Design of Metallic Pressure Vessels - A Fracture Mechanics based Approach

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Abstract - *A pressure vessel is a container designed to hold gases or liquids at a higher pressure. Pressure vessels can be dangerous, and fatal accidents have occurred in the history of their development and operation. Consequently, pressure vessel design, manufacture, and operation are to be thoroughly regulated. Design involves parameters such as maximum safe operating pressure and temperature, safety factor, corrosion allowance and minimum design temperature for brittle fracture. Fracture mechanics is the field of mechanics concerned with the study of the propagation of cracks in materials. It uses methods of analytical solid mechanics to calculate the driving force on a crack and those of experimental solid mechanics to characterize the material's resistance to fracture. In modern materials science, fracture mechanics is an important tool used to improve the performance of mechanical components. This paper focuses on the design of the pressure vessel based on fracture mechanics approach using the failure assessment diagram by R6 procedure, estimation of fracture parameters using non – linear FE analysis and the comparison of elasto-plasic design to the fracture based design.*

Key Words: **Fracture Mechanics, Failure Assessment Diagram, Pressure Vessels, Stress Intensity Factor, Crack Tip Opening Displacement, J-Integral.**

1. INTRODUCTION

A pressure vessel is a container designed to hold gases or liquids at a pressure substantially different from the normal pressure. Pressure vessels can be dangerous, and fatal accidents have occurred in the history of their development and operation. For these reasons, the definition of a pressure vessel varies from country to country. Design involves parameters such as maximum safe operating pressure and temperature, safety factor, corrosion allowance and minimum design temperature for brittle fracture. Hypothetically, pressure vessels can take many different shapes. However, the most common shapes are cylinders, spheres, and cones. The combination of a long cylinder with two caps (heads) is a typical design. Industrial uses for pressure vessels are plenty. They are also used in satellites.

1.1 Fracture Mechanics

Fracture mechanics is the field of mechanics concerned with the study of the propagation of cracks in materials. It uses methods of analytical solid mechanics to calculate the driving force on a crack and those of experimental solid mechanics to characterize the material's resistance to fracture. In modern materials science, fracture mechanics is an important tool used to improve the performance of mechanical components. It applies the physics of stress and strain behavior of materials, in particular the theories of elasticity and plasticity, to the microscopic crystallographic defects found in real materials in order to predict the macroscopic mechanical behavior of those bodies. There are three ways of applying a force to enable a crack to propagate:

- Mode I fracture – Opening mode (a tensile stress normal to the plane of the crack),
- Mode II fracture – Sliding mode (a shear stress acting parallel to the plane of the crack and perpendicular to the crack front), and
- Mode III fracture – Tearing mode (a shear stress acting parallel to the plane of the crack and parallel to the crack front).

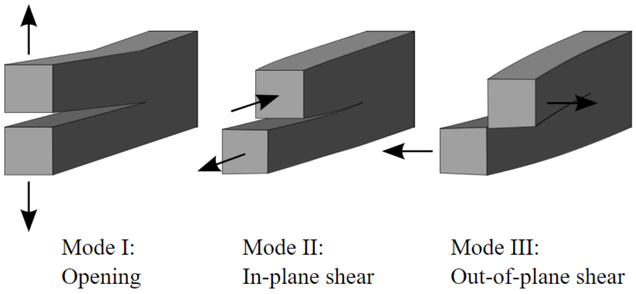

Fig -1: Modes of Fracture

The cause of most structural failures generally falls into one of the following categories:

1. Negligence during design, construction, or operation of the structure.
2. Application of a new design or material, which produces an unexpected and undesirable result.

One of the most famous Type 2 failures is the brittle fracture of the World War II Liberty ships. Fracture mechanics quantifies the critical combinations of the following three variables. There are two alternative approaches to fracture analysis: the energy criterion and the stress intensity approach.

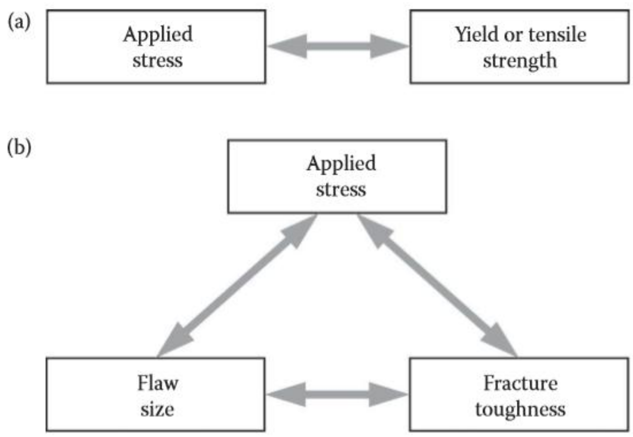

Fig -2: (a) strength of materials approach (b) fracture mechanics approach

1.2 Literature Review

S J Garwood et al. [1] learned that Fracture mechanics assessment procedures, such as BSI PD6493:1991, R6 and ASME XI, have become well established in industry. These published procedures provide methods for assessing the acceptability of flaws in fusion welded structures. For such procedures to be used with confidence, it is essential that their application be validated by comparison with large scale fracture mechanics tests, and actual structural failures. It also highlights the importance of the property of fracture toughness.

Yu. G. Matvienko [2] studied about the cohesive zone model and the criterion of average stress in the cohesive zone ahead of the crack/notch tip are used to describe failure assessment diagrams for cracked and notched bodies. The type of loading as well as the elastic stress concentration factor can significantly change the character of the failure assessment diagram. The critical stress intensity factor at the notch tip is a decreasing function of the elastic stress concentration factor and trends to the fracture toughness of a body with a crack under small scale yielding.

Tong et al. [3] published their paper 'Stress intensity factor K and the elastic T-stress for corner cracks'. The stress intensity factor K and the elastic T-stress for corner cracks have been determined using domain integral and interaction integral techniques. The results show that the stress intensity factor K maintains a minimum value at the mid-plane where the T-stress reaches its maximum, though negative, value in all cases. Poisson's ratio influences both T and K. The stress intensity factor K increases and the T-stress decreases with increase in Poisson's ratio.

Joseph Mutava and Mutuku Muvengei [4] in their paper named, 'Fracture Mechanics Approach to Pressure Vessel Failures: A Review' learnt that cracking is said to be one of the main causes of failure where most of the failures have been traced to surface cracks. To successfully prevent any possible failure of a pressure vessel, one must be able to accurately predict the crack growth behaviour. LEFM approach is mostly applied and therefore majority of these studies have used this approach. This method is not suitable for elasto-plastic fracture behaviour normally exhibited by the highly tough and ductile material.

NASA-STD-5009[5]. This standard is published by the National Aeronautics and Space Administration (NASA) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs and projects, including requirements for selection, application, and design criteria of an item

1.3 Linear Elastic Fracture Mechanics

Griffith's criterion: Griffith suggested that the low fracture strength observed in experiments, as well as the size-dependence of strength, was due to the presence of microscopic flaws in the bulk material.

