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Pressure Container Surface Crack Analysis

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Abstract: High-pressure containers are widely used in modern industries, including chemical industry, oil, nuclear power, aviation and many other fields. As pressure vessels are widely used in various fields, it will face a more complex and changeable working environment. the effects of media environment and fatigue stress cause defects, which will greatly affect the normal work of the container. Therefore, this article conducts static analysis of the surface with cracks on the surface through the finite element numerical simulation method, analyzing the rules of crack expansion and the impact on the life of pressure vessels. Research results: The container was stretched vertically under the load of 10MPa, and the maximum deformation occurred at the top of the ellipse sealed head, with a maximum deformation of 1.63mm; The maximum stress value does not occur at the top of the container, but occurs in the crack, and the maximum stress value is 538.18MPa; The minimum value of the safety factor of the safety coefficient cloud diagram is 0.50, which is located at the crack. The intensity of cracks has a great impact on the intensity of high -pressure containers. It needs to be checked regularly on high -pressure containers to ensure the safe operation of the equipment.

Keywords: High-pressure container, Finite element numerical simulation, Crack, Static analysis.

1. Introduction

High-pressure container is a closed equipment between 10MPa and 100MPa [1]. It is widely used in modern industries. It includes many fields such as chemical industry, petroleum, pharmaceutical, nuclear energy and aviation [2]. The necessary key equipment during operations. It is a key equipment for the storage, mixing, transportation, response and other operations of the material [3].

High-pressure containers have a history of more than a hundred years, and their use in industry is not very long. As early as the late 19th century, with the needs of industrial development, people began to realize the importance and inevitability of high -pressure containers, and the ideas of high -pressure technology research have germinated. Subsequently, in 1910, German chemist Haber and Rossingnol first obtained industrial products for synthetic ammonia at 10MPa and 500 °C. Two years later, the German chemist Claude further developed on the basis of this to increase the pressure to 100MPa. Since then, in order to improve the efficiency of industrial production, various countries have begun to encourage the development of high-pressure container technology [4-5]. At present, the equipment in the synthetic ammonia technology can reach 15-60MPa, the equipment in the hydrogenation technology is 8-70MPa, and the equipment pressure in polyethylene device can even be as high as 150-250MPa [6-8].

In the normal operating environment and service life, when the stress in a certain place in the container is too large, and the shape and performance change, the phenomenon of losing work capacity is called the failure of the pressure container [8-10]. As a special pressure container, high -pressure container, once it fails, will affect production progress, increase the cost of engineering, and endanger personal safety. High-pressure container harsh and special working conditions make its failure forms of complex and changeable characteristics. Its failure form is strength failure, stiffness failure, stability failure, corrosion failure, etc [11-16].

With the needs of industrial technology, high-pressure containers are widely used and the working environment is complicated, which often leads to cracks in pressure vessels, which will greatly affect the normal work of the equipment. In this article, this article analyzes the laws and changes in stress container crack expansion and changes in stress. The results of this article will be of great significance to understanding cracks on pressure containers.

2. Pressure Container Numerical Model

2.1. Numerical modeling

Try to analyze the effects of cracks on the design pressure of 10MPa, observe the pressure and strain distribution of the container, explore the impact of cracks on the container, and calculate the life of the pressure container. The model is shown in Fig 1. The basic size is 1.84m inner diameter, 4.0m in length, 0.16m wall thickness, 1.84m inner diameter of the sealed head, and 0.16m wall thickness.

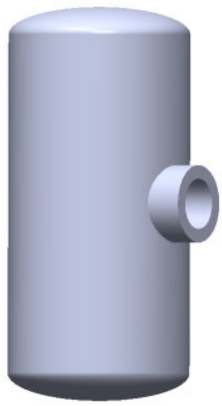

Figure 1. 3D model

2.2. Definition of material attributes and boundary condition settings

The pressure container material is Q345, the elastic modulus of the material and the specific parameters of Poine ratio are 1.92 × 10^5MPa, and 0.3. First, apply a fixed constraint on the pressure vessel, and then apply 10MPa to the inside of the container. The application of the load is shown in Fig 2.

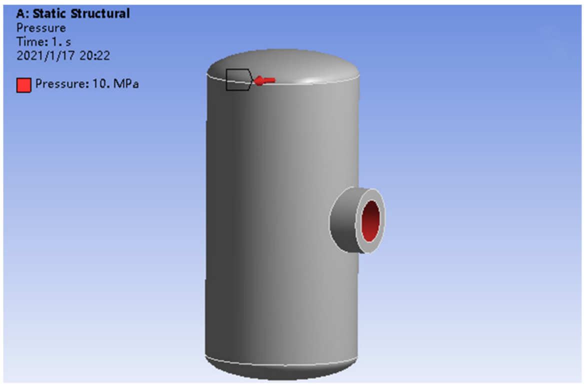

Figure 2. The container load is applied

2.3. Set the division of the surface cracks of the container and the grid

Set the ellipse crack, insert Fraction in the model, insert the crack (Semi-Elliptical) through the Fracture, and set the crack parameter settings. Major Radius is set to 100mm, and the minor radius is 50mm, and the maximum contour radius is 50mm. The ellipse crack setting is shown in Fig 3, and the grid is divided into Fig 4, including the overall grid and crack grid.

