

Simulation on the Weak Links of Certain Liquid Chlorine Tank

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Abstract. Using Solidworks software, this paper constructed the geometry model of liquid chlorine tank, established the liquid chlorine tank model in the normal operation, identified various boundary conditions based on simplified assumptions, made meshing and simulated calculation on the tank and flange by employing the FEA block, and analyzed the weaknesses in its operation.

Introduction

As a strong engineering analysis instrument, FEA has been widely used in fields of structure[1], vibration and thermal transmission. In this sense, based on certain assumptions, this paper made simulations on the normal operation of one certain liquid chlorine tank, investigated the tank enclosure and the stress of flange, and then confirmed the weaknesses during its operation.

Designing and Modeling of Liquid Chlorine Tank

The characteristics-based entity modeling is made on certain liquid chlorine tank by using SolidWorks, and the tank is designed and modeled by stretching, rotating, ablating and model-drawing. On this base, the relevant components are assembled by various constraints (parallel, coincide, concentricity, distance, angle, and so on) and then the objective model is built. In addition, numbers of commonly used standard components (such as gasket, bolt and sealing ring), which are in the Toolbox SolidWorks comes with, could be directly used in modeling[2][3]. The Figure1 demonstrates the modeling diagram of the liquid chlorine tank designed by this paper.

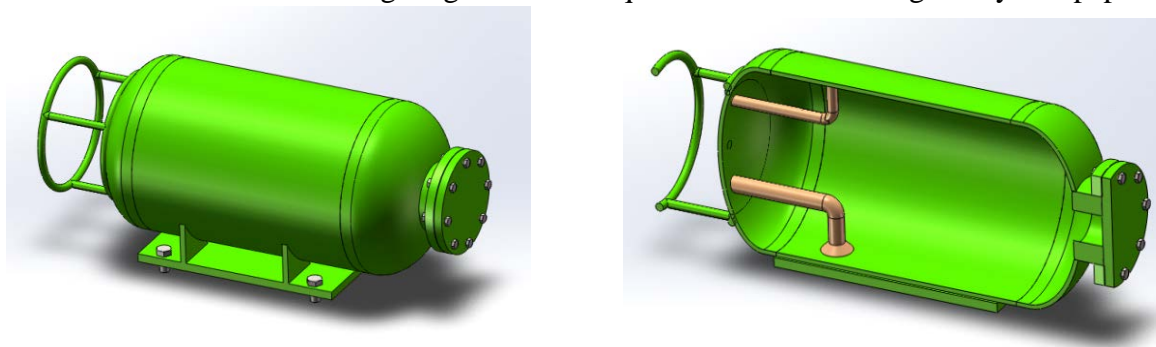


Fig.1 Modeling diagram of one certain liquid chlorine tank

This liquid chlorine tank is composed of shielding, supporting stand, interface tube, end cover, interface flange, pressurized tube, sealing ring, liquid chlorine inlet and outlet, and bolts, which functions as storage and transfer of liquid chlorine[4]. Table 1 shows the specifications of this liquid chlorine tank.

Table 1 Specifications of certain liquid chlorine tank

No	Item	Specification	No	Item	Specification
1	The category of pressure vessel	CM- II	8	Designed pressure	2MPa
2	The volume of vessel	0.06m ³	9	Designed temperature	50℃
3	The inner diameter of vessel	Φ 350mm	10	The mode of installation	horizontal vessel
4	The length of vessel	908mm	11	Nondestructive testing proportion	100%
5	Material	Q345R	12	The mode of main structure	monolayer
6	The thickness of enclosure	8mm	13	Shell side medium	liquid chlorine (high risk)
7	Welded joint efficiency	1.0	14	Corrosion allowance	4 mm

Simulation Settings

Material Characteristics.

The main body of liquid chlorine tank and its corresponding tubes are made in Q345R corrosion-resistance alloy steel which specifications are shown in Table 2.

Table 2 Specifications of Q345R corrosion-resistance alloy steel

No	Item	Specification	No	Item	Specification
1	Ultimate tensile strength	412MPa	5	Modulus of Elasticity	25.3×10 ⁻⁶
2	Tensile yield strength	210MPa	6	Poisson's ratio	0.33
3	Average thermal expansion coefficient	7.6×10 ⁻⁶	7	Specific heat capacity	0.09
4	Heat conductivity	5.56×10 ⁻⁴			

Model Simplification.

