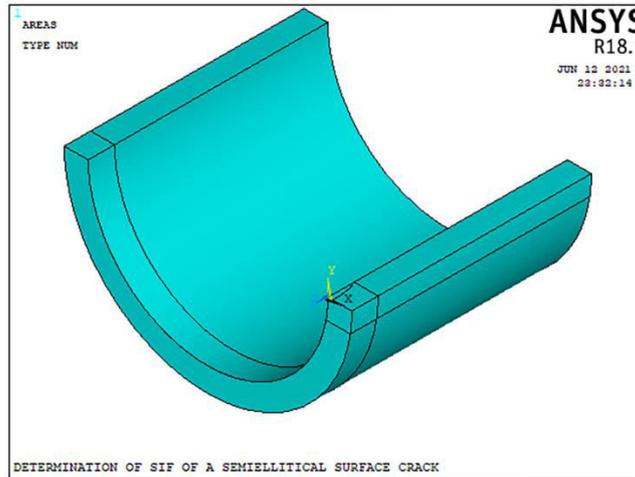


Figure 4.6: Symmetry areas around crack

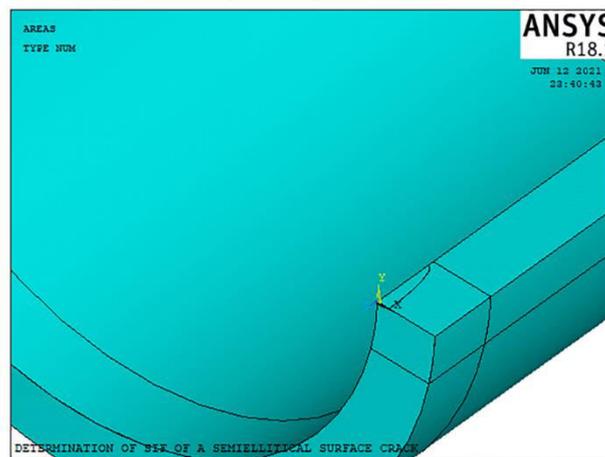


Figure 4.7: Symmetry areas around the model

The previous thing prior to settling the matter is applying the hundreds. In the event that the mechanical burden are to be loaded, compressive burdens to positive and elastic burdens ought to be negative. During this investigation interior pressing factor or hub pressure load is applied steady with the calculation. In this manner while interior pressing factor is expressed as a positive sum, ductile burden is expressed as a negative sum. Then, at that point the matter is tackled. In the event that it's a warm issue, first warm issue is settled warm outcomes document is perused and primary arrangement is applied.

At the point once the matter is tackled, SIFs are determined utilizing D.C.T. Toward understand this, recipes are written in an APDL code. In the wake of settling the matter, ANSYS figures uprooting at every hub. Utilizing this uprooting value in equations, SIF's are determined. The formulas are given in Non dimensional SIF's are determined as follows:

$$K I^* = \frac{KI}{(\sigma \times \sqrt{\pi \times a})}$$

Wherever  $\sigma$  is the inside pressure or tensile stress.

- Validation of FEA Model

By Nabavi [4], presently Stress Intensity Factor (SIF) for a pivotally broken chamber has been thought of and subsequently the outcomes from ANSYS APDL are confirmed and crafted.

By Nabavi [4], SIF's are gotten for inside semi-circular, longitudinal breaks during a thick walled chamber. Insightful and weight work technique is utilized for estimations. 10Mpa interior pressing factor is applied inside the issue. Interior pressing factors are useful together on the inward surface of the chamber and thusly the break face. Results are given as per a chart in Nabavi's investigation [4].Results from ANSYS APDL have been checked and crafted in below figure.

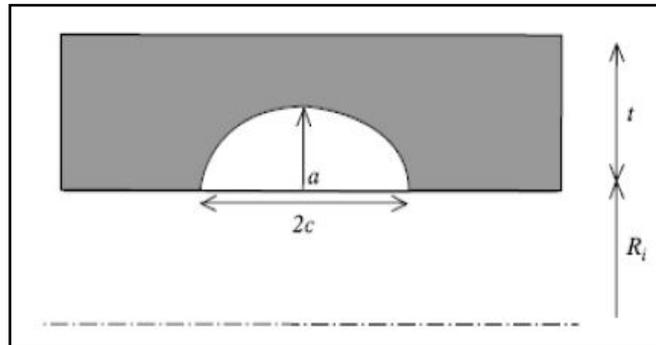


Figure 4.8: Geometry used by Nabavi[4] for Axial Semi-elliptical Crack

SIF values determined at the most profound focuses are thought about for the accompanying calculations.

