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Effect of impact position and initial velocity on structure of collided tanker

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Abstract. Ship-ship collision is a very complicated process, different collision parameters will lead to different results. Using ANSYS/LS-DYNA to build a model of ship-ship collision, it studies the side structure collision characteristics at different impact position and initial velocity. Based on the results of calculation, the collision force-displacement curves, energy absorbing-displacement curves, and