The Finite Element Strength Calculation of 70T Concentrated Nitric Acid Tank

Song Cang

Guidaojiaotong Polytechnic Institute, Shenyang 110023, China

Keywords: Concentrated nitric acid tank; finite element analysis; strength;

Abstract. In this paper, the static load of 70t aluminum railway tank is calculated by the calculation of the FEM in different working conditions. It describes the selection of allowable stress about Aluminum material 1050A which used in stress analysis intensity calculation of Aluminum railway tank. The results will be helpful for the structure design of the tank structure.

1. Introduction

To satisfy the demands of railway freight overloading, the optimization design of the 70T concentrated nitric acid tank is developed which can meet the need of the nitric acid transportation in the chemical fertilizer enterprises. The nitric acid medium is a kind of media with highly corrosive, the aluminum tank truck with good corrosion-resistance characteristic for transportation is the best choice.70T concentrated nitric acid tank has larger capacity , because of this, we calculate and analyze its structural strength to ensure the stress can meet the requirements or not in different conditions.

2. The finite element model of tank truck

Using 5083 aluminum magnesium alloy production, the saddle support of tanks to add 5 mm thick steel 1200 mm wide,, preloaded pressure is 0.038 MPa to 0.058 MPa.

Table 1 The main technical parameters of tank

length	inner diameter	wall thickness	End wall thickness	dead load	volume	Evaporation gas pressure
11400mm	2400mm	24mm	24mm	10.4t	48.3m³	0.038MPa

Take the whole tank as an object when calculating, using finite element analysis software Ansys divided the vehicle body into discrete structure, made up of 73924 units and 29602 nodes, finite element discrete model of tank as shown in figure 1. Calculated with Ansys.

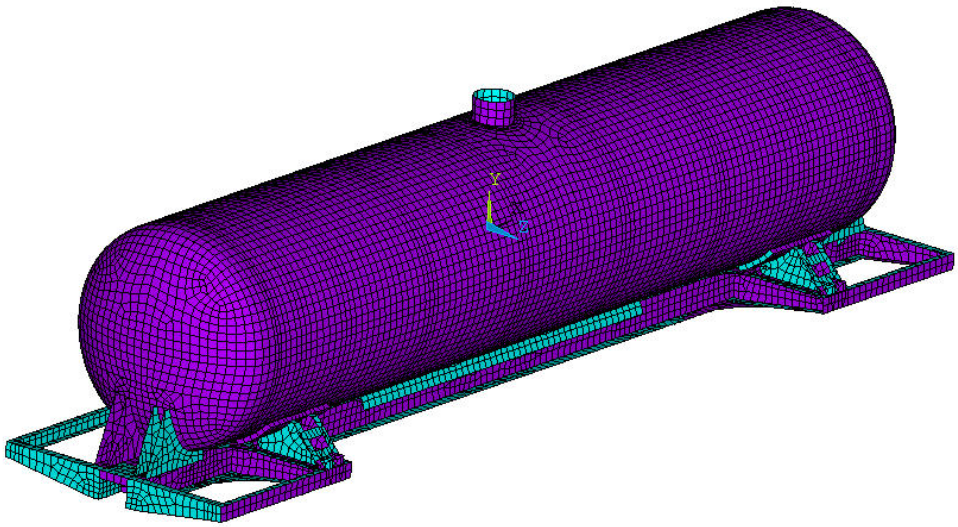

Fig.1 Tank truck body finite element model

3. Load calculation and evaluation standard

The allowable stress of material under various operating conditions in the following table:

Table 2 The allowable stress of material

Material	Yield limit	The first working condition	The second working condition	Tanker up working condition
Q235	235	161	212	235
Q345	345	216	293	345
Q450	450	281	380	450
1050A	35	17	31.3	35
5083	125	68	83	125

There is the vertical static load, dynamic load, longitudinal force and their combined effects on the tank truck. Load calculation is as follows:

Vertical load

Vertical static loading(P_j): According to the data that provided by the factory, using top-down method for calculating the sum of weight and load of truck body.

P_j=(Vehicle capacity ＋ Light weight － Bogie weight×2)×9800

=(68＋25.8-4.8×2)×9800=8.2516×10^5 N

The vertical dynamic load coefficient: $K_d = \frac{1}{f_j}(a+bv)+\frac{dc}{\sqrt{f_j}}$

$f_j = 42.6mm$， $v = 120km/h$

$a = 1.5, b = 0.05, c = 0.427, d = 1.65$

So, $K_d = \frac{1}{42.6}(1.5+0.05\times120)+\frac{1.65\times0.427}{\sqrt{42.6}} = 0.17605+0.10795 = 0.284$

Total normal load: P_d= P_j ×(1 ＋K_d)

P_d=8. 2516×(1+0.284)×10^5 =10.595×10^5 N

Thrust load:
The first working condition of vertical load is:
（1）Tensile load:1780kN
（2）Compressive load:1920kN
The second condition of vertical load is: Tensile load:2500kN
Lateral force: The lateral force that trucks under vertical load is increased by equivalent; the figure was 10% of the vertical static load.
Torsion load: The truck body that adopting the center plate supporting wheel structure, need to consider the torsion load of 40kN.m in the first condition of torsion load.

4. The calculation of load cases

The calculation load is divided into two kinds of load conditions. First condition refers to the longitudinal tensile and compressive load along the center line of the coupling effect on the way from the bracket at the ends of the vehicle, the second condition refers to the longitudinal compressive force 2500kN along the direction of the center line of the coupling effect on rear draft lug.
The first working condition: Total vertical load + Longitudinal tensile loa + Torsion load＋Lateral force
Total vertical load on the tanks and chassis, 1780kN longitudinal tensile loa is along the direction of the center line of the coupling effect on front draft lug.

