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Fracture Analysis for a Crack Emanating From a Hole in a Pressurized Cylinder

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ABSTRACT

In this thesis, the main emphasis is to determine the Stress Intensity Factors of crack emanating from a hole in pressurized cylinder using finite element analysis. The analysis is carried for different a/D ratios 0.5, 1, 1.5, 2 where 'a' is half crack length and 'D' is diameter of hole. Fracture analysis and static analysis aredone to determine the stress intensity factors, stresses and deformation and compared for Steel, Kevlar, Carbon Fiber. 3D modeling isdone in Creo 2.0 and Static & fracture analysis is done in Ansys.

INTRODUCTION TO PRESSURE VESSEL

A pressure vessel is a closed container designed to hold gases or liquids at a pressure substantially different from the ambient pressure.

INTRODUCTION TO COMPOSITE MATERIALS

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications.While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry.

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.

LITERATURE REVIEW

In the paper byAkash[1],determine SIF (Plane Strain) for a crack emanating from a hole in a Pressurized cylinder using Finite Element Method (FEM). From this study it was observed that the value of SIF rises suddenly when the crack tip is near to the hole and it stabilizes as the crack tip move far from the hole. The SIF values evaluated for different crack length using FEM is normalized with the analytical values obtained from theoretical equation with respect to (a/D) ratio which provides important information for subsequent studies such as the crack growth rate determination and prediction of residual strength with plane strain and plane stress conditions.In the paper by T. NISHIOKA [3], Multiple surface cracks in pressure vessels, t-An alternating method, in conjunction with the finite element method and a solution for multiple coplanar elliptical cracks in an intinite solid, is used to determine stress intensity factors for semi-elliptical surface flaws in cylindrical pressure vessels.

The solution technique for multiple cracks in an infinite body has recently been developed by the present authors which implements a well-known analytical solution for a single crack in an infinite body. The present finite element alternating method leads to a very inexpensive procedure for routine evaluation of accurate stress intensity factors for flawed pressure vessels. Numerical examples are presented for the situation of two equal surface cracks in a pressure vessel. Comparison is made

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between these results and the procedure for multiple cracks in the ASME Boiler and Pressure Vessel Code.

AIM OF THE PROJECT

The machine elements with cylindrical profile such as pressure vessel, cylindricalshells, which have been used extensively as the structural configuration in aerospace andshipping industries needs to be leak proof. But however it's not possible to fabricate 100%leak proof pressure vessel / cylindrical shell as the industrial materials do not have uniformcomposition. Thus defects or cracks are inevitable in their substructure, also during theirservice life a crack may initiate on an internal/external boundary of circular cylinder whichhas important influence on stress distribution in the structure.

Hence the structuralassessments of hallow cylinders ranging from thick walled pressure vessel to thin walledpipes has to be carried out, that in-turn relay's on availability of Stress Intensity Factor (S.I.F) for fracture analysis. The magnitude of the S.I.F determines the propagation of crack.In this thesis, Fracture analysis and static analysis aredone to determine the stress intensity factors, stresses and deformation and compared for Steel, Kevlar, Carbon Fiber. The analysis is carried for different a/D ratios 0.5, 1, 1.5, 2 where 'a' is half crack length and 'D' is diameter of hole.

3D MODEL OF PRESSURIZED CYLINDER

Modeling is done by taking dimensions from the paper "Determination of Stress Intensity Factor For A Crack Emanating From A Hole In A Pressurized Cylinder Using Displacement Extrapolation Method" by Akash.D.A, International Journal of Mechanical Engineering and Technology (IJMET), Volume 4, Issue 2, March - April (2013), pp. 373-382 specified as [1] in References chapter.

