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Design And Analysis Of Pressure Vessel At Welded Joints For Different Weld Efficiences

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Abstract: **Pressure vessel cylinders find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and fluid supply systems in industries. Good design practice is allowable pressure for weld strength expressed as weld efficiency. Efficiency is defined as the ratio of longitudinal (axial) strength of a welded joint to the longitudinal strength of pipe or tank shell. In this thesis, the pressure vessel is designed according to the weld efficiency and analyzed for its strength using Finite Element analysis software ANSYS. Mathematical correlations will be considered for the design of pressure vessel whose design parameters are specified by a company according to the required weld efficiency. Modeling will be done in Pro/Engineer. Structural and fatigue analysis will be done in ANSYS on the welded joint of pressure vessel for different weld efficiencies.**

Keywords: **Pressure Vessel; Weld Efficiencies; CREO; ANSYS; Linear Layer Analysis;**

I. INTRODUCTION

The term pressure vessel referred to those reservoirs or containers, which are subjected to internal or external pressures. The pressure vessels are used to store fluids under pressure. The fluid being stored may undergo a change of state inside the pressure vessels as in case of steam boilers or it may combine with other reagents as in chemical plants. Pressure vessels find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and in water, steam, gas and air supply system in industries.

The material of a pressure vessel may be brittle such as cast iron, or ductile such as mild steel.

SOLID WALL PRESSURE VESSEL:

A solid wall vessel consists of a single cylindrical shell, with closed ends. Due to high internal pressure and large thickness the shell is considered as a 'thick' cylinder. In general, the physical criteria are governed by the ratio of diameter to wall thickness and the shell is designed as thick cylinder, if its wall thickness exceeds one-tenth of the inside diameter. A solid wall vessel is also termed as Mono Block pressure vessel.

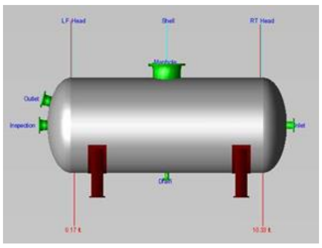


Fig.1 pressure vessel

WHEN TO USE A MULTILAYER VESSEL:

It is hard to give firm and fast rules as when a multilayer vessel is more suitable than a solid wall vessel. Generally, though, the thicker the vessel wall and the longer the vessel, the more attractive a Multilayer vessel will be, since the economy is gained solely in the shell of the vessel.

It often is more economical to make a Multi layer vessel as long as possible considering a constant volume. This is due to the fact that the shell of a multilayer vessel is the least expensive portion of the vessel on a Rs/kg/N/mm^2. Therefore, the more weight in the shell, in proportion to the weight of the heads, the less the total cost of the vessel.

Usually, the selection of a Multilayer vessel is predicated on economics. However, in some cases where solid wall limits are exceeded for e.g. Nuclear reactors, which use water as a coolant and hence evolve hydrogen by radiolysis. Storage vessels for missiles, which must operate at extremely high stresses to minimize the weight, carried a lot, are failing due to hydrogen in suspension.

II. LITERATURE SURVEY

The importance of a well engineered vessel, manufactured with careful inspection and quality control methods, remain as the crucial factor for obtaining a safe, economical, and serviceable unit.

As early as 1890 Mr. Carl Schaeffer of Oberhauson, Germany, obtained a U.S. patent covering the multiple layer construction for "riveted" boilers and the like vessels. The patent is required for the ever-increasing tension of steam required for steam boilers, the damage imparted to thick sheet iron during forming and the un proportional cost of the thick plates. But from the early investigations, the patent was prompted by the current limitations of the solid wall constructions and was never widely accepted.

However, with advent of welding and the increase need for high-pressure vessels, designers in the 1930's started to develop vessel concepts, which employed multiple layers of material for the vessel wall. Since that time thousands of multiple wall vessels have been put into service, both here and abroad, with an excellent record of performance. There are a number of multilayer vessel concepts available to the user today. The wicker type vessel, developed in Germany, uses a corrugated metal tape or ribbon spiral wound around an inner core cylinder. Spiral grooves to match the corrugations of the tape are first machined into the outer surface of the inner cylinder. Then, layer at a time, until the full wall thickness is reached.