Considering that the built liquid chlorine tank model consists of both thin part and thick part, the main body unit must mixed with the enclosure unit in practical analysis[5]. In order to make the mixed mesh compatible, the model must be simplified as follows when the contact regime is properly defied:

- (1) Shielding: it has small influence on simulation and can be neglected.
- (2) Main body: it is made of thick alloy steel and is very thin compared with the outside diameter. In this sense, it is optimal to choose enclosure unit to model.
- (3) The interface tube, pressurized tube, liquid chlorine inlet and outlet: compared with the tube's diameter, these tube is not thick and so it is proper to model by using enclosure unit.
- (4) Tube mouth flange and end cover: the flange is not thin and could bear great bending moment; end cover is also thick and connected to the flange with bolt. In this sense, it is a must to investigate the these positions' precise stress by modeling main body unit[6].
- (5) Supporting stand: modeling the main body unit.
- (6) Sealing gasket: it has small influence on simulation and can be settled down by setting "always neglecting the gap".
- (7) Wind load and seismic load: neglected.

Simulation Settings.

In that there is a gap between the two contact characteristics in surfaces integration and they are never compatible, there is a need to define the partial integration contact so as to connect main bodies to gap, including: the integration of enclosure surfaces, the integration of enclosure edge and enclosure surface, and the integration of enclosure and main body[7], as shown in Table 3.

Table 3 Connecting the main bodies with gap

No	Contact Surfaces	Types of Contact Surface
1	Contact surface of main body's welding lines	Integration of enclosure surfaces
2	Interface tube and main body	Integration of enclosure edge and enclosure surface
3	Liquid chlorine inlet / outlet and main body	Integration of enclosure edge and enclosure surface
4	Pressurized tube and main body	Integration of enclosure edge and enclosure surface
5	End cover and tube mouth flange	Integration of enclosure and main body
6	Interface tube and tube mouth flange	Integration of enclosure and main body

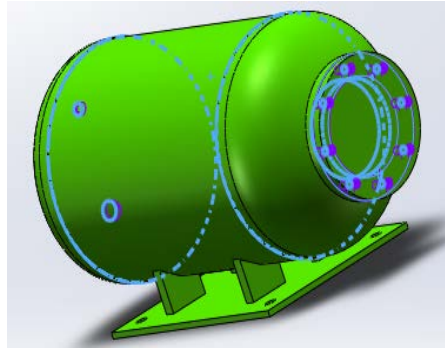


Fig.2 Main body contact simulation diagram of one certain liquid chlorine tank

Mesh Generation and Analysis on the Numerical Simulation Results

Computing the Mesh Generation.

The mesh generation is made on the liquid chlorine tank model by using Solidworks Simulation module. The structured mesh is most used and the mixed mesh is adopted in the contact space of gaped main body, with encrypting welding lines, tube mouth, flange and bolt holes[8]. Figure3 shows the mesh generation of model.

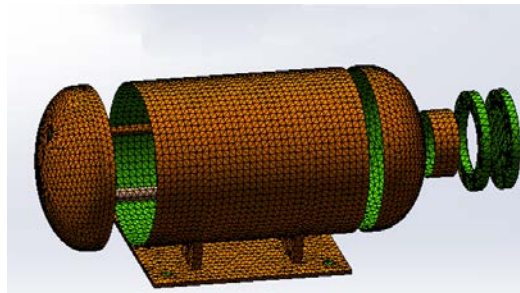


Fig.3 Mesh generation of one certain liquid chlorine tank

The Stress Numerical Simulation in Liquid Chlorine Operation.

The initial validation on liquid chlorine tank model is made and its boundary conditions are set according to the operation parameters of the same type pressure vessel[9], including inner pressure, operation temperature, external bending moment and force, and tank weight during operation, as shown in Table 4.

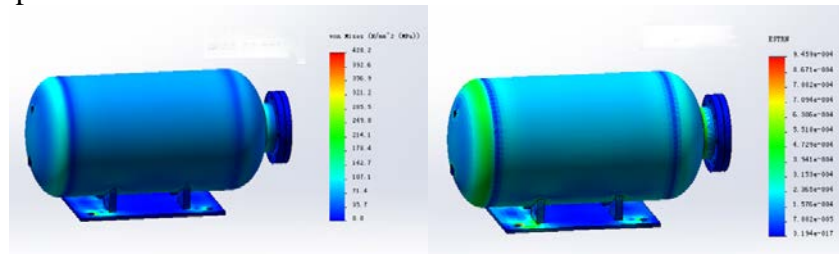
Table 4 Simulation Boundary Conditions Setting

Boundary Conditions	Setting values	Boundary Conditions	Setting values
Configuration of pressure reducer	Main body+enclosure	Tank's inner pressure (MPa)	2.0
Analysis type	Static Suan cases	External bending moment and force (N)	1100
Conditions of tank wall	Non-slip	Tank weight (kg)	146
Thermal boundary conditions	diathermic wall	Operation gas	Chlorine gas
Operation temperature (K)	300		

