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Fracture Mechanics Analysis of a Semi-Elliptical Surface Crack in Pressure Vessel using AFGROW

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Abstract-Fracture mechanics is concerned with the study of the propagation of cracks in materials. In safety evaluation of industrial components subjected to cyclic loading, analysis of crack growth is one of the important steps. Different approach for fracture mechanics are Linear Elastic Fracture Mechanics, Elastic Plastic Fracture Mechanics and Dynamic time dependent fracture Mechanics. Linear Elastic Fracture Mechanics (LEFM) method is used in present study mainly based on the assumption of small scale plastic zone formation at the crack tip. This is expressed by means of two parameters, the stress intensity factor and the T stress. If the loads are above a certain threshold, microscopic cracks will begin to form in the material mainly in the irregular geometry or sharp edges and also at dislocation region. Eventually a crack will reach a critical size, and the structure will suddenly fracture. To predict the fatigue crack growth with numerical approach, ASTM standard fracture test specimens viz., compact tension specimen, semi-elliptical crack specimen and single edge notch specimen are simulated and its fatigue crack growth is predicted and validated using analytical method. Further, the approach is applied to simulate and predict the fatigue crack growth on an axial semi-elliptical surface crack in a section metallic pressure vessel using AFGROW.

Keywords—stress intensity factor; fatigue crack growth; semi-elliptical crack; pressure vessel; axial crack;crack growth rate;

1. INTRODUCTION

Many investigations have shown that sudden failures of aircraft components, pressure vessels or pipeline systems might occur due to presence of surface cracks. Potential sources of these cracks are material defects or geometric discontinuities i.e. zones where stress increase happens. These zones, known as local stress concentrations, are regions where the points with an extremely high magnitude of stresses could appear. These points are areas where cracks are most often initiated and later propagate under cyclic loadings. Fatigue process consists of three stages, initiation and early crack propagation, subsequent crack growth, and final fracture Due to previous reasons the ability to assess the effects of these defects on structural integrity under fatigue and fracture loadings is of much practical significance.

In concert to safety evaluation the demand for oil and gas transportation place a new requirement large diameter pipelines and also to store the gases pressure vessel is very much essential. The safety assessment of gas and pipelines must take fatigue properties into consideration. During it working condition it may be able to be subjected to fluctuation in the internal operating pressure or by the variation of external loads. Most of failure in the pressure vessel and piping components are mainly because of fatigue loading. The failure will occur below the allowable stress limit. This can be encountered with appearance of flaws on the surface of components

Yanyao Jiang et al. [1] presented an investigation on both standard and non-standard compact specimen to determine the fatigue crack growth behaviour of 7075-T651 aluminium alloy experimentally in normal environment condition. The effect of the stress ratio on the crack growth was studied with overloading and under loading. From the experiment they observed relationship between da/dN and ΔK are practically independent of the geometry and also the size of the specimen.Slobodanka Boljanovie [2] made an investigation on estimating the fatigue crack growth behaviour on the finite plate having semi-elliptical crack which is subjected to cyclic tensile loading. The Stress intensity factor was obtained by applying analytical and numerical methods. The analytical results were compared with experimental results and it has shown good results. K. Ray et al. [3] presented an methodology to determine the fatigue crack growth rate curves without integration of it. Exponential model has been used to predict the crack growth. The model provided a good agreement with experimental data.Ashok Saxenaet al. [6] presented some 3D finite element analyses on pipe made of 6061-Aluminum alloy which are subjected to internal bursting pressure having axial semi-elliptical crack. They have undergone experiment on the pipes, till they burst with various crack length. They have observed that the J integral dependent on the deformation as well as the crack length.

2. BENCHMARK

For benchmark mainly three test specimens are taken from journals paper of references section of [1], [2] and [3] which are compact tension, semi elliptical crack specimen and single edge notch specimen. It is important to find stress intensity factor which represents the stress state at crack tip region, which is very essential factor in fracture mechanics.ANSYS workbench 17 is used for it. For better feasibility of modelling standard test specimens CATIAV5 modelling software is used. The standard test specimens were modelled in CATIA and then imported to ANSYS workbench. A stress intensity factor result which is obtained from ANSYS workbench is validated with the theoretical results. The theoretical formulas used for validation are again taken from same journals paper of stated above reference section. Air Force Crack Growth(AFGROW) software is used for finding the fatigue crack growth of standard test specimens by using geometrical similarity model which are inbuilt in the AFGROW software. Material properties are available in NASGRO equation model.

A. Compact tension specimen

The material used for analysis is 7075-T651 aluminium alloy. The specimen was modelled according to the ASTM E647 method as shown in below figure. Initial crack length (a_n) was 3.54mm and thickness of 4.85mm and also edge radius (r_0) of 0.80mm. Young`s modulus is 71GPa and Poisson ratio is 0.33.

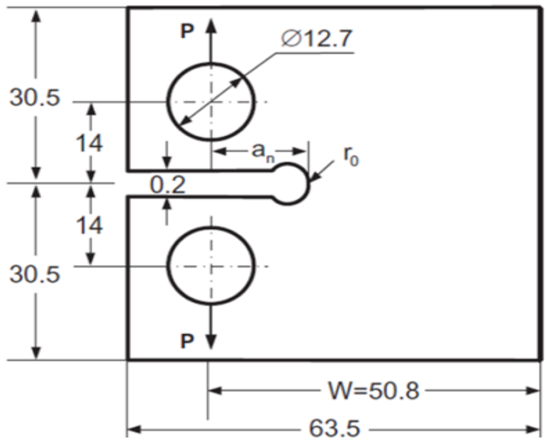


Figure 1: Dimension of compact tension specimen.

In order increase accuracy of the result at the crack tip, the elements are increased at the crack tip by decreasing the element size to 0.1mm at crack tip.Meshed model of compact tension specimen shown below having element size 5mm as global mesh. Hex20 (hexahedra) element is used near the crack tip.

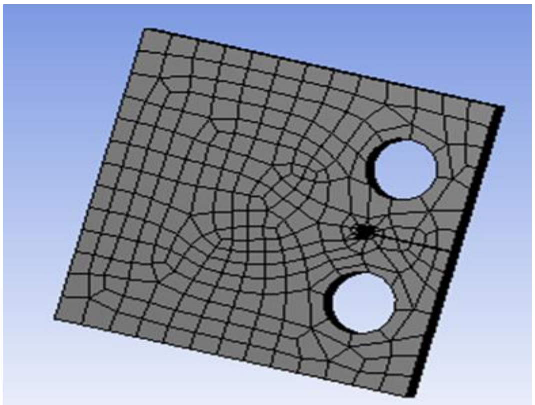


Figure 2: Meshed model of compact tension specimen.

Boundary condition applied for compact tension specimen by applying fixed support at bottom of the hole and force applied at upper hole of the specimen, force applied is of 2700N.

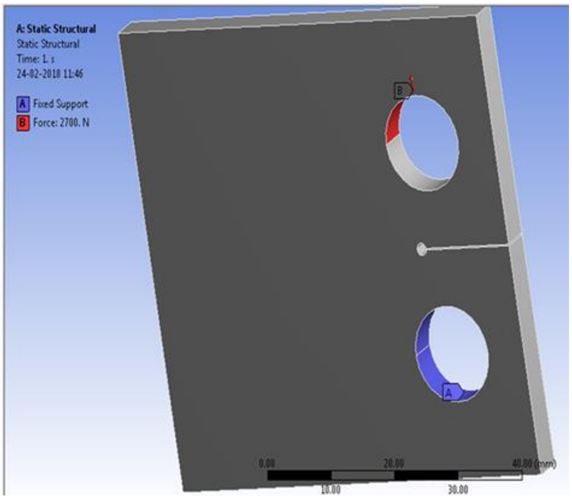


Figure 3: Boundary condition.

Figure below shows the value of stress intensity factor of compact tension specimen, maximum value is of 204.66MPa√mm and minimum value is of 133.25MPa√mm.