III. PROBLEM DESCRIPTION

Pressure vessel cylinders find wide applications in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and fluid supply systems in industries. Good design practice is allowable pressure for weld strength expressed as weld efficiency. Efficiency is defined as the ratio of longitudinal (axial) strength of a welded joint to the longitudinal strength of pipe or tank shell.

IV. INTRODUCTION TO CREO

PTC CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself. It has many advantages like Optimized for model-based enterprises, Increased engineer productivity, Better enabled concept design, Increased engineering capabilities, Increased manufacturing capabilities, Better simulation, Design capabilities for additive manufacturing.

INTRODUCTION TO FINITE ELEMENT METHOD

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

ANSYS Software:

ANSYS is an Engineering Simulation Software (computer aided Engineering). Its tools cover Thermal, Static, Dynamic, and Fatigue finite element analysis along with other tools all designed to help with the development of the product. The company was founded in 1970 by Dr. John A. Swanson as Swanson Analysis Systems, Inc. SASI. Its primary purpose was to develop and market finite element analysis software for structural physics that could simulate static (stationary), dynamic (moving) and heat transfer (thermal) problems. SASI developed its business in parallel with the growth in computer technology and engineering needs. The company grew by 10 percent to 20 percent each year, and in 1994 it was sold. The new owners took SASI's leading software, called ANSYS®, as their flagship product and designated ANSYS, Inc. as the new company name.

STATIC ANALYSIS OF PRESSURE VESSEL

CASES

Case 1: welding efficiency -1.0

Case 2: welding efficiency -0.85

USED MATERIALS

Materials	Models	Software's	Problems
Steel, S2glass fiber & e-glass fiber	Weld efficiency 0.85 and weld efficiency 1.0	CREO for modeling ANSYS for analysis	Static analysis , fatigue analysis and linear layer analysis

- Steel
- S2 glass fiber
- E –glass fiber

Material properties of steel

Young's modulus=205000Mpa

Poisson's ratio=0.3

Density=0.0000078kg/mm^3

Material properties of S2 glass fiber

Young's modulus=89000Mpa

Poisson's ratio=0.23

Density=0.00000249kg/mm^3

Material properties of e-glass fiber

Young's modulus=80000Mpa

Poisson's ratio=0.21

Density=0.00000255kg/mm^3

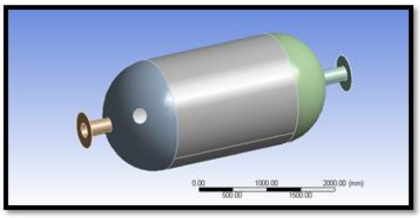
CASE 1: WELDING EFFICIENCY -1.0

MATERIAL -STEEL

Used software for this project work bench

Open work bench in Ansys 14.5

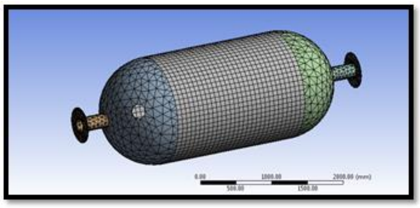
Select static structural>select geometry>import IGES model>OK



Click on model>select EDIT

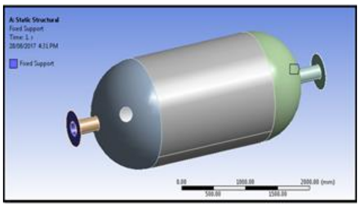
Select model >apply materials to all the objects (different materials also)

Mesh> generate mesh>ok

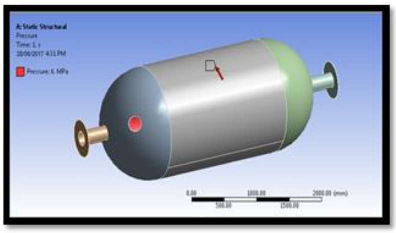


Finite element analysis or FEA representing a real project as a "mesh" a series of small, regularly shaped tetrahedron connected elements, as shown in the above fig. And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required.

