Stress Analysis of an FRP Pressure Vessel

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Abstract----Light weight composite pressure vessels can be used in space applications. Composite pressure vessels need number of layers to achieve required thickness and also to achieve required strength to bear the pressure of gases/liquids.The aim of this paper is to provide composite pressure vessel with sufficient strength using different layer orientations.Structural calculations will be done to find the stress and strains values theoretically.3D modeling will be done according to the allowable standards.Structural and thermal analysis will be conducted on pressure vessel using different layer orientations and the above analysis will be done on traditional material for comparison.

I. INTRODUCTION

In the early years of the commercialization of membrane technology, the early 1970s, the focus of development was on applying membranes in competition with conventional separations technologies (thermal) and on improving the membrane element itself. Membrane pressure vessels or housings were simple assemblies of coated carbon steel, or stainless steel pipe with end closures made with grooved pipe couplings. Significant problems with corrosion, and the occasional release of an end closure, led to a more rigorous approach to membrane housing design and to the search for materials that were inherently corrosion resistant. The membrane industry found an economical solution in filament-wound fiber-reinforced plastic (FWFRP) pipe. FWFRP pipe has exceptional strength hand corrosion resistance due to the favorable orientation of continuous strands of high-strength glass-fiber reinforcement bonded together in a matrix of corrosion resistant polymer resin. Furthermore, filament-wound pipe or tubing is superior to commercial steel pipe for use in membrane housings because it has a smooth and truly round interior surface as a consequence of being formed on precision-ground mandrel tooling. At the time, FWFRP pipe was well established in the chemical and process industries with more than 20 years of successful application. The tubular body wall of membrane housing was, and is wound in the same manner as pipe, i.e. the continuous fiber reinforcement is wound at a precise angle to align with the resultant of the biaxial stress in the wall. The closure at each end of the tubular body however, presented a serious technical challenge to the FWFRP industry. The challenge was that directly outboard of the fluid-tight seal at each end of the vessel, principal stress in the wall is oriented axially but the orientation of the reinforcing fiber is predominantly circumferential. This mismatch in alignment was fundamentally wrong for filament-wound structures. The experienced FWFRP pipe suppliers felt that because "full-bore" access to the vessel precluded continuous winding over at least a portion of the end closures, filament-winding was not an appropriate method of manufacture. Established FWFRP pipe companies declined to participate because they felt that catastrophic end failure was likely over time. The companies that did enter the membrane housing market in the early 1970s were specialty filament winders who made parts to customer's specifications. These contract manufacturers required the membrane suppliers to design their own housings and thereby accept the design liability as well. This led to distinctively different methods to retain the end closure. Some used adhesive bonded FRP collars (National Vulcanized Fibre [NVF] for Fluid Systems). Others designed housings that were machined on the outside diameter and used large "clam-shell" clamps to retain the head (Spaulding for Hydranautics). Yet others cut a retaining ring groove into the inside diameter of a thickened section of the pipe (Amalga, NVF and Spaulding for DuPont). Regardless of the type of end closure, it was up to each membrane supplier to complete their own risk assessment and then establish margins of safety for their designs.

