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Finite Element Analysis on Mounded LPG Bullets

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Abstract - *The storage is highly inflammable, toxic and pressurized gases such as LPG is of prime importance in petrochemical industry. In recent years, many owners demand the design of mounded underground bullets instead of conventional LPG storage above ground in cylindrical or spherical tanks. Increased safety concerns for above ground storage requirements require a large spacing between tanks. In addition fire protection system and fire proofing become more complex and expensive .for the above-mentioned safety and economic reasons mounded storage has become preferred storage method for a significant number of systems .the designs are performed using guidelines specified in well accepted codes. Considering the safety concerns, the code based designs are further verified using finite element analysis. The present work performs finite element analysis of mounded bullets using general purpose finite element software. The mounded bullets are several hundred meters in length, several meters in diameter and are subjected to approximately 15 times atmospheric pressure. The bullets are stiffened using tee sections in the circumferential direction. In additional to the internal pressure of the vessel, loads due to mound pressure, weight of the vessel, weight of the fluid and uneven displacement/settlement of the sand bed have been considered. The stresses are classified according to codes and are presented in graphical and tabular form. The deformation plots are also provided.*

Keywords *– ANSYS, Mound, Stiffner, LPG Bullets, Shell, APDL*

I. INTRODUCTION

The storage of highly inflammable, toxic and pressurized gases such as LPG is of prime challenging task and there is a need to design storage facilities for such gases with safety of the persons in and around, the locations, where it is situated. The safety is of prime importance, because it not only leads to the loss to the industry but also to the lives of the people. In the present work an attempt is made to design a mounded bullet with a huge capacity of hundreds of cubic meters of LPG at a pressure of several MPa. The MOUNDED BULLET which is nothing but a pressure vessel, being buried underground, the chances of explosion and consequent throwel of debris is almost nullified. The vessel has been designed considering various parameters such as internal pressure, hydro test pressure etc., based on ASME codes. For the required quantity of gas to be stored, the length and diameter of the MOUNDED BULLET have been chosen according to the codes.

The storage of dangerous gases became a challenging problem, which posed a question mark on safety of surroundings, as well as to the lives of the people. The accident that occurred in 1984, which cause disaster in Mexico City depot, is an unforgettable and unrecoverable accident, where 16000 m^3 of LPG was stored in 6 spheres and 48 horizontal vessels. A leak occurred in 8” fill line to one of the spheres and within in 15 minutes of leakage, a series of BLEVES occurred producing a fire ball of 350m diameter which engulfed all the remaining spheres and horizontal vessels whose debris flew up to 1200m distance killing 500 people and injuring 7000 people. A good majority of the people were within 300m of the depot. A similar accident has occurred in HINDUSTAN PETROLUM CORRORATION LIMITED, VISAKHAPATNAM, where nearly 30 lives were lost. The main cause of this accident was found to be the leakage occurred in the fill line. Due to this leakage a fire accident occurred to a sphere thus spreading to all other spheres It appears that the main causes of these accidents is due to the unavailability of proper storage facilities and also close spacing of the spheres and horizontal vessels. It appears that the main causes of these accidents is due to the unavailability of proper storage facilities and also close spacing of the spheres and horizontal vessels.

LPG bullets Volumes are from 500 cubic meter to 20000 cubic meter Total Storage, as well as Refrigerated mounded for propane storage. The LPG Mounded Bullets are designed as per ASME Sec. VIII Div.1, ASME Sec. VIII Div.2 and BS 5500 codes. .These tanks become extremely cool in the lower half during conversion of liquid to vapor of petroleum gas due to endothermic reaction. When moisture in the air comes in contact with this surface, gets converted to water droplets and gets condensed over the tank surface. This causes heavy rusting of the surface. This is costing us heavily and increasing the energy bills. There is heat leakage from the shell or joints of vaporizers.

These are extensively used in different industries for various applications. To ensure eminence and flawlessness, these are thoroughly tested on various industry parameters.

II. ANALYSIS OF THE STIFFENED CYLINDRICAL SHELL WITH HEMISPHERICAL ENDS

2.1. Coordinate system

The x-axis is taken as the axial direction of the vessel. The leftmost Centre of the hemispherical head is considered as the origin of the coordinate system. The z-axis is the vertically upward direction.