Static structural A5>insert>select .displacement>select fixed areas>ok



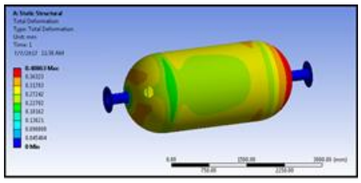
>Select pressure>select pressure areas> enter pressure value



Solution A6>insert>total deformation>right click on total deformation>select evaluate all result Insert>stress>equivalent (von misses)>right click on equivalent >select evaluate all results

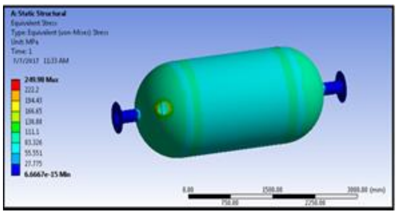
Insert>strain>equivalent (von misses)>right click on equivalent >select evaluate all results

Deformation



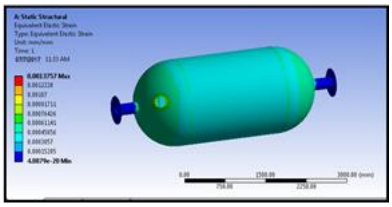
According To the Counter Plot, the maximum deformation at head of the pressure vessel and minimum deformation at nozzle of the pressure vessel. The maximum deformation is 0.40863 mm and minimum deformation is 0.045404 mm.

Stress



According To the Counter Plot, the maximum stress is inside of the pressure vessel and minimum stress at nozzles of the pressure vessel. The maximum stress is 249.98 N/mm^2 and minimum is 6.6667e-15.

Strain

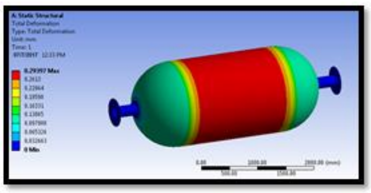


According To the Counter Plot, the maximum strain is inside of the pressure vessel and minimum strain at nozzles of the pressure vessel. The maximum strain is 0.0013757 and minimum is 4.88e-20.

CASE 2: WELDING EFFICIENCY -0.85

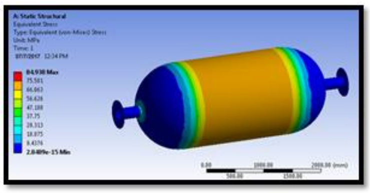
MATERIAL -STEEL

Deformation



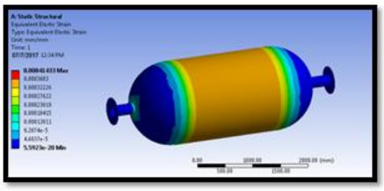
According To the Counter Plot, the maximum deformation at head of the pressure vessel and minimum deformation at nozzle of the pressure vessel. The maximum deformation is 0.29397 mm and minimum deformation is 0.032663 mm.

Stress



According To the Counter Plot, the maximum stress is inside of the pressure vessel and minimum stress at nozzles of the pressure vessel. The maximum stress is 84.938 N/mm^2 and minimum is 2.8489e-15.

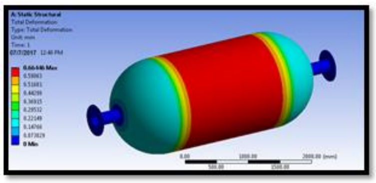
Strain



According To the Counter Plot, the maximum strain is inside of the pressure vessel and minimum strain at nozzles of the pressure vessel. The maximum strain is 0.00041433 and minimum is 5.5923e-20.

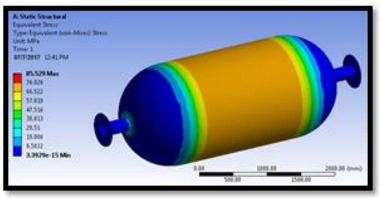
MATERIAL –S2 GLASS

Deformation



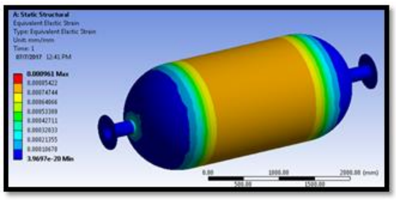
According To the Counter Plot, the maximum deformation at head of the pressure vessel and minimum deformation at nozzle of the pressure vessel. The maximum deformation is 0.66446 mm and minimum deformation is 0.073829 mm.