To verify the flaw hypothesis, Griffith introduced an artificial flaw in his experimental glass specimens. The artificial flaw was in the form of a surface crack which was much larger than other flaws in a specimen. The experiments showed that the product of the square root of the flaw length (a) and the stress at fracture (σ_f) was nearly constant, which is expressed by the equation:

$$\sigma_f\sqrt{a}\,\sqrt{a}\approx C$$

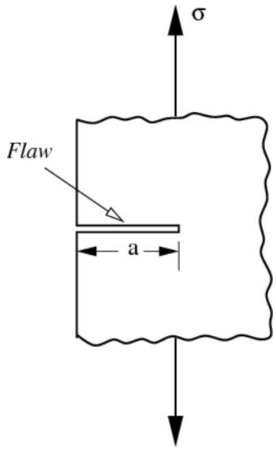

Fig -3: An edge crack of length 'a' in a material

Irwin's modification: Griffith's work was largely ignored by the engineering community until the early 1950s. The reasons for this appear to be (a) in the actual structural materials the level of energy needed to cause fracture is orders of magnitude higher than the corresponding surface energy, and (b) in structural materials there are always some inelastic deformations around the crack front that would make the assumption of linear elastic medium with infinite stresses at the crack tip highly unrealistic.

Irwin's strategy was to partition the energy into two parts: Total energy is,

$$G = 2^{\gamma} + G_p$$

Where $^{\gamma}$ is the surface energy and G_p is the plastic dissipation (and dissipation from other sources) per unit area of crack growth.

Stress intensity factor:

The method of calculating the amount of energy available for fracture in terms of the asymptotic stress and displacement fields around a crack front in linear elastic solid was found. This asymptotic expression for the stress field in mode I loading is related to the stress intensity factor K_I following.

$$\sigma_{ij} = \left(\frac{K_I}{\sqrt{2\Pi r}}\right) f_{ij}\,(\theta)$$

Where σ_{ij} are the Cauchy stresses, r is the distance from the crack tip, ϑ is the angle with respect to the plane of the crack, and f_{ij} are functions that depend on the crack geometry and loading conditions. Irwin called the quantity K the stress intensity factor.

Strain Energy Release:

The size of the plastic zone around a crack is small compared to the size of the crack, the energy required to grow the crack will not be critically dependent on the state of stress (the plastic zone) at the crack tip. In other words, a purely elastic solution may be used to calculate the amount of energy available for fracture.

The energy release rate for crack growth or strain energy release rate may then be calculated as the change in elastic strain energy per unit area of crack growth, i.e.,

$$G = \left[\frac{\partial U}{\partial a}\right]_p = -\left[\frac{\partial U}{\partial a}\right]_u$$

Where U is the elastic energy of the system and a is the crack length.

Crack Tip Plastic Zone:

In theory the stress at the crack tip where the radius is nearly zero, would tend to infinity. This would be considered a stress singularity, which is not possible in real-world applications. For this reason, in numerical studies in the field of fracture mechanics, it is often appropriate to represent cracks as round tipped notches, with a geometry dependent region of stress concentration replacing the crack-tip singularity

1.4 Elastic - Plastic Fracture Mechanics

Most engineering materials show some nonlinear elastic and inelastic behavior under operating conditions that involve large loads. In such materials the assumptions of linear elastic fracture mechanics may not hold.

CTOD:

CTOD is the displacement at the original crack tip and the 90 degree intercept. The latter definition was suggested by Rice and is commonly used to infer CTOD in finite element models of such. Note that these two definitions are equivalent if the crack tip blunts in a semicircle.

J-Integral:

In the mid-1960s James R. Rice and G. P. Cherepanov independently developed a new toughness measure to describe the case where there is sufficient crack-tip deformation that the part no longer obeys the linear-elastic approximation. Rice's analysis, which assumes non-linear elastic or monotonic deformation theory plastic deformation ahead of the crack tip, is designated the J-integral. The elastic-plastic failure parameter is designated JIc and is conventionally converted to KIc.

Failure Assessment Diagram:

Structures made from materials with sufficient toughness may not be susceptible to brittle fracture, but they can fail by plastic collapse if they are overloaded. The CTOD design curve does not explicitly address collapse, and can be non-conservative if a separate collapse check is not applied. The FAD is probably the most widely used methodology for elastic–plastic fracture mechanics analysis of structural components. The original FAD was derived from the strip yield plastic zone correction. The strip yield model has limitations, it does not account for strain hardening. A more accurate FAD can be derived from an elastic–plastic J-integral solution.

$$L_r = \frac{\sigma_{ref}}{\sigma_{ys}}$$

Where, σ_{ref} is the reference stress. To assess the likelihood of failure, we need to incorporate fracture toughness into the analysis. This is accomplished by plotting an assessment point on the FAD. The y coordinate of this point is defined as follows:

$$k_r = \frac{k_1}{k_{mat}}$$

Where, k_{mat} is the material's fracture toughness in stress intensity units. The x coordinate of the assessment point is computed from the previous Equation.

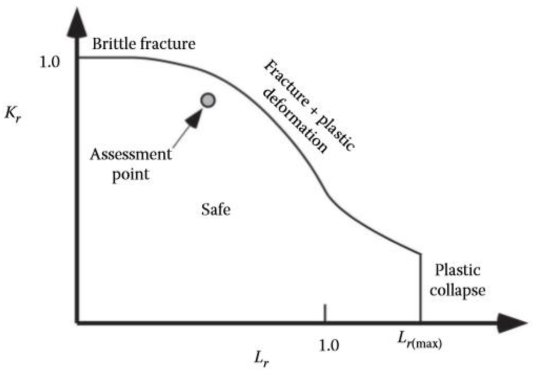

Fig -4: FAD, which spans the range of fully brittle to fully ductile behavior

Figure above illustrates a hypothetical assessment point plotted on the FAD. If the assessment point falls inside the FAD, the structure is considered safe. Failure is predicted when the point falls outside of the FAD.

Fitting Elastic–Plastic Finite Element Results to a FAD Equation:

The y axis is a dimensionless representation of the J integral and the x axis is the applied load or stress in a dimensionless form. Most FAD approaches normalize the x-axis by the limit load or yield load solution. This practice can lead to apparent geometry dependence in the FAD curve, however.

For a Ramberg – Osgood material, the material-specific FAD can be written in the following form:

$$K_r = \left(1 + L_r^{n-1} + \frac{0.5L_r^2}{1+L_r^{n-1}}\right)^{-\frac{1}{2}}$$

The relative magnitude of the contained-yielding contribution to Jpl is geometry dependent, so it is necessary to introduce an additional fitting parameter into the equation:

$$K_r = \left(1 + L_r^{n-1} + \frac{\beta L_r^2}{1+L_r^{n-1}}\right)^{-\frac{1}{2}}$$

The reference stress for a pipe configuration is defined as follows:

$$\sigma_{ref} = H\frac{pR_i\alpha^{\frac{1}{n-1}}}{t}$$

Where, H is a geometry factor. An elastic–plastic J solution can be fit with three parameters:β, H, as well an elastic geometry factor that characterizes the KI solution. The total reference stress for combined loading is,

$$\sigma_{ref}^{total} = \sqrt{\left(\sigma_{ref}^{m}\right)^2 + \left(\sigma_{ref}^{b}\right)^2 + 2\sigma_{ref}^{m}\sigma_{ref}^{b}\cos(\gamma)}$$

Where, γ, is the phase angle.