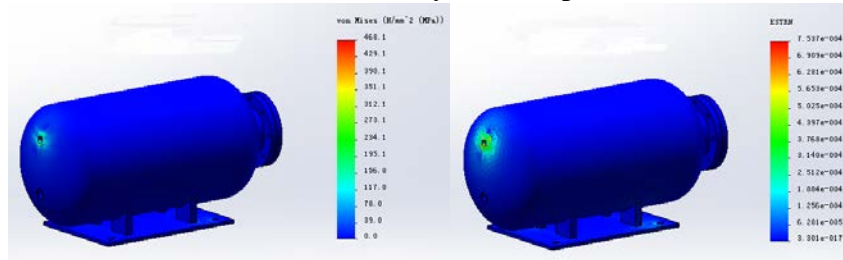
(1) Stress Simulation Results for Different Load

Figure4 shows stress and strain simulation results of liquid chlorine tank for different loads: in (a) the internal pressure of inside tank wall is 2.0MPa; in (b) tank's external bending moment and force

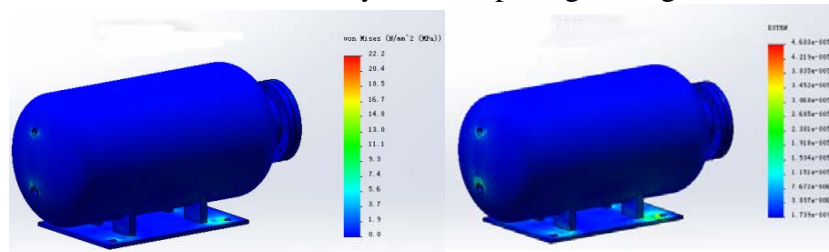
is 1100N, which is resulted by tube system; (c) shows the tank weight. Above three static numerical examples are independent.



(a) Influenced by internal pressure



(b) Influenced by external pre-tightening load



(c) Influenced by tank weight

Fig.4 Stress and Strain Simulations for Different Loads

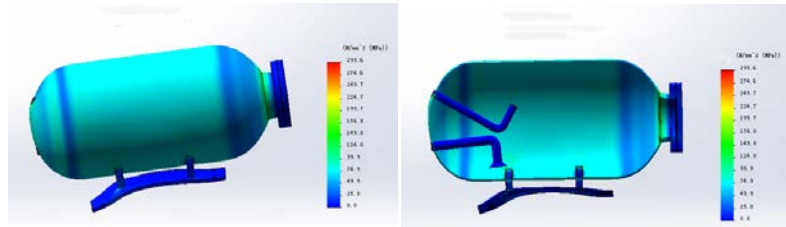
(2) Stress Simulations for the Combination of Loads

The analyzed numerical examples are linearly combined (not considering the temperature load), and the result X (stress, strain and so on) is calculated by the following formula:

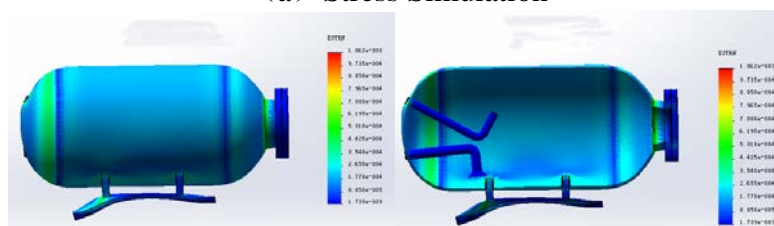
$$X = \sum_{i=1}^N x_i \quad (1)$$

In above formula, N stands for the numbers of numerical examples included in the combination; x_i stands for numerical value (displacement, stress and so on) in numerical example i .

Figure5 and 6 show the liquid chlorine tank's stress/strain simulations and their corresponding safety for the load combinations.



(a) Stress Simulation



(b) Strain Simulation

Fig.5 Stress/Strain Simulations for the Load Combinations

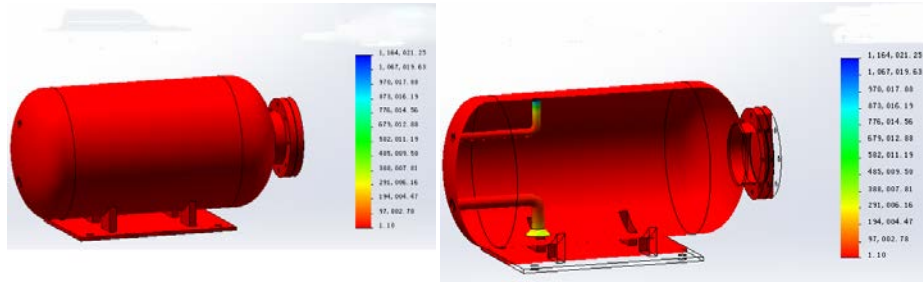


Fig.6 Tank's Safety Simulation for the Load Combinations

The Simulation results demonstrate that: in comparison with the liquid chlorine tank itself, the deformation of liquid chlorine tube inlet/ outlet tube during operation may threaten the overall safety of tank. Therefore, enough attention must be paid to the tube welding, assembling and stress relieves in early preparatory work.

