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Analysis and Improvement of Stress Concentration in Composite Structure Tank Roof

Jingwen Ren*, Bo Liu, Yubin Lv, Chengcai Ge, Xuhui Chen

College of Mechanical and Electrical Engineering, China University of Petroleum (East China), Qingdao, Shandong, China.

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***Corresponding author:** Jingwen Ren, College of Mechanical and Electrical Engineering, China University of Petroleum (East China), Qingdao, Shandong, China.

Abstract

At present, the method of adding reinforcing bars is usually used to improve the poor stability of composite structure tank roof. However, the addition of reinforcement leads to serious stress concentration in the tank top, which seriously affects the service life and safety of the tank top. Therefore, in this paper, the finite element analysis method is used to analyze the stress and strain of the roof of the composite structure with reinforcement under the two conditions of combined load and internal pressure. The stress curves of different positions of reinforcement are output and the stress concentration area is found out. The structure of reinforcement is optimized according to the stress concentration area. The results show that the stress concentration problem of the tank top with reinforcement mainly exists at the lower edge of the reinforcement. Properly extending the reinforcement length can effectively improve the degree of stress concentration, and the maximum stress in the stress concentration area can be reduced by more than 60%. The results can provide guidance for the design and optimization of composite structure tank roof.

Keywords

Composite structure tank roof, Glass fiber, Stress concentration, stiffener

1. Introduction

The roof of large petrochemical composite structure storage tank has the advantages of corrosion resistance, light weight and strong thermal insulation performance. Structural instability is one of the main forms of tank roof failure. In order to ensure the high stability of the composite structure tank roof, it is the most economical and effective method to increase the reinforcement. However, many tank tops with reinforcement have serious stress concentration problems, which will lead to fatigue failure or corrosion perforation of tank tops more easily. Therefore, it is urgent to optimize the structure of tank tops with reinforcement to reduce the negative impact of stress concentration [1, 2].

2. Establishment of composite structure tank roof model

The top diameter of the composite structure tank is 11m and the dip Angle is 15°. Tank top reinforcing bars are divided into main reinforcing bars and auxiliary reinforcing bars, of which the number of main reinforcing bars is 12, and the number of auxiliary reinforcing bars is 12. The main stiffener is staggered with the secondary stiffener. The main and auxiliary reinforcing bars are fixed on the top of the composite structure tank in the form of bonding. The composite structure tank top material adopts sandwich structure, which is composed of glass fiber layer, sandwich layer and glass fiber layer. The glass fiber layer is the main bearing layer. The thickness of the glass fiber layer and the sandwich layer are 3.5mm and 10mm respectively, and the total thickness of the tank top is 17mm.

Soild185 solid element was used to establish the finite element model of composite structure tank roof. The tank roof was divided into 6 hedral meshes with a mesh size of 100mm by the method of free mesh division. A total of 19291 nodes and 5893 units were generated by grid division. The average mesh quality is 0.76266, and the mesh quality is

good. Based on the Cohesive Zone Materials, contact debonding method is used to simulate the bonding between the reinforcement bars and the top of the tank [3]. According to the mechanical properties of the bonding material, the normal tensile strength and tangential shear strength of the bonding contact area were set as 70MPa and 40MPa respectively. Load loading is divided into two loading modes: combined load (wind load 300Pa, snow load 600Pa, three-person maintenance load 1500Pa, negative pressure 400Pa) and internal pressure load (positive internal pressure 1500Pa). The simulation model of tank roof is shown in Fig. 1.

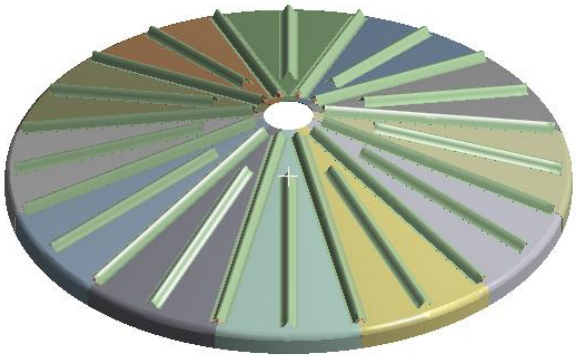

Figure 1. Finite element analysis model of tank roof.

3. Stress analysis of composite structure tank roof

Combined load and internal pressure load were applied to the finite element model respectively. In order to see the stress concentration position more clearly, a reinforcement bar was selected as the research object, and the stress curve under combined load condition and internal pressure condition was drawn by output stress value of the composite structure tank top at the position of reinforcement bar. The stress curve under combined load condition and internal pressure condition is shown in Fig. 2 and Fig. 3 respectively.

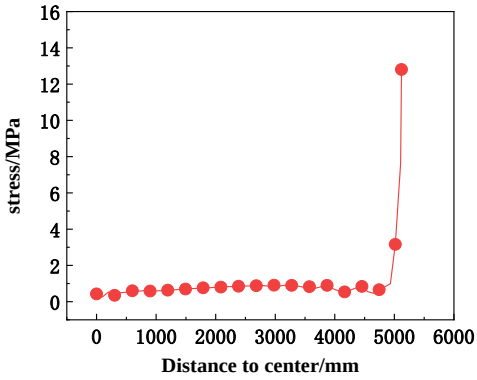

Figure 2. Stress curve under combined load

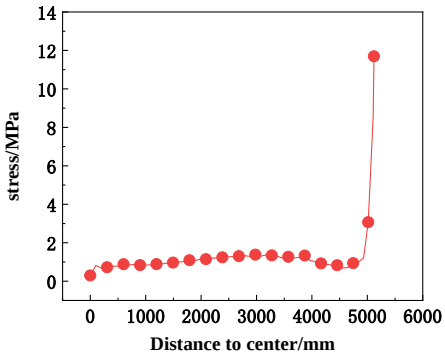

Figure 3. Stress curve under internal pressure load.