2. Fracture Parameter Evaluation

Fracture parameters are evaluated for the parent material for the case studies mentioned in Table 5.1. Elastic and Elastic – plastic FE analysis is carried out on all the case studies. 'J integral elastic' and 'J integral total' evaluated from elastic and elastic – plastic analysis respectively. This is used to fit the FAD expression to get the fracture parameter β and H.

Table -1: Thickness and Crack sizes of different cases for fracture parameter evaluation

Parent Material (Thickness)	Crack Sizes (a × 2c)
1.6mm	0.76mm × 7.6mm
2.5mm	0.76mm × 7.6mm 1.65mm × 3.3mm
3.6mm	0.76mm × 7.6mm 1.65mm × 3.3mm

Parent Material

For Parent material, 3 different thickness are considered. 1.6mm, 2.5mm and 3.6mm thick plates, each for 2 crack sizes are analysed.

Specimen Details:

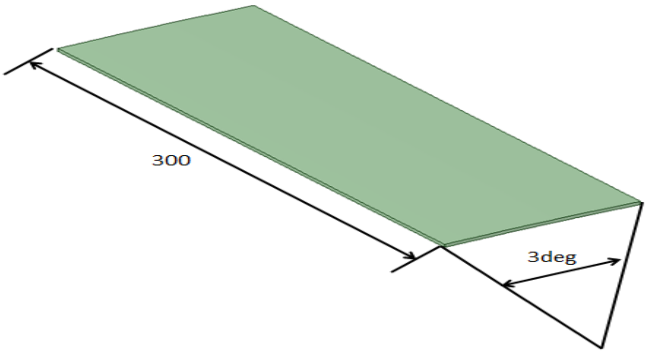

Fig -5: A typical specimen configuration for membrane loading

For membrane loading, specimen configuration as shown in figure 5.6 is used, which is a typical configuration used for tensile testing. 3 degree cylindrical specimens having internal diameter 4000 mm and length 30 mm. Thickness varies (1.6mm, 2.5mm, and 3.6mm).

Crack modelling details

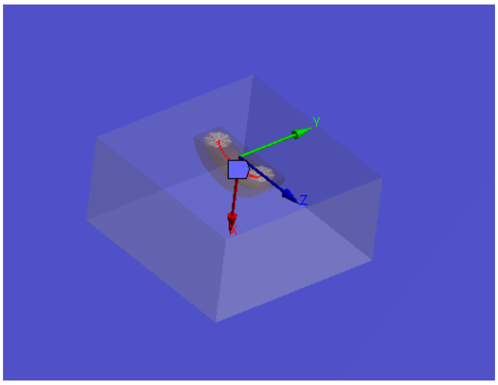

Fig -6: Typical crack modeling

Semi elliptical surface crack is modelled with crack length in the transverse direction perpendicular to the loading diection.

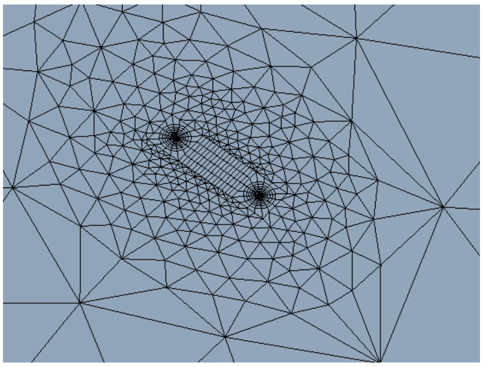

Fig -7: A typical mesh near crack front

Regular brick mesh is provided near the crack front and followed by tetrahedral mesh on the surroundings.

Loads and boundary conditions

1. Circumferential side of the specimens are given symmetry boundary conditions.
2. One end of the specimen is fixed in axial direction.
3. Internal pressure is applied on the internal diameter.
    - For 1.6 mm thick specimen internal pressure applied is 0.4MPa
    - For 2.5 mm thick specimen internal pressure applied is 0.625MPa
    - For 3.6 mm thick specimen internal pressure applied is 0.9MPa
4. Meridional stress is applied as pressure on other side of the specimen, 250MPa.

Case 1: AA2219 Parent material, thickness 1.6mm

Only one crack size is considered for the fracture parameter evaluation.

Case 1a: Crack size 0.76mm x 7.6mm (a x 2c)

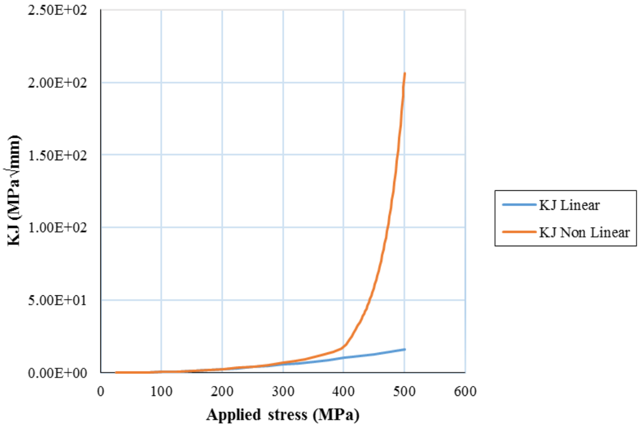

Fig -8: Stress intensity factor corresponding to J integral in the elastic and elastic-plastic analysis

J integral in the elastic and elastic plastic analysis matches well in the lower loads, but once the plasticity effects are appreciable 'J integral nonlinear' increases rapidly compared to 'J integral linear'.

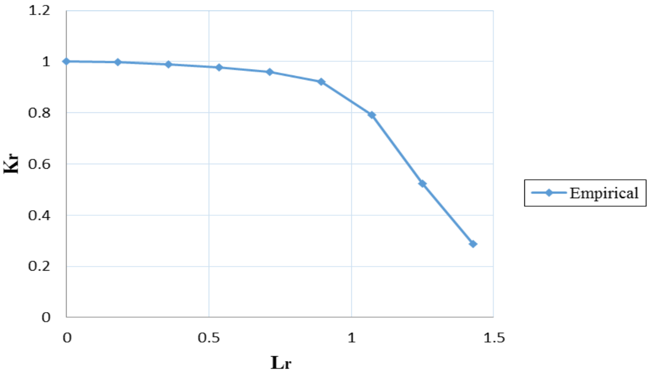

Fig -9: FAD generated from the J integral results of FE analysis

FAD is generated from the J integrals of elastic and elastic – plastic FE analysis.

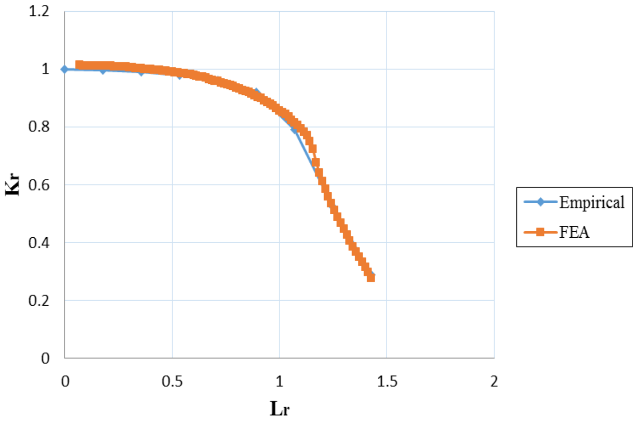

Fig -10: FAD from FE analysis & FAD from curve fitting

FAD generated from the J integrals of FE analysis is curve fitted to get the values of fracture parameters, β and H.

