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Numerical Analysis of Liquid Storage Tank Subjected to Dynamic Loading

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Abstract – *Liquid storage tanks are used to store water, liquid petroleum, petroleum products and other similar liquids. Most of the storage tanks are designed and built to the American Petroleum Institute API-650 specification. Different types of environmental regularities are considered to the design and operation of storage tanks. All tanks are must be designed as crack free structures to eliminate leakage problems. This paper mainly focuses on numerical analysis of liquid storage tank subjected to dynamic loading. The maximum stress due to various loading conditions was analyzed by using ABAQUS software. The optimization study of shell was also studied to reduce the maximum stress due to blasting.*

Key Words: API 650, Dynamic loading, ABAQUS, optimization, blasting.

1. INTRODUCTION

Storage tanks are the important structures. For storing petroleum, chemicals and other hazardous materials, above ground storage tank can be used. Storage tanks are available in many shapes, but large tanks are generally cylinder that has rounded corners which is easier to withstand hydrostatically induced pressure of the liquid. Petroleum liquids have explosive in nature and cause hazardous problems. Therefore the analysis of petroleum storage tank is very important. In this paper, the numerical analysis of liquid storage tank subjected to dynamic loading as per American Petroleum Institute (API) 650 was considered and the stress of tank due to internal pressure, wind and blasting was analyzed. The tank was optimized under the blast load by varying shell thickness.

2. DESIGN OF STORAGE TANK

A model of liquid storage tank was designed based on API Standard 650. The shell thickness of tank was designed by using 1-Foot method as per API 650. The designed tank was used for different analysis.

Tank inside diameter, D : 17500 mm
Shell height, H : 20000 mm
Design specific gravity, G : 1.06
Design material : ASTM A516 Gr.60
Design internal pressure, P_i : 1.470 kPa
Design external pressure, P_e : 0.5 kPa
Thickness of roof plate : 8 mm
Provided thickness of bottom plate: 10 mm
Allowable stress for design, S_d : 147 MPa
Shell course height : 2500 mm
Shell thickness was calculated based on 1-Foot method
Shell thickness obtained as per API 650 was 16,14,12,10 and 9mm from bottom to top respectively.

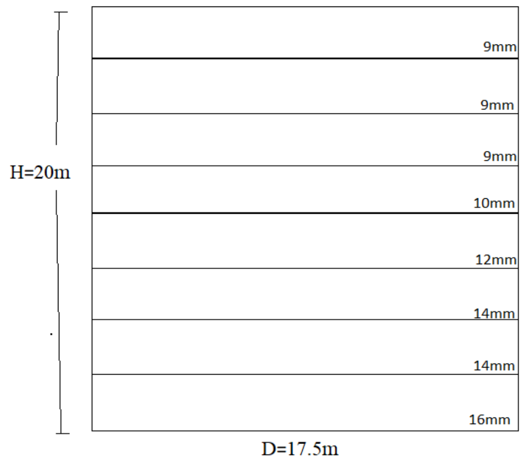

Fig -1: Schematic representation of tank shell alignment

3. NUMERICAL ANALYSIS

The designed model of tank with a liquid density of 800 kg/m³ was used for all the analysis. The model was analyzed using ABAQUS software.

3.1 Internal Pressure Analysis

Stress due to internal pressure was analyzed by using ABAQUS software. The designed model of tank as per API 650 was used for the analysis. The liquid of density 800 kg/m³ was used and the pressure was applied on the inner surface of shell.

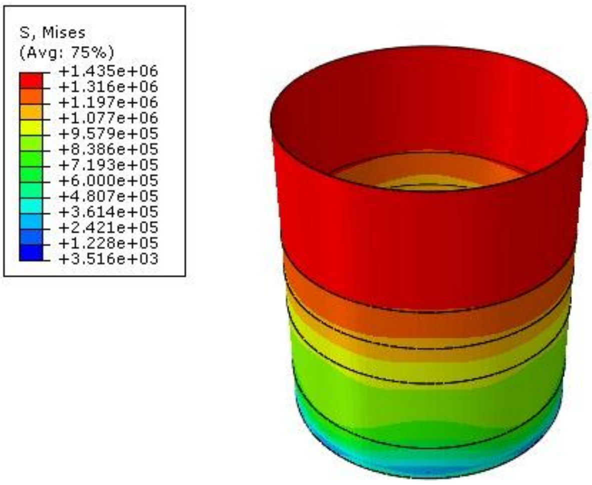

Fig -2: Stress due to internal pressure

Table -1: Maximum stress values of shell due to internal pressure

Shell course size (mm)	Maximum stress (Pa)
16	6.4×10^5
14	7.94×10^5
12	9.87×10^5
10	13.8×10^5
9	14.2×10^5

From the internal pressure analysis of tank, a maximum value of stress is found to be 14.2×10^5 Pa for a 9mm thick shell course.