The Linearization of Flange Plate.

Inlet flange is the key part of this liquid chlorine and its connection with end cover effectively ensures the tank safety. Therefore, there is a need to investigate its precise stress. However, in this paper, the flange is modeled by using entity and the Diaphragm's stress strength and bending stress strength can not be directly provided like enclosure unit. In this sense, there is a need to specifically settle down, that is stress linearization.

Figure7 shows the overall stress simulation of flange plate and end cover during the operation.

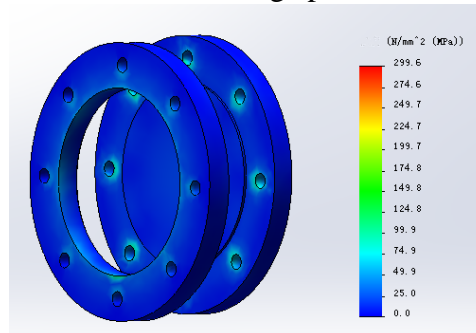


Fig.7 Stress Simulation Results of Flange and End Cover

In this paper, the vector value between inside flange surface and inside bolt hole is defied as the linearization route of stress results, as shown in Figure8.

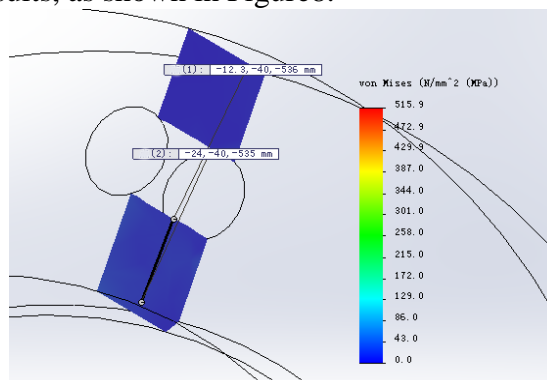


Fig.8 Designated Area of Flange Linearization Analysis

Figure9 shows that the change of actual stress variable in the cross section. In this figure, the actual stress variable is represented by the red triangle, and the linearized variable is represented by the blue square (stands for the diaphragm stress) and the green diamond (stands for the diaphragm's stress and bending). From these two variables, it is shown that the change process of actual stress is very complex. In that the liquid chlorine tank is unusual pressure tank, although its pressure is relatively small during operation, its corrosiveness and danger is very large[10]. In this sense, much attention must be paid to the pre-tightening force exerted on flange plate.

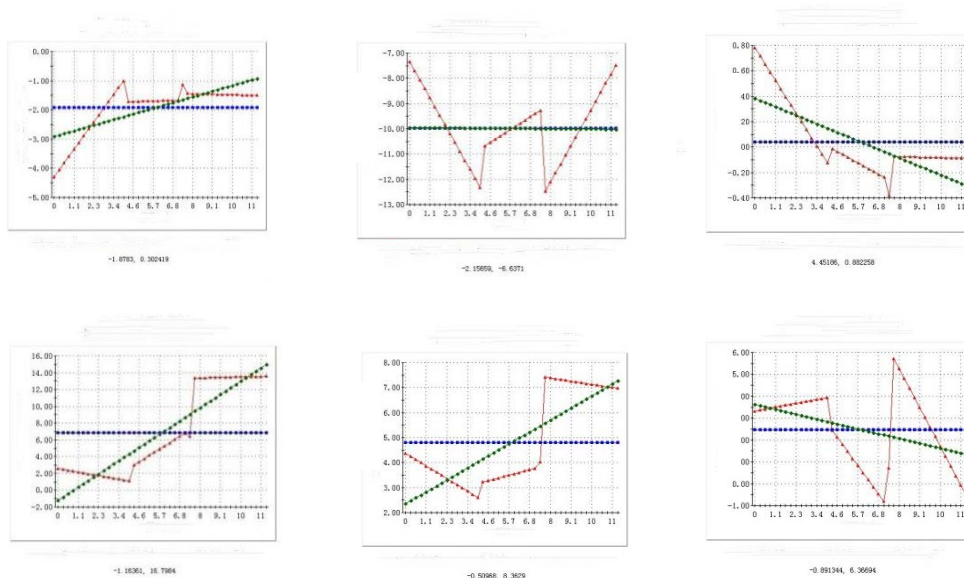


Fig.9 Designated Area of Flange Linearization Analysis

Conclusion

By building finite element model, this paper actually reflects the force and stress distribution of one certain liquid chlorine tank during normal operation, investigates out the weaknesses influencing on tank's overall safety and linearized the flange stress of the tank, providing technological support for tank's use and maintenance on certain extent.

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