II. MODELING OF PRESSURE VESSEL

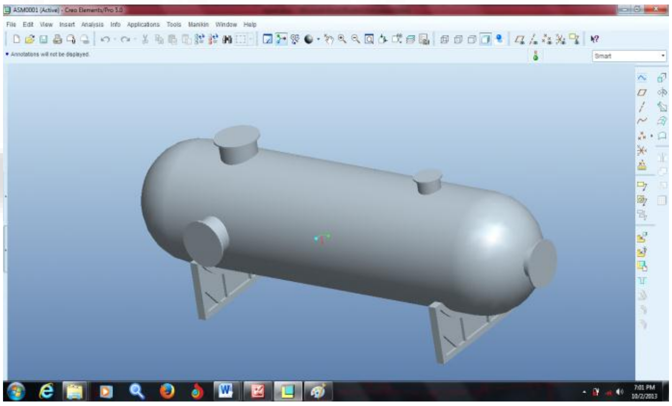

Fig. 1: The above image shows the complete vessel

III. STRUCTURAL ANALYSIS OF PRESSURE VESSEL USING HIGH CARBON STEEL

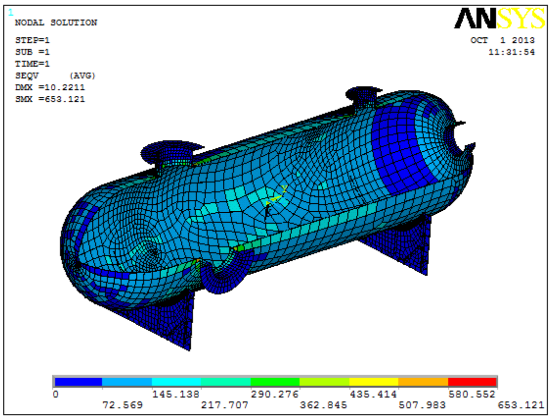

Fig. 2: The above image shows von-misses stress value 653.121 N/mm^2

Thermal Analysis

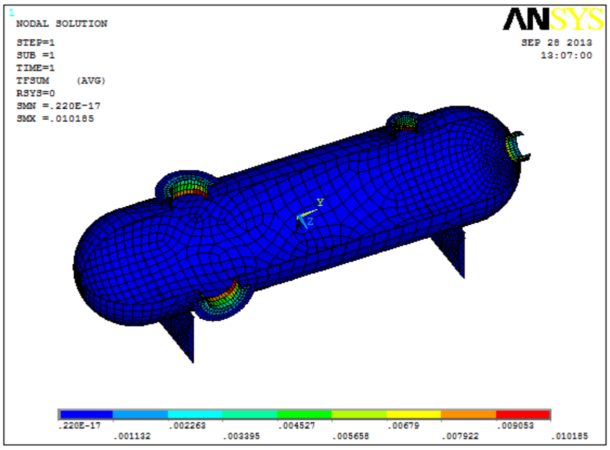

Fig.3: The above image shows the thermal flux, value is 0.010185 K/mm

IV. STRUCTURAL ANALYSIS OF PRESSURE VESSEL USING THREE LAYER WITH E-GLASS EPOXY

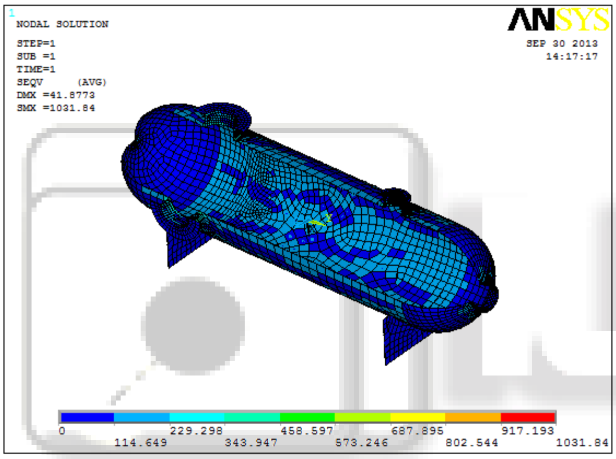

Fig.4: The above image shows von-misses stress value 1031.84 N/mm^2

Thermal Analysis

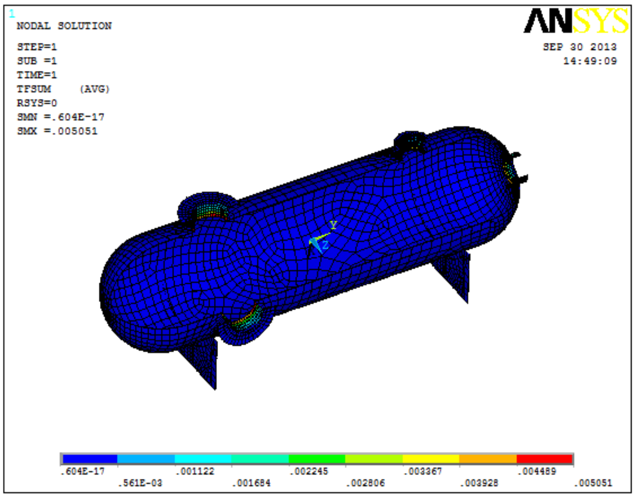

Fig.5: The above image shows the thermal flux, value is 0.005051 K/mm

V. STRUCTURAL ANALYSIS OF PRESSURE VESSEL USING FIVE LAYER WITH E-GLASS EPOXY

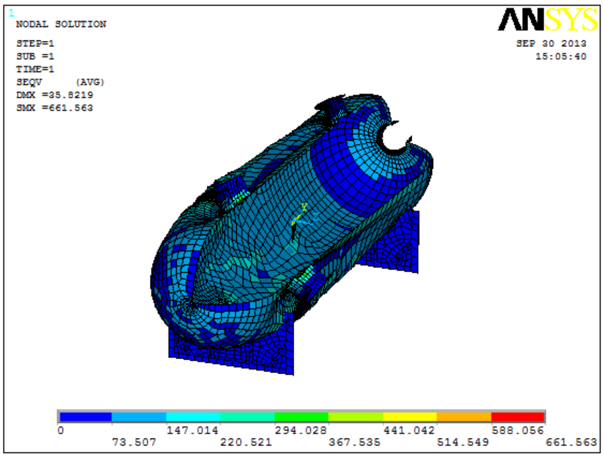

Fig.6: The above image shows von-misses stress value 661.563 N/mm^2

Thermal Analysis

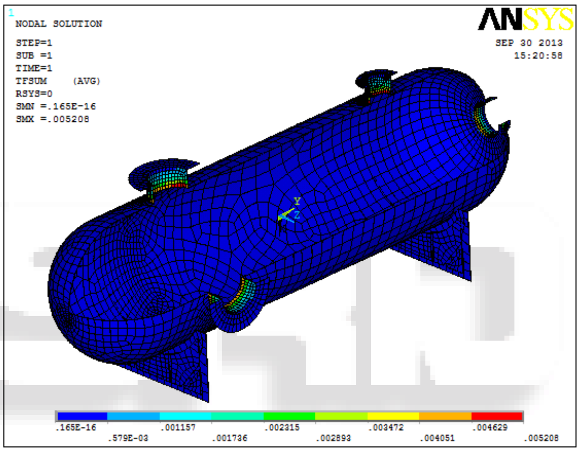

Fig.7: The above image shows the thermal flux, value is 0.005208 K/mm

VI. STRUCTURAL ANALYSIS OF PRESSURE VESSEL WITH 10MM WALL THICKNESS USING E-GLASS EPOXY WITH 5-LAYERS

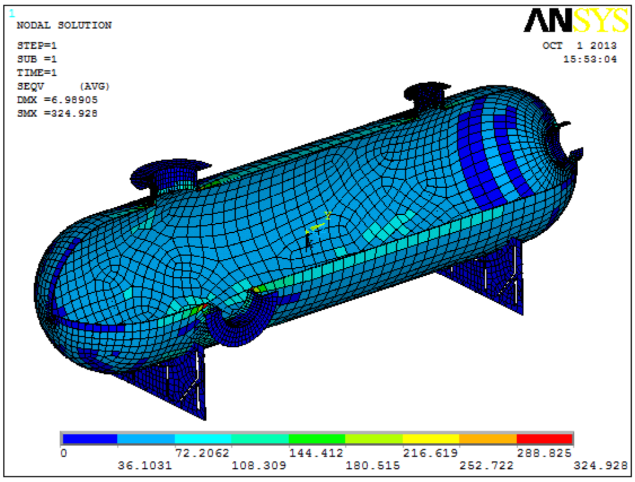

Fig.8: The above image shows von-misses stress value 324.928 N/mm^2

Thermal Analysis

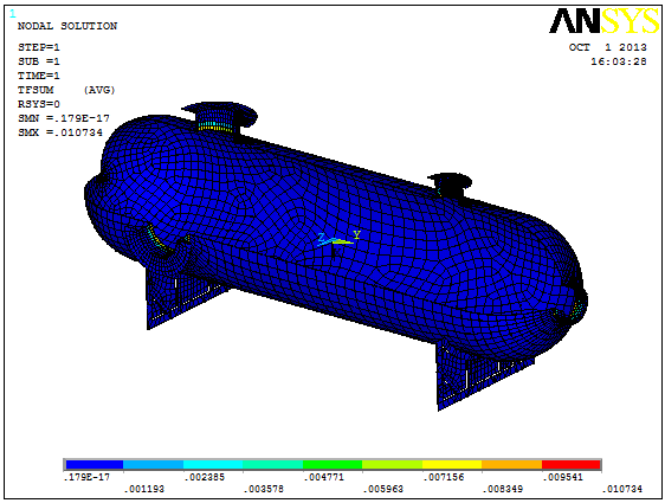

Fig.9: The above image shows the thermal flux, value is 0.10734K/mm

VII. RESULTS

A. *Static Analysis*

material	**Stress In N/mm^2**	**Displacement In mm**	**Mode1**	**Mode2**	**Mode3**	**Mode4**	**Mode5**
High carbon steel	653.121	10.2211	0.407964	0.408846	0.79454	0.86849	0.375363
E-glass 3 layers	1031.84	41.8773	0.151316	0.149181	0.134976	0.144539	0.135163
