ATLANTIS PRESS
Advances in Engineering Research, volume 164
8th International Conference on Manufacturing Science and Engineering (ICMSE 2018)

Strength Analysis of ship Anti-heeling Airbag Connector

Wu Jun-jie[1],Long Pei-ji[1], Li Wen-hua[1,a],Chen Hai-quan[1],
Wang Zhi-liang[1]
(1.Dalian Maritime University, Liaoning Dalian 116026)
([a]email:18580122017@163.com)

Keywords: Airbag, Anti-heeling, Connector

Abstract： According to the arrangement mode of ship anti-heeling airbag and the principle of various connecting and fixing modes, the corresponding connection device is put forward, and the force condition of the connection device is studied, and the strength of the connection device is analyzed. The results show that the design of airbag connection device meets the requirements. Provide further theoretical basis for anti-capsizing airbag

Introduction

The overturning events occur in the bad sea conditions, which seriously endangers the safety of the life and property of the crew and passengers. The anti-heeling air bag used on the ship is a kind of anti-heeling measure. Anti-heeling airbags and ships are mainly connected by connecting devices. In order to realize the connection between the anti-heeling airbag and the ship, according to the principle of various connection and fixation modes, this paper designs a kind of airbag connection fixing device for the ship, and analyzes its strength..

The main components of anti-heeling airbag connection device include box, connecting rod, air bag and connecting block. The three view of the device is shown in figure 1. The working principle of the device is as follows: on both sides of the ship, at the front, middle and rear three positions, respectively, the front, middle, and rear sides are symmetrically welded to several boxes or several recessed boxes are arranged. A connecting rod is arranged inside the box, which passes through the connection block and is fixed by the box at both ends. Usually the airbag is folded inside the box body, and the airbag is inflated to open the lid of the box, and fixed by the connecting block and connecting rod connected to itself, which can prevent the deviation of the airbag. Airbags provide anti-tilting torque to ships through their own buoyancy[1]. After work, separate the inflatable line of the air bag for exhaust, then withdraw the airbag and close the cap of the airbag box. The structure of the device is simple, easy to install and disassemble the airbag in the ship, and the existing ship will not be changed greatly, so it is feasible.

calculation of static loads on airbags under different heeling conditions

Considering the complexity of the ship's movement and the irregularity of the shape of the airbag, assuming that the ship is in still water, it is subjected to hydrostatic forces. The waterline plane is a horizontal plane and neglects the trim effect caused by the asymmetry of the hull head when the ship is tilting. That is not to consider the coupling effect between them the airbag can be approximated as a cylinder analysis.

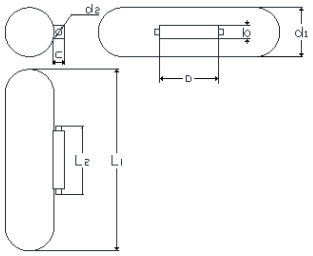


Fig 1Standard three views diagram of "ship-airbag" connection device

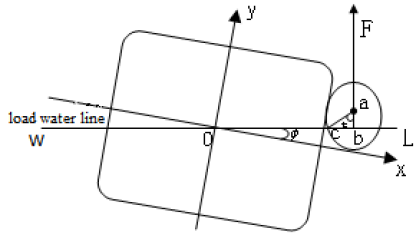


Fig. 2 Ship steady heel state diagram

When the ship floats on the waterline WL, the ship is tilted under the action of external disturbance torque, and only under the static force, the angular velocity is considered to be zero. According to static analysis and airbag force analysis, the moment of ship changes with the angle of heeling. At the same time, the airbag provides the anti-dumping moment for the ship under the action of its own buoyancy, neglects the airbag's own gravity, and finally reaches the equilibrium state. The diagram of the ship's stable heeling state is shown in Fig. 2.

If the center of the airbag is a(x_1,y_1), the radius of the airbag is *r*, the angle of inclination is 0, and the length of the airbag is L, then the distance between the center line of the ship and the water line *O* and the center of the airbag a is obtained.

$$d_1 = \sqrt{(x_1^2 + y_1^2)} \tag{1}$$

The angle between the intersection point o and the line where the airbag center a is located and the waterline.

$$a_{aob} = \arctan \frac{y_1}{x_1} - \Phi \tag{2}$$

Distance from airbag center a to full load waterline

$$d_2 = d_1 \sin a_{aob} \tag{3}$$

Distance between airbag and waterline contact point c to buoyancy line

$$d_3 = \sqrt{r^2 - d_2^2} \tag{4}$$

The angle of a straight line between ab and ac

$$\mathrm{t} = \arccos \frac{d_2}{\mathrm{r}} \tag{5}$$

Cross sectional area of single airbag entering water

$$A = \frac{1}{180} pr^2 \mathrm{t} - d_2 d_3 \tag{6}$$

Finally, a single airbag is subjected to the force of water.

$$F = \frac{1}{180} Lrgpr^2 t - d_2 d_3 Lrg \tag{7}$$

The variation of the water force on the airbag is obtained by calculation and analysis, as shown in Fig. 3.

