Volume 3, Issue 5, May-2016, pp. 246-250 ISSN (O): 2349-7084

International Journal of Computer Engineering In Research Trends

Available online at: www.ijcert.org

Design Optimization and Buckling Analysis of Pressure Vessel

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Abstract: - Pressure vessels like pre-water heaters essentially heat exchangers that are used in closed power cycles. These pressure vessels are used to preheat the water fed into Boilers or heat the water before entering the boiler using expanded steam to increase the efficiency of the cycle. These heavy duty pressure vessels are in working condition throughout the year. The vessel strength will be reduced with time. This can be reduced by providing a winding coil around the vessel as a strip. The strip material will not affect the boiler but increases the life. The modeling was done by using Creo 2.0. Which is an advanced modeling software used in almost all the manufacturing industries. After the modeling the model was imported into the ANSYS 14.0. The linear buckling analysis of the pressure vessel will be done before and after the winding coil was placed at different load conditions and the maximum buckling load will be estimated. By considering some different type of materials to the mod el for showing the differences. Finally the results will be tabulated and graphs will be plotted.

Keywords – Pressure Vessel, Creo-2.0, Linear Buckling, Ansys 14.0 and Modeling

1. INTRODUCTION

Pressure vessels are used to store and transmit liquids, vapors, and gases under pressure in general. The pressure of these finds will exert pressure equally in all directions and walls and ends of the pressure vessels. Because of the internal loading, stress are including on certain sections of the cylinder (pressure vessel) wall.

TYPES OF PRESSURE VESSELS

The pressure vessels (cylindrical or spherical tanks) are generally used in engineering to store fluid under pressure.

Types of pressure vessels:

Following are the main types of pressure vessels:

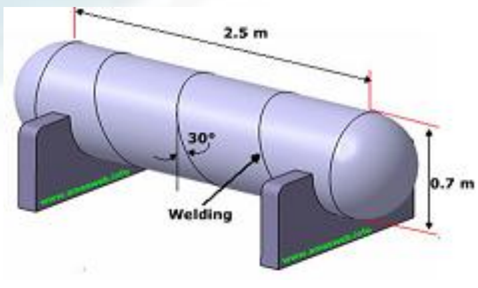
According to the end construction

According to the dimensions

There are three main types of pressure vessels in general

- Horizontal Pressure Vessels
- Vertical Pressure Vessels
- Spherical Pressure vessels

However there are some special types of Vessels like Regeneration Tower, Reactors but these names are given according to their use only.



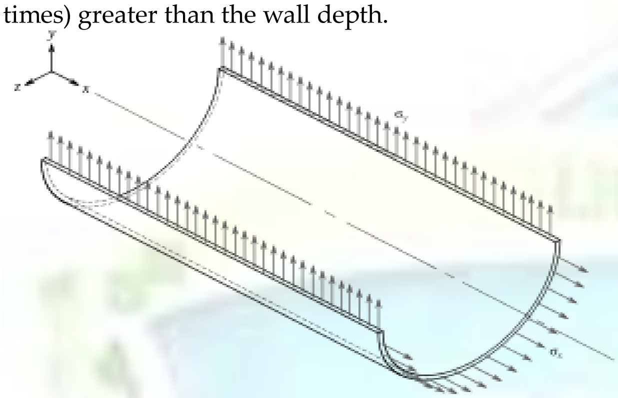
Design of Pressure Vessel

2. STRESSES IN THIN-WALLED PRESSURE VESSELS

Stress in a shallow-walled pressure vessel in the shape of a sphere is

$$\sigma\theta = \sigma \text{ Log} = pr/2t$$

A vessel can be considered "shallow-walled" if the diameter is at least 10 times (sometimes cited as 20 times) greater than the wall depth.



Stresses in the cylinder body of a pressure vessel

Stress in a shallow-walled pressure vessel in the shape of a cylinder is

$$\sigma\ \theta = pr/t$$

$$\sigma \log = Pr/2t$$

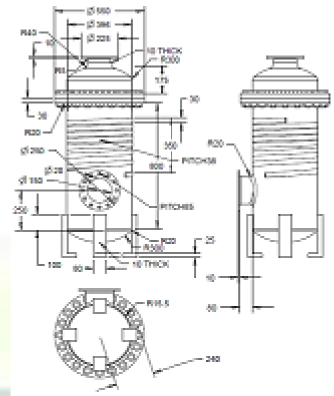
Where:

- σ_θ is hoop stress, or stress in the circumferential direction
- σ_{long} is stress in the longitudinal direction
- p is internal gauge pressure
- r is the inner radius of the cylinder
- t is thickness of the cylinder wall.