D= Diameter of the hole (20mm),a= Half Crack length, σ=applied hoop stress (Pr/t), P= Internal pressure 1MPa, t=Thickness of the cylindrical shell=10mm, h= height of the cylinder = 2000mm

Hole distance from one end of cylinder = 1000mm. Here the cases are a/D ratio of crack is changed where Diameter is kept constant and changing the crack length

1st

a/D ratio

Diameter 20mm

Crack length 10mm

2nd

a/D ratio

Diameter 20mm

Crack length 20mm

3rd

a/D ratio

Diameter 20mm

Crack length 30mm

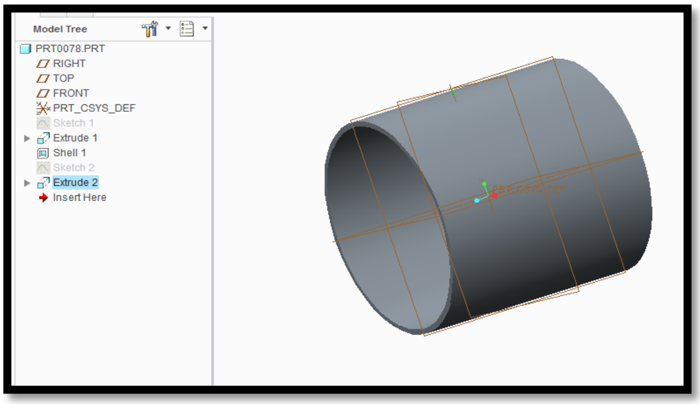

Fig – 3D model of pressurized cylinder

ANALYSIS OF PRESSURIZED CYLINDER
BOUNDARY CONDITIONS

Input parameters are taken from the below journal. "Determination Of Stress Intensity Factor For A Crack Emanating From A Hole In A Pressurized Cylinder Using Displacement Extrapolation Method" by Akash.D.A

