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Design and Analysis of Composite Wounded Pressure Vessel

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Abstract - Pressure vessel cylinders to find broad functions in thermal and nuclear power plants, process and chemical industries, in space and ocean depths, and fluid provide programs in industries. The wire-wound technique is a method which has been using from many years for the fabrication of thick-walled pressure vessels at high working pressures, mainly in the food industry. In this method a wire of generally of steel is wounded around the cylindrical vessel to reduce the stresses.

On this work, the strength of the pressure vessel is analyzed by Finite element evaluation software ANSYS. Mathematical correlations are considered to design a pressure vessel whose design parameters are distinct by an organization in keeping with the required filament wounded pressure vessel. Modeling will likely be finished in CREO.

Structural and multi-layer evaluation might be executed in ANSYS workbench on pressure vessel. Static analysis to investigate the stress, deformation and strain at specific composite materials metal, CFRP ,Epoxy Resin& E-glass and multi- layer analysis with four and eight layers to determine the stress, deformation and strain.

Keywords: wounded pressure vessel, Multi-layer Analysis

1. INTRODUCTION

The time interval pressure vessel mentioned these reservoirs or containers, which can be subjected to interior or external pressures. The pressure vessels are used to retailer fluids underneath stress. The fluid being stored may bear a transformation of state in the course of the stress vessels as in case of steam boilers or it's going to mix with exceptional reagents as in chemical vegetation. Pressure vessels find significant services in thermal and nuclear vigor vegetation, process and chemical industries, in condo and ocean depths, and in water, steam, gas and air deliver method in industries.

1.1 Design code

The listed vessels are designed to EN13445/ PD5500 category 2, which for most functions supplies essentially the most economic vessel scantlings. For a given design, class 1 vessels are of exactly the equal thickness fabric however the welds are discipline to a hundred% NDT. Class three vessels are simplest field to visible inspection of welds and at the same time some small vessels can be economically viable, this category often results in thicker vessels because of the confined design stress. Vessels designed to ASME Vlll can differ in thickness (+/-) when in comparison with the identical EN13445 or PD5500 vessel. Integ vessel engineers with many years of design expertise and aided by means of the modern pc application can advisor clients to obtain the premiere design code/class for precise software.

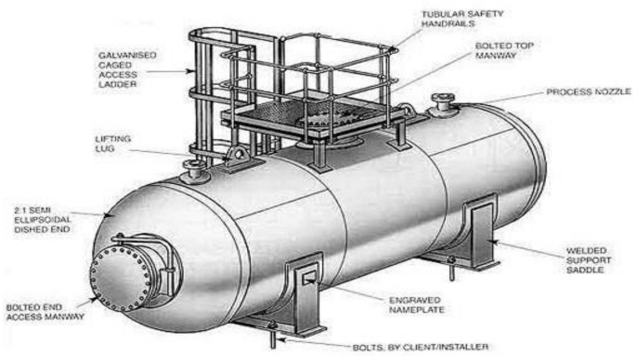


Fig 1.1: Pressure Vessel

1.2 High Pressure Vessels

High Pressure vessels are used as reactors, separators and heat exchangers. They are vessel with an integral bottom and a removable top head, and are generally provided with an inlet, heating and cooling system and also an agitator system. High Pressure vessels are used for a pressure range of 15 N/mm2 to a maximum of 300 N/mm2. These are essentially thick walled cylindrical vessels, ranging in size from small tubes to several meters diameter. Both the size of the vessel and the pressure involved will dictate the type of construction used.

The following are few methods of construction of high pressure vessels.

- A solid wall vessel produced by forging or boring a solid rod of metal.
- A cylinder formed by bending a sheet of metal with longitudinal weld.
- Shrink fit construction in which, the vessel is built up of two or more concentric shells, each shell progressively shrunk on from the inside outward. From economic and fabrication considerations, the number of shells should be limited to two.
- A vessel built up by wire winding around a central cylinder. The wire is wound under tension around a cylinder of about 6 to 10 mm thick.