The values of fracture parameters obtained are,

H	β
0.95	0.2

Case 2: AA2219 Parent material, thickness 2.5mm

Two crack sizes are considered for the fracture parameter evaluation.

Case 2a: Crack size 0.76mm x 7.6mm (a x 2c)

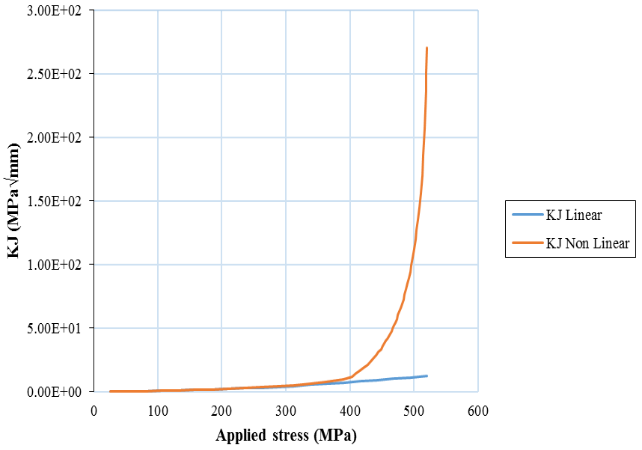

Fig -11: Stress intensity factor corresponding to J integral in the elastic and elastic-plastic analysis

J integral in the elastic and elastic plastic analysis matches well in the lower loads, but once the plasticity effects are appreciable 'J integral nonlinear' increases rapidly compared to 'J integral linear'.

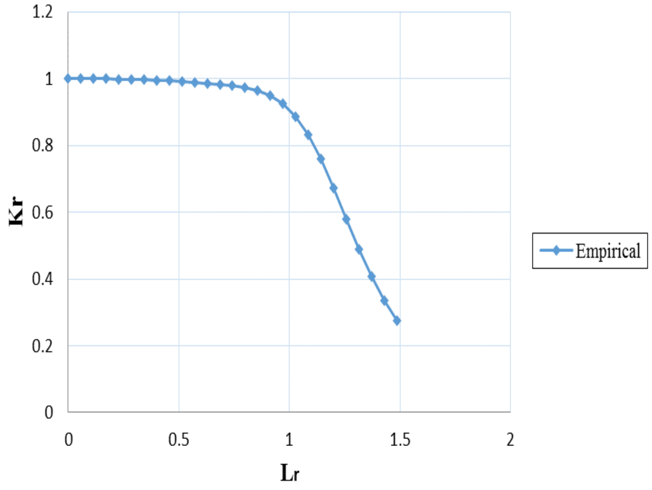

Fig -12: FAD generated from the J integral results of FE analysis

FAD is generated from the J integrals of elastic and elastic – plastic FE analysis.

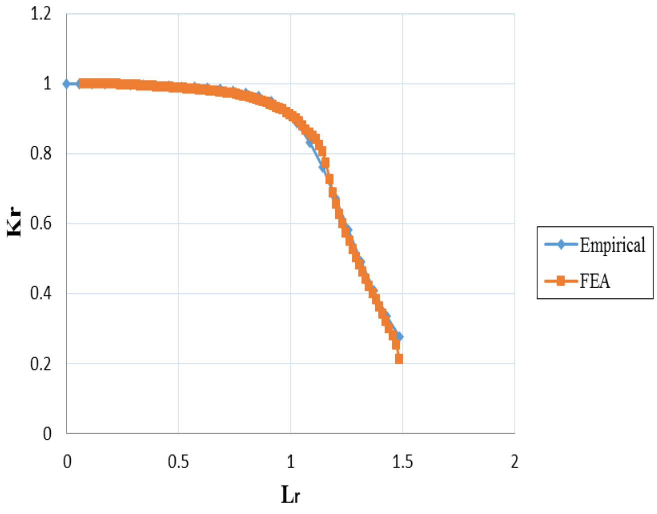

Fig -13: FAD from FE analysis & FAD from curve fitting

FAD generated from the J integrals of FE analysis is curve fitted to get the values of fracture parameters, β and H. The values of fracture parameters obtained are,

H	β
0.92	0.095

Case 2b: Crack size 1.65mm x 3.3mm (a x 2c)

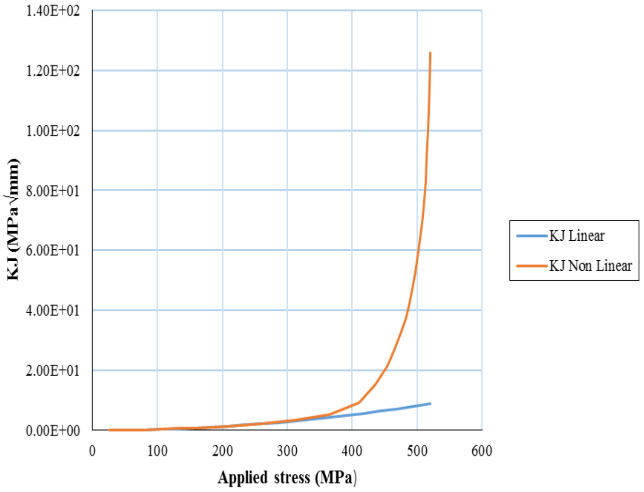

Fig -14: Stress intensity factor corresponding to J integral in the elastic and elastic-plastic analysis

J integral in the elastic and elastic plastic analysis matches well in the lower loads, but once the plasticity effects are appreciable 'J integral nonlinear' increases rapidly compared to 'J integral linear'.

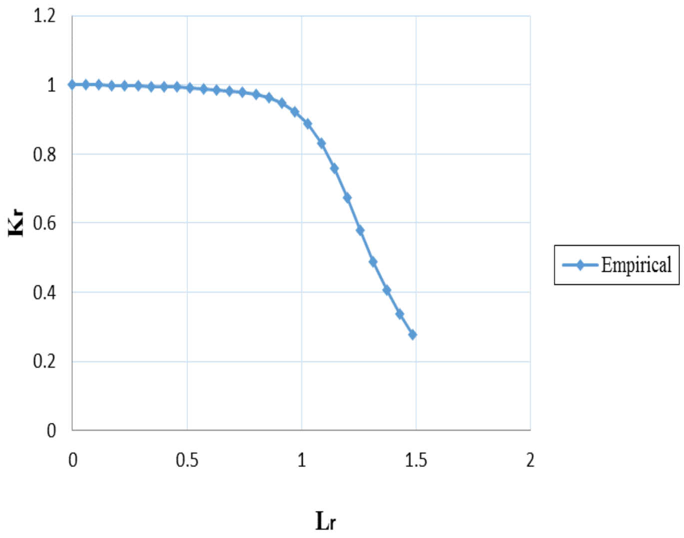

Fig -15: FAD generated from the J integral results of FE analysis

FAD is generated from the J integrals of elastic and elastic – plastic FE analysis.