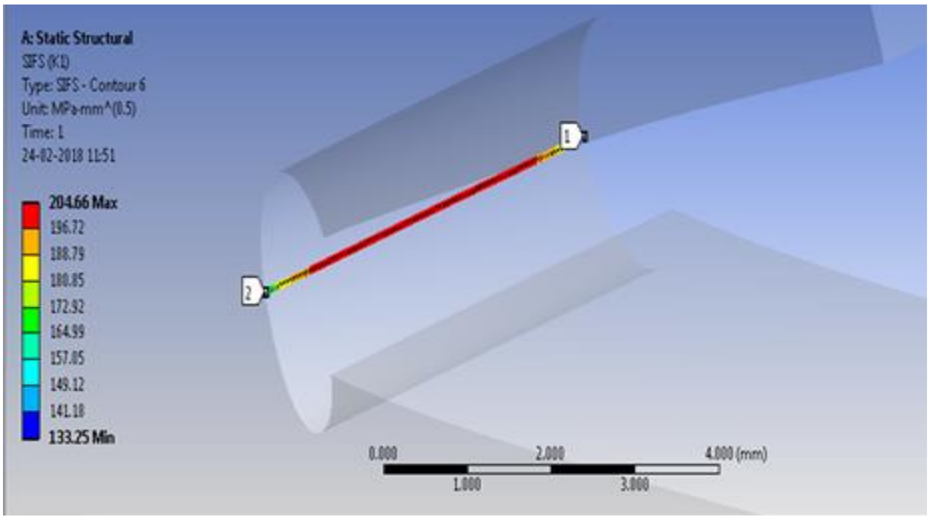


Figure 4: Stress intensity factor of compact tension specimen.

From the reference section [1] journal paper, theoretical validation of compact tension specimen is made

$$K = \frac{P(2+\xi)}{B\sqrt{W}(1-\xi)^{\frac{3}{2}}}(0.886 + 4.64\xi - 13.32\xi^2 + 14.72\xi^3 - 5.6\xi^4) \quad (1)$$

K= Stress intensity factor
P= applied load
Crack length to width ratio (ξ) = $\frac{a}{w}$
a= Crack length
w =Width
B= thickness

By substituting and simplification to main equation we get K= 206.96MPa√mm and the difference (error) between theoretical value and ANSYS result is of 1.11%.

Fatigue crack growth is determined using Air Force Crack Growth (AFGROW) software which is subjected to load ratio of 0.1. Figure below shows the graph of crack length verses number of cycle up to failure and finial crack length along width direction is of 0.0494m.

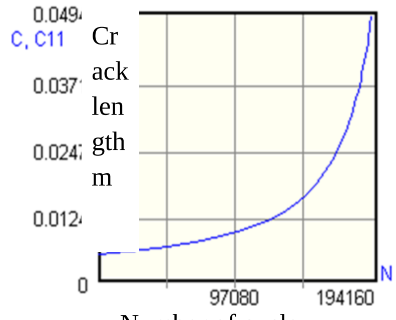


Figure 5; Crack length verses number of cycles.

Figure below shows the crack growth of compact tension specimen and graph is plotted log da/dN verses logΔK for a load ratio of 0.1.

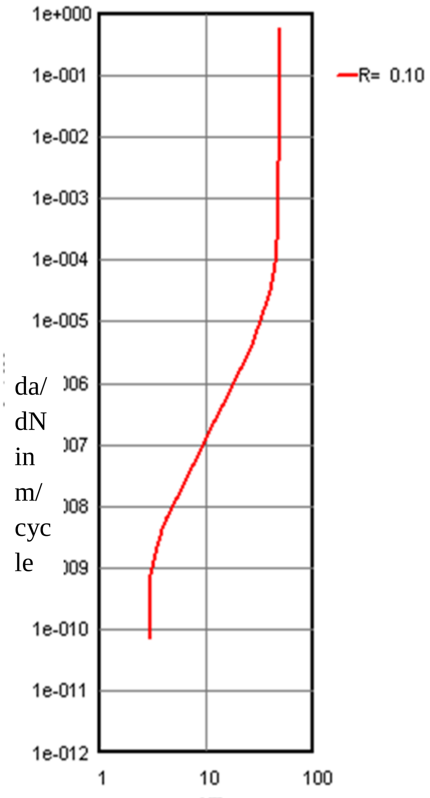


Figure6: Crack growth rate.

B. Semi-elliptical crack

The below figure shows geometry of semi elliptical crack having length(L) 100mm, width(w) of the specimen is 50mm and thickness is of 10mm. The initial crack length along thickness and width direction is 3mm. that is a equal to 3mm and b equal to 3mm. The material used for analysis is 2219T851 aluminium alloy. Young`s modulus is 71GPa and Poisson ratio is 0.33.Since ansys workbench has capability to insert the semi elliptical, so the specimen was modelled using CATIA without any crack inserted to the model, the crack is inserted in ANSYS workbench with the selection of semi-elliptical (not a pre-meshed crack). The major radius in workbench software specifies the length of b, which is crack length in width direction, similarly minor radius in workbench specifies the length of a, which is crack length in thickness direction.

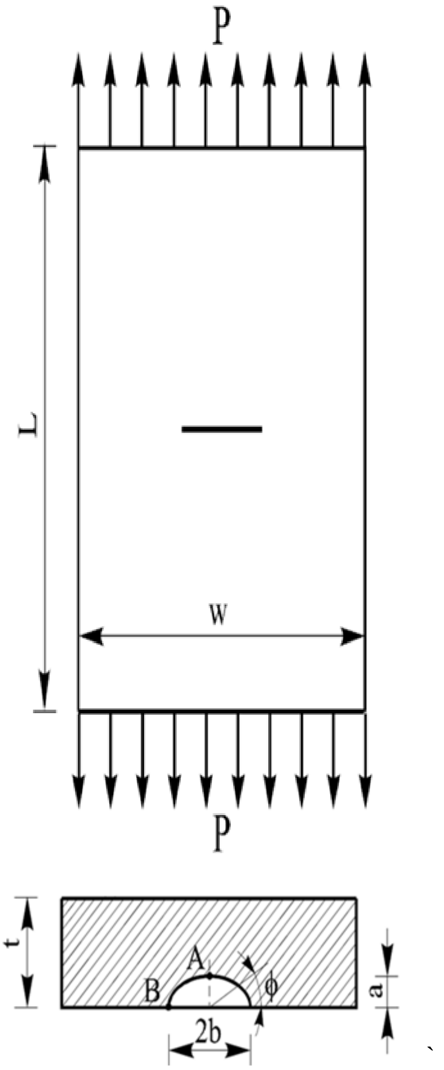


Figure 7: Geometry of semi elliptical crack.

Tet 10(Tetrahedron element) is used to mesh the specimen having element size 1mm. The upper face of the specimen is applied with the pressure of -100MPa and lower face is fixed.

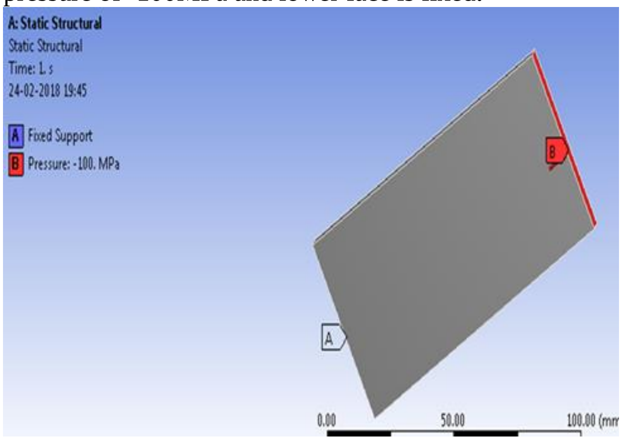


Figure 8: Boundary condition.

Figure below shows the value of stress intensity factor, maximum value is of 226.6MPa√mm and minimum value is of 203.89MPa√mm.

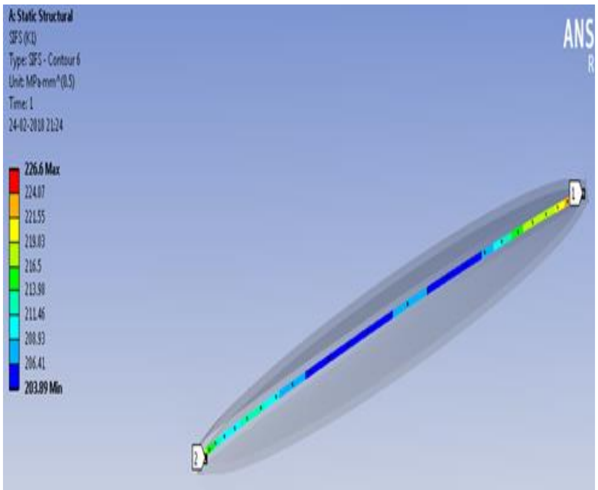


Figure 9: Stress intensity factor of semi elliptical specimen.