2.2. Finite Element Modeling

A standard commercial finite element software ANSYS is used for analysis. The pressure vessel is modeled using 4 node shell elements (SHELL63). The dome, man-way and the nozzle are modeled using both SHELL63 and SHELL93 elements. These elements have both membrane and bending capabilities. At each node both of the elements have three translation and three rotation degrees of freedom. SHELL63 is a four node element while SHELL93 has eight nodes. The SHELL63 element allows specification of elastic foundation stiffness (EFS) in its set of real constants. The stiffeners are modeled using three-dimensional beam elements (BEAM4) with third point specification for appropriate orientation of area moment of inertia. The geometric model and the finite element mesh are shown in Figure 2.1 and Figure 2.2 respectively. Figure 2.3 shows the different regions with different thickness and elastic foundation stiffness. For a tee-section the distance of the extreme end of the web is more from the centroid than that of the flange. The bending stress at the end of the web will be more than that in the flange. The tee-section is shown in Figure 2.4. Only half of the pressure vessel is analyzed using symmetry boundary conditions. The displacement along the y-axis in the x-z plane is prevented.

The value of the sub grade modulus stiffness is obtained by placing the shell over a distributed stiffness. This distributed elastic foundation stiffness (EFS) extends symmetrically over an angle of 120 degrees at the bottom of the shell along with the hemispherical heads (Figure 2.5). The value of the EFS is changed until a differential settlement of 40 mm is obtained. A value of 3000 KN/m^3 is taken as the value of the elastic foundation stiffness. The middle soft and middle hard conditions are obtained by appropriate change in EFS along the length of the vessel. In both middle soft and middle hard boundary conditions the soil pressure is automatically applied to the vessel as reaction force from the foundation stiffness.

In the finite element analysis corroded dimensions are considered. All the dimensions are shown in Table 2.1.

Table 2.1 Correction in shell thickness due to corrosion

	Actual Dimension(mm)	Corroded dimension considered in FEA (mm)
Shell Plate	t_{SP}	$t_{SP} - 3$
Dish end	t_{DE}	$t_{DE} - 3$
Dome 1	t_{DM1}	$t_{DM1} - 3$
Dome 2	t_{DM2}	$t_{DM2} - 3$
Man way	t_{MY}	$t_{MY} - 3$
Stiffener flange length	l_f	$l_f - 6$
Stiffener flange thickness	t_f	$t_f - 6$
Stiffener web thickness	t_w	$t_w - 6$