The density of nitric acid $1.5\times10^{3}kg/m^{3}$， Vertical static pressure caused by the weight of the liquid:

$$P_{\text{hydrostatic pressure}}=\rho gh=1.5\times10^{3}\times9.8\times2.4=0.0353MPa$$

$$P_{\text{total vertical static pressure}}=0.038+0.035\times1.284=0.083MPa$$

The second working condition: Vertical static loading＋2500kN Axial compressive load
2500kN longitudinal compressive force is along the direction of the center line of the coupling effect on back draft lug:

$$P_{\text{normal load}}=0.038+0.035=0.073MPa$$

Tanker up condition: Tanks loaded with dielectric, the density of nitric acid is 1.5 x 103 kg/m3, and the influence of the weight of tanks. Finite element model is similar to the above, just change the center plate center vertical displacement constraints to lateral beam top parking vertical displacement constraints.
Vertical static pressure caused by the liquid weight is:

$$P_{\text{vertical static pressure}}=0.038+0.035=0.073MPa$$

5. The calculation results

The first working condition: The biggest stress appears on the web of draft sill, the place of front draft lug, the stress is 178 MPa, as shown in figure 2. Does not exceed the material allowable stress at the first condition (281MPa).

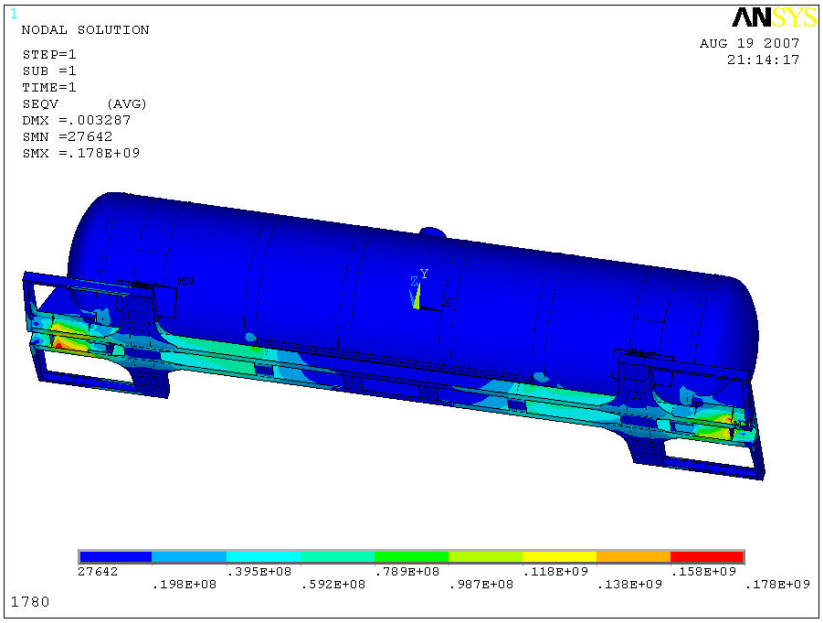

Fig.2 Stress nephogram of truck body under the first working condition

The second working condition: The biggest stress appears on the web of draft sill, the place of back draft lug, the stress is 203MPa, As shown in figure 3. Does not exceed the material allowable stress at the second condition (380MPa). As shown in figure 3.

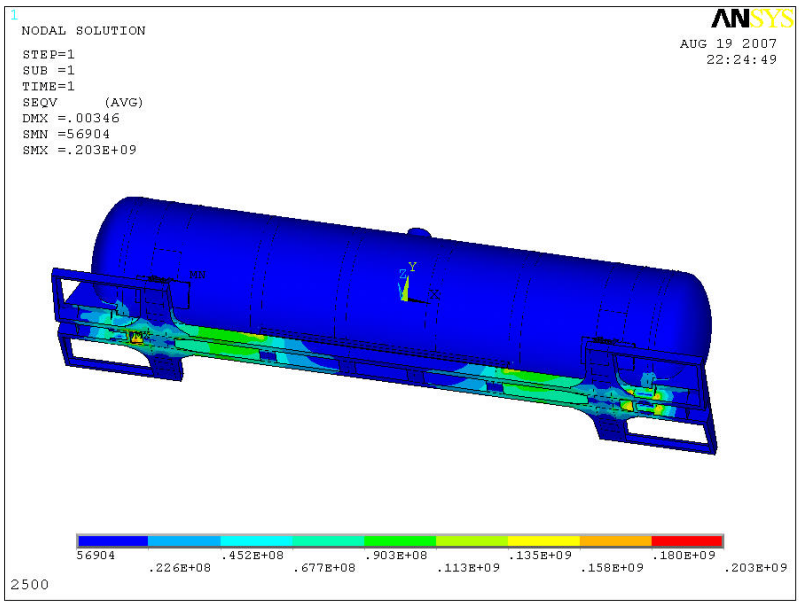

Fig.3 Stress nephogram of truck body under the second working condition

6. Summary

According to the analysis of the finite element calculation, the following conclusions are drawn: the tanks and truck body can both meet the strength requirements under different load conditions.

References

[1] WANG Da-hong, YU Ming, ZHANG Fu-dong, Optimization Design of the Aluminum Tanker of 23 t Axle Load for Concentrated Nitric Acid, J. RAILWAY LOC0M0TIVE& CAR Oct(2012) 18-21