TABLE 4.1: Comparison OF KI\* for axial crack (between ANSYS RESULTS V/S NABAVI ET AL.[4])

a (mm)	R/t	a/c	a/t	KI*, NABAVI [4]	KI*, ANSYS	Variatio-n (%)
2	4.51	0.211	0.21	5.80	5.75	0.86
3	4.51	0.211	0.31	6.20	6.03	2.74
4	4.51	0.211	0.41	6.70	6.51	2.84
5	4.51	0.211	0.51	7.25	7.15	1.38
6	4.51	0.211	0.61	8.00	7.91	1.13
7	4.51	0.211	0.71	8.90	8.78	1.35
8	4.51	0.211	0.81	9.90	9.88	0.20
2	4.51	0.411	0.21	5.70	5.00	12.28
3	4.51	0.411	0.31	5.75	5.09	11.48
4	4.51	0.41	0.41	5.90	5.23	11.36
5	4.51	0.41	0.51	6.20	5.44	12.26
6	4.51	0.41	0.61	6.40	5.71	10.78
7	4.51	0.41	0.71	6.80	6.03	11.32
8	4.5	0.41	0.81	7.20	6.47	10.14



2	4.51	1.01	0.21	5.30	3.49	34.15
3	4.51	1.01	0.31	5.30	3.45	34.91
4	4.51	1.01	0.41	5.30	3.43	35.28
5	4.51	1.01	0.51	5.30	3.42	35.47
6	4.51	1.01	0.61	5.30	3.42	35.47
7	4.51	1.01	0.71	5.30	3.45	34.91
8	4.51	1.01	0.81	5.30	3.52	33.58

Presently diagrams are plotted between KI\* value and diverse a/t value. Figure 4.23 underneath shows many diagrams produced from Nabavi's [4] work and from the investigation of this proposition for different upsides of a/c proportion.

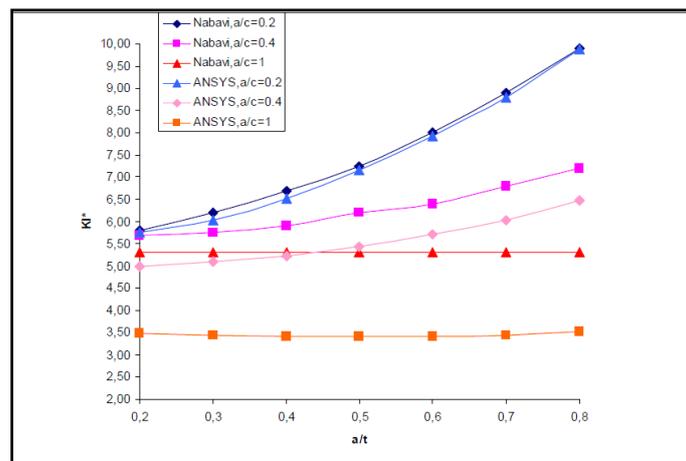


Figure 4.9: ANSYS results comparison with Nabavi [4]

By means of it the normal seen inside the Figure 4.9 above that, results follow comparable ways. Anyway as per a/c approaches to 1, ANSYS 18 results comparison with Nabavi [4].

## VI. RESULT COMPARISON WITH COMPOSITE MATERIAL

- The Pressurized Partial Inner Axial Semi-elliptic Crack

In this part a case has been concentrated on assurance of SIF (KI) and dimensionless SIF (KI\*) of a hub break onto the internal surface of a round and hollow design for mode I disappointment. Upsides of KI and KI\* has been recognized through FEA technique utilizing ANSYS 18.0 programming. The definite advances which are embraced in ANSYS 18.0 are referenced in Appendix B.

For this situation study a semi elliptical breaks arranged on the Inner Surface of the chamber have been considered having a break front reached out from  $\Phi=0^\circ$  to  $\Phi=90^\circ$ . This reality has been portrayed inside the Figure below.

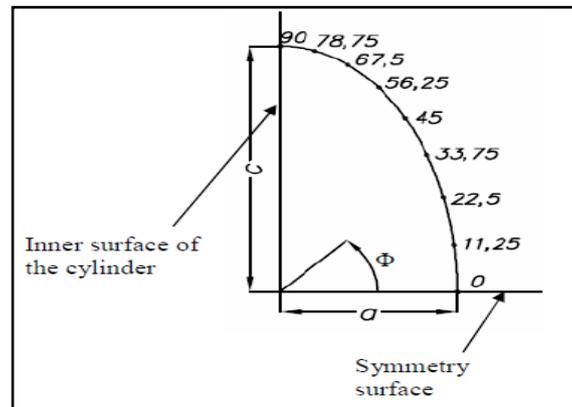


Figure 5.1: Front Crack with point at different  $\Phi$  angles.

