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Design and Analysis of Pressure Vessel Using F.E.M

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ABSTRACT:

A pressure vessel is designed to work under high pressure condition so that the selection of material and the design of the pressure vessel are most important. In this paper, the thermal analysis of pressure vessel made of a composite material and subjected to give the total heat flux.The analytical design of the pressure vessel is by using as per ASME code. The heat flux for a pressure vessel are calculated with composite material. The modeling of pressure vessel is carried out in CATIA V5 and this model is imported in ANSYS Workbench where thermal analysis is carried out. The shrink fit is applied during the CAD modeling of pressure vessel. Also weight and heat flux are carried out for the pressure vessel.

INTRODUTION:

The pressure vessels (i.e. cylinder or tanks) are used to store fluids under pressure. The fluid being stored may undergo a change of state inside the pressure vessel as in case of steam boilers or it may combine with other reagents as in a chemical plant. The pressure vessels are designed with great care because rupture of pressure vessels means an explosion which may cause loss of life and property. The material of pressure vessels may be brittle such that cast iron or ductile such as mild steel. Cylindrical or spherical pressure vessels (e.g., hydraulic cylinders, gun barrels, pipes, boilers and tanks) are commonly used in industry to carry both liquids and gases under pressure. When the pressure vessel is exposed to this pressure, the material comprising the vessel is subjected to pressure loading, and hence stresses, from all directions. The normal stresses resulting from this pressure are functions of the radius of the element under consideration, the shape of the pressure vessel (i.e., open ended cylinder, closed end cylinder, or sphere) as well as the applied pressure. Two types of analysis are commonly applied to pressure vessels. The most common method is based on a simple mechanics approach and is applicable to “thin wall” pressure vessels which by definition have a ratio of inner radius, r, to wall thickness, t, of $r/t \geq 10$. The second method is based on elasticity solution and is always applicable regardless of the r/t ratio and can be referred to as the solution for “thick wall” pressure vessels. Both types of analysis are discussed here, although for most engineering applications, the thin wall pressure vessel can be used.

SPECIAL PROBLEMS

Thick Walled Pressure Vessels

Mono-bloc- Solid vessel wall.

Multilayer—Begins with a core about ½ in. thick and successive layers are applied. Each layer is vented (except the core) and welded individually with no overlapping welds. Multi-wall—Begins with a core about ½ in. to 2 in. thick. Outer layers about the same thickness are successive “ shrunk fit” over the core. This creates compressive stress in the core, which is relaxed during pressurization. The process of compressing layers is called auto-frettage from the French word meaning “self-hooping.” Multilayer auto-frettage—Begins with a core about ½ in. thick. Bands or forged rings are slipped outside and then the core is expanded hydraulically. The core is stressed into plastic range but below ultimate strength. The outer rings are maintained at a margin below yield strength.

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The elastic deformation residual in the outer bands induces compressive stress in the core, which is relaxed during pressurization. Wire wrapped vessels: Begin with inner core of thickness less than required for pressure. Core is wrapped with steel cables in tension until the desired auto-frettage is achieved.Coil wrapped vessels: Begin with a core that is subsequently wrapped or coiled with a thin steel sheet until the desired thickness is obtained. Only two longitudinal welds are used, one attaching the sheet to the core and the final closures weld. Vessels 5 to 6 ft in diameter for pressure up to 5000psi have been made in this manner.

THERMAL STRESS:

Whenever the expansion or contraction that would occur normally as a result of heating or cooling an object is prevented, thermal stresses are developed. The stress is always caused by some form of mechanical restrain. Thermal stresses are "secondary stresses" because they are self-limiting. Thermal stresses will not cause failure by rupture. They can however, cause failure due to excessive deformations.

DISCONTINUITY STRESSES:

Vessel sections of different thickness, material, diameter and change in directions would all have different displacements if allowed to expand freely. However, since they are connected in a continuous structure, they must deflect and rotate together. The stresses in the respective parts at or near the juncture are called discontinuity stresses. Discontinuity stresses are " secondary stresses" and are self-limiting. Discontinuity stresses do become an important factor in fatigue design where
cyclic loading is a consideration.

FATIGUE ANALYSIS:

When a vessel is subject to repeated loading that could cause failure by the development of a progressive fracture, the vessel is in cyclic service. Fatigue analysis can also be a result of thermal vibrations as well as other loadings.