As can be seen from Figures 2 and 3, as the distance from the center gradually increases, the empowerment stress also gradually increases. When the distance from the tank top is less than 4800mm, the stress of the tank top increases slowly with distance, but when the distance to the center of the tank top is more than 1800mm, the stress of the tank top rises sharply, from less than 2MPa suddenly to more than 12MPa. The stress growth law is roughly the same under both combined load and internal load conditions. The analysis shows that the stress increases rapidly along the bottom of the main reinforcement of the tank top. Therefore, we can determine that the addition of reinforcing bars causes serious stress concentration problems along the lower edge of reinforcing bars.

4. Solution of stress concentration problem

The stress concentration in the top of the reinforced reinforcement tank is mainly due to the sharp change of the stiffness along the position under the reinforced reinforcement. There is a great difference in stiffness between the position of tank top with reinforcement and the position without reinforcement. Therefore, it is necessary to optimize the structure of reinforcement bars to solve the problem of stress concentration caused by sudden change of tank top stiffness [4, 5].

Appropriately extending the length of reinforcement bars is one of the solutions to solve the current stress concentra-

tion problem, so the length of reinforcement bars is extended in this paper, and the composite structure tank top after the extension of reinforcement bars is shown in Figure 4.

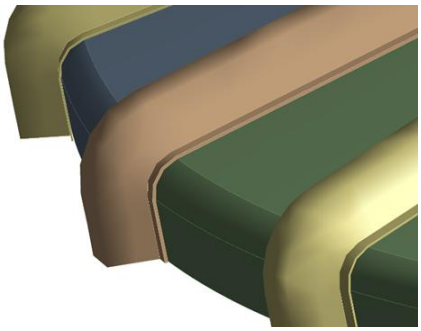

Figure 4. Optimization scheme of tank top reinforcement.

As shown in Fig. 4, the length of the main reinforcement and the auxiliary reinforcement is extended so that the reinforcement covers the entire top of the tank. Because the upper edge of the reinforcement has small deformation, it is not a dangerous failure position even if there is stress concentration, so it only needs to extend the length of the lower edge [6].

The load conditions of the roof of the optimized composite structure tank are combined load and internal load. Select the same reinforcing bar, and output the stress of different positions of reinforcing bars to obtain the stress curve of the top of reinforcing bar after structure optimization. The stress curve under combined load condition and internal pressure condition is shown in Figure 5 and Figure 6.

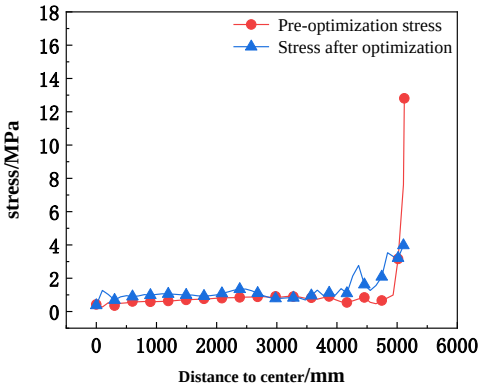

Figure 5. Stress curve under combined load.

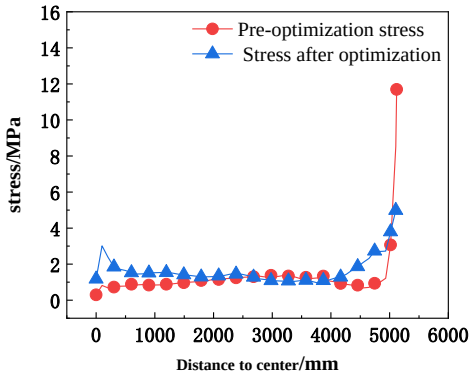

Figure 6. Stress curve under internal pressure.

As can be seen from Fig. 5 and Fig. 6, after structural optimization, the stress at the original stress concentration location has been significantly reduced, and the stress at the location has hardly changed except for the stress concentration area. The maximum stress in the stress concentration area is compared before and after structural optimization, and the comparison results are shown in Table 1.

Table 1. Comparison of maximum stress in stress concentration area before and after optimization

Stress (MPa)	Before structural optimization	After structural optimization
Stress under combined load	13	4
Stress under internal pressure	12	5

It is obvious from Table 1 that the stress concentration phenomenon on the roof of the composite structure tank has been obviously improved under both combined load condition and internal pressure condition. The maximum stress before and after optimization is reduced by nearly 70% under combined load, and the maximum stress under internal pressure condition is reduced by nearly 60%. Therefore, the simulation results show that the optimization scheme of the extension reinforcement can effectively solve the stress concentration problem of the tank roof with reinforcement, and provide a strong theoretical support for the solution of the stress concentration problem.

5. Summary

(1) At present, there are some drawbacks in the main structural forms of reinforcement bars in China, which cause quite serious stress concentration problems and increase the risk of fatigue failure and corrosion perforation of composite structure tank roof.

(2) Through the simulation analysis, the stress concentration area of the top of the composite structure tank with reinforcement exists along the lower part of the reinforcement, whether under the combined load condition or under the internal pressure condition. The main reason for the stress concentration in this region is that the stiffness changes too fast, which leads to the obvious difference in local regional stiffness.

(3) The problem of stress concentration can be effectively improved by the optimization scheme of proper extension of reinforcement bars. The analysis shows that the maximum stress in the force concentration area is reduced by nearly 70% under combined load condition and 60% under internal pressure condition.

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