Strength Analysis and Optimization of Tank Truck Based on ANSYS

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Abstract. With the vigorous development of the oil industry, the number of tank trucks has increased significantly in recent years. Accidents such as explosion and leakage of oil tank truck during transportation are common. Therefore, it is particularly important to study the stress analysis, strength optimization and safety reliability of oil tank truck. This paper establishes the three-dimensional parametric model of the tank car by the solid works software and changes the thickness and height of the wave preventer, and analyze the influence of the thickness and height of the wave preventer on the tank car under the starting and braking conditions by the ANSYS software. The deformation diagram, strain nephogram and stress nephogram under different working conditions were compared and analyzed to optimize the dimension parameters of the wave preventer. The results show that the optimal thickness and height of the wave preventer are 10-15mm and 990-110mm. It can not only meet the oil transportation safety of tank truck, but also save the manufacturing cost, which provides important reference value for the design of tank truck.

Keywords. Tank truck; wave preventer; ANSYS; optimization.

1. Introduction
With the rapid development of China’s economy, China’s demand for crude oil has been growing. By 2020, China’s demand for crude oil will be close to 20 billion tons. Oil transportation accounts for 50% of the world’s crude oil transportation. Oil tank truck is one of the most important transportation modes in China [1-3]. In recent years, accidents such as explosion, fire and leakage caused by the impact of oil tank truck in the transportation process are common, and the safety of oil tank truck has been paid more and more attention by relevant departments [4-6]. Therefore, it is particularly important to study the stress analysis, strength optimization and safety reliability of oil tank truck.

2. Main Research Contents
2.1. Main Structure and Material Selection
In this paper, the common semi-trailer tank car as the research object, its structure mainly includes tank, frame, traction device, supporting device, electrical system, walking system, protective device, accessories and so on [7-8]. The shape of the tank is mostly oval or round, and the inside is equipped with a wave board. The function of the wave board is to reduce the sloshing and influence of the liquid in the tank and improve the driving stability. When the viscosity of the medium in the tank is relatively low and the liquid volume is between 20% and 80%, the anti wave preventer must be set inside the tank [9-10]. The tank body of oil tanker can be made of carbon steel,
stainless steel and aluminum alloy. Carbon steel has the best economy but is not resistant to corrosion; Stainless steel is corrosion resistant but expensive; Aluminum alloy has good corrosion resistance, pressure processing, and casting processing performance, its light weight, high strength is recognized by the automotive industry. To sum up, 5083 aluminum alloy is the material selected for the shell and anti wave preventer of semitrailer tank truck, and its material characteristics are shown in table 1.

**Table 1.** Material properties of 5083 aluminum alloy.

| Property       | Value           |
|----------------|-----------------|
| Elasticity     | $7.0 \times 10^4$MPa |
| Poisson ratio  | 0.33            |
| Yield limit    | 125MPa          |
| Tensile strength | 275MPa      |
| Density        | $2.68 \times 10^{-3}$g/mm$^3$ |

2.2. **Building Models**

According to the size of the tank truck, establish the three-dimensional model of the tank body and the wave preventer by solid works software, as shown in figures 1 and 2.

**Figure 1.** Three dimensional model of tank truck.

**Figure 2.** Three dimensional model of wave preventer.

Assemble the wave preventer and the tank body, and the three-dimensional half section is shown in figure 3.

**Figure 3.** Semi sectional three dimensional drawing of semitrailer tanker.

2.3. **Force Analysis**

In the actual work, the stress of each part of the tank truck is different under different driving conditions, so the stress will be different. In this analysis, the limit working condition is considered, and the full load of oil tank truck is calculated. Because the driving conditions are very complex, in order to more
comprehensively analyze the stress of the oil tank truck in various working environments, two working conditions of starting and braking of the oil tank truck at constant speed are selected for the finite element analysis of the strength of the anti wave preventer.

According to the relevant requirements of GB 18564.1-2006 road transport liquid dangerous goods tank vehicle, the load applied to the tank vehicle in this paper is shown in tables 2 and 3.