Theoretical validation of semi elliptical crack specimen is made by taking the expressions from the journal paper of reference section [2].

$\Delta K = \Delta S \sqrt{\frac{\pi a}{Q}} \times M_e$ (2)

Q =elastic shape factor
ΔK = Stress intensity factor range
a = crack length in the depth direction
M_e= correction factor
$Q = 1 + 1.47 \times (\frac{a}{b})^{1.64}$ $(\frac{a}{b} \leq 1.0)$ (3)

$[M_1 + (\sqrt{Q\frac{b}{a}} - M_1) \times (\frac{a}{t})^P] f_w g$ (4)

$1.13 - 0.1\frac{a}{b}, \left(0.02 \leq \frac{a}{b} \leq 1.0\right)$ (6)

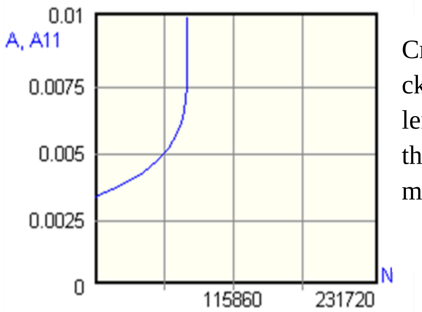
$\sqrt{\frac{1}{\cos\left(\frac{\pi b}{w}\sqrt{\frac{a}{t}}\right)}}$ (7)

$g = 1 + (0.1 + 0.35(\frac{a}{t})^2)(1 - \sin\phi)$ (8)

Where g = geometrical correction
$\Phi = 90^0$

By substituting and simplification to main equation we get K= 228.316MPa√mm and the difference (error) between theoretical value and ANSYS result is of 0.7515%.From the ANSYS result stress intensity factor is higher at crack end. So that crack propagation is higher along width direction than along thickness direction for the above loading condition and geometrical dimension of the semi elliptical crack specimen.

Fatigue crack growth of semi elliptical specimen is determined with the load ratio of 0. The crack growth was seen in both the thickness and width direction. Below figure shows crack length for both thickness (A) and also for width direction. Finial crack length along thickness was 0.01m and crack length along width direction was 0.0169m. Fatigue crack growth is determined by using NASGRO equation.

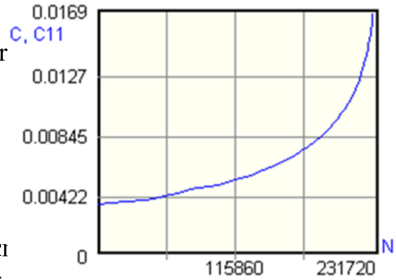


Crack length m

Number of cycle

Figure 10:Crack length along thickness verses number of cycles.

Wher



Crack length m

b = cı
M_e =

Number of cycle

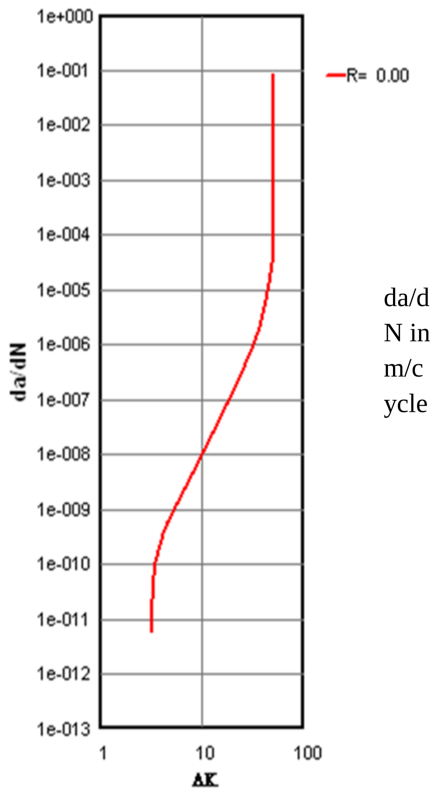
Figure 11: Crack length along width verses number of cycles.

$P = 2 + 8(\frac{a}{b})^3$ (5)

M_1 =

The below figure shows the fatigue crack growth of semi elliptical specimen having crack length of 3mm in width direction and 3mm along thickness direction.

The term f_w is the finitewidth correction factor
f_w =



da/dN in m/cycle

ΔK in MPa√m

Figure12: Crack growth rate.

C. Single edge notch specimen

The below figure shows single edge notch specimen geometry having thickness of 6.5mm and initial crack length of 17.75mm. The material used for analysis is 2024T3 aluminium alloy. Young`s modulus is 73100MPa and Poisson ratio is 0.33. The model of single edge notch specimen was modelled using CATIA with crack inserted in the model. Crack is defined in ANSYS workbench with the pre- meshed option.

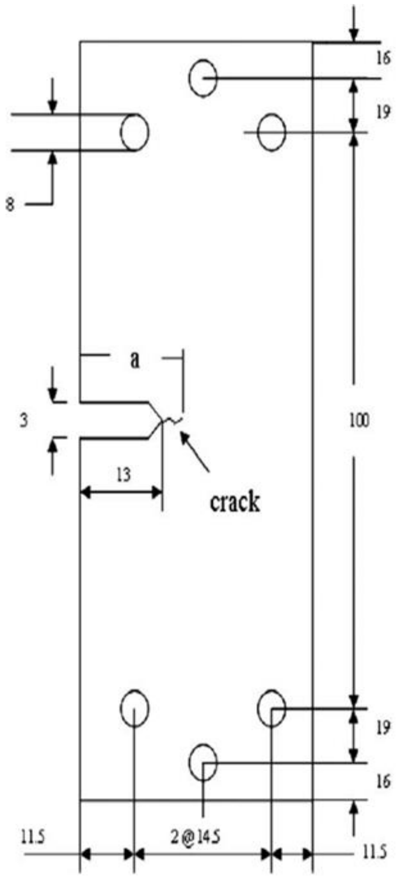


Figure 13: Geometry of single edge notch crack.

Tet 10(Tetrahedron element) is used to mesh the specimen having element size 1mm.In order to increase the accuracy of result near crack edge, element size is reduced to 0.1mm, the upper face of the specimen is applied with the pressure of -21.3MPa and lower face is fixed. In order to increase the accuracy of stress intensity factor result element size near crack tip is reduced to 0.1mm so that element are more at the crack tip.

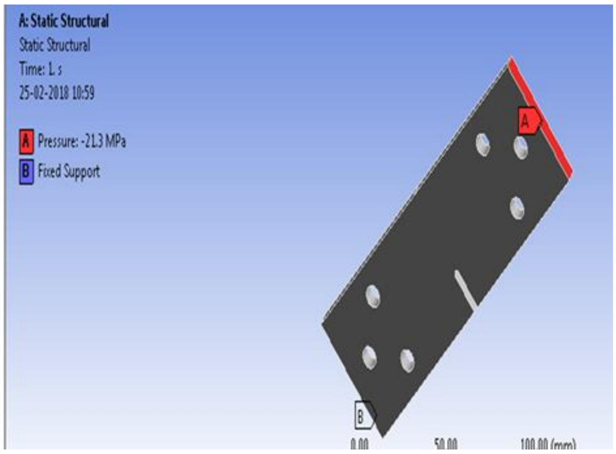


Figure 14: Boundary condition.

Figure below shows the value of stress intensity factor for single edge notch, having maximum value of 288.44MPa√mm and minimum value is 204.94MPa√mm.

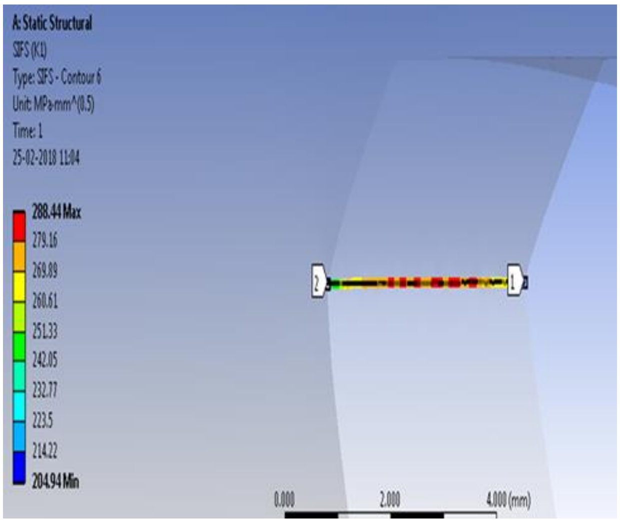


Figure 15: Stress intensity factor of single edge notch crack specimen.