1.3. Factors considered in designing high pressure vessels

The application of high pressure to the chemical process industries opened a new field to the design engineer. This relatively new technique originated in the industrial synthesis of ammonia from its elements and with the process for the cracking of oil. Now the high pressure vessels are extended up to 350 MPa. In designing high pressure vessels, the main factors to be considered are:

- Dimensions – Diameter, length, and their limitations.
- Operating conditions – Pressure and temperature.
- Available materials and their physical properties and cost.
- Corrosive nature of reactants and products.
- Theories of failure.
- Types of construction i.e. forged, welded or casted.
- Method of fabrication
- Fatigue, Brittle failure and Creep.
- Economic considerations.

Various codes governing the procedures for the design, fabrication, inspection, testing and operation of pressure vessels have been developed, partly as a safety measure. These procedures furnish standards by which any state can be assured or the safety of pressure vessels installed within its boundaries. The specifications in these codes were originally based upon the specifications developed for steam boilers. The code used for unfired pressure vessels is Section VIII of ASME Boiler and Pressure Vessel Code, 1956.

2. Wire wound pressure vessel

Generally, wire wound high pressure vessels are designed as cylinders which have their ends closed. In isostatic presses the end closures are constructed as axially slidable plugs, which during the pressing action are kept in place by an external frame. In hydrostatic extrusion presses one end of the cylindrical member is sealed off by the extrusion die, while the other end is sealed by the high pressure plunger that creates the pressure. Thus, the cylindrical members contain only the radial forces exerted by the pressure medium, while the axial forces on the closures are contained by external means.

2.1 Advantages of Multilayer pressure vessel

1. Permits the use of steels with higher mechanical properties than the obtainable from very thick plates. Since the layer plates are approximately 6 mm thick, the mechanical properties are known and recorded for every 6 mm of total wall thickness, assuming uniformity and known properties throughout the vessel wall.
2. As in other layer vessels, only the inner shell needs to be of environment resistant materials, providing the same resistance as solid wall construction at less cost. The inside layer may be constructed of corrosion resistant material either weldable or non-weldable to the base metal. If corrosion occurs through the first layer, a system of vent holes gives early warning to the vessel outside layer of product penetration prior to any extensive damage or unsafe operating condition.
3. The thin plats used as layer material exhibit better mechanical properties than thick plates made to the same specifications.
4. Since the layer plates are approximately 6 mm thick, the mechanical properties are known and recorded for every 6 mm of total wall thickness, assuming uniformity and known properties throughout the vessel wall.
5. Multilayer construction has an inherent notch toughness, which is superior to solid wall construction, assuming identical material. It is estimated that transition temperatures are lowered approximately 27 to 350 C due to the construction alone in the multi layer shells.
6. A Multilayer vessel has been observed to retard and/or arrest the propagation of cracks. Every vessel tested to destruction has failed in a ductile manner without fragmentation.
7. Vent holes through the outer layers permit the inner shell to be constantly and effectively monitored for possible leakage. Thus, any leak in the inner shell is detectable at a time when the vessel itself is still structurally sound.

3. Modeling of wounded pressure vessel

Computer-aided layout (CAD) is the usage of computer structures (or workstations) to beneficial useful resource within the introduction, amendment, assessment, or optimization of a design. CAD software is used to boom the productivity of the fashion designer, enhance the superb of layout, beautify communications through documentation, and to create a database for production. CAD output is often inside the shape of digital files for print, machining, or different production operations. The term CADD (for Computer Aided Design and Drafting) is also used.

3.1 Introduction to CREO

CREO, previously referred to as Pro/ENGINEER, is three-d modeling software program applied in mechanical engineering, layout, manufacturing, and in CAD drafting provider corporations. It modified into one of the first 3D CAD modeling packages that used a rule-based parametric device. Using parameters, dimensions and functions to seize the behavior of the product, it is able to optimize the improvement product further to the format itself.

The name comes to be changed in 2010 from Pro/ENGINEER Wildfire to CREO. It changed into introduced by means of way of the business enterprise who superior it, Parametric Technology Company (PTC), for the duration of the release of its suite of format merchandise that consists of programs collectively with meeting modeling, 2D orthographic views for technical drawing, finite element analysis and greater.

The present wounded pressure vessel was modeled in Creo by using sketcher and part modules. Two dimensional model helpful in model the pressure vessel was shown below.