### Table 2. Load on the tank during working.

| Force of oil on tank | 294.11KN |
|----------------------|-----------|
| lateral force        | 540KPa    |
| Longitudinal force   | 1200KN    |
| Longitudinal tensile force | 1200KN |
| Compression force    | 1500KN    |
| Design temperature   | 50℃       |

### Table 3. Load on the tank during braking.

| Initial speed | 75Km/h |
|---------------|--------|
| Acceleration  | ax=5m/s|
| Inertia force | F=max=297.3KN |
| Lateral force | 540KPa |
| Longitudinal force | 1200KN |
| Longitudinal tensile force | 1200KN |
| Compression force | 1500KN |
| Design temperature | 50℃ |

Through the finite element analysis, the overall deformation diagram, strain diagram and stress diagram of the wave preventer with thickness of 5mm and height of 970mm can be obtained, as shown in figure 4.

![Deformation](image1)
![Strain diagram](image2)
![Stress diagram](image3)

**Figure 4.** Result of thick 5 mm and high 970 mm wave preventer.

The height of the breakwater plate is fixed at 970 mm, and the thickness is 10 mm, 15 mm, 20 mm...
and 25 mm respectively.

2.4. Result Analysis

Summarize the ANSYS analysis data to table 4, and draw the comparison diagram of the maximum stress value when the thickness of the increasing wave preventer starts to brake, as shown in figure 5.

Table 4. The maximum stress of the wave preventer with 970 mm height and increasing thickness in turn.

| Thickness | Working condition | Braking condition |
|-----------|------------------|------------------|
| 5mm       | 9.8626×10^5      | 9.4707×10^5      |
| 10mm      | 6.1641×10^5      | 8.2188×10^5      |
| 15mm      | 5.9189×10^5      | 5.9189×10^5      |
| 20mm      | 4.1094×10^5      | 3.9459×10^5      |
| 25mm      | 2.0547×10^5      | 1.9732×10^5      |

![Comparison diagram of maximum stress value when working condition and braking condition of wave break plate with increasing thickness.](image)

It can be seen from the figure that when the height of the baffle plate is fixed at 970 mm, the thicker the thickness of the baffle plate is, the smaller the stress value is under the starting and braking conditions; Under the working condition, the thickness of 10-15mm wave preventer has the least influence on the stress; When the minimum thickness of the baffle is 5 mm and greater than 15 mm, the maximum stress of the baffle is the same under the starting and braking conditions. In conclusion, from the point of view of reducing the material thickness and strength, the 10 mm thick wave board is the best.

Similarly, the thickness of the wave break plate is fixed at 5mm, and the heights are 970 mm, 990 mm, 1100 mm, 1130 mm and 1150 mm respectively. The results are analyzed and drawn into the comparison diagram of the maximum stress value when the wave break plate with increasing height starts braking, as shown in figure 6.

![Comparison of the maximum stress value of the wave break plate with increasing height when starting and braking.](image)
It can be seen from the figure that when the thickness of the breakwater plate is fixed at 5 mm, the higher the breakwater plate height is, the smaller the stress value is under the starting and braking conditions; As a whole, the change of the height of the breakwater has little effect on the stress reduction. When the height of the breakwater is 990-1100mm, the change of the height has the greatest effect on the stress; when the minimum height of the baffle is 970 mm and is greater than 1100 mm, the maximum stress of the baffle is the same under starting and braking conditions. To sum up, from the angle of reducing material thickness and strength, 990 mm high wave preventer is the best.

3. Conclusion
In this paper, ANSYS software is used to simulate and analyze the different thickness and height of the breakwater. Through stress analysis and result comparison, it is found that the maximum stress appears at the top of the breakwater, and with the increase of height and thickness, the maximum stress gradually decreases, but the position of the maximum stress does not change, and the top stress is always the largest. From the point of view of reducing the thickness and strength of the material, the 10 mm and 990 mm high wave preventer are the best.

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