Stress



According To the Counter Plot, the maximum stress is inside of the pressure vessel and minimum stress at nozzles of the pressure vessel. The maximum stress is 85.529 N/mm^2 and minimum is 3.3929e-15.

Strain



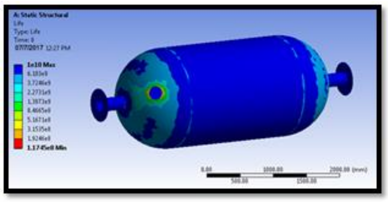
According To the Counter Plot, the maximum strain is inside of the pressure vessel and minimum strain at nozzles of the pressure vessel. The maximum strain is 0.000961 and minimum is 3.9697e-20.

FATIGUE ANALYSIS OF PRESSURE VESSEL

CASE 1: WELDING EFFICIENCY -1.0

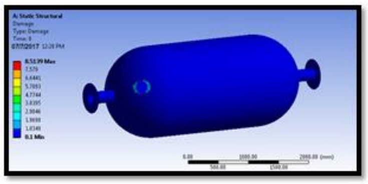
MATERIAL -STEEL

Life



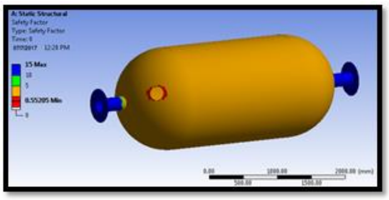
According To the Counter Plot, the maximum life at head of the pressure vessel and minimum life at nozzle of the pressure vessel. The maximum life is 1e10 and minimum life is 1.1745e8.

Damage



According To the Counter Plot, the maximum damage at head of the pressure vessel and minimum damage at nozzle of the pressure vessel. The maximum damage is 8.5139 and minimum life is 0.1.

Safety factor



According To the Counter Plot, the maximum safety factor at head of the pressure vessel and minimum life at nozzle of the pressure vessel. The maximum safety factor is 15 and minimum life is 0.55205.

LINEAR LAYER STATIC ANALYSIS OF PRESSURE VESSEL

CASE 1: WELDING EFFICIENCY -1.0

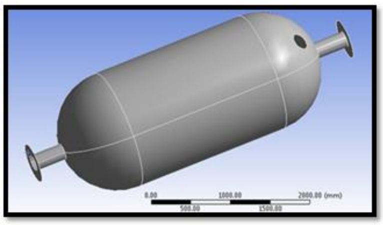
MATERIAL -STEEL

3 LAYERS

Used software for this project work bench

Open work bench in Ansys 14.5

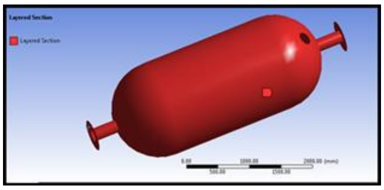
Select static structural>select geometry>import IGES model>OK



Click on model>select EDIT

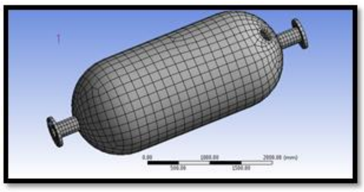
Select geometry> right lick >layered selection>select object>work sheet >entered no.of layers

Select model >apply materials to all the objects (different materials also)



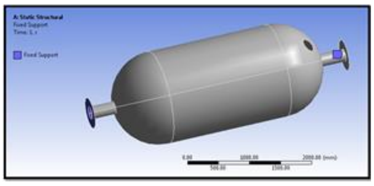
Layer	Material	Thickness (mm)	Angle (°)
(+Z)			
3	Structural Steel	15.98	-90
2	s2	15.98	0
1	e glass	15.98	90
(-Z)			

Mesh> generate mesh>ok

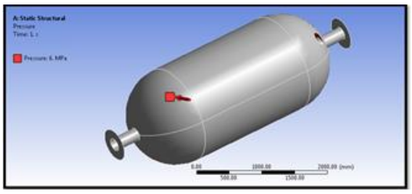


Finite element analysis or FEA representing a real project as a "mesh" a series of small, regularly shaped tetrahedron connected elements, as shown in the above fig. And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required.