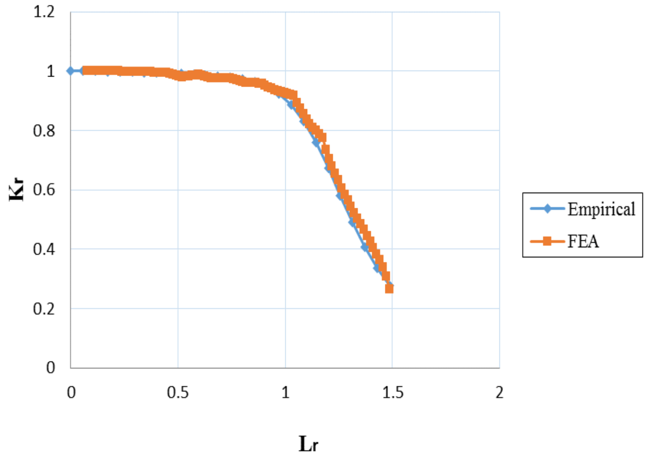

Fig -16: FAD from FE analysis & FAD from curve fitting

FAD generated from the J integrals of FE analysis is curve fitted to get the values of fracture parameters, β and H.

The values of fracture parameters obtained are,

H	β
0.90	0.095

Case 3: AA2219 Parent material, thickness 3.6mm

Two crack sizes are considered for the fracture parameter evaluation.

Case 3a: Crack size 0.76mm x 7.6mm (a x 2c)

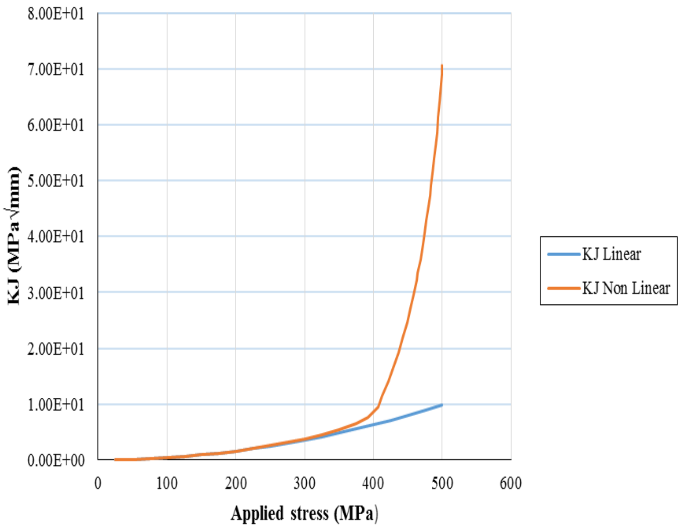

Fig -17: Stress intensity factor corresponding to J integral in the elastic and elastic-plastic analysis

J integral in the elastic and elastic plastic analysis matches well in the lower loads, but once the plasticity effects are appreciable 'J integral nonlinear' increases rapidly compared to 'J integral linear'.

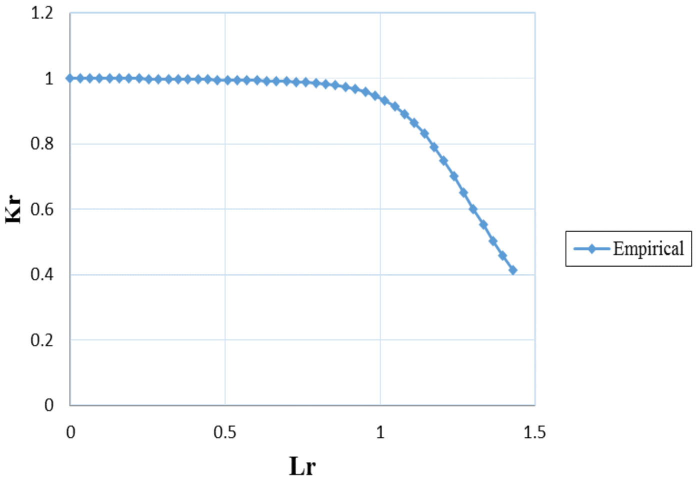

Fig -18: FAD generated from the J integral results of FE analysis

FAD is generated from the J integrals of elastic and elastic – plastic FE analysis.

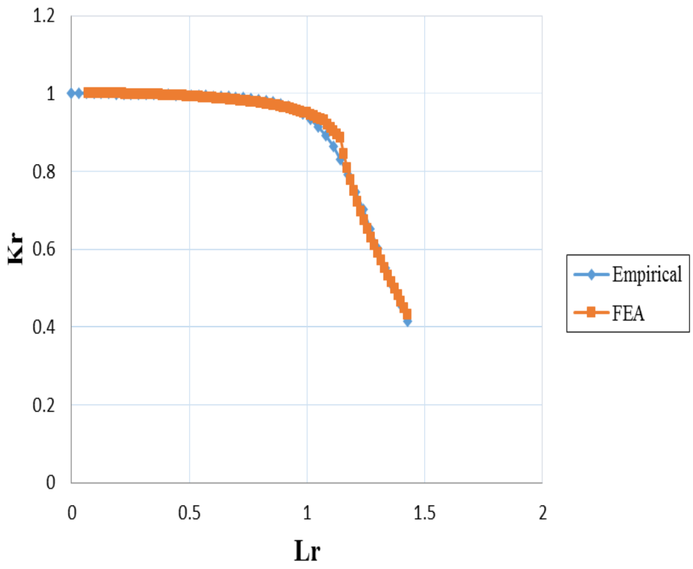

Fig -19: FAD from FE analysis & FAD from curve fitting

FAD generated from the J integrals of FE analysis is curve fitted to get the values of fracture parameters, β and H.

The values of fracture parameters obtained are,

H	β
0.87	0.080

Case 3b: Crack size 1.65mm x 3.3mm (a x 2c)

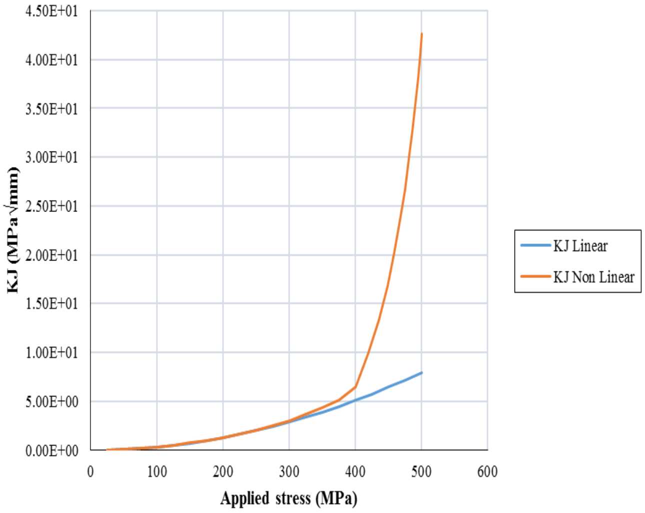

Fig -20: Stress intensity factor corresponding to J integral in the elastic and elastic-plastic analysis

J integral in the elastic and elastic plastic analysis matches well in the lower loads, but once the plasticity effects are appreciable 'J integral nonlinear' increases rapidly compared to 'J integral linear'.