From the reference section [3] journal paper, theoretical validation of single edge notched specimen is made.

$$K = f(g) \times \frac{F\sqrt{\pi a}}{wB} \quad (9)$$

Where F = applied force
a = crack length
w = width
B = thickness

$$f(g) = 1.12-0.231\times\left(\frac{a}{w}\right) + 10.55\times\left(\frac{a}{w}\right)^2 - 21.72\times\left(\frac{a}{w}\right)^3 + 30.39\times\left(\frac{a}{w}\right)^4 \quad (10)$$

By substituting and simplification to main equation we get K= 289.136MPa√mm and the difference (error) between theoretical value andANSYS result is of 0.2407%.

Fatigue crack growth of single edge notch specimen is determined with load ratio of 0.1. The crack length verses number of cycles up to failure is shown along width direction and having finial crack length of 0.039m.

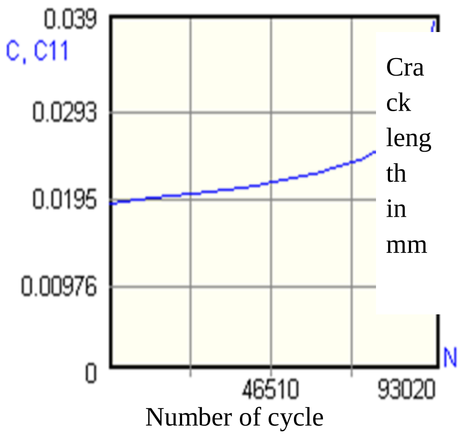


Figure 16: Crack length verses number of cycle.

The below figure shows the crack growthrate of single edge notched specimen having crack length of 17.75. NASGRO equation was used to determine the fatigue crack growth.

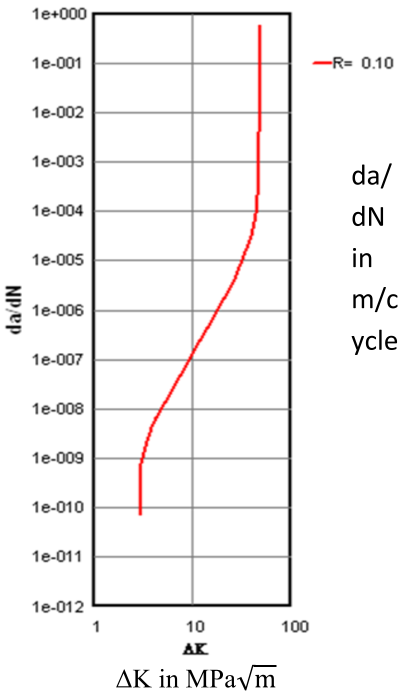


Figure 17: Crack growth rate.

3. CASE STUDY ON PRESSURE VESSEL

The piping component or pressure vessel may fail under service loads or under normal operating condition, so such, failure need to be detected and detailed stress and strain analysis for the safe design of pressure vessel, Leak Before-Break (LBB) is important phenomenon required to prevent catastrophic failure of pressure vessel. So it is essentially need to find the leak pressure for safe design of pressure vessel. In present work semi-elliptical crack length was taken as four times of thickness length, since it represents a typical fatigue crack geometry observed at failure location in fatigue tested cylinders. In the present study, initially finding out the fracture pressure through theoretical means and then finding out stress intensity factor with theoretical way than with ANSYS workbench also.

The below figure shows diagram of axial semi elliptical crack, having outer diameter 228.6mm and thickness of 7.2mm and minor radius of crack is 5.4mm and major radius is 25.4mm. Length of specimen is of 1400mm. The material used for analysis is AISI 4130 steel. Young`s modulus is 205GPa and Poisson ratio is 0.32.

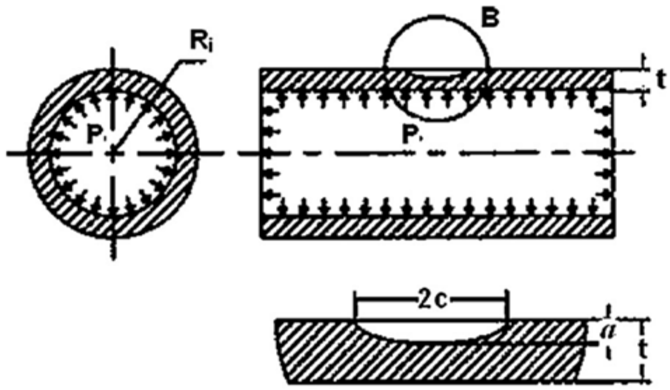


Figure 18: Geometry of the model.

Since large dimension of geometry involved in pressure vessel mainly in case of length, taking in the mind of computational time involved in meshing, computer configuration and also computational time involved in result extraction. It is essential to use symmetry of model. The figure below shows symmetry of pressure vessel model.

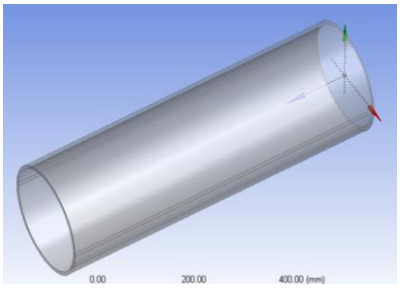


Figure 19: Symmetry region 1.

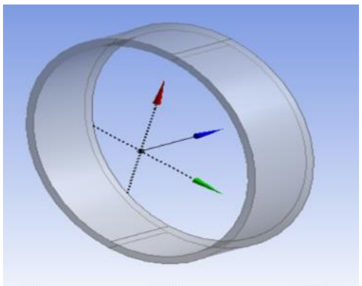


Figure 20: Symmetry region 2.

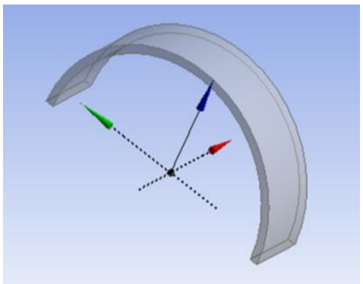


Figure 21: Symmetry region 3.

Tet 10(Tetrahedron element) is used to mesh the specimen having element size 1mm. Since of symmetry boundary condition, we are applying or restricting Z=0 and X = 0 as shown below and applying pressure of 31.48N/mm^2 on the internal surface of pressure vessel.

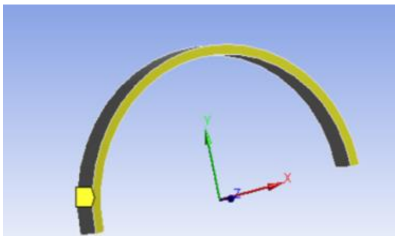


Figure22: Restricting along Z direction.

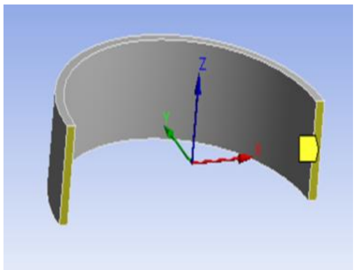


Figure 23: Restricting along X direction.

Figure below shows the value of stress intensity factor for pressure vessel, having maximum value of 4048.7MPa√mm and minimum value is 2412.8MPa√mm.

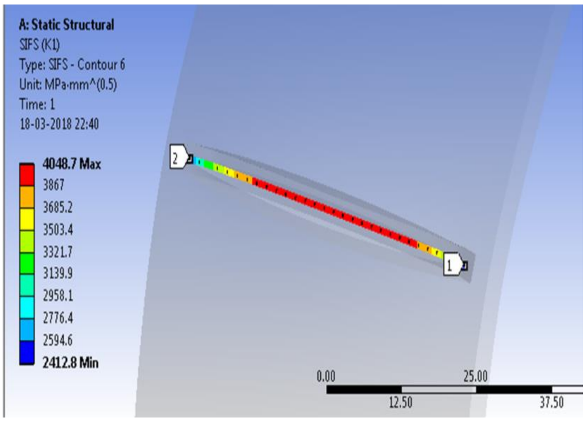


Figure 24: Stress intensity factor of pressure vessel.

From the reference section [4] journal paper, theoretical validation of pressure vessel is made. Than pressure value was applied to dtermine stress intensity factor.