FRACTURE ANALYSIS DUE TO CRACK NEAR A HOLE
MATERIAL – KEVLAR
Crack details

Diameter is constant, changing the crack length

a/D ratio = 0.5

whereDiameter D = 20mm

Crack length a = 10mm

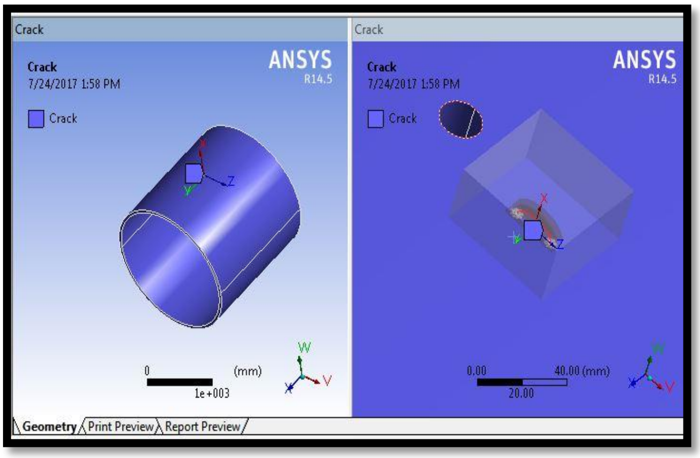

Fig - Crack with a/D = 0.5near hole in cylinder

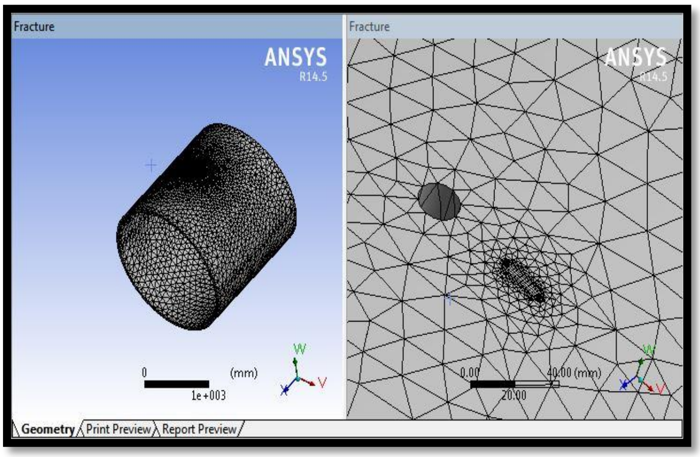

Fig – Fracture meshed model of a cylinder with a/D = 0.5

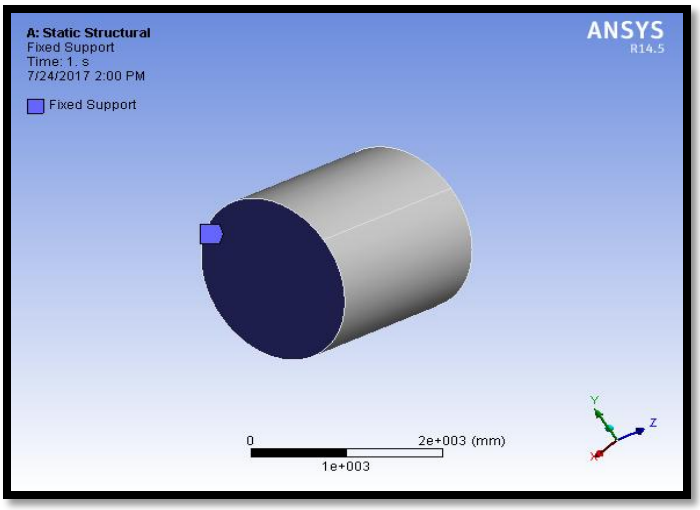

Fig – Fixed support Applied at one end of cylinder

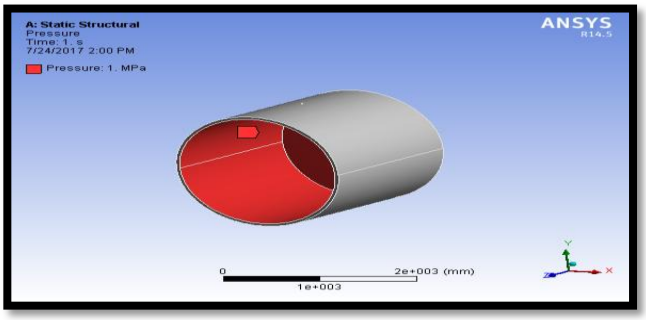

Fig – Pressure Applied inside cylinder

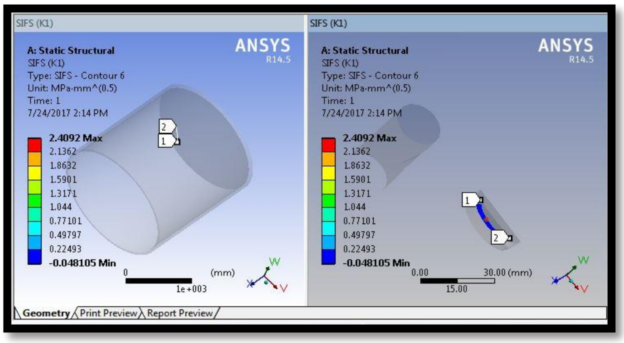

Fig - Stress intensity factor in cylinderusing Kevlar with a/D = 0.5

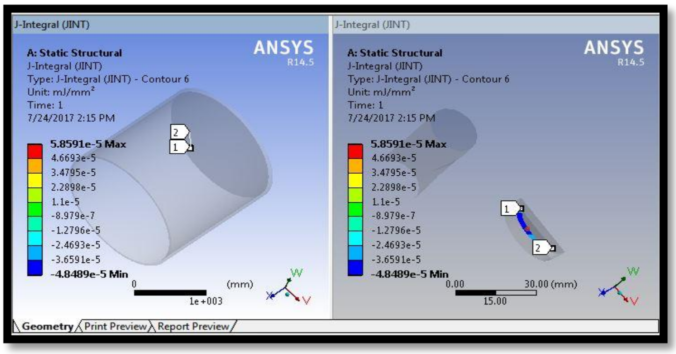

Fig – J – Integral in cylinderusing Kevlar with a/D = 0.5

STATIC ANALYSIS

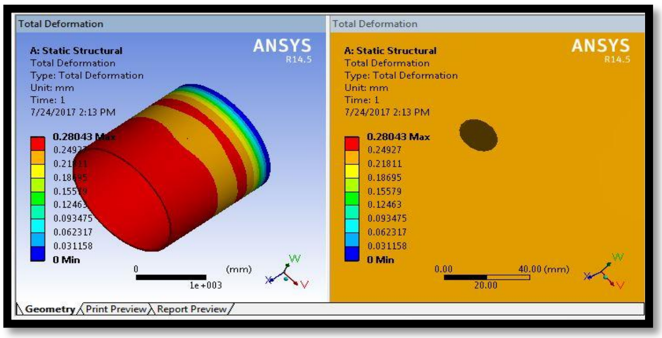

Fig - Total deformation of cylinderusing Kevlar with a/D = 0.5

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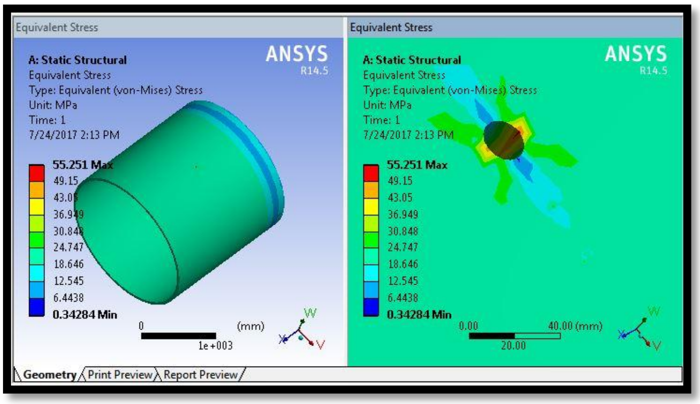

Fig – Equivalent Von-Mises Stress of cylinderusing Kevlar with a/D = 0.5

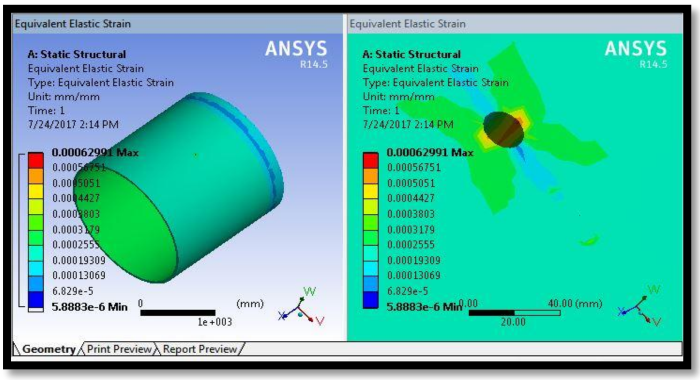

Fig - Equivalent Von-Mises Strain of cylinderusing Kevlar with a/D = 0.5

RESULTS TABLES

Material	a/D ratio	Deformation (mm)	Stress (MPa)	Strain	Stress Intensity factor(Mpa.mm$^{0.5}$)	J-Integral
Steel	0.5	0.12521	54.422	0.00027981	2.4004	2.6548e-5
	1	0.12521	55.465	0.00028488	2.8049	5.097e-5
	1.5	0.12521	57.912	0.000291	3.3522	6.0085e-5
	2	0.12521	60.382	0.00030304	5.0942	0.00010973