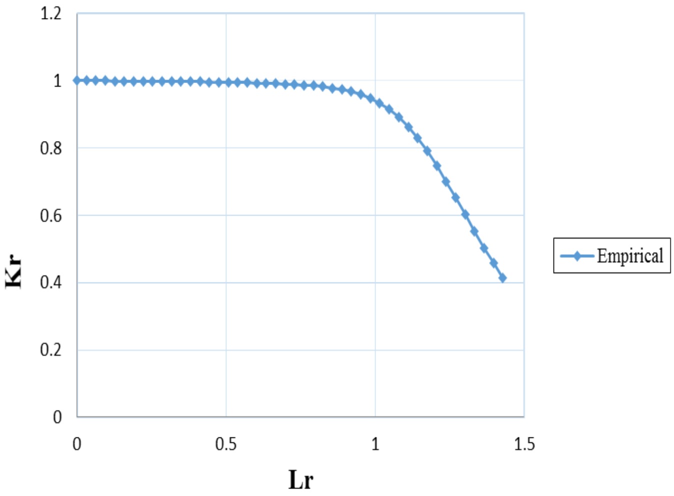

Fig -21: FAD generated from the J integral results of FE analysis

FAD is generated from the J integrals of elastic and elastic – plastic FE analysis.

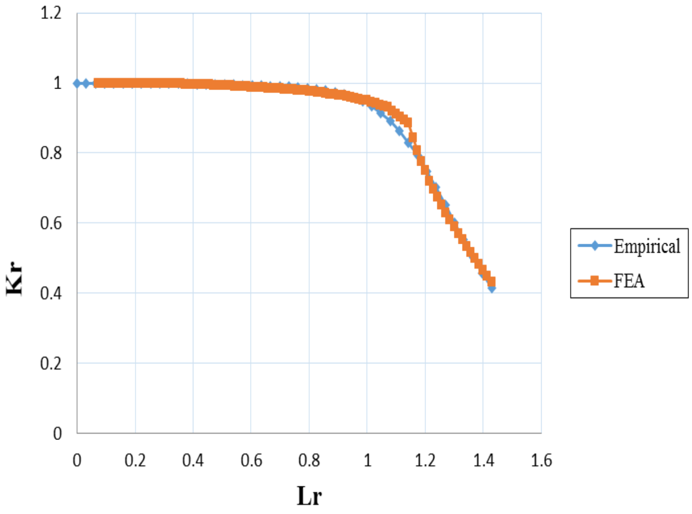

Fig -22: FAD from FE analysis & FAD from curve fitting

FAD generated from the J integrals of FE analysis is curve fitted to get the values of fracture parameters, β and H.

The values of fracture parameters obtained are,

H	β
0.88	0.055

3. Design of the Pressure Vessel

Shown in Figure is the detailed picture of the cylindrical pressure vessel with hemispherical end dome, on which fracture assessment is to be done. The end domes and cylindrical regions are connected by transition rings. The internal diameter is 4m. Height of the pressure vessel is 6.5m. The nominal thickness of the cylinder is 3.6mm and 2.5mm for the spherical region.

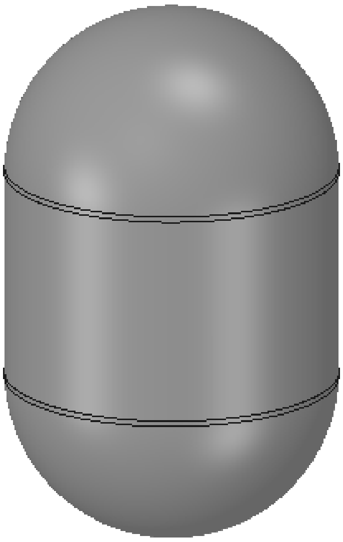

Fig -23: Pressure Vessel for Fracture Assessment

PRESSURE VESSEL DESIGN - ELASTO-PLASTIC APPROACH

A nonlinear Finite Element analysis is done for designing the pressure vessel. The material used for the construction is AA2219 alloy. The operating pressure considered is as 0.64MPa, the design factor considered is 1.25, and design pressure considered is 0.8MPa. Elasto-plastic based approach is used for the design of the pressure vessel. As per design methodology, no yielding should be there in the operating pressure. At design pressure equivalent plastic strain should be less than 20% of the ultimate strain of the material. The material properties are:

Modulus of elasticity, E = 68670MPa
Poisson ratio, ν = 0.3
Yield strength of the material, YS = 350MPa
Tensile strength of the material = 440MPa
Percentage elongation = 6%
Ultimate strain = 3%

A 3D sector model (30°) is used for the FE analysis of pressure vessel. Multi-linear kinematic model is used for material nonlinearity. Stress strain data of AA2219 is used for the FE analysis. Geometric non linearity is used in the analysis.

The boundary conditions used are:

- Symmetric boundary conditions are used in the lateral surface.
- Internal pressure of 0.8MPa is applied on the internal diameter.

The Finite Element analysis results are as provided. The results contain total deformation, Von- Mises stress distribution and equivalent plastic strain. The maximum equivalent plastic strain is calculated and checked.

Total Deformation

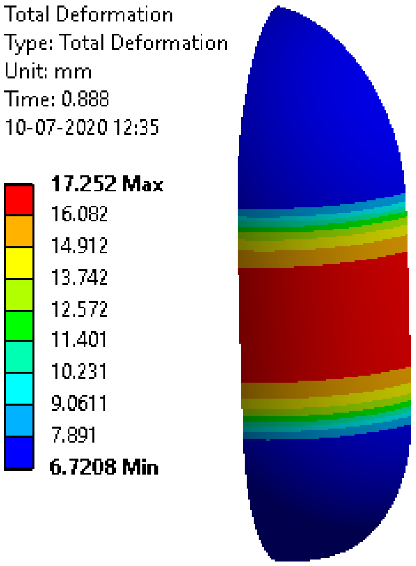

Fig -24: Total Deformation of the Pressure Vessels

Maximum deformation of the pressure vessel is around 17.25mm

Von Mises Stress Distribution

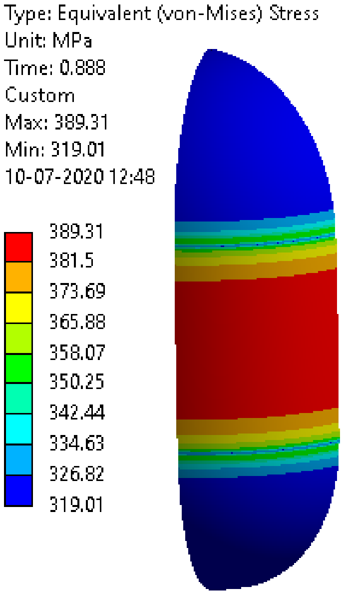

Fig -25: Von Mises Stress Distribution of the Pressure Vessels

Maximum Von Mises stress distribution is observed around the cylindrical region. Maximum value is around 389MPa at design pressure of 0.8MPa. Hence yielding is there at design ultimate pressure.