$q = 2+8(\frac{a}{c})^3$ (11)

a = Depth of surface crack

c = Length of surface crack

λ_s

$\frac{c}{\sqrt{R_i \times t}} \times \frac{a}{t}$ (12)

R_i = inner radius of pressure vessel

t = thickness of pressure vessel

$f_s =$

$(1 + 0.52 \times \lambda_s + 1.29 \times \lambda_s^2 - 0.074 \times \lambda_s^3)^{\frac{1}{2}}$ for $0 \leq \lambda_s \leq 10$ (13)

$M_1 = 1.13 - 0.1 \times \left(\frac{a}{c}\right)$ for $a \leq c$(14)

$\phi^2 = 1 + 1.464 \times (\frac{a}{c})^{1.65}$ for $a \leq c$ (15)

⟦

Crack shape factor

$M_1 + \left(\phi \times \sqrt{\frac{c}{a}} - M_1\right) \times (\frac{a}{t})^q$ (16)

$M = M_e \times f_s$ (17)

M = Magnification factor

Fracture strength equation is given as

$$m) \times (\frac{\sigma_f}{\sigma_u})^P + \left(m + \frac{\sigma_u \times (\pi a)^{\frac{1}{2}} \times M}{\phi K_F}\right) \times \left(\frac{\sigma_f}{\sigma_u}\right) - 1 = 0$$
(18)

$\sigma_u = \frac{P_b R_i}{t}$(19)

σ_u= hoop stress of unflawed cylindrical vessel

P_b = bursting pressure of unflawed cylindrical vessel

t = thickness of pressure vessel

$P_b = \frac{2}{\sqrt{3}}\sigma_{ys}\left(2 - \frac{\sigma_{ys}}{\sigma_{ult}}\right)\ln\left(1 + \frac{t}{R_i}\right)$ (20)

σ_{ys} = yield strength of material (1097MPa)

σ_{ult} = ultimate tensile strength of material (1180MPa)

By substituting and simplification

$$\sigma_f = 468.30\text{MPa}$$

$$\sigma_f = \frac{P_f \times R_i}{t} \quad (21)$$

By substituting and simplification

$$P_f = 31.48235 \text{ N/mm}^2$$

$$K_{max} = \sigma \times \sqrt{\frac{\pi a}{\phi^2}} \times M \quad (22)$$

$$K_{max} = 4496.21 \text{ MPa}\sqrt{\text{mm}}$$

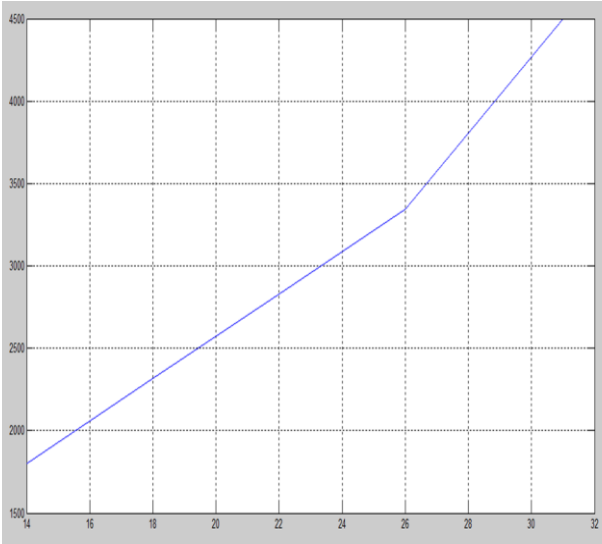
The difference (error) between theoretical value and ANSYS workbench result is of 9%.

4. PARAMETRIC STUDY ON PRESSURE VESSEL WITH EXTERNAL AXIAL CRACK

A. Parametric study using ANSYS workbench

Parametric study is made on pressure vessel by varying pressure with fixed thickness of 7.2mm till to the fracture pressure. The graph is plotted with stress intensity factor verses pressure. After the point A sudden increase in the stress intensity factor was seen mainly because pressure at a point A is nearer to the fracture pressure of the experimental results. With increase of pressure, stress intensity factor also increases.

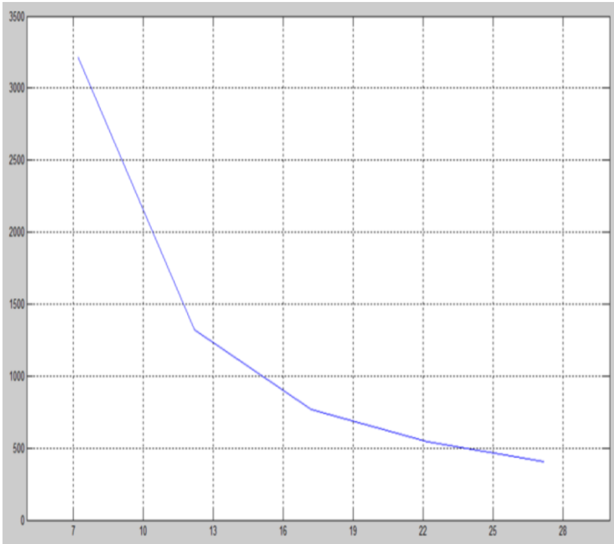
Stress intensity factor in MPa√mm



Pressure in MPa

Figure 25: Stress intensity factor verses pressure.

Stress intensity factor in MPa√mm



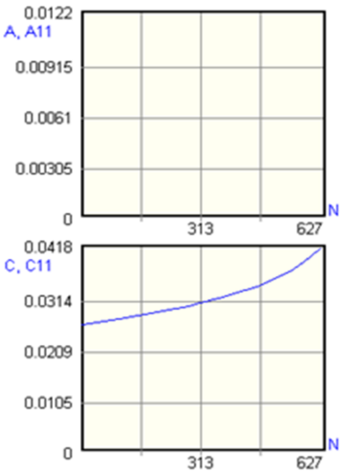
Thickness in mm

Figure 26: Stress intensity factor verses thickness.

The above graph shows stress intensity factor verses thickness. The thickness variation is made with fixed pressure of 25MPa which is nearly below the fracture pressure. The stress intensity factor decreases with increase in the thickness and reaches to a minimum value, thereafter stress intensity factor does not decrease with increase in thickness which is known as plain strain fracture toughness. With the help of plain strain fracture toughness it is possible to calculate the leak pressure.

B. Parametric study using AFGROW

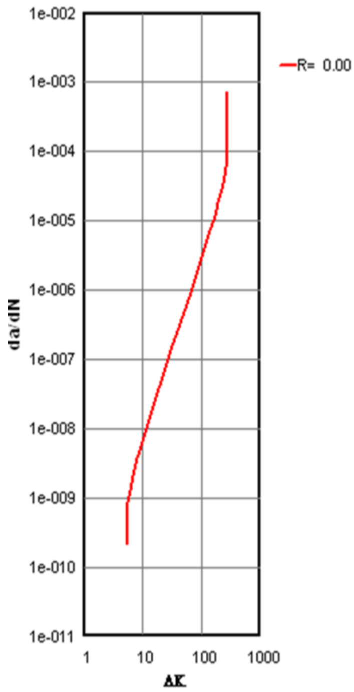
Parametric study is done on HY (higher yielding material) 130 steel pipe material using AFGROW. Same dimension are taken as earlier to that of pressure vessel. Same variation of pressure and thickness has been made as earlier to parametric study. Since due to insufficient material data of AISI 4130 steel material which is required for AFGROW software as input, so material chosen was HY 130 steel pipe which come under pressure vessel of NASGRO material data base file. Pressure variation has been made on pressure vessel having thickness of 12.2mm. For pressure of 22MPa there is no crack length because of crack growth is less than 2.54e^{-15}m.The below figures shows crack length verses number of cycle up to failure along the thickness and length direction. Crack growths for the pressure of 14MPa, 18MPa and 22MPa with the fixed thickness of 12.2mm.