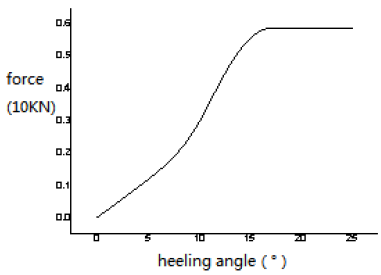


Fig.3 The curve of the force acting on the airbag

According to the four states of stable heeling 5°、10°、10°、16°、20°, the force of airbag is calculated when the ship is heeling. The specific force values of the airbags under four inclination angles are calculated, as shown in Table 1.

Tab.1 The force value acting on the airbag from different angles

heeling angleΦ/(°)	5	10	16	20
Single airbag force/（10^4N）	0.1192	0.2951	0.5888	0.5888

Strength analysis of connecting device

Establishment of 3D Model of Connector

In the device, the airbag is connected with the connecting block, and the connecting block is mounted on the connecting rod of the ship, and the connecting rod is fixed on the side of the ship. n size selection, by analyzing the specific parameters of the ship, the size of each part set in the air bag working condition is as follows: the air bag length is L1=3000mm, the diameter is d1=500mm, the thickness is c1=8mm. The length of the connection block is a=1000mm, the width is b=150mm, and the thickness is c=80mm. The length of the connecting rod is l2=1120mm, and the diameter is d2=50mm. The radius of the round corner of the airbag and the connecting block is 10 mm. A three-dimensional model is built according to the size of the airbag and the connector, as shown in figure 4.

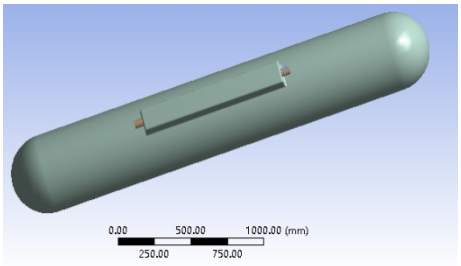


Fig 4 Three-dimensional model diagram of "ship-airbag" connecting device

As a fixed device, the connecting rod should bear the tension and bending moment of the airbag due to the action of entering water, so it has more stringent requirements in determining the material quality. Considering that the structural steel in engineering has good comprehensive properties, such as strong impact resistance, high strength and easy processing, structural steel is used as the connecting rod material. The airbag and the connecting block mainly take the gas in the capsule as the working energy, and bear a relatively large impact at the moment of water. Its working environment and properties require airbag materials to have the following properties: light weight, low permeability, high tensile and tear strength, suitable stiffness, good aging resistance and installation and processing properties[2]. According to the material of landing cushion airbag, the material of fabric is selected.

Tab.2 Material parameter

Material	Density kg/mm^3	modulus of elasticity/Pa	Poisson's ratio	Application
Textile material	8.7E-07	5E+08	0.2	Airbags and connectors
Structural steel	7.85E-06	2E+11	0.3	Connecting rod

Coupling device constraints and loads

Mesh the model and encrypt the mesh between airbag and connection block. The mesh division is shown in figure 5. A fixed contact condition is used between the airbag and the connecting block and between the connecting block and the connecting rod to ensure the connection between them. The fixed support is applied to both ends of the connecting rod and the atmospheric pressure is applied on the outer surface of the airbag and the 1.5 atmosphere pressure on the inner surface of the air bag is applied to simulate the condition of filling the airbag.

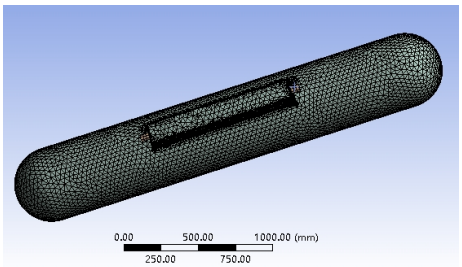


Fig. 5"Ship-airbag" connecting device meshing

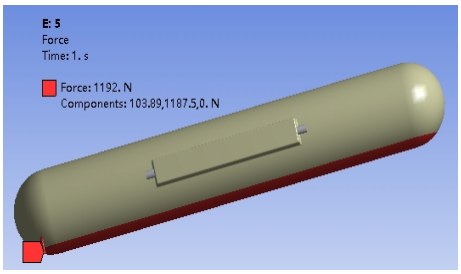
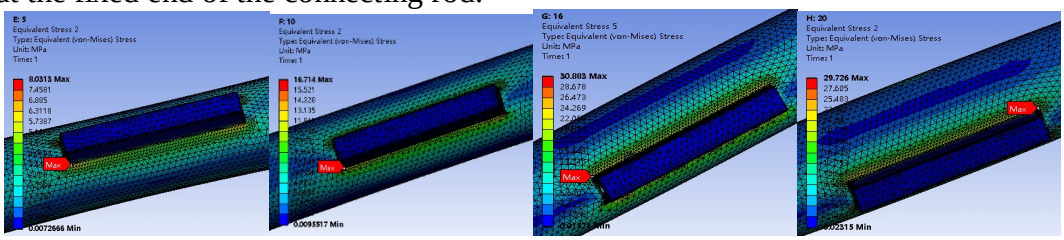