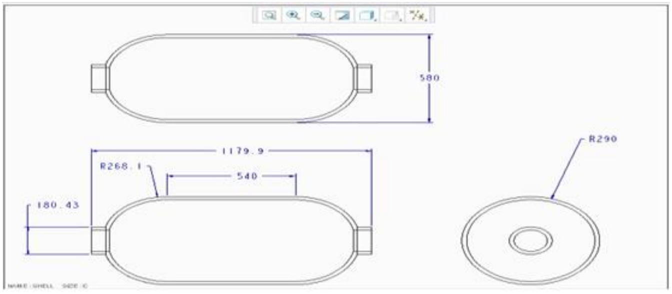


Fig 3.1: 2 Dimensional view of pressure vessel

By considering the above mentioned dimensions pressure vessel was modeled. In the process of modeling first symmetrical part of vessel was created in sketcher and was revolved in part module. After that wire wounded was attached to the pressure vessel using heliacal sweep. Finally the3D model was as shown below.

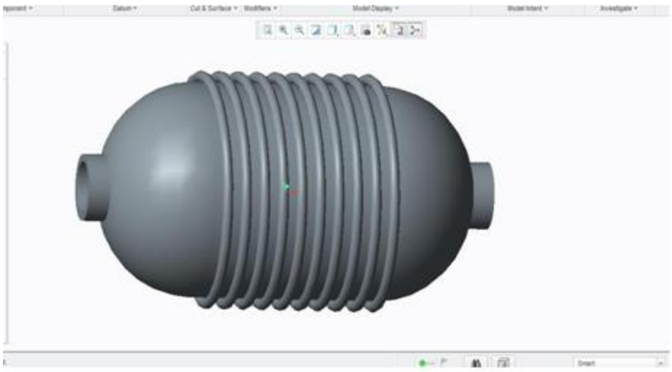


Fig 3.2: 3 Dimensional view of wounded pressure vessel

4. Introduction to FEA

Finite Element Method (FEM) is also called as Finite Element Aanalysis (FEA). Finite element approach is a common evaluation method for resolving and substituting problematic issues by means of easier ones, acquiring approximate options Finite element process being a bendy device is utilized in various industries to resolve a couple of useful engineering issues. In finite element system it's viable to generate the relative outcome.

Within the modern-day, finite detail system is likely one of the most robust and extensively used tools. By way of doing more computational analysis the approximate solution will also be increased or sophisticated in Finite element system. In Finite element process, matrices play an main role in dealing with tremendous quantity of equations. The process for FEM is a variation approach the place this idea has contributed appreciably in formulating the approach.

4.1 Structural Analysis of wounded pressure vessel

After modeling the wounded pressure vessel was exported in to ANSYS software for making analysis. In ansys the model was imported and analysis was carried out.

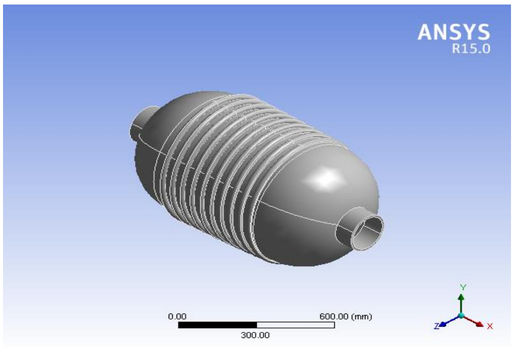


Fig 4.1: Imported model of wounded pressure vessel in ANSYS

After importing we need to apply material property to the model. In this work the wounded pressure vessel was analyzed with four different materials. The properties of these materials was give below

Material properties of steel:
Young's modulus=205000Mpa
Poisson's ratio=0.3
Density=7800kg/m^3
Thermal conductivity =w /m-k
Specific heat = 477j/kg-k

Material properties of CFRP:
Young's modulus=135000Mpa
Poisson's ratio=0.27
Density=1570kg/m3
Thermal conductivity = 1.1w/m-k
Specific heat = 740j/kg-k

Material properties of E-GLASS:

Young's modulus=85000Mpa

Poisson's ratio=0.25

Density=2600kg/m3

Thermal conductivity = 1.35w/m-k

Specific heat = 805j/kg-k

Material properties of Epoxy resin:

Young's modulus=3400Mpa

Poisson's ratio=0.3

Density=1200kg/m3

Thermal conductivity = 1.35w/m-k

Specific heat = 805j/kg-k

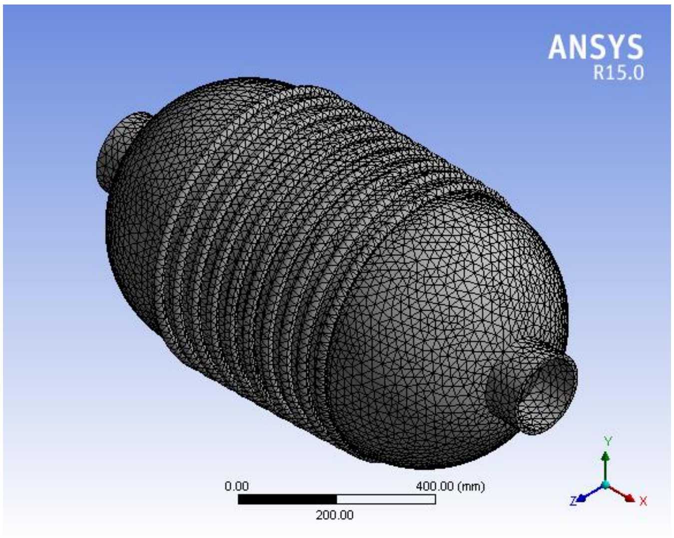


Fig 4.2: Meshed model of wounded pressure vessel

Boundary conditions were applied on the wounded pressure vessel. Here the two ends of the vessel are assumed to be fixed and there is an internal pressure applied on the inner portion.