Static structural A5>insert>select .displacement>select fixed areas>ok



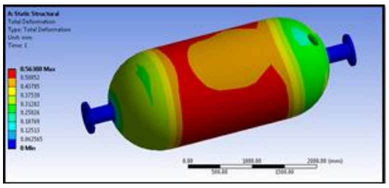
>Select pressure>select pressure areas> enter pressure value



Solution A6>insert>total deformation>right click on total deformation>select evaluate all result Insert>stress>equivalent (von misses)>right click on equivalent >select evaluate all results

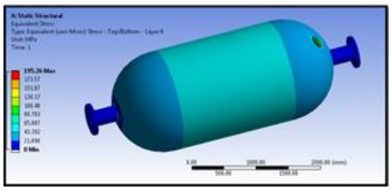
Insert>strain>equivalent (von misses)>right click on equivalent >select evaluate all results

Deformation



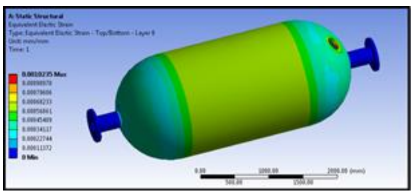
According To the Counter Plot, the maximum deformation at head of the pressure vessel and minimum deformation at nozzle of the pressure vessel. The maximum deformation is 0.56308 mm and minimum deformation is 0.062565 mm.

Stress



According To the Counter Plot, the maximum stress is inside of the pressure vessel and minimum stress at nozzles of the pressure vessel. The maximum stress is 195.26 N/mm^2 and minimum is 21.696.

Strain



According To the Counter Plot, the maximum strain is inside of the pressure vessel and minimum strain at nozzles of the pressure vessel. The maximum strain is 0.0010235 and minimum is 0.00011372.

V. RESULT TABLES

STATIC ANALYSIS RESULT TABLES

Cases	Material	Deformation (mm)	Stress (N/m m^2)	Strain
Welding efficiency - 1.0	**Steel**	0.40863	249.98	0.0013757
	S2 glass fiber	1.0275	260.6	0.0032303
	E glass fiber	1.177	262.73	0.0036296
Welding efficiency - 0.85	**Steel**	0.29397	84.938	0.00041433
	S2 glass fiber	0.66446	85.529	0.000961
	E glass fiber	0.73561	85.691	0.0010711

FATIGUE ANALYSIS RESULT TABLES

Cases	Material	Life	Damage	Safety factor	
				Min	**Max**
Welding efficiency -1.0	**Steel**	1 e10	8.5139	0.55205	15
	S2 glass fiber	1 e10	9.81887	0.52954	15
	E glass fiber	1 e10	10.086	0.52525	15
Welding efficiency -0.85	**Steel**	1 e10	2.9103	0.74737	15
	S2 glass fiber	1 e10	2.9852	0.74221	15
	E glass fiber	1 e10	3.006	0.7408	15

LINEAR LAYER STATIC ANALYSIS RESULT TABLES

Cases	Layer stacking	Deformation (mm)	Stress (N/m m^2)	Strain
Welding efficiency -1.0	**3**	0.56308	195.26	0.0010235
	6	0.5684	197.69	0.0010356
	9	0.56212	195.64	0.0010245
	12	0.5612	195.36	0.0010229
Welding efficiency - 0.85	**3**	1.9772	437.5	0.0033964
	6	1.9882	444.48	0.0030543
	9	1.9953	447.53	0.0029582
	12	1.9942	448.07	0.0029053

VI. CONCLUSION

In this thesis, the pressure vessel is designed according to the weld efficiency and analyzed for its strength using Finite Element analysis software ANSYS. Mathematical correlations will be considered for the design of pressure vessel whose design parameters are specified by a company according to the required weld efficiency. Modeling will be done in CREO Parametric software.

Structural and fatigue analysis will be done in ANSYS on the welded joint of pressure vessel for different weld efficiencies.

By observing the static analysis the stress values are increases by increasing the weld efficiency. The stress values are less for steel material compare with S2 glass fiber and e-glass fiber. But s-2 glass has more yield strength compare with steel.

By observing the fatigue analysis the safety factor values increases by decreasing the weld efficiency 0.85.

So it can be concluded the s2 glass fiber material is better material for pressure vessel at welding efficiency 0.85.

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