In fatigue service the localized stresses at abrupt changes in section, such as at a head junction or nozzle opening, misalignment, defects in construction, and thermal gradients are the significant stresses.

CATIA V5 R18 (Computer Aided Three Dimensional Interactive Applications):

As the world's one of the supplier of software, specifically intended to support a totally Integrated product development process. Dassault Systems (DDS) in recognized as a strategic partner which can help a manufacturer to the turn a process into competitive advance, greater market share and higher profits and industrial and mechanical design to functional simulation manufacturing and information management. Catia Mechanical design solution will improve our design productivity. Catia is a suit of programs that are used in design, analysis and manufacturing of a virually unlimited range of the product." Feature based" means that we create parts and assemblies by defining feature like extrusion sweeps, cuts, holes, round and so on instead of specifying low level geometry like lines, areas circles.

This means that the designer can think of the computer model at a very high level and leave all low geometry detail for Catia to figure out."Parametric" means that the physical shape of the part as assembly is driven by the value assigned to the attributes of its features. We may define or modify a feature dimension or other attributes at any times. Any changes will automatically propagate through the model. "Solid Modeling " means that the computer model we create is able to contain all the information that a real solid object would have. It has volumes and therefore, if you provide a value for the density of the material it has mass and inertia.

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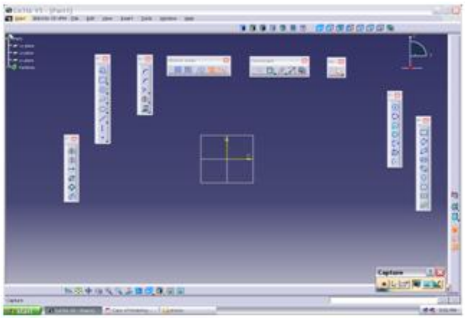
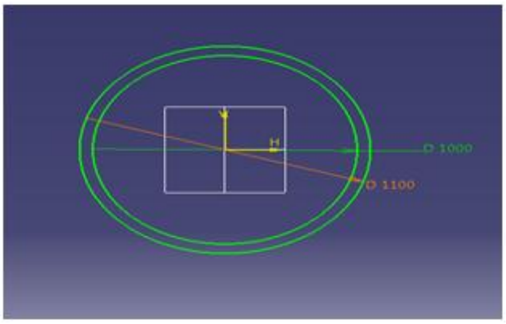


Sketcher module

Sketcher 1



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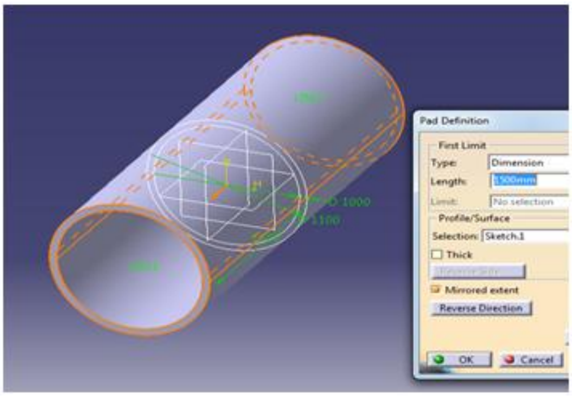
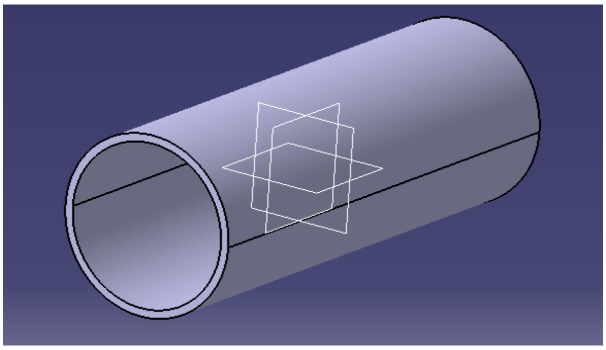


Presser vessel final model



FINITE ELEMENT METHODS:

The finite element method is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in engineering schools and industries. In more and more engineering situations today, we find that it is necessary to obtain approximate solutions to problems rather than exact closed form solution. It is not possible to obtain analytical mathematical solutions for many engineering problems. An analytical solutions is a mathematical expression that gives the values of the desired unknown quantity at any location in the body, as consequence it is valid for infinite number of location in the body. For problems involving complex material properties and boundary conditions, the engineer resorts to numerical methods that provides approximate, but acceptable solutions.