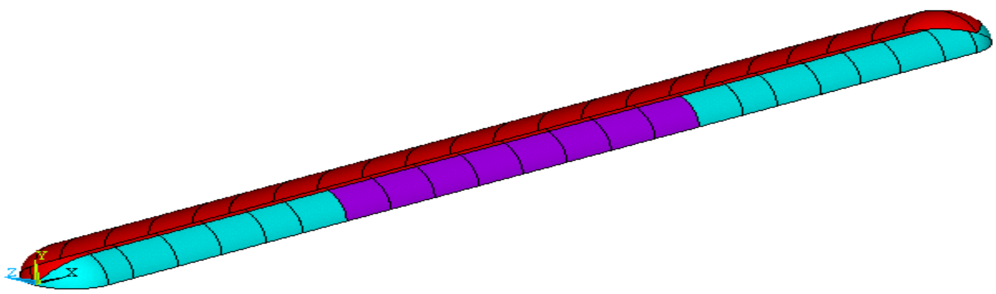

Fig.2.1. Geometric model of shell with stiffener

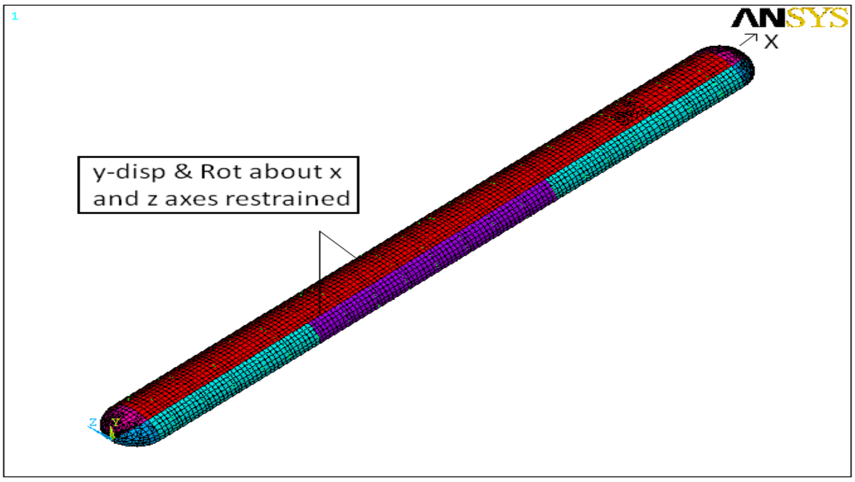

Fig.2.2. Finite element mesh

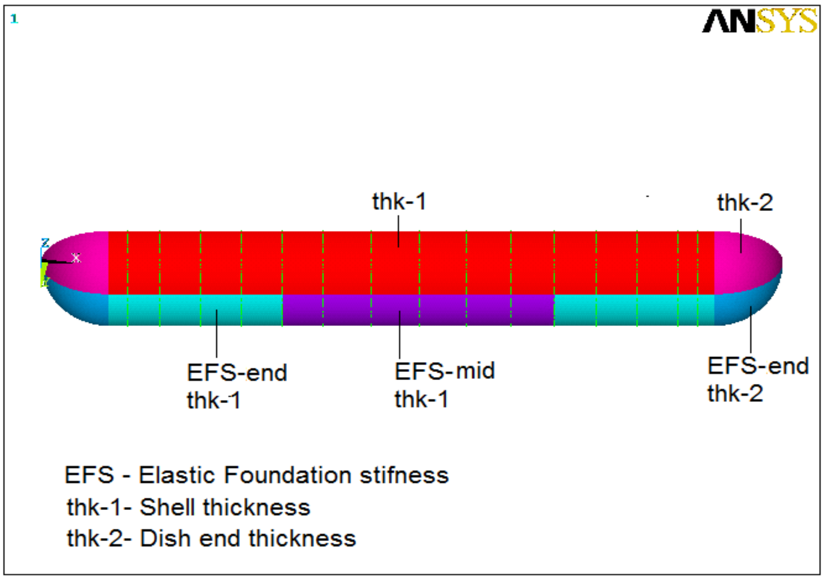

Fig.2.3. Thickness and elastic foundation stiffness used in different regions.

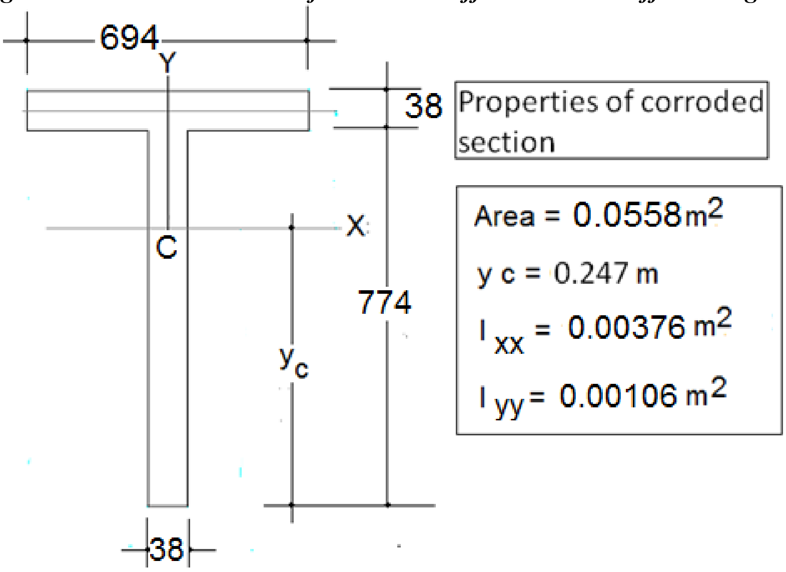

Fig.2.4. The cross-section of the stiffener

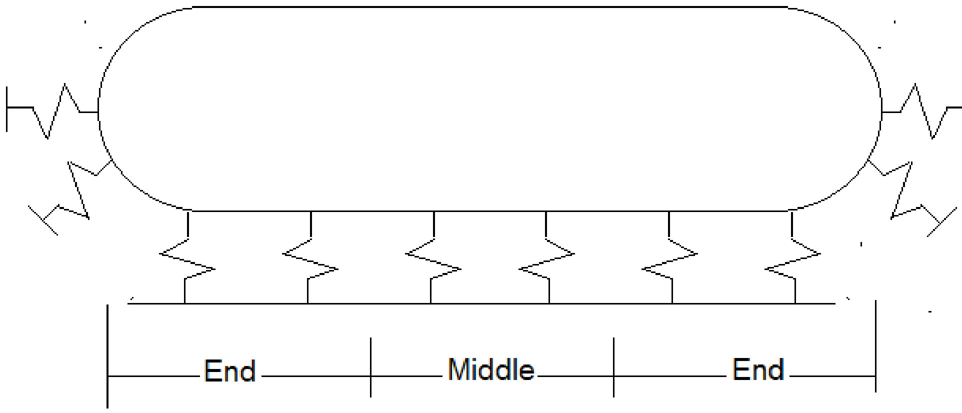

Fig.2.5. Vessel on elastic foundation

2.3. Loads

2.3.1. Self-Weight

The self-weight of the vessel with stiffeners is modeled by applying acceleration to it. Self-weight is considered in all the load cases in the analysis. This acceleration equals the value of acceleration due to gravity (g).