Equivalent plastic strain

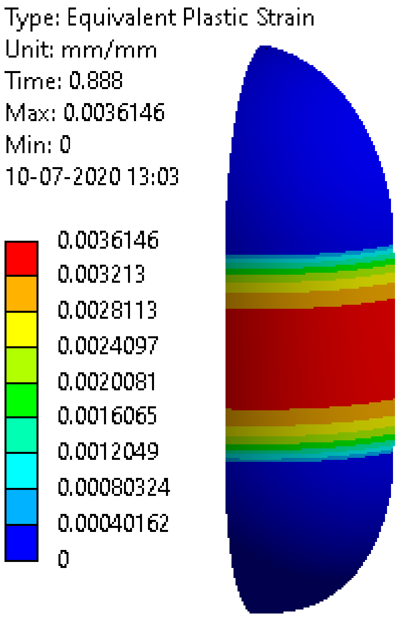

Fig -26: Equivalent Plastic Strain Distribution of the Pressure Vessels

Maximum Equivalent plastic strain is observed around the cylindrical region. Maximum value is around 0.36% at design pressure of 0.8MPa. The ultimate strain of the material AA2219 is 3%. Maximum value of equivalent plastic strain is less than 20% of the ultimate strain of the material, hence it is acceptable.

The design pressure of the Pressure vessel as per elasto-plastic FE analysis is 0.8MPa.

PRESSURE VESSEL DESIGN - FRACTURE BASED ASSESSMENT

Fracture parameters are evaluated for the parent material for the case studies mentioned in Table 5.1

Table – 2: Fracture Parameter Evaluated For AA2219 Parent Material

Thickness (mm)	Crack size (a x 2c) in mm	H	β
1.6	0.76 × 7.6	0.95	0.2
2.5	0.76 × 7.6	0.92	0.095
	1.65 × 3.3	0.90	0.095
3.6	0.76 × 7.6	0.87	0.080
	1.65 × 3.3	0.88	0.055

The fracture assessment for a design pressure of 0.8MPa is carried out. The critical locations are identified based on FE analysis performed earlier.

Two critical locations:

1. Middle of the cylindrical region from inner radius to outer radius.
2. Transition from cylindrical to spherical junction from inner radius to outer radius.

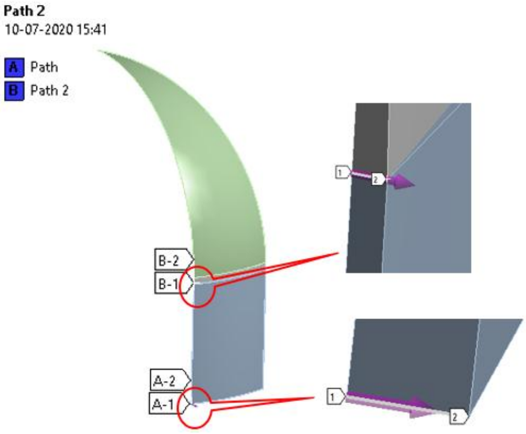

Fig -27 Identified Critical Path

The stresses acting at Critical locations are, **Path A 1-2**

Stresses such as hoop and meridional stresses acting at path A 1-2 are shown here.

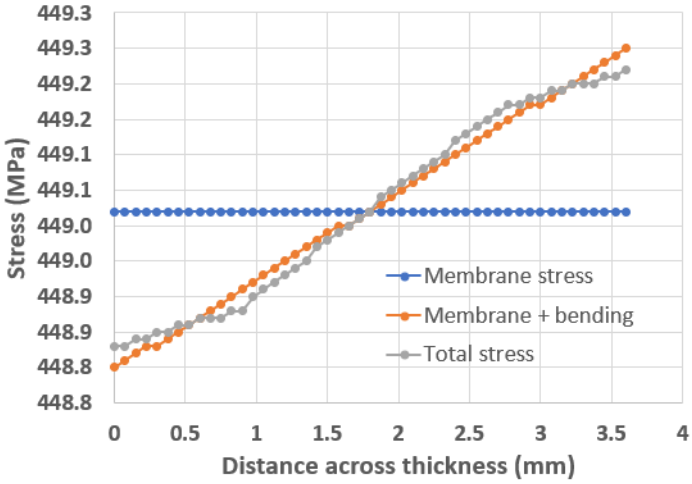

Fig -28: Hoop Stress Acting on the Path A 1-2

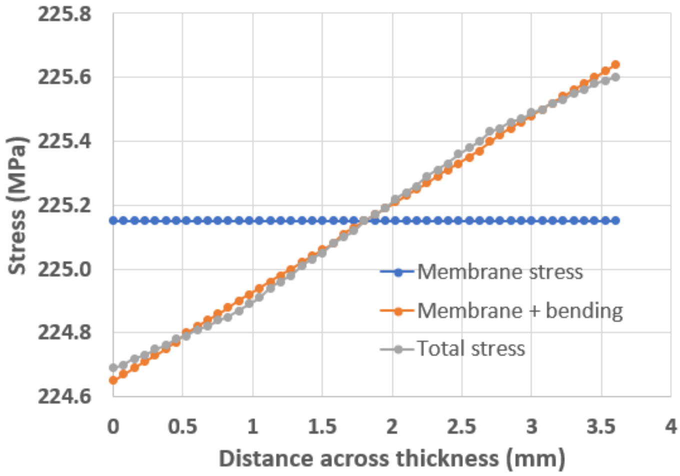

Fig -29: Meridional Stress Acting on the Path A 1-2

Path B 1-2

Stresses such as hoop and meridional stresses acting at path B 1-2 are shown here.

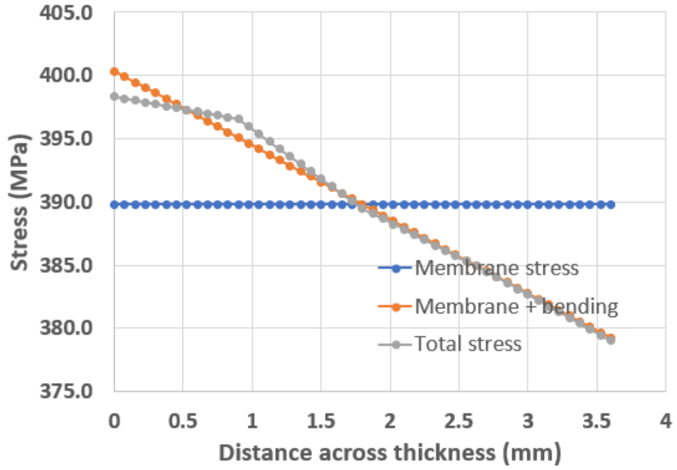

Fig -30: Hoop Stress Acting on the Path B 1-2

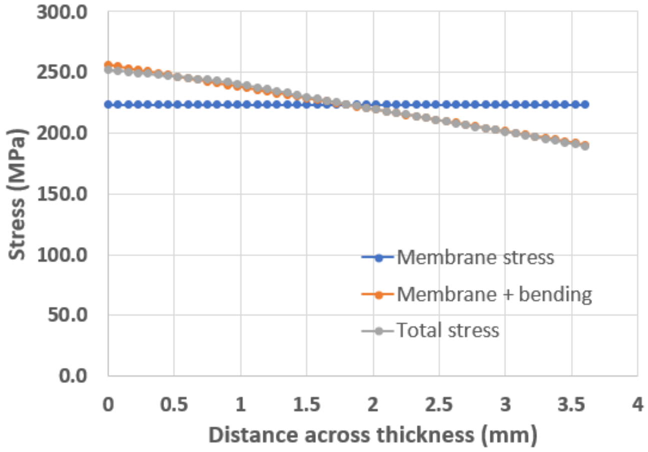

Fig -31: Meridional Stress Acting on the Path A 1-2

Failure Assessment Diagram (FAD)

