Design of mobile pressure vessel with dynamic Analysis

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Abstract: The aim of this study is to design the pressure vessel or find out the pressure of the fuel when it is in motion (dynamic pressure) and eliminate the heavy impact of the flowing fuel when the vehicles suddenly stop by using 3G effect .Then compare and analysis of the design with 3G effect and without 3G effect. There are a few international standards applied to design a safe pressure vessel, but the most widely referred codes are American Society of Mechanical Engineers Code (ASME), British Standards and Boiler and Pressure Containers .In the ASME Code, Section VIII, contains a method for designing a pressure vessel. All calculations in the procedure are done manually.

Index Terms – Pressure Vessel, ASME cod

1 Introduction[5].

A pressure vessel is a container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. ... For these reasons, the definition of a pressure vessel varies from country to country. Pressure vessels are ubiquitous in modern society and commonly go unseen by the general public. However, industrial pressure vessels are essential to the continual processing and manufacturing by industrial and commercial concerns and therefore have a direct impact on the both the economic and physical wellbeing of society. With this complex interaction ongoing, it would be easy to assume that pressure vessels are widely varied in design, when in fact, there are three common types and these are found in many industrial and commercial applications. The pressure vessels are used fluid to store such as liquid vapours and gases under pressure. Major uses of pressure vessels are as follows.

- Pressure vessels are used in steam boilers.
- Pressure vessels are also used in storage of chemical in chemical plants.
- Use in storage of petroleum products (petrol, diesel etc.)
- It is also used in engine cylinders.

There are specialized application pressure vessels such as reactors and regeneration vessels, however most correspond to the three common types. 1 Heat Exchangers. 2 Process vessels.3. Storage Vessels.

A large number of road fed bottling plants have been put up by the Oil Industry during the last five years.

The industry fleet of tank trucks has also increased considerably during the last decade. Prior to 1981, there were no separate statutory regulations governing design, fabrication, and operation and licensing of fuel tank trucks. After introduction of SMPV Rules - 1981, old tank trucks which were conforming to different codes and Tandards have been modified to the extent possible and new tank trucks have been fabricated and licensed in line with the SMPV Rules, 1981 and Petroleum Industry Standards. Industry, CCEE and OISD have been analysing fuel tank truck accidents from time to time. Based on the experience gained some modifications have already been introduced on piece meal basis by the Industry members individually. There has hardly been any damage to the bullets and it is the fittings which mostly give way.

An OISD committee consisting of members drawn from Oil Industry therefore discussed this subject in detail and after deliberations has identified the problems and prepared these recommendations for improvements of the existing fuel tank truck fleet to prevent leakage of fuel in the event of fuel tank trucks overturning on the road.

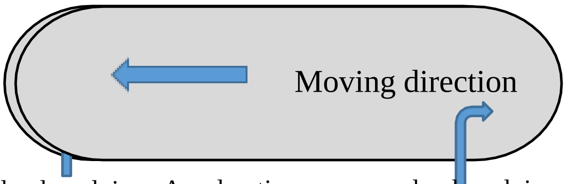
2.1 Define problem.

Baffles in the tank evenly dissipate force of liquid moving when truck is accelerating or braking. When braking without baffles, the liquid keeps moving forward to surge and push against the front wall of the tank, dramatically shifting the weight in the tanker and increasing risk of jack-knife or rollover. Baffles spread the energy evenly to the entire truck, making the truck easier and safer to handle. Some tankers have baffles (internal compartment dividers) and some don't…. it depends what the customer prefers and the nature of the product. Baffles prevent excessive movement of the liquid product in the trailer. In these trailers, the internal movement of the product is minimal. Baffles prevent excessive movement of the liquid product inthe trailer. In these trailers, the internal movement of the product is minimal. However, in a tanker without baffles, where there's just one liquid product, it's a completely different story. A tanker without baffles handles differently than any other trailer. The braking and handling of the trailer when driving is very different, due to the product movement. If the product gets too much motion when the truck is traveling down the road, the movement of the product can actually take over the direction and control of the truck. Just stopping at a set of lights, a stop sign or just slowing down can be quite an adventure for the driver! Try to imagine dealing with product movement on an icy road or in heavy traffic…. it's not a fun experience.