Crack length in m

Number of cycle

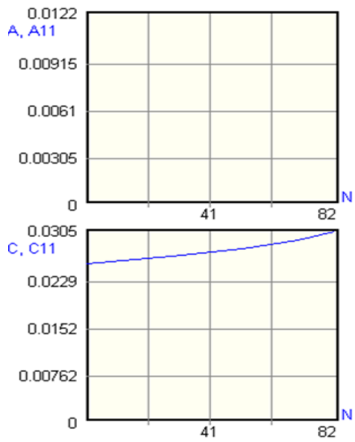
Figure 27: Crack length verses number of cycle for pressure of 14MPa.



da/dN in m/cy

ΔK in MPa$\sqrt{m}$

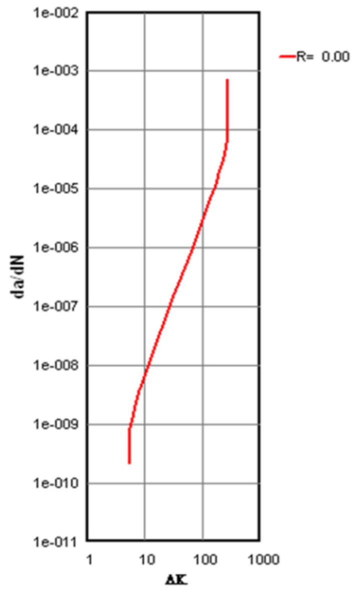
Figure 28: Crack growth rate for pressure 14MPa.



Crack length in m

Number of cycle

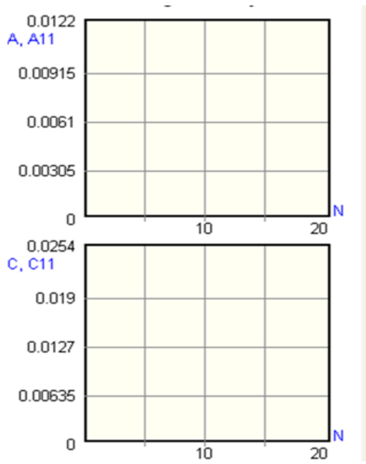
Figure 29: Crack length verses number of cycle for pressure of 18MPa.



da/dN in m/cycle

ΔK in MPa$\sqrt{m}$

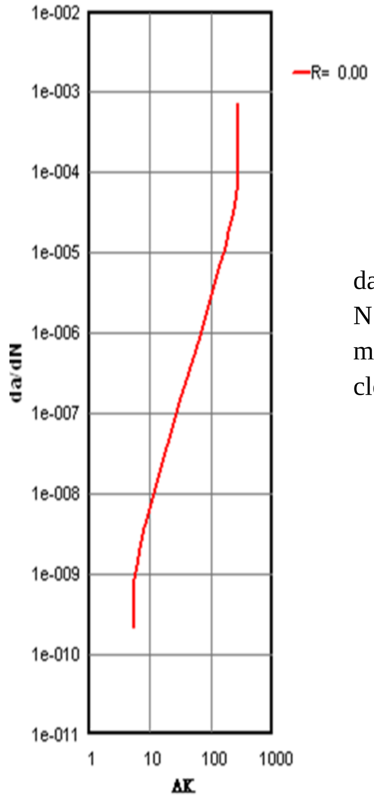
Figure 30: Crack growth rate for pressure 18MPa.



Crack length in m

Number of cycle

Figure31: Crack length verses number of cycle for pressure of 22MPa.

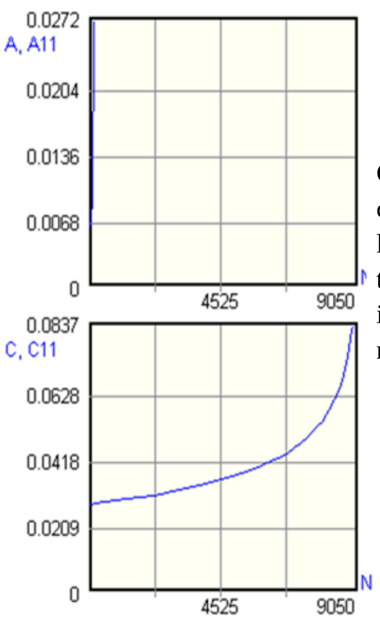


da/dN in m/cycle

ΔK in MPa$\sqrt{m}$

Figure 32: Crack growth rate for pressure 22MPa.

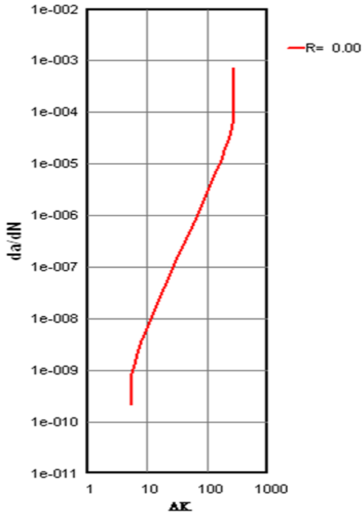
Thickness variation has been made on pressure vessel having fixed pressure of 25MPa. For thickness of 12.2mm there is no crack length because of crack growth is less than 2.54e-15.The below figures shows crack length verses number of cycle up to failure along the thickness and length direction. Crack growths for the thickness of 27.2mm, 22.2mm, 17.2mm and 12.2mm with the fixed thickness of 12.2mm correspondingly are also shown below.



Crack length in m

Number of cycle

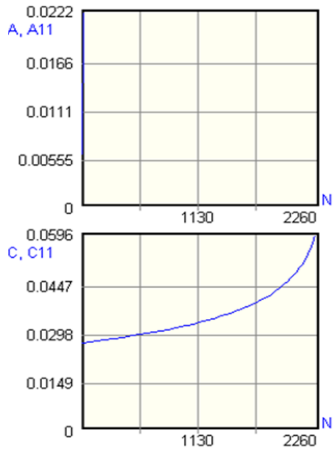
Figure 33: Crack length verses number of cycle for thickness of 27.2mm.



da/dN in m/cycle

ΔK in MPa√m

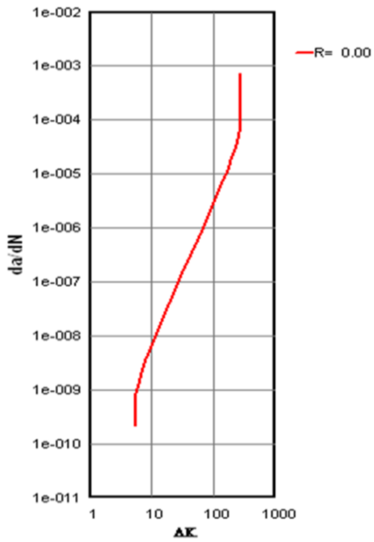
Figure 34: Crack growth rate for thickness 27.2mm.



Crack length in m

Number of cycle

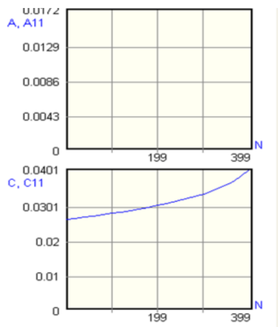
Figure 35: Crack length verses number of cycle for thickness of 22.2mm.



da/dN in m/cycle

ΔK in MPa√m

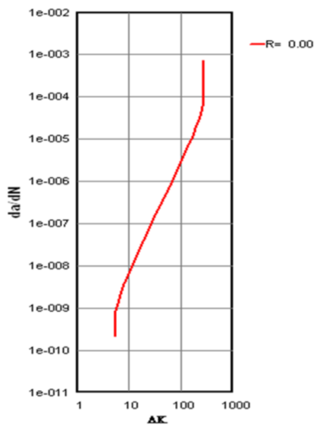
Figure36: Crack growth rate for thickness 22.2mm.



Crack length in m

Number of cycle

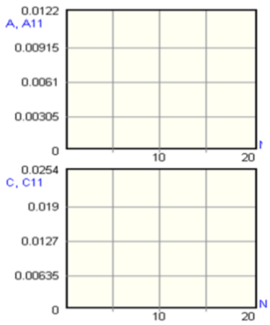
Figure 37: Crack length verses number of cycle for thickness of 17.2mm.



da/dN in m/cycle

ΔK in MPa√m

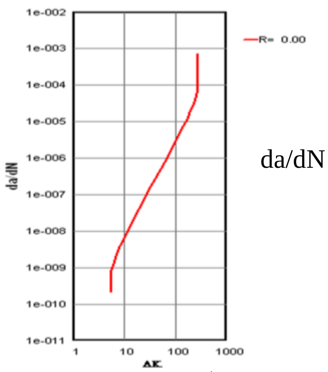
Figure 38: Crack growth rate for thickness 17.2mm.



Crack length in m

Number of cycle

Figure 39: Crack length verses number of cycle for thickness of 12.2mm.



da/dN in m/cycle

ΔK in MPa√m

Figure 40: Crack growth rate for thickness 12.2mm.