Almost all pressure vessel design standards contain variations of these two formulas with additional empirical terms to account for wall thickness tolerances, quality control of welds and in-service corrosion allowances

3. DESIGN

To work with CREO2.0 first we should know about the main modules to design any part or assembly with required documentation.
They are:
Sketcher
Part Modeling
Assembly
Drawing/Drafting
Sheet Metal
Part Modeling: To enter into part modeling - select new - we get the following window



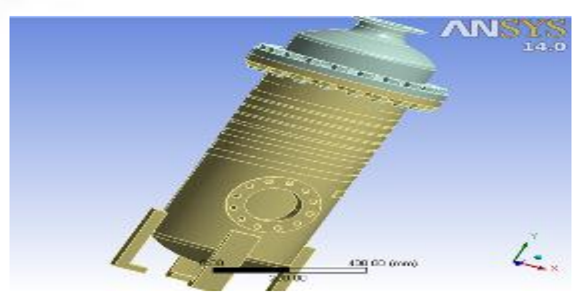
The Pressure Vessel Dimensions

The Assembly of Pressure Vessel part in Creo2.0

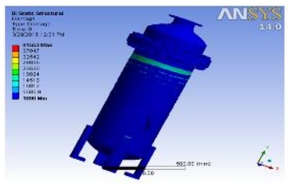
4. ANSYS

LOADING TYPES IN THE ANSYS PROGRAM

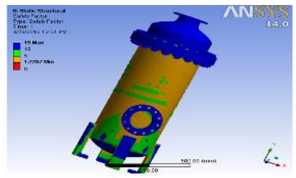
- Static (or steady-state)
- Transient
- Harmonic
- Modal
- Spectrum
- Buckling
- Sub structuring