2.2 Solution of problem.

2.2.1 Define 3G effect.

- In the mobile pressure vessel the total load (static pressure + dynamic pressure) is applied. When the dynamic load is applied there is either accelerations or retardation. In the accelerations load is applied on the rear disk.



load applying Acceleration load applying Retardation

In the retardation load is applied on the front disk. When the load is applied on the pressure vessel during the accelerations or retardation we can take the 3 times of the total weight (3 × weight).this scenario is scientifically proven. It's 3G effect or dynamic analysis.

2.2.2 Advantages of 3G effect.

The main purpose of implementing a 3G effect on pressure vessel is to ensure that each mobile pressure vessel is safely operated and transported .1) Public safety.2) Improvement of facility.3) Design approach of pressure vessel are by ASME codes and 3G effect of which analysis of Pressure vessel by 3G effect method is easy and get optimum solution.

3.1 THEORITICAL DESIGN AND METHODOLOGY.

3.1.1 Design steps for pressure vessel without 3G effect.

1. Design Data.
2. Schematic Diagram.
3. Pressure Estimation.
4. Design Calculations for Shell
5. Design Calculations for Dished Ends.
6. Design Calculations for Cap Ends
7. Hydro Test Pressure Estimation. 8. Weight & Volume Calculations 9. Lifting Lug calculation.

Design Pressure Estimation.

- Design Code **IS: 2825-1999 Class 1 and S.M.P.V. (Unfired) Rules2016**

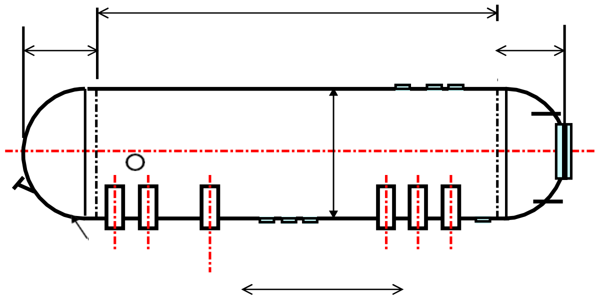
Shell Design Internal Pressure		14.5	Kg/cm2
Inner Diameter of Tanker		2340	mm
Volumetric Capacity of Tanker Vessel		38300	Ltr
Filling Ratio		95	%
Density of L.P.G		495	Kg/m3
Weight of Content in Vessel		18011	Kg
Cross Section Area		43005	cm2
Pressure due to EG Retardation =	3 x W / Cross Section Area		
	3 x 18011/ 43005	1.26	Kg/cm2

Design data [2]

Orientation	Horizontal
Type of Supports	Saddles
Inside diameter of Vessel	2340 mm
Length of Vessel	7346 mm
Type of dished	Hemispherical

Geometrical data [2]

Schematic Diagram of Storage Tank:



Material of Construction [7]

Shell	SA 516 Gr. 70
Dished Ends	SA 516 Gr. 70
Flanges	SA 105
Nozzles	SA 106 Gr. B
Reinforcement Pad	SA 516 Gr. 70
Saddles	IS 2062 Gr. B
Fasteners	A 193 Gr. B7
Gaskets	AF 120

Pressure Estimation:

Shell Design Internal Pressure	1.45	MPa
Inner Diameter of Tanker	2340	mm
Filling Ratio	95	%
Density of L.P.G	495	Kg/m3

As per ASME SecII Part D 2015[7]

Material of Construction		A 516 Gr. 70
Tensile Strength of Material	485	MPa
Yield stress at 40 oC	262	MPa
Yield stress at 65 oC	246	MPa

MOC & STRESS [7]:

- As per ASME SecII Part D 2015

Material of construction of Lifting Lug		SA 516 Gr. 70	
Allowable stress in Tension	SA	137.99	MPa
Allowable stress in Bending = 1.5 x SA	SB	207.01	MPa
Allowable stress in Shear = 0.8 x SA	SS	110.42	MPa