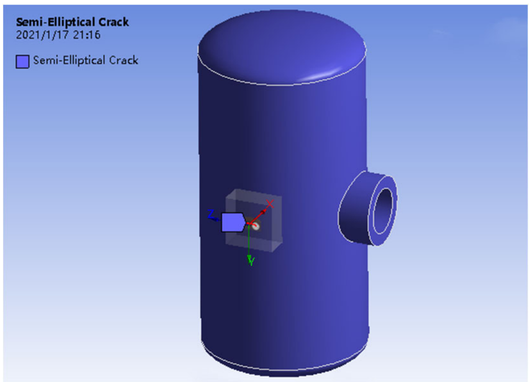

Figure 3. Settings of cracks

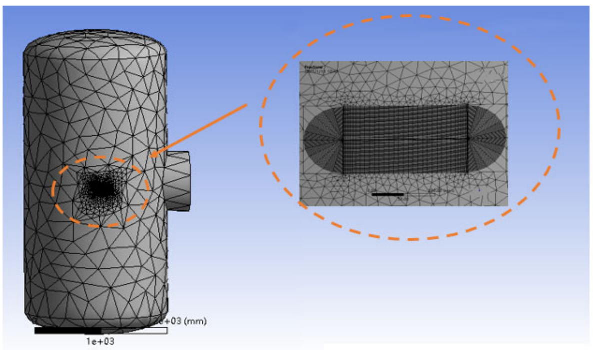

Figure 4. Grid division

3. Results analysis

3.1. Pressure container stress

From the perspective of the total strain cloud diagram in Fig 5, the container is stretched vertically under the load of 10MPa, causing the container to deform both vertical and horizontally. The maximum deformation occurs at the top of the oval head, the maximum deformation is 1.63mm, and the maximum variable volume of the horizontal direction occurs at the contact part of the cylindrical part of the export to take over the container, with a maximum deformation of 0.41mm.

Through observing the Fig 6, the maximum stress value is not the top of the container, but occurs in the crack. The maximum stress value is 538.18MPa, while the maximum stress value of other parts does not exceed 300.90MPa. Because the container material is Q345 and the yield strength is 345MPa, the container is under 10MPa pressure, because the existence of cracks will cause yield deformation.

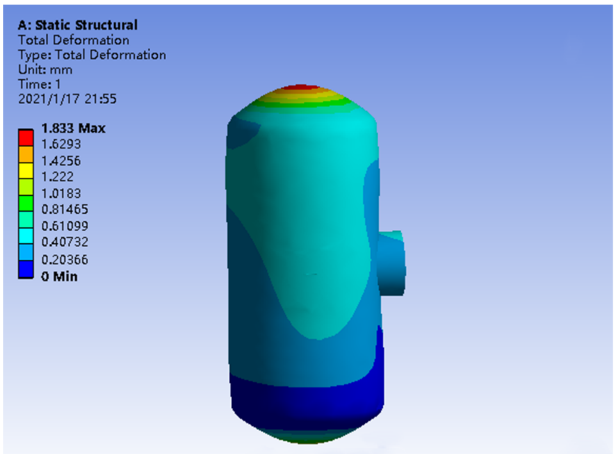

Figure 5. Strain cloud map

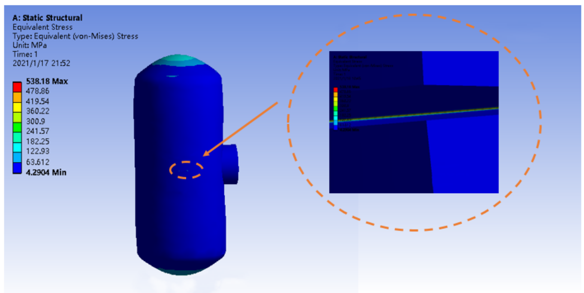

Figure 6. Specification and crack stress cloud map

3.2. Crack analysis

Select the Fracture Tool Fracture tool insertion in Solution, click the stress intensity factor (SIFS (K1)), J points (J-Integral) to solve, and the results are shown in Figure 7 and 8 respectively. Fig 7 Display the range of stress intensity factor is 268.46 ~ 400.93MPA.mm^(0.5), indicating that the tip of the crack is the easiest position. Fig 8 shows that when the J points is 0.74, the cracking stress reaches the critical value of the cracks to start expansion, and the crack will begin to expand.