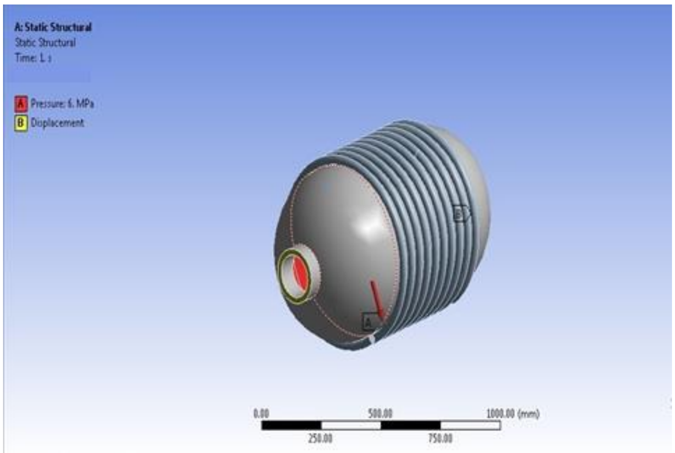


Fig 4.3: Boundary conditions applied on the wounded pressure vessel

5. Results

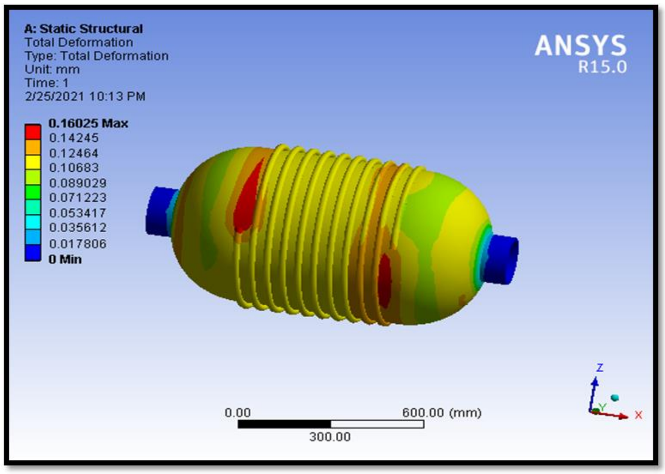


Fig 5.1: Total Deformation of Wounded Pressure Vessel with Steel

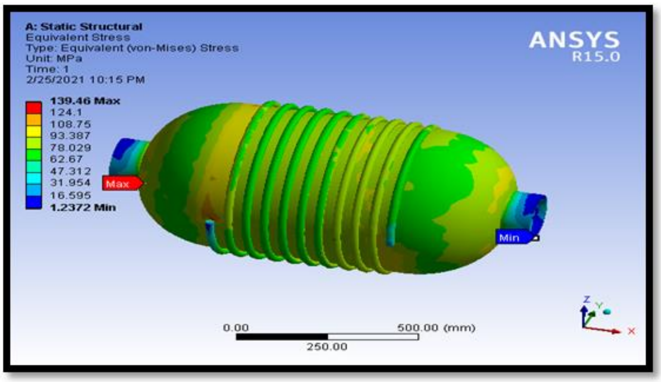


Fig 5.2: Equivalent stress of Wounded Pressure Vessel with Steel

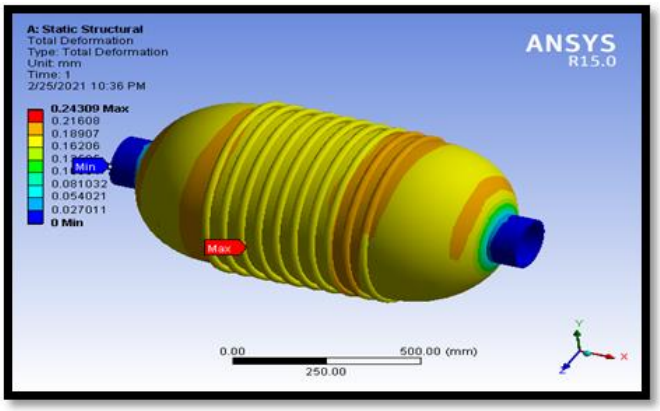


Fig 5.3: Total Deformation of Wounded Pressure Vessel with CFRP

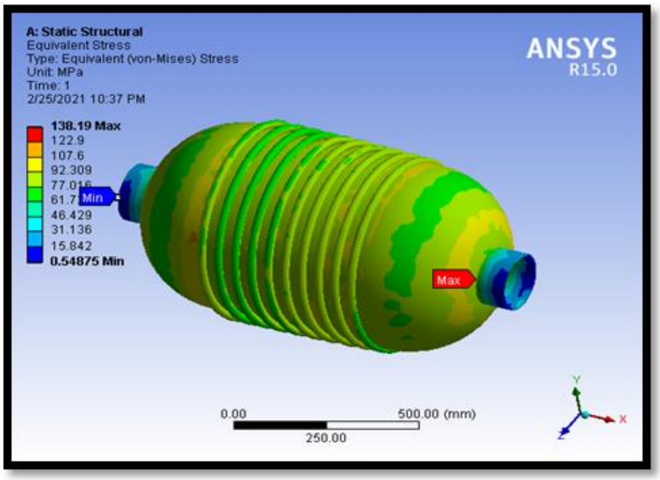


Fig: 5.4: Equivalent stress of pressure vessel with CFRP

Table 1: structural analysis results with different materials

Material	Deformation (mm)	Von mises Stress(MPa)	Strain
Steel	0.16025	139.46	0.00750
CFRP	0.24309	138.19	0.00113
Epoxy Resin	0.91914	140.48	0.00431
E-glass	0.39235	139.46	0.04416

5.1 Multilayered wounded pressure vessel results

Finally after making the analysis of wounded pressure vessel with different material, the pressure vessel as now modeled with layers. Two types of analysis were carried out. In first case four layers was considered with same thickness and with different orientations and in second case eight layers was considered. The layer details as follows.

Wounded pressure vessel with four layers			
Layer	Material	Thickness(mm)	angle
1	Steel	5	-90
2	CFRP	5	-45
3	Epoxy Resin	5	45
4	E-Glass	5	90

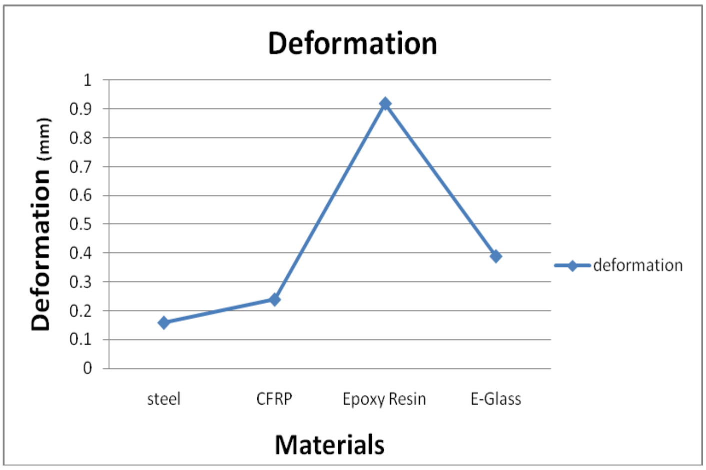
Table 2: Details of 4 layered pressure vessel