Fracture assessment is done at critical location using the stress results obtained from FE analysis, for the following crack sizes,

Crack sizes 1 (a × 2c) = 0.76mm × 7.6mm
Crack sizes 2 (a × 2c) = 1.65mm × 3.3mm

Path A 1-2

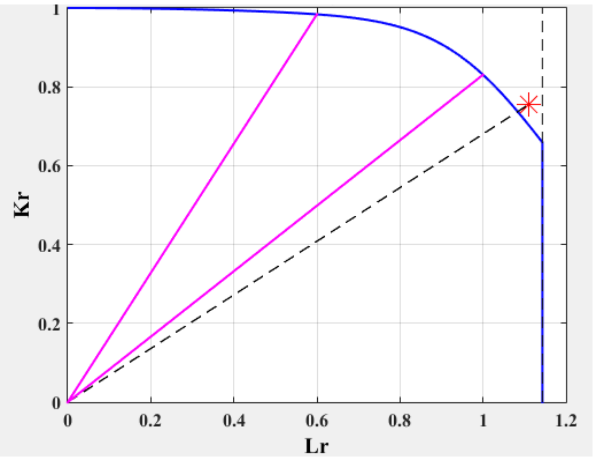

Fig -32: Failure Assessment Diagram for Crack Sizes 1 at Path A 1-2

Failure Assessment Diagram for crack size 1 shows the assessment point falls outside the FAD, which means, pressure vessel is not safe for a pressure of 0.8MPa in presence of a crack size of 0.76mm × 7.6mm. Burst pressure for this condition is 0.78MPa.

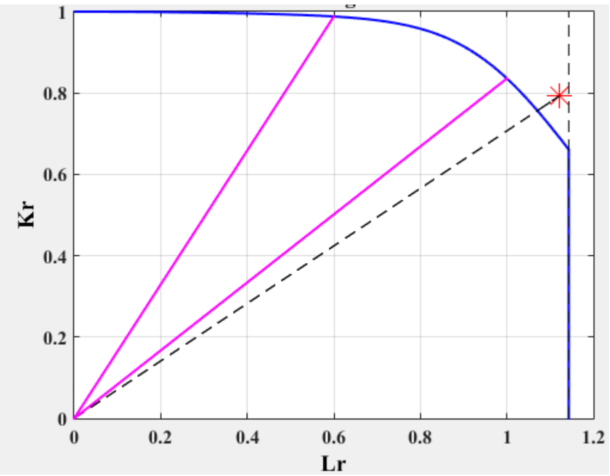

Fig -33: Failure Assessment Diagram for Crack Sizes 2 at Path A 1-2

Failure Assessment Diagram for crack size 2 shows the assessment point falls outside the FAD, which means, pressure vessel is not safe for a pressure of 0.8MPa in presence of a crack size of 1.65mm × 3.3mm. Burst pressure for this condition is 0.76MPa.

Path B 1-2

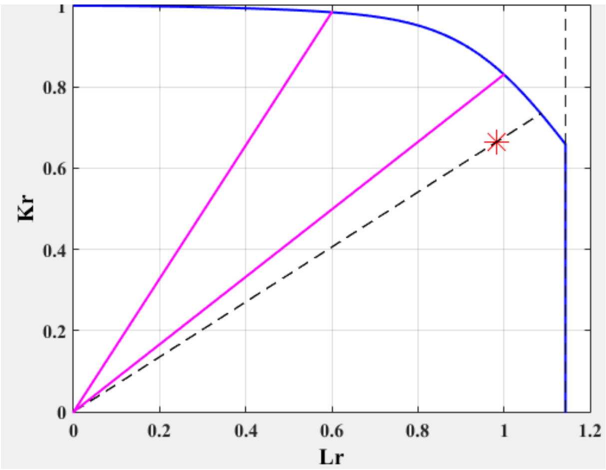

Fig -34: Failure Assessment Diagram for Crack Sizes 1 at Path B 1-2

Failure Assessment Diagram for crack size 1 shows the assessment point falls inside the FAD, which means, pressure vessel is safe for a pressure of 0.8MPa in presence of a crack size of 0.76mm × 7.6mm. Burst pressure for this condition is 0.88MPa.

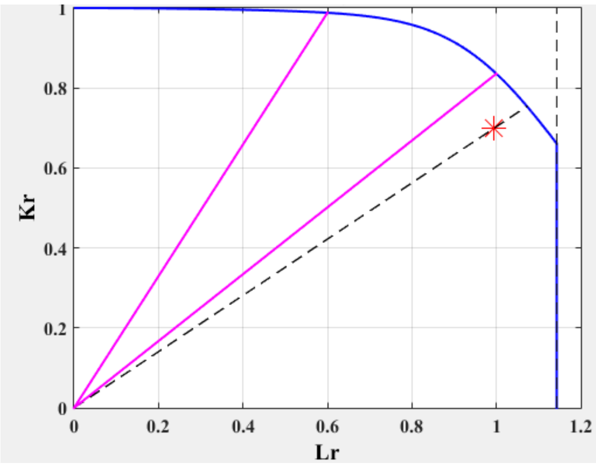

Fig -35: Failure Assessment Diagram for Crack Sizes 2 at Path A 1-2

Failure Assessment Diagram for crack size 2 shows the assessment point falls inside the FAD, which means, pressure vessel is safe for a pressure of 0.8MPa in presence of a crack size of 1.65mm × 3.3mm. Burst pressure for this condition is 0.86MPa.

Considering the FAD of all critical locations for the identified cracks, minimum burst pressure is obtained at path A 1-2 (middle of the cylindrical region) for a crack size of 1.65mm × 3.3mm. Burst pressure at this condition is 0.76MPa. **Hence the design pressure based on the fracture-based assessment shall be 0.75MPa with a margin of 0.01.**

4. CONCLUSIONS

The objective of this project was to study the importance of fracture mechanics, using Failure Assessment Diagrams (R6 procedure). For this purpose, a cylindrical pressure vessel with hemispherical end dome, having internal diameter 4m, height 6.5m and nominal thickness 3.6mm (cylinder) and 2.5mm (spherical region). The end domes and cylindrical regions are connected by transition rings. Due to large size and type of construction, pressure vessel needs to be realized via welded route. A nonlinear Finite Element analysis was done for designing the pressure vessel. Then, design of the pressure vessel based on Fracture based assessment was done. Stress analysis was done prior to fracture assessment, stresses at critical locations were used for the fracture assessment using R6 procedure.

The design pressure based on Elasto plastic design was found to be 0.8MPa and the design pressure based on Fracture based design was found to be 0.75MPa. Hence it can be concluded that, fracture based design shall be carried out for materials that are fracture prone to prevent the premature failure during loading. Due to large size and type of construction, pressure vessel needs to be realized via welded route. Since the pressure vessel is assumed to be having no welded joints for the numerical study. In actual structure thickness near the weld area are to be increased to reduce the stresses, since weld strength is less compared to parent material. Fracture parameter evaluation of weld would be included as a future scope.

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