Fig.6 Schematic diagram of the airbag force when heeling 5 °

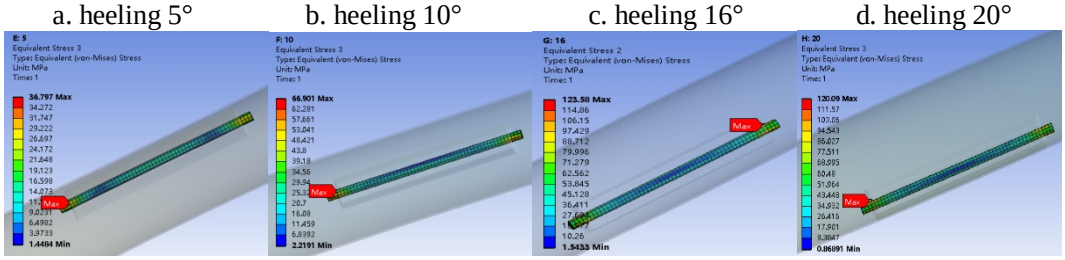
Due to the change of the force direction and the volume of water entering the airbag under different heeling angles, the force size, direction and action surface of the imported device model need to be changed constantly. In this chapter, four stable states of 5 °10 °10 °/ 16 °/ 20 °are analyzed respectively by finite element method[4], in which the force of airbag at 5 °heeling is schematic, as shown in figure 6.

Integral stress Analysis of Connector

The stress distribution diagram of the device can be obtained by applying the force value of the airbag to the corresponding water entry surface area of the air bag at different heeling angles, as shown in fig. 7. It can be seen from the overall stress distribution diagram that the stress of the airbag connecting device changes with the angle of heeling, but the overall stress value is relatively small, mainly concentrated on the connecting block and the connecting rod. The maximum stress appears at the fixed end of the connecting rod.



a. heeling 5° b. heeling 10° c. heeling 16° d. heeling 20°



a. heeling 5° b. heeling 10° c. heeling 16° d. heeling 20°

Fig.7 The overall stress diagram

In the process of ship heeling, the stress distribution of airbag connection is a problem that needs to be paid attention to. According to the stress cloud diagram, the stress value of the airbag connection device changes greatly when the angle of heel is small. When the heeling reaches 16 °, the stress value of the airbag connection device changes very little. This is mainly caused by the variation of the size of the airbag due to the different volume of air bag entering water. The maximum stress of the device is 123.58 MPA, which appears at the two ends of the connecting rod. This is because the position plays a fixed limiting role in the operation of the airbag, which bears the tension and bending moment of the airbag due to the effect of entering water. The force is transferred to the connecting rod through the connection block structure to limit the maximum stress. The stress of the upper and lower parts of the joint is concentrated, the maximum value is 30.883MPa, which is due to the tension and bending moment generated by the load at the joint. The results show that the yield strength of structural steel is 460MPa and the tensile strength of fabric material is 200MPa, so the stress of airbag connection device is far less than the ultimate strength, which conforms to the safety requirements. In practical application, some measures, such as strengthening belt or thickening, can be used to protect the part with high stress.

In addition, the peak value of the partial stress of the airbag and the connecting block changes continuously with the angle. When the angle of heeling angle is small, the peak stress is mainly concentrated at the position where the joint is located at the bottom of the connecting block and the airbag, which is because the airbag is just entering the water, and because of the force of water, it tends to move upward along the side. At this time, the lower part of the connection block will be pulled upward. Then the maximum stress will gradually move up with the increase of the heeling angle. When the angle reaches 16 °, the peak value of the stress will appear at the position where the upper part of the joint is connected with the airbag. This is because the inlet of the airbag is changed by the force of the water, which is inclined to the hull gradually, and the upper part of the connecting block is squeezed.

Conclusion

In this paper, the static load of the airbag in four stable states of 5 °,10 °,16 °, 20 °is obtained by calculating the static load of the airbag under the condition of different heeling. According to the strength analysis of the static load obtained, the strength of the airbag connection device is in accordance with the operating conditions under four stable states. The peak value of the joint stress between the airbag and the connecting block is obtained and the peak value of the stress varies with the angle.

Acknowledgment

This work was financially supported by the Fundamental research funds for the Central Universities (3132014332, 3132015025, 3132016345) and National Science Foundation of China (51779026).

References:

[1] Lei Lin, Tang Yihu. Design of flank inflatable air bag device [J]. Journal of Chongqing University of Technology,2009,23(07):58-63.

[2] Huang Guo. Study on the cushioning performance of double cylinder air bag[D]. Beijin: Beijing Jiaotong University,2012.

[3] Li Liangchun,Huang Gang,Li Wensheng, et al. Simulation and analysis of a new landing buffer air bag based on ANSYS/LS-DYNA[J]. ,2012 (15) Packaging engineering:16-20

[4] Wang Cheng. Finite element method. Beijin: Tsinghua university press,2003：617-624