The fundamental areas that have to be learned for working capability of finite element method include:

- MATRIX ALGEBRA.
- SOLID MECHANICS.
- VARIATION METHODS.
- COMPUTER SKILLS.

Matrix techniques are definitely most efficient and systematic way to handle algebra of finite element method. Basically matrix algebra provides a scheme by which a large number of equations can be stored and manipulated. Since vast majority of literature on the finite element method treats problems in structural and continuum mechanics, including soil and rock mechanics, the knowledge of these fields became necessary. It is useful to consider the finite element procedure basically as a Variation approach. This conception has contributed significantly to the convenience of formulating the method and to its generality.

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FEA SOFTWARE – ANSYS

Ansys result

- **Material Data**
  - Structural Steel

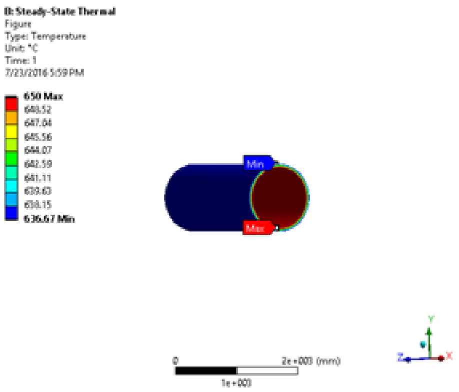


FIGURE 5 Model (B4) > Steady-State Thermal (B5) > Solution (B6) > Total Heat Flux

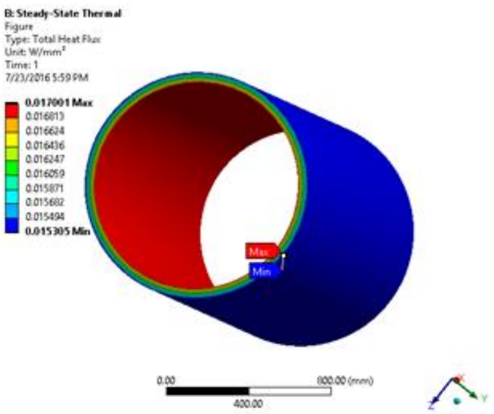
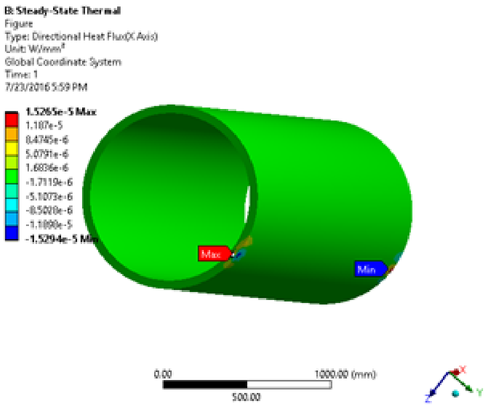


FIGURE 7 Model (B4) > Steady-State Thermal (B5) > Solution (B6) > Directional Heat Flux



Material Data

Structural Steel

TABLE 17 Structural Steel > Constants

Density	7.85e-006 kg mm^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm

TABLE 23 Structural Steel > Alternating Stress Mean Stress

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

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214	20000	0
138	1.e+005	0
114	2.e+005	0
86.2	1.e+006	0

TABLE 24 Structural Steel > Strain-Life Parameters

Strength Coefficient MPa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient MPa	Cyclic Strain Hardening Exponent
920	-0.106	0.213	-0.47	1000	0.2

TABLE 25 Structural Steel > Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.e+005	0.3	1.6667e+005	76923

TABLE 26Structural Steel > Isotropic Relative Permeability

Relative Permeability
10000

Conclusion:

The paper has led to numerous conclusions.
However, major conclusions are as below:

• The design of pressure vessel is initialized with the specification requirements in terms of standard technical specifications along with numerous requirements that lay hidden from the market.

•The design of a pressure vessel is more of a selection procedure, selection of its components to be more precise rather designing each and every compo-nent.

•The pressure vessel components are merely selected, but the selection is very critical, a slight change in selection will lead to a different pressure vessel altogether from what is aimed to be designed.

•It is observed that all the pressure vessel components are selected on basis of available ASME standards and the manufactures also follow the ASME standards while manufacturing the components. So that leaves the designer free from designing the components. This aspect of Design greatly reduces the Development Time for a new pressure vessel.

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