Internal pressures by 10Mpa magnitude are concrete to the structures. Grades are got for various R/t, a/t and a/c values. R is 50mm for entire cases but a, c and t change. The Results are to be obtained for the subsequent standards are as follows.

- R / t = 5, 10 & 20
- a / t = 0.2, 0.4 & 0.6
- a / c = 0.2, 0.4 & 0.8

Now different graphs are plotted between values of KI\* and values of various input parameters like, different values of crack front angle  $\Phi$ , Different values of R/t ratio, a/t ratio and a/c ratio.

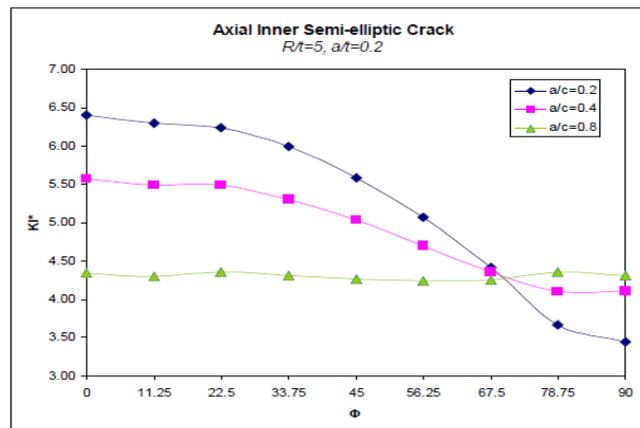


Figure 5.2: For R / t = 5, a/t=0.2,  $\Phi$  V/s KI\* Type 1,

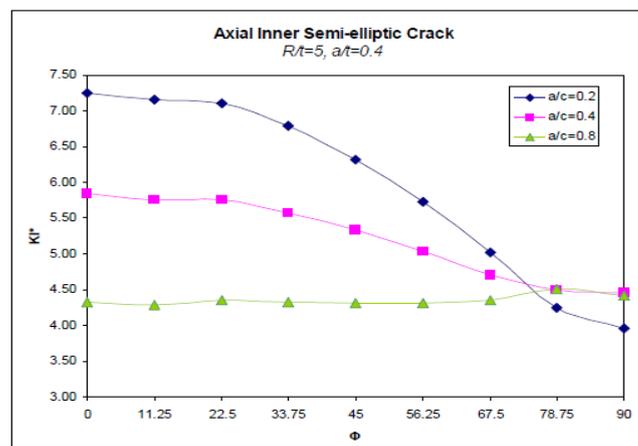


Figure 5.3: For R / t = 5, a/t=0.4,  $\Phi$  V/s KI\*, Type 1

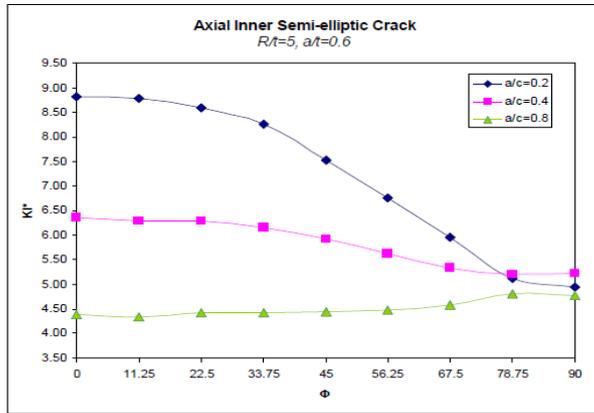


Figure 5.4: For  $R/t=5, a/t=0.6, \Phi$  V/s  $KI^*$ , Type 1

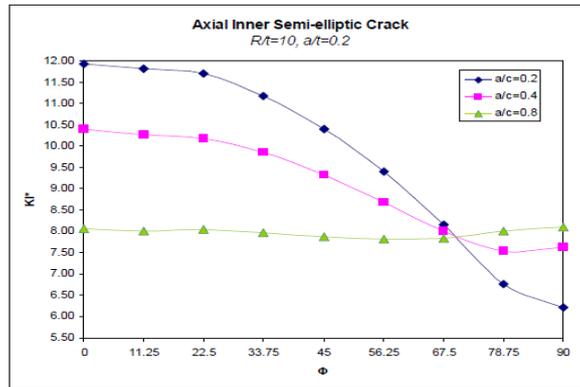


Figure 5.5: For  $R/t=10, a/t=0.2, \Phi$  V/s  $KI^*$ , Type 1

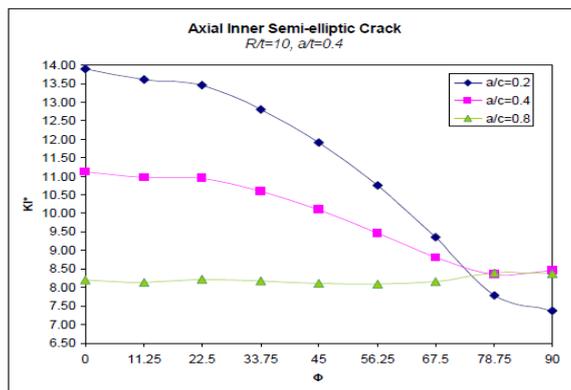


Figure 5.6: For  $R/t=10, a/t=0.4, \Phi$  V/s  $KI^*$ , Type 1

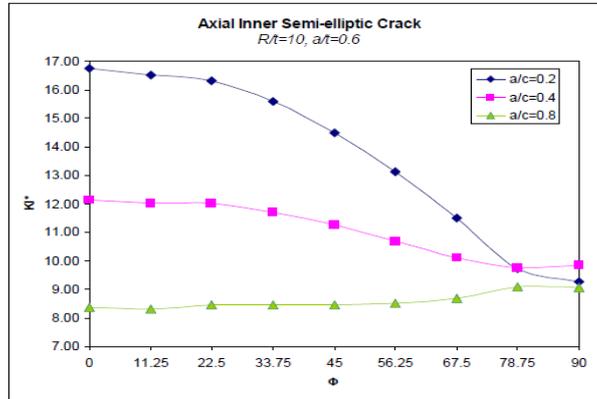


Figure 5.7: For  $R/t=10, a/t=0.6, \Phi$  V/s  $KI^*$ , Type 1

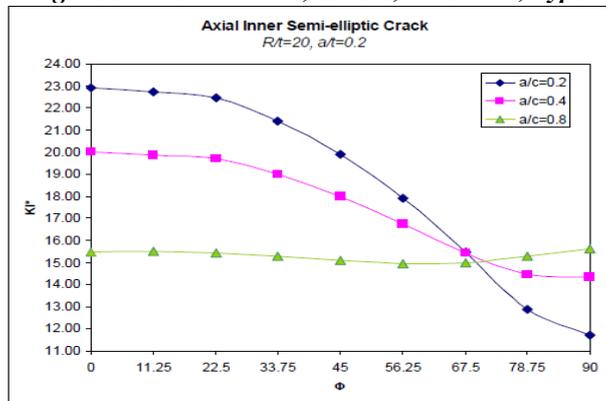


Figure 5.8: For  $R/t=20, a/t=0.2, \Phi$  V/s  $KI^*$ , Type 1