Kevlar	0.5	0.28043	54.235	0.00062991	2.4092	5.8591e-5
	1	0.28042	55.251	0.00061764	2.8636	0.00011542
	1.5	0.28042	57.84	0.00064773	3.3957	0.0001383
	2	0.28042	59.625	0.00085592	5.6462	0.00037186
Carbon fiber	0.5	0.33546	55.37	0.00083198	2.2842	6.9719e-5
	1	0.33546	56.29	0.00082243	2.2859	0.00011979
	1.5	0.335425	58.311	0.0008391	2.9618	0.0001193
	2	0.335425	61.8	0.00087609	4.1787	7.7371e-5

CONCLUSION

By observing analysis results, the stress intensity factors and stresses are increasing by increasing the a/D ratios.The variation of S.I.F with respect to a/D ratio is used to obtain thecharacteristic curve of SIF which depends only on the geometrical factor and its variation withinthe given domain (a/D). It is observed that the value of SIF rises suddenlywhen the crack tip is near to the hole and it stabilises as the crack tip move far from the hole.The Stress Intensity Factor is increasing by about 40% for a/D = 1, by about 28% for a/D = 1.5, by about 52.8% for a/D = 2 when compared with a/D = 0.5 using material Steel. Increasing by about 18% for a/D = 1, by about 29% for a/D = 1.5, by about 57% for a/D = 2 when compared with a/D = 0.5 usingmaterial Kevlar.

Increasing by about 7% for a/D = 1, by about 22% for a/D = 1.5, by about 45% for a/D = 2 when compared with a/D = 0.5 using material Carbon Fiber.The Stresses are increasing by about 2% for a/D = 1, by about 6% for a/D = 1.5, by about 10% for a/D = 2 when compared with a/D = 0.5 using all materials.

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