3.2 Wind Analysis

Stress due to wind pressure was analyzed. Wind pressure was applied on the outer surface of the whole body. The designed model of tank as per API 650 was used for the analysis and the density of the liquid is 800 kg/m³. The wind design was done as per IS 875 Part-3-2015. Basic design parameters are:

Basic design wind speed, V : 52 m/s
Category : III
Modified wind pressure for roof (uplift), P_w: 2.740 kPa
Wind uplift pr on roof, P_{wr} : 3.289 kPa (as per design)

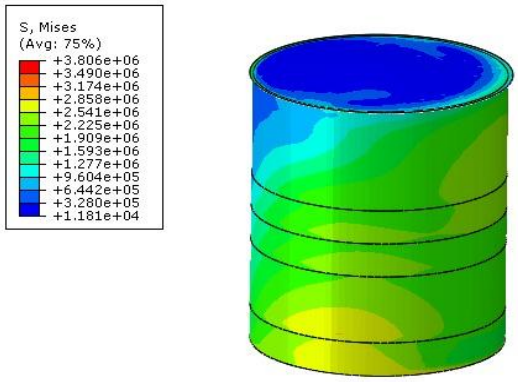

Fig -3: Stress due to wind pressure

Table -2: Maximum stress values of shell due to wind pressure

Shell course size (mm)	Maximum stress (Pa)
16	2.68×10^6
14	2.12×10^6
12	2.01×10^6
10	1.92×10^6
9	1.28×10^6

From the analysis of wind pressure, it was found that the maximum stress is 2.68×10^6 Pa for a 16 mm thick shell.

3.3 Blast Analysis

Stress due to blast load is to be analyzed. 75 kg of Trinitrotoluene (TNT) was used for the blasting at a distance 1m from the tank and blasting was carried out in ground level. The impulsive time duration of blast wave is 0.8 ms and the reflected blast pressure is 17 MPa.[5]

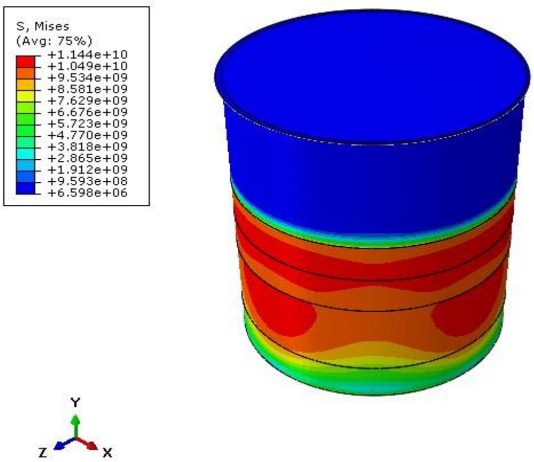

Fig -4: Stress due to blasting

Table-3: Maximum stress values of shell due to blasting

Shell course size (mm)	Maximum stress (Pa)
16	4.68×10^9
14	1.08×10^{10}
12	1.05×10^{10}
10	1.03×10^{10}
9	9.98×10^9

From the blast analysis of tank shell, the maximum stress value was obtained is 1.08×10^{10} Pa on the shell course of thickness 14 mm.

3.4 Optimization of Shell Based on Blast Loading

The optimization of shell was done by increasing the shell thickness. The different thicknesses were analyzed and the suitable thickness was selected for the optimization. The 10mm additional thickness was provided for the optimization.

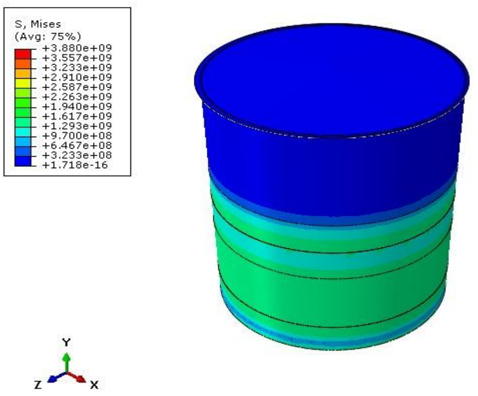

Fig -5: Stress value of optimized shell

Table -4: Percentage reduction of stress in optimized shell

Shell course size (mm)	Maximum stress (Pa)	Percentage reduction of stress (%)
16	1.24×10^9	73.5
14	2.14×10^9	80.2
12	1.32×10^9	87.4
10	1.28×10^9	87.6
9	2.86×10^8	97.1

4. CONCLUSIONS

A petroleum storage tank was designed as per API 650 and different loading conditions were analyzed using ABAQUS. The maximum stress obtained from the internal pressure and wind pressure were minimum compared with allowable stress of the material. Hence provided shell thickness was safe. In the blast analysis of shell, the values of maximum stress exceed the allowable stress and the shell deformation is also increases. For that, an additional thickness of 10 mm was provided throughout the height. The maximum stress at 14mm thick shell decreased from 1.08×10^{10} Pa to 2.14×10^9 Pa, it will shows 80.2% of percentage reduction in maximum stress. Overall the blasting effect is very important, when a tank shell is designed as per API 650.

5. SCOPE FOR FUTURE WORK

The designed storage tank can be analyzed with different materials and different loading conditions. It can be further analyzed for optimization with respect to baffle walls.

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