Wounded pressure vessel with eight layers			
Layer	Material	Thickness(mm)	angle
1	Steel	5	-90
2	CFRP	5	-45
3	Epoxy Resin	5	45
4	E-Glass	5	90
5	Steel	5	-90
6	CFRP	5	-45
7	Epoxy Resin	5	45
8	E-Glass	5	90

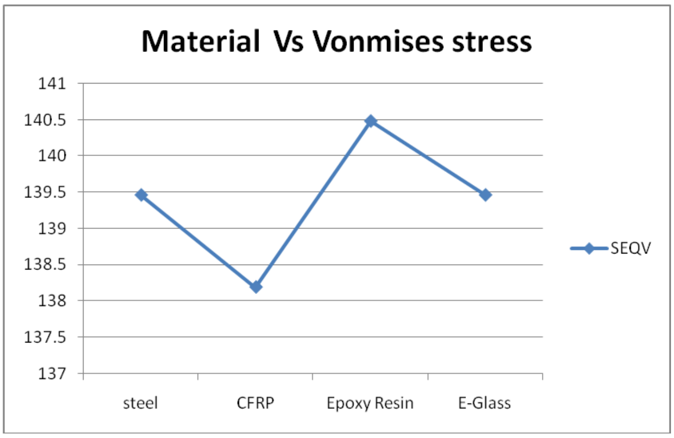
Table 3: Details of 8 layered pressure vessel

layers	Deformation (mm)	Vonmises stress(Mpa)	strain
4	0.0953	71.882	0.000366
8	0.0942	72.232	0.000368

Table 4: Results of wounded pressure vessel the 4 & 8 layers



Graph 1: Deformations of wounded pressure vessel with different materials



Graph 2: Von-mises stress of wounded pressure vessel with different materials

6. Conclusions

In this thesis, the pressure vessel is designed in line with the analyzed for its strength making use of Finite element evaluation application ANSYS. Mathematical correlations might be viewed for the design of pressure vessel whose design parameters are specific via a enterprise consistent with the specified wounded filament pressure vessel. Modeling was completed in CREO Parametric application.

Structural evaluation was performed on the pressure vessel in ANSYS .From the analysis report it is observed that for CFRP material the minimum equivalent stress is 138.19 MPa which is minimum when evaluate with steel, Epoxy Resin and e-glass.

Pressure vessel was also modeled as multilayer body with four and eight layers. It was analyzed to calculate vonmises stress. It is observed that there is big change in the generated equivalent stress. Finally it was concluded that pressure vessel with 4 layers of given orientations will give better performance.

REFERENCES

[1] Mutahir Ahmed, Rafi Ullah Khan, "Finite Element Investigation of Geometry Effect on Pressure Vessel under Combined Structural and Thermal Loads". International Journal of Engineering and Advanced Technology, Volume-4 Issue-2, December 2014.
[2] S. Takalkar Atul Shantanu S Bhat "Finite element analysis of composite Overwrapped Pressure vessel for hydrogen storage". International conference on advances in computing Communications and informatics (ICACCI), 03 November 2016.
[3] Madhavi M, K. Narayana "Design and Analysis of Filament Wound Composite Pressure Vessel with Integrated-end Domes". Defence Science Journal . 2009, Vo.59 Issue 1, p73.
[4] Q.Zhang[a] Z.W.Wang "Analytical solution of the thermo-mechanical stresses in a multilayered composite pressure vessel considering the influence of the closed ends." International journal of pressure vessels and piping, volume 98 October 2012.
[5] Mohammad Z. Kabir "Finite element analysis of composite pressure vessels with a load sharing metallic liner." Journal of composite structure. Volume 49, Issue 3, July 2000
[6] Calculations of Plastic collapse Load of pressure Vessel utilisingFea, Peng- FeiLiu,Jin; Institute of Chemical machinery and procedure gear, Zhejiang institution, Hangzhou 310027, China)
[7] Stress attention At Openings In strain Vessels – A assessment, Avinash Kharat1, V.V. Kulkarni2; study pupil, Dept. Of production Engineering, ok. I.T."S.
[8] Stresses In A Pressurized Ribbed Cylindrical Shell with A reinforced gap, A. J Dureli& V. J. Parks The Journal of strain evaluation For Engineering Design,1973