5. STUDIES ON INTERNAL AXIAL CRACK OF PRESSURE VESSEL

Studies have been carried on semi elliptical internal axial crack independently mainly based on the experience and knowledge gained from external axial crack. Main aim is to know how stress intensity factor varies in pressure with internal axial crack to that of external axial crack and also to know fatigue crack growth in internal axial crack. The geometry and load condition are similar to the external axial crack. Pressure of 31.48MPa is applied on the internal surface of pressure. Boundary condition and also Symmetry of the model remains same as that of external axial crack, the below figure shows result of stress intensity factor of internal axial crack. It is observed that stress intensity is very high at the centre which results in faster crack growth in depth direction than to crack growth in width direction.

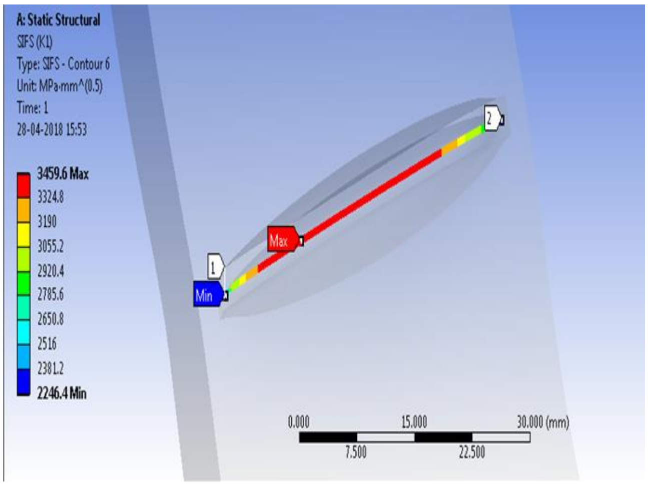


Figure 41: Stress intensity factor of internal axial crack in pressure vessel.

6. PARAMETRIC STUDY ON PRESSURE VESSEL WITH INTERNAL AXIAL CRACK

A. Parametric study using ANSYS workbench

Parametric study is made on pressure vessel having internal axial semi elliptical crack. Pressure variation is made for fixed thickness of 7.2mm. The pressure is varied from 14MPa to 31.48MPa and graph is plotted, stress intensity factor verses pressure. It is observed that with increase of pressure stress intensity factor also increases.

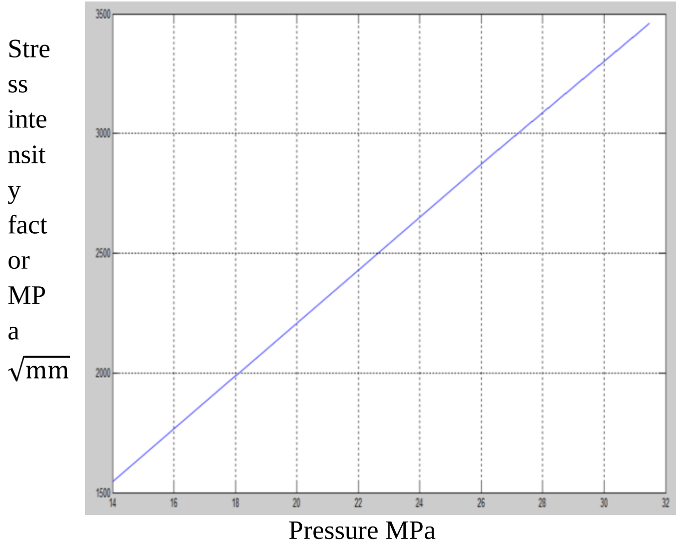


Figure: 42 Stress intensity factor verses pressure.

Thickness variation is made by keeping pressure as fixed that is by fixing 25MPa, which is nearly below to that of fracture pressureof pressure vessel. With increasing in the thickness stress intensity factor decreases and it is known that when stress intensity factor falls below the plain strain fracture toughness crack growth takes places at stable manner.

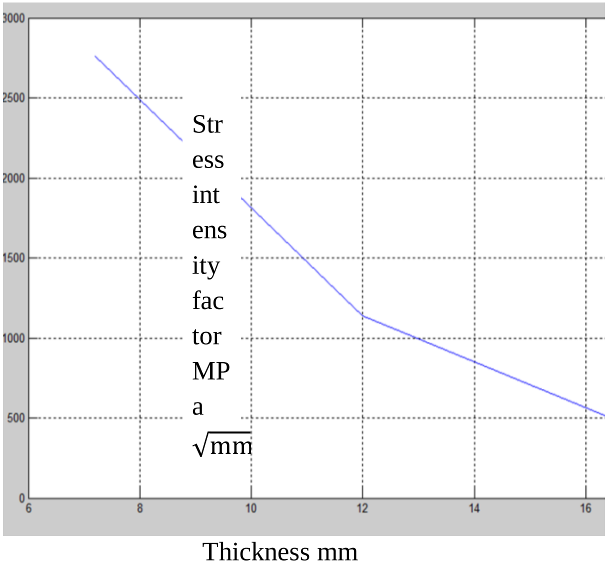


Figure: 43 Stress intensity factor verses thickness.

B. Parametric study using AFGROW

Fatigue crack growth study has been made using AFGROW software on HY 130 steel pipe used for analysis. The geometry is same to that of external axial crack specimen. The material property is near to AISI 4130 steel material. NASGRO equation is used for analysis. For pressure of 14,18 and 22 there is no crack growth mainly because of crack growth is less than $2.54e^{-15}$m and also same reason for no crack growth in both thickness direction and width direction mainly in case of 22 pressure with the thickness of 12.2. Figures below shows crack length and also crack growth rate for various pressure with fixed thickness of 12.2mm.

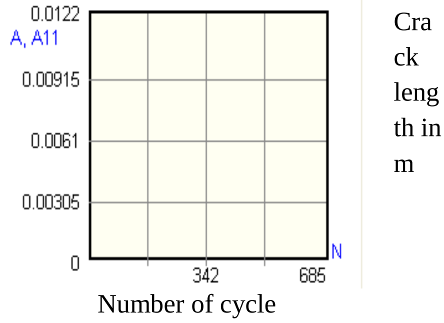


Figure: 44 Crack length along thickness verses number of cycle for pressure 14MPa.

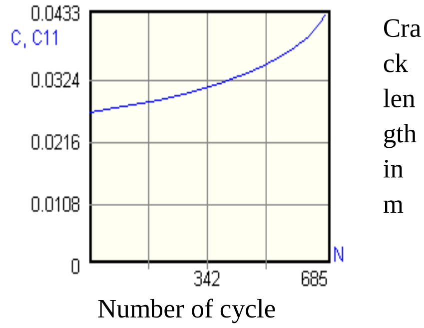
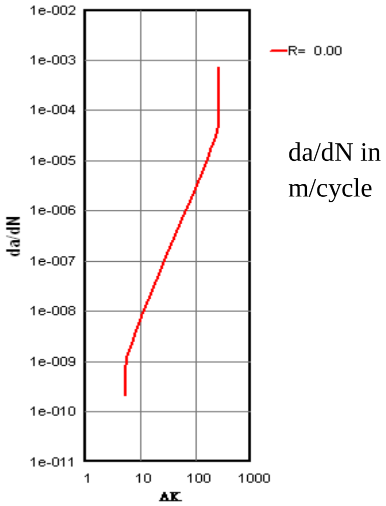


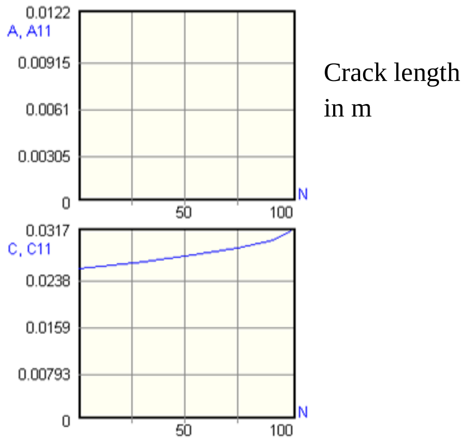
Figure: 45 Crack length along width verses number of cycle for pressure 14MPa.

In further studies pressure is held constant and thickness is varied so that variation of stress intensity with thickness is obtained .Stress intensity factor decreases with increase in thickness. So by selecting suitable thickness and determining the safe service pressure, crack growth can takes place in stable manner and reducing human risk.