Table no: 3.13 MOC & Stress

STRESS ANALYSIS:

- **Tensile Stress (Case 1)[12]**

$$A_1 = t \times \left(OR - \left(\frac{d}{2} \right) \right) \times 2$$

$$\text{Stress} = \frac{\text{Load}}{A} < S_A$$

= 600 mm^2

= 105.42 MPa <137.99 MPa

- **Shear Stress (Case 2)** [12]**:**

  - $Area = w \times t \langle Ss$

= 90×20

= 1800 mm^2

$$Stress = \frac{Load\ A}{} \langle S_S$$

= 35.13 MPa < 110.42 MPa

- **Pin Bearing Stress (Case 1 & 2)** [12]**:**

  - $A_2 = t \times d$

= 600 mm^2

$$Stress = \frac{Load}{A_2} \langle S_A$$

= 105.42 MPa < 137.99 MPa.

3.1.2 Results and Discussion without 3G (Dynamic pressure) effect.

ITEM	**DIMENTION**	
Calculation For Shell Design	Tr = 11.06 mm	
Design Calculations For Dished Ends.	Tr = 8 mm.	
Cap Ends Design For N1	Tr = 8 mm.	
Cap Ends Design For N4	Tr = 8 mm.	
Hydrostatic Test Pressure Estimation:	1.84 MPa	
VolumeCalculation	38.30 m^3	
Weight Calculation	8279 kg	
Stress Analysis	Shear stress	35.13 MPa < 137.99MPa
	Tensile stress	105.42 MPa < 137.99MPa
	Pin Bearing Stress	105.42 MPa < 137.99MPa

3.13 Results and Discussion with 3G (Dynamic pressure) effect.

ITEM	DIMENTION	
Calculation For Shell Design	Tr = 12 mm	
Design Calculations For Dished Ends.	Tr = 10 mm.	
Cap Ends Design For N1	Tr = 12 mm.	
Cap Ends Design For N4	Tr = 12 mm.	
Hydrostatic Test Pressure Estimation:	2.01 MPa	
VolumeCalculation	38.30 m^3	
Weight Calculation	7500 kg	
Stress Analysis	Shear stress	30.64 MPa < 137.99 MPa
	Tensile stress	91.93 MPa < 137.99 MPa
	Pin Bearing Stress	91.93 MPa < 137.99 MPa

Here's the two different dimension we get 1st is without 3G (dynamic pressure) and 2nd is with 3G (dynamic pressure) effect. Both dimension is define and with 3G effect is more precious and accurate.

4 Analysis of Pressure vessel.

4.1 3D model.

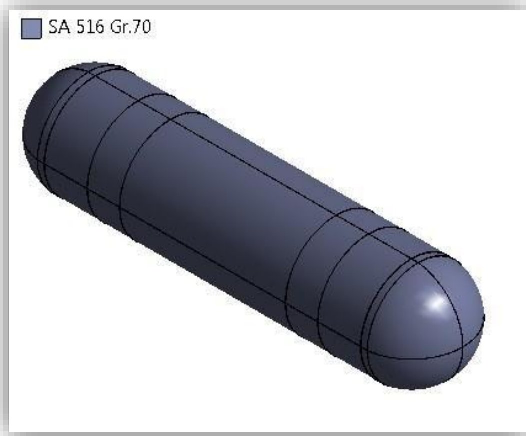


Figure: 3D Model of vessel

4.2 Meshing.

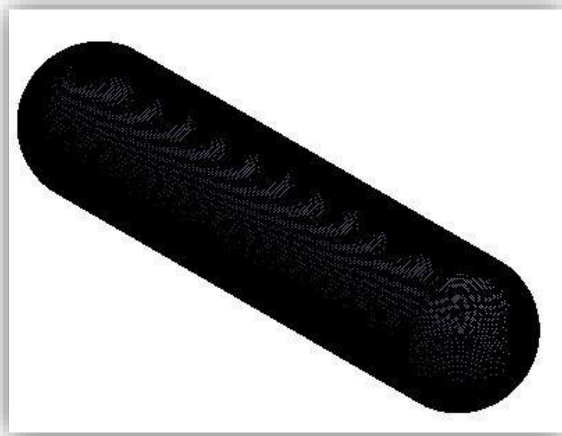


Figure: Meshing

Mesh generation is the practice of generating a polygonal or polyhedral mesh that approximates a geometric domain. Three dimensional meshes created for finite element analysis need to consist tetrahedral, pyramids, prism or hexahedra.