E-glass 5 layers	661.563	35.8219	0.139397	0.148467	0.131413	0.144805	0.373047

B. *Thermal analysis*

material	**Nodal temperature**	**Thermal gradient**	**Thermal flux**
High carbon steel	-20	0.1951864	0.010185
E-glass 3 layers	-20	0.388507	0.005051
	270	2.027706	0.2627
E-glass 5 layers	-20	0.400604	0.005208
	270	2.08314	0.27081

C. *Static Analysis Using 5 Layers with 10mm Thick*

Material	Stress In N/mm^2	Displacement In mm	Mode1	Mode2	Mode3	Mode4	Mode5
E-glass	324..928	6.98905	0.095646	0.92369	0.89203	0.81235	0.142305

D. *Thermal analysis*

Material	Nodal temperature	Thermal gradient	Thermal flux
E-glass	-20	0.825679	0.10734
	270	0.153573	0.19964

Fig.10: Final model of FRP Pressure vessel

VIII. CONCLUSION

This paper deals with pressure vessel structure design with composite (FRP) material along with layered material matrix in Ansys. A 3D model is generated using pro/engineer then it was converted in to IGES (initial graphical exchanging specification) for further usage in Ansys. Structural and modal analysis is done to determine structural and vibration characteristics. Thermal analysis done using -20^{0}c and 270^{0}c to determine thermal behavior in sub-zero and high temperatures.FRP (fiber reinforced polymer) E-glass is used as replacement material; thickness is increased for E-glass to improve structural stability. Comparison is done between traditional material high carbon steel and E-glass. After increment of thickness also E-glass vessel is low weight only because of very low density than high carbon steel. This E-glass is low weight cost effective, easy to manufacture and corrosive free material.Above discussion concludes that E-glass with 10 thick along with 5-layers is the better option.

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