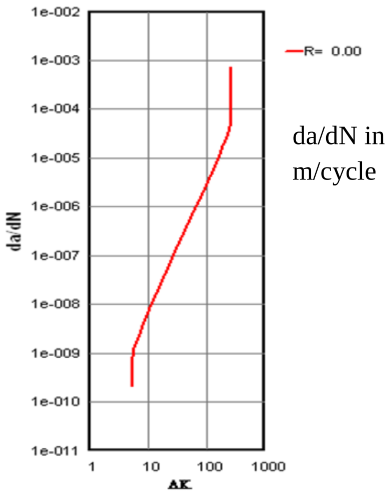
ΔK in MPa√m

Figure: 46 Crack growth rate for pressure 14MPa.



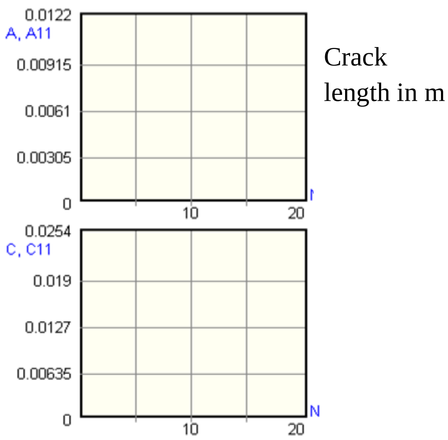
Number of cycle

Figure: 47Crack length for pressure 18MPa.



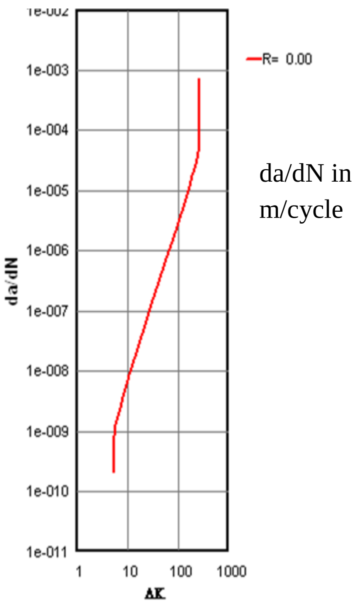
ΔK in MPa√m

Figure: 48 Crack growth rate for pressure 18MPa.



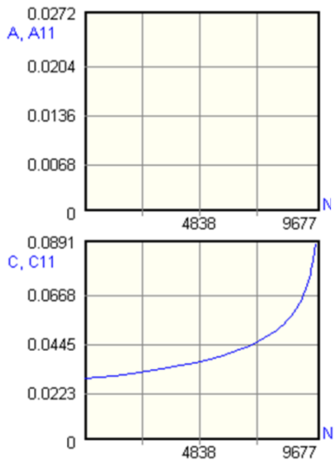
Number of cycle

Figure: 49 Crack length for pressure 22MPa.



ΔK in MPa√m

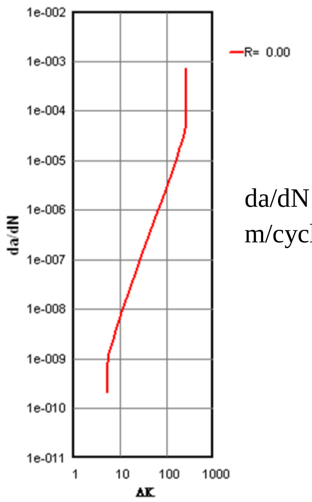
Figure: 50 Crack growth rate for pressure 22MPa.



Crack length in m

Number of cycle

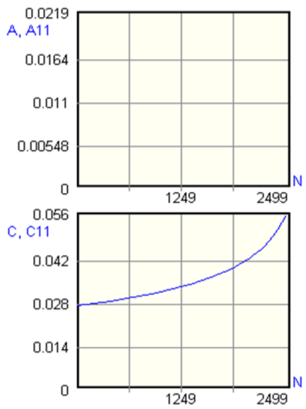
Figure: 51 Crack length for thickness 27.2mm.



da/dN in m/cycle

ΔK in MPa $\sqrt{m}$

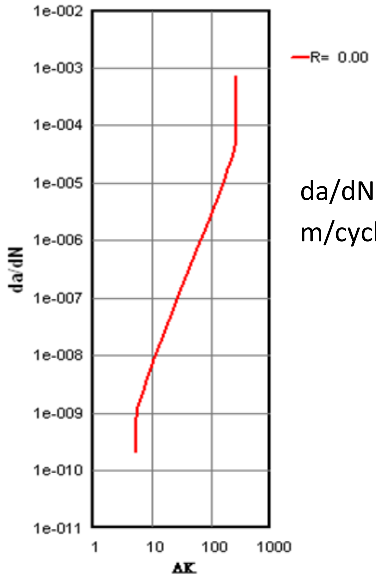
Figure: 52 Crack growth rate for thickness 27.2mm.



Crack length in m

Number of cycle

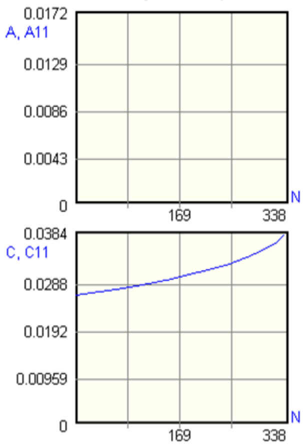
Figure: 53Crack length for thickness 22.2mm.



da/dN in m/cycle

ΔK in MPa$\sqrt{m}$

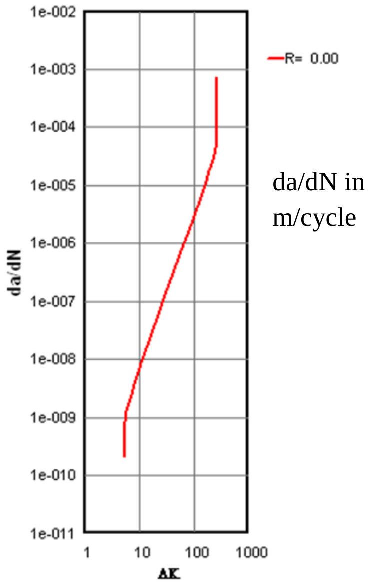
Figure: 54Crack growth rate for thickness 22.2mm.



Crack length in m

Number of cycle

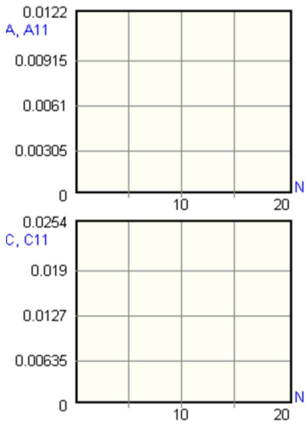
Figure: 55 Crack length for thickness 17.2mm.



da/dN in m/cycle

ΔK in MPa$\sqrt{m}$

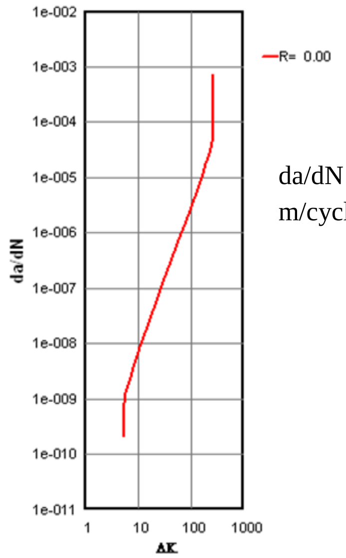
Figure: 56 Crack growth rate for thickness 17.2mm.



Crack length in m

Number of cycle

Figure: 57 Crack length for thickness 12.2mm.



da/dN in m/cycle

ΔK in MPa$\sqrt{m}$

Figure: 58 Crack growth rate for thickness 17.2mm.

7. CONCLUSION

Predication of stress intensity factor and fatigue crack growth for standard test specimens has been carried out. Finite Element Analysis results are good argument with theoretical values. Case study has been made on pressure vessel, Finite Element Analysis result is in good argument with theoretical value. Parametric study is done on pressure vessel on both using ANSYS workbench and AFGROW software, which gives knowledge how stress intensity factor varies with thickness and pressure and also how crack length varies with the pressure and thickness value. Studies have been carried on internal axial crack, followed by parametric study on it. It was observed that external axial crack has high stress intensity factor at it ends and internal axial crack has high stress intensity at the mid surface.

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