Those use for finite difference method usually need to consist of piecewise structured array of multi block structured meshes.A mesh is otherwise a discretization of a domain existing in one, two or three dimensions Meshing is very important part to obtain accurate results. Mesh is generated with 5 elements in the radial direction. Figure 3.5 shows the cylinder with generated mesh and applied boundary and loading conditions. Saddle have the vital role to support the pressure vessel and to maintain its stability, it should be designedin such a way that it can afford the vessel load and internal pressure of the vessel due to liquid contained in vessel.

A saddle support is created in ANSYS.

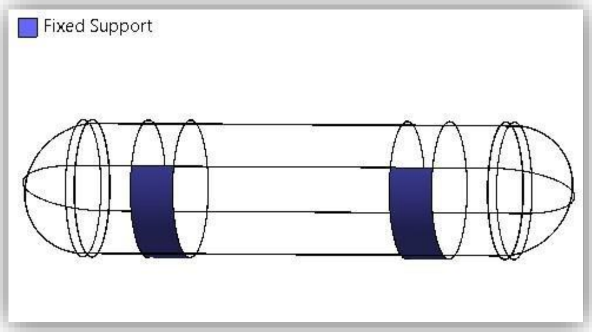
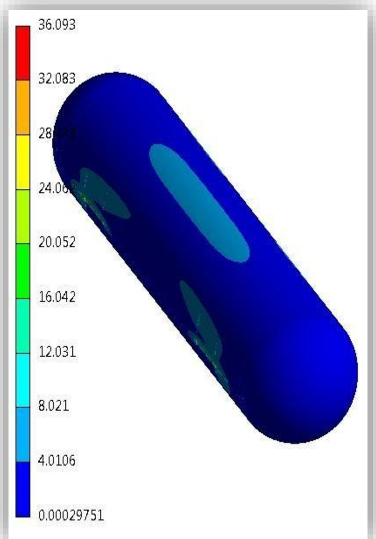


Figure: Fixed support

4.3 Applied load:



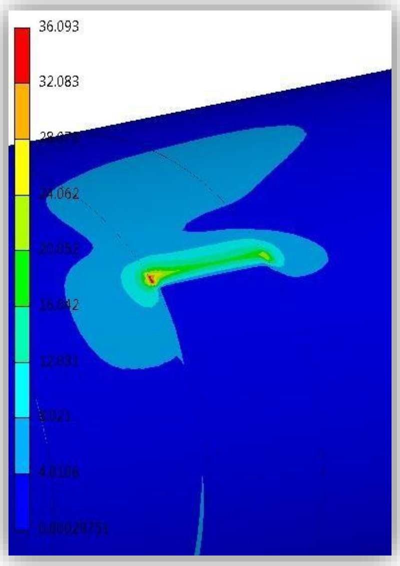


Figure A: Maximum tension (MPa)

Figure B: Maximum tension (MPa)

The stress distribution plot fig 3.4, shows that after adding bands, there is minimum variation in the magnitude of stress concentration. It means that the bands have no significant effect on the stress distribution. The value of stress is max. At the shell joints top and bottom covers. In figure A & B show the maximum load is 36.093 which is less than ASME Standardisation load

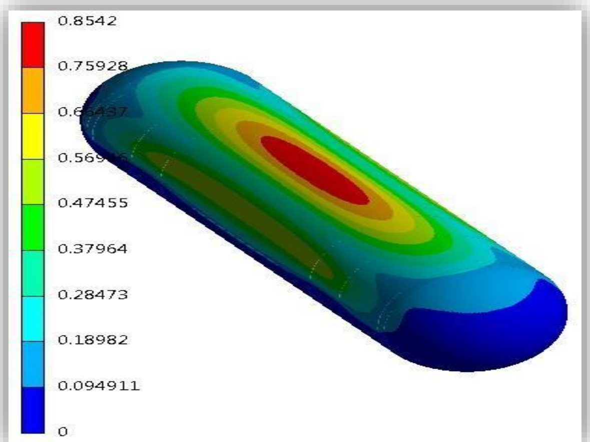


Figure: Deformation of vessel (mm)

In figure define the bending on vessel .Red area is define the maximum bending is 0.8542 mm and this is less than 1 mm so as per ASME code is acceptable.

5 Conclusion

- 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 component.
- The pressure vessel components are merely selected, a slight change in selection will lead to a different pressure vessel 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.
- Many finite element methods and analysis software are made available that do precise fatigue analysis of the vessels for failure in the design stage. Few of them are ANSYS, ABAQUS, Caesar, etc. Software's such as PV Elite are helping a lot to save design time and cost by providing accurate results complying with the standards.

REFERENCES

1. D. Moss, *Pressure Vessel Design Manual: Illustrated Procedures for Solving Major Pressure Vessel Design Problems.* 3rd Edition Gulf Professional Publishing, Elsevier, 2004.
2. Devchand engineers PVT. Ltd. design data, geometrical data, material construction, schematic diagram.
3. ASME, ASME Boiler and Pressure Vessel Code Sections III and VIII. The American Society of Mechanical Engineers, New York, NY, 2003.
4. Kirkwood, M.G and Moffatt, D.G., Plastic loads for piping branch junctions subjected to combined pressure and in-plane moment loads. Proc. Instn Mech Engrs ImechE, Part E, Journal of Process Mechanical Engineering, 1994, 208, 31-43.
5. Kouji Shiratsuchi, Honda Giken Kogyo Kabushiki Kaisha (1984): "A vehicle fuel tank1 ", US4449723 A.
6. Michael Davis, Zhingxing fu, Qunhui Han, "optimizing fuel tank design for high speed vehicles"June 9-12 2009.
7. ASME Section VIII Pressure Vessel - Transportation Analysis.
8. prev_MOSS_Pressure Vessel Design Manual (Ed. 3rd)
9. C. Santos and F. Taveira-Pinto, "Analysis of different criteria to size rainwater storage tanks using detailed methods," *Resour. Conserv. Recycl.*, vol. 71, pp. 1–6, 2013.
10. Donald M. Fryer, John F. Harvey, High Pressure Vessels, Springer, pp.1-10,1998.
11. Somnath Chattopadhyay, Overview of pressure vessels, Pressure vessels design and practice, pp.1-14, 2004.
12. Dennis R. Moss, Pressure vessel design manual, Gulf Professional Publishing, ELSEVIER, 3rd ed , pp.14-45, 2004.
13. Shaik Abdul Lathuef, K.Chandra Sekhar, Design And Structural Analysis Of Pressure Vessel Due To Change Of Nozzle Location And Shell Thickness, IJAERS,Vol. I, Issue II, pp. 218-221, 2012.
14. N.A. Weil, J.J. Murphy The M. W. Kellog Company New York N Y ASME m m r, "D s n n Analysis of Welded Pr ssur V ss l Sk rt Support", ASME Journ l o En n r n for Industry Feb 1960.
15. M. Pradeep Kumar, K. Vanisree, Design And Implementation Of Circular Cross Sectional Pressure Vessel Using Pro-E And ANSYS, IJMER, Vol. 3, Issue. 4, pp.2350-2355, 2013.
16. V.N. Skopinsky, A.B. Smetankin, Modeling And Stress Analysis Of Nozzle Connections In Ellipsoidal Heads Of Pressure Vessels Under External Loading, Int. J.of Applied Mechanics and Engineering, vol. 11, issue. 4, pp. 965-979. 2006