2.3.2. Liquid Pressure

A fully filled vessel is considered. Pressure of liquid at the topmost point of the vessel is zero. The pressure linearly increases with the depth. The maximum pressure occurs at the bottommost point of the vessel. The liquid pressure can be expressed as follows:-

$$P_l = \gamma\,(R-z) \qquad (2.1)$$

2.3.3. Mound Weight and Pressure

The mound weight on a vessel is calculated as per EEMUA 190, section A.4.2.5 (EEMUA Publication 190:2000+amendment: 2004 Guide for the design, construction, and use of mounded horizontal cylindrical steel vessels for pressurized storage of LPG at ambient temperatures (Figure 2.6). The maximum pressure at the top of the vessel is computed from the following relation. The pressure varies as a cosine function. The depth of the topmost point of the vessel is constant along the cylindrical part of the vessel. However, this depth increases at the hemispherical head. At the junction of the vessel with its hemispherical head the pressure is computed as described above. The pressure then increases linearly with the depth of the hemispherical head.

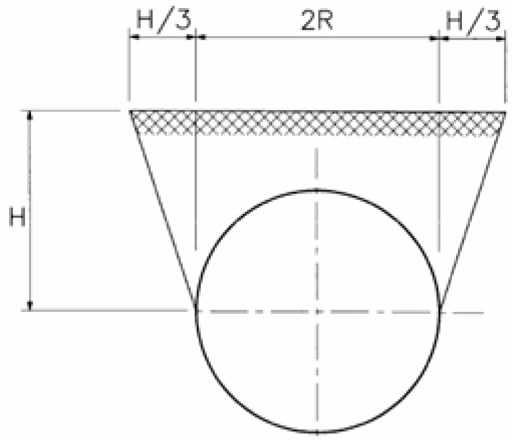

Fig.2.6. weight of mound on the vessel

The distribution of pressure from the mound is such that the pressure (q_0) is maximum at the top of the vessel and then it decreases as a cosine function. The pressure at any angle ψ is

$$q = q_0 \cos\psi \qquad (2.2)$$

The total load on the cylinder is the weight of the mound as specified in A.4.2.5 of EEMUA 190. This load is balanced by the pressure distribution on the vessel.

$$Q_5 = \int_{-\frac{\Pi}{2}}^{\frac{\Pi}{2}} qRL\; d\psi\; \cos\psi = \int_{-\frac{\Pi}{2}}^{\frac{\Pi}{2}} q_0 RL\; d\psi\; \cos^2\psi = \frac{q_0 RL\Pi}{2}$$

Therefore the maximum force is

$$q_0 = \frac{2Q_5}{\Pi RL} \qquad (2.3)$$

A maximum pressure of 90 kN/m^2 is considered in this work.

Table 2.2. Different load cases and their description

Load case number	Description of load cases
1.1	Middle soft Erection condition (Hydro) Filled with water at Test Pressure + Liquid Head , Test Temperature (Corroded)
1.2	Middle soft Hydro Test Filled with Water with Hydro Test Pressure ,Test temperature + Liquid Head and Weight of Mound, Live Load (corroded)
1.3	Middle soft Service [Filled with fluid with Design Internal Pressure + Liquid Head, Design Temperature + Weight of Mound+ Live Load and Seismic Loads(Earthquake)]
1.4	Middle soft Vacuum
2.1	Middle hard Erection condition(Hydro) [Filled with Hydro with Design Test Pressure ,Test temperature + Liquid Head, Test Temperature]
2.2	Middle hard Hydro Test Filled with Water with Hydro Test Pressure + Liquid Head and Weight of Mound, Live Load(corroded)
2.3	Middle hard Service [Filled with LPG with Design Internal Pressure + Liquid Head, Design Temperature + Weight of Mound+ Live Load and Seismic Loads(Earthquake)] + Vacuum
2.4	Middle hard Vacuum
2.5	Dome 1, Dome 2, Man way, Nozzle

III. CONCLUSION

By studying nos. of research paper I concluded that work done for design and analysis for underground LPG storage pressure vessel is been very less. Radoslav Stefanovic[4] had done work for supporting the bullet tank underground with multiple saddle supporting. K.Yogesh, M.S.R. Lakshmi [5] has carried out design and analysis of LPG storage bullet tank in October 2012. They had designed bullet tank using ASME VIII div-1 and checked design by finite element analysis software (ANSYS). They got safe results. The finite element analysis for different configurations of pressure vessel on saddle supports has been done using ANSYS. The stress intensities in various cases were analyzed and the optimal location when the saddles are placed away from heads is considered as the most suitable design for the large horizontal vessels. The effect of stiffening is also considered in three cases. The reduction in stress intensity is found for one of the cases. For this the optimization of thickness was done which resulted huge reduction of weight.

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In additional to the internal pressure of the vessel, mound load, earthquake load, uneven displacement/settlement of the sand bed, weight of the vessel, test conditions have been considered for the analysis.

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