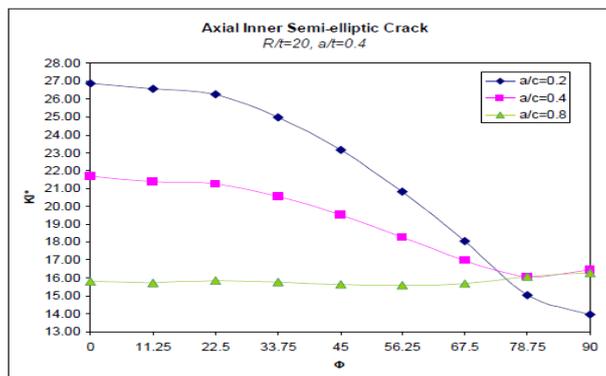


Figure 5.9: For  $R/t=20, a/t=0.4, \Phi$  V/s  $KI^*$ , Type 1

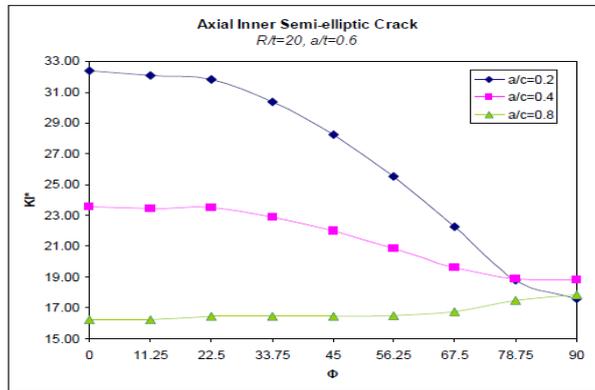


Figure 5.10: For  $R/t=20, a/t=0.6, \Phi$  V/s  $KI^*$ , Type 1

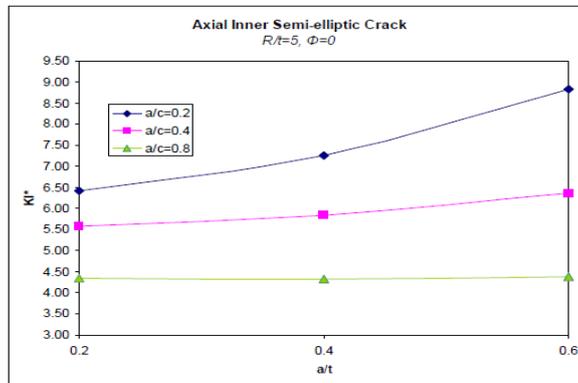


Figure 5.11: For  $R/t=5, a/t$  V/s  $KI^*$  (at the deepest point)

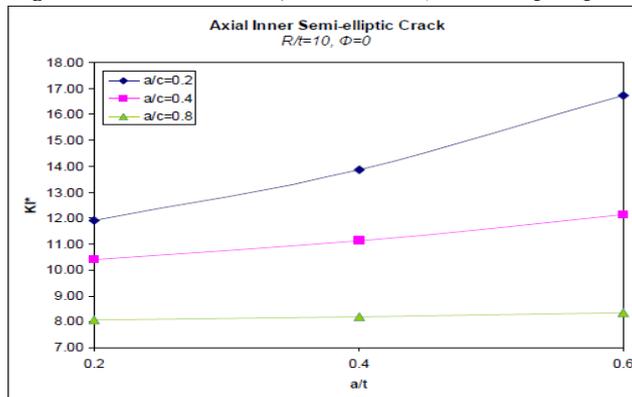


Figure 5.12: For  $R/t=10, a/t$  V/s  $KI^*$  (at the deepest point)

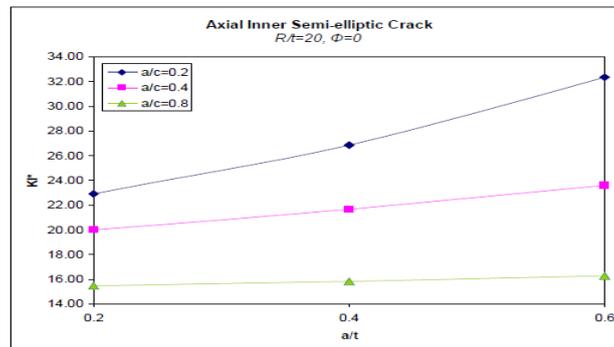


Figure 5.13: For  $R/t=20$ ,  $a/t$  Vs  $KI^*$  (at the deepest point)

Here is the sincere intention is to bigger the value of  $KI^*$  and the  $KI^*$  at the surface reason for the cases  $a/c$  is up to 0.2 and 0.4. The cases for  $a/c$  are up to 0.8,  $KI^*$  value on the break front measure almost steady. Also  $R/t$  will increment as  $KI^*$  value increments

Once  $a/c$  are up to 0.2 and 0.4,  $KI^*$  value increments as per the  $a/t$  worth will increments. Regardless, once  $a/c$  worth is up to 0.8 than  $KI^*$  doesn't alteration such bounty, as  $a/t$  will increment. In this way  $a/t$  doesn't affect  $KI^*$  once  $a/c$  is 0.8.

## VII. CONCLUSIONS

The investigation administered during this project results in a really important conclusion. As a semi-parametric method in ANSYS 18.0 has succeeded to get SIF ( $KI$ ) and dimensionless SIF ( $KI^*$ ) of an axial crack onto the internal surface of a cylinder efficiently, it's going to be concluded that FEA method is enough capable to look at different cracks situated differently during a body. After verifying data with the result obtained analytically by many researchers a case study has been done and grades will be obtained for various  $R/t$ ,  $a/c$  and  $a/t$  value of crack. Here beauty lies in numerical methods. The semi-parametric method in ANSYS 18.0 software which has been generated for determining the leads to the case study are often used very efficiently for the other cases with some minor and straightforward changes within the program. Whereas to work out SIF by analytical method it's very cumbersome to formulate mathematical model for various cases and people aren't similar with one another.

Nevertheless for certain cases, sharp elliptical path (e.g.  $a/c=0.2$ ), meshing cannot be through with a straightforward method. Distinct efforts are needed. Various section size are bring into line consistent with the geometry.

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