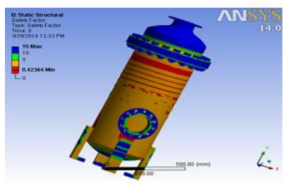
Importing into ANSYS



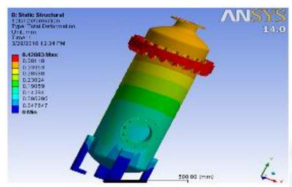
Applying Stress Loads in ANSYS



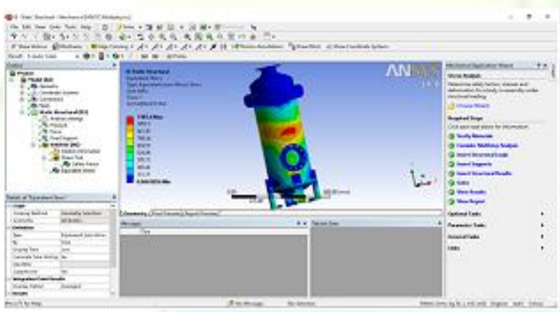
Applying Strain Loads in ANSYS



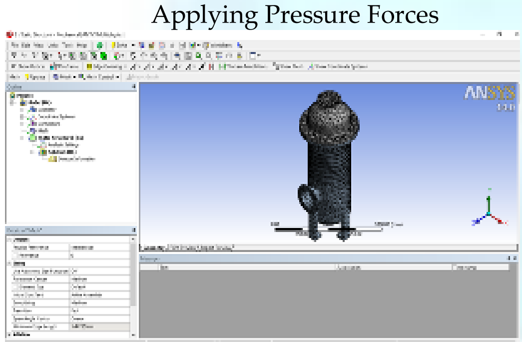
Applying Displacement Loads in ANSYS



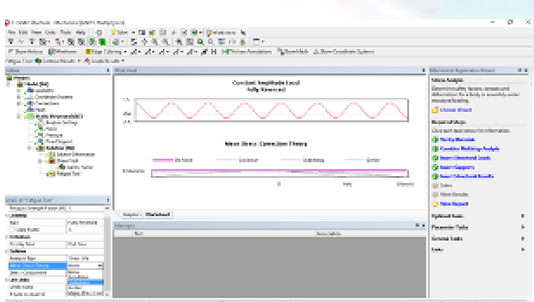
Applying Von-Miss Loads in ANSYS



Applying Pressure Forces



Meshing in ANSYS



Graph Results in ANSYS

5. RESULTS

Model (B4) GEOMETRY

Units		
Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius	
Angle	Degrees	
Rotational Velocity	rad/s	
Temperature	Celsius	
Bounding Box		
Length X	550. mm	
Length Y	1276.1 mm	
Length Z	565. mm	
Properties		
Volume	2.3177e+007 mm³	
Mass	181.94 kg	
Statistics		
Nodes	54216	
Elements	27761	
Material		
Assignment	Structural Steel	
Properties		
Volume	8.429e+006 mm³	1.4748e+007 mm³
Mass	66.168 kg	115.77 kg
Centroid X	-2.0377e-006 mm	0.16719 mm
Centroid Y	896.95 mm	352.44 mm
Centroid Z	3.0713e-003 mm	12.616 mm
Moment of Inertia Ip1	1.8443e+006 kg·mm²	1.8607e+007 kg·mm²
Moment of Inertia Ip2	2.9065e+006 kg·mm²	5.2262e+006 kg·mm²
Moment of Inertia Ip3	1.846e+006 kg·mm²	1.8268e+007 kg·mm²
Tolerance Value	3.7501 mm	
Minimum Edge Length	1.44750 mm	

All Coordinates of model (B4) Geometry

STATIC STRUCTURAL (B5)

Definition			
Physics Type	Structural		
Analysis Type	Static Structural		
Options			
Environment Temperature	22. °C		
Definition			
Type	Fixed	Pressure	Force

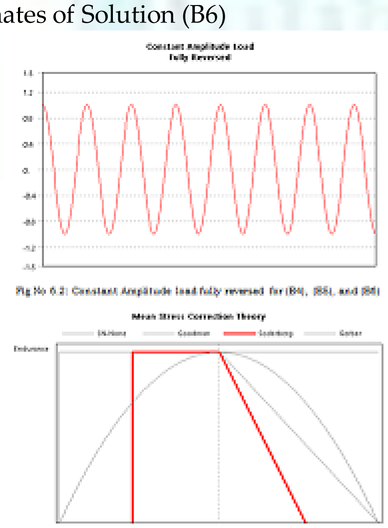
	Support		
Define By		Normal To	Vector
Magnitude		5. MPa (ramped)	10. N (ramped)
Direction			Defined

All Coordinates of Static Structural (B5)

SOLUTION (B6)

Solution Information	
Update Interval	2.5 s
FE Connection Visibility	
Draw Connections Attached To	All Nodes
Line Thickness	Single
Display Type	Lines
Definition	
Display Time	End Time
Options	
Analysis Type	Stress Life
Mean Stress Theory	Soderberg
Stress Component	Equivalent (Von Mises)
Life Units	
Units Name	cycles
1 cycle is equal to	1. cycles

All Coordinates of Solution (B6)



Graph Drawn for the above Results

Alternating Stress MPa	Cycles	Mean Stress MPa
3999	10	0
2827	20	0
1896	50	0
1413	100	0
1069	200	0
441	2000	0
262	10000	0
214	20000	0
138	1.e+005	0
114	2.e+005	0
86.2	1.e+006	0

Alternating stress V/s Cycles

Note: Same Procedure is repeated for Linear Buckling

6. CONCLUSION

Design approach of pressure vessel are by ASME codes and Finite element analysis out of which analysis of Pressure vessel by FEA method is easy and get optimum parameters.

- Design calculation of FEA is compare with ASME boiler and pressure vessel regulations.
- In Comparison of the results and design parameters calculated by ASME boiler and pressure vessel code and finite element analysis are in thickness and reduces in weight of pressure vessel.
- Design by FEA is in weight reduction of pressure vessel. Optimize design by FEA reduces the total Cost of pressure vessel.
- The optimization in design of pressure vessel using FEA is safe and has successfully satisfied the goal of economics.

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