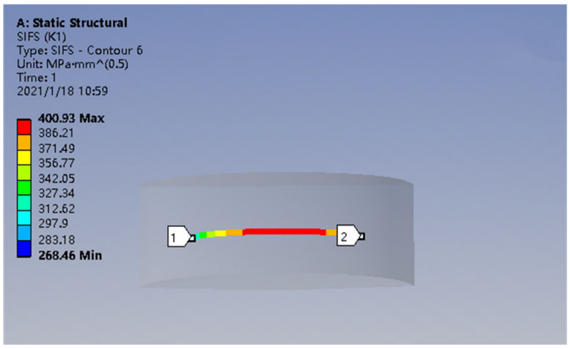

Figure 7. Stress intensity factor cloud diagram

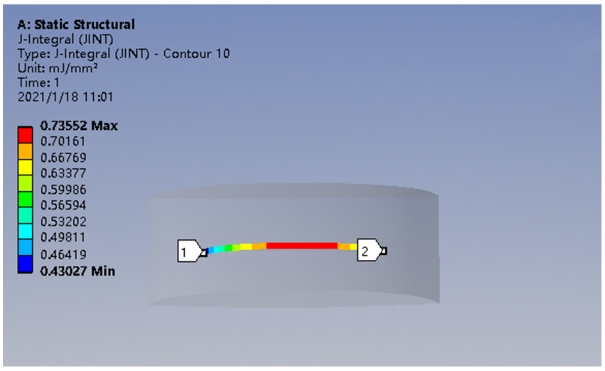

Figure 8. J Point Cloud Map

3.3. Container life

Select the Fatigue Tool fatigue computing tool insertion in Solution, click Fatigue Tool to set the parameter settings, the load ratio is set to 0.67, the Mean Stress theory is set to Goodman, and other parameters are unchanged, as shown in Fig 9. For the analysis of the fatigue life of pressure vessels, the life cloud diagram is shown in Fig 10. Under the stress ratio conditions, the fatigue container has a greater fatigue damage. The main reason is that the existence of the crack greatly reduces the fatigue life of the container. It can be seen from the safety factor cloud chart 11 that the minimum safety factor of the container is 0.49824, which is located at the crack.

Details of "Fatigue Tool"

Domain	
Domain Type	Time
Materials	
Fatigue Strength Factor (Kf)	1.
Loading	
Type	Ratio
Loading Ratio	0.67
Scale Factor	1.
Definition	
Display Time	End Time
Options	
Analysis Type	Stress Life
Mean Stress Theory	Goodman
Stress Component	Equivalent (von-Mises)
Life Units	
Units Name	cycles
1 cycle is equal to	1. cycles

Figure 9. Parameter settings

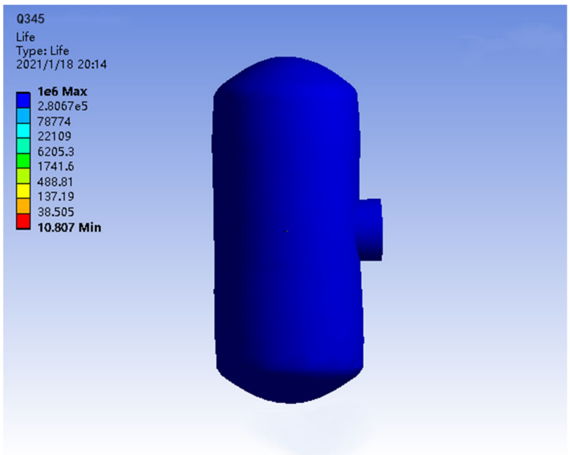

Figure 10. Lifetime Cloud Map

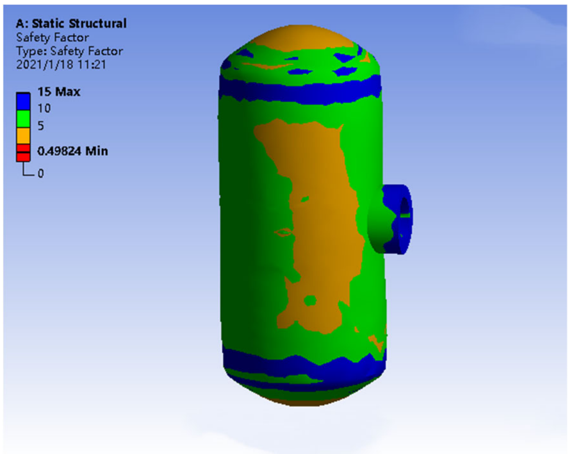

Figure 11. Safety Coefficient Cloud Map

4. Summary

(1) The container is stretched vertically under the load of 10MPa, and the maximum deformation occurs at the top of the ellipse sealed head, with a maximum deformation of 1.63mm;

(2) The maximum stress value is not the top of the container, but occurs in the crack, and the maximum stress value is 538.18MPa;

(3) The safety factor cloud diagram shows that the minimum safety factor of the container is 0.50, which is located at the crack. The intensity of the crack has a great impact on the intensity of high-pressure containers. It is necessary to regularly check the high-pressure container to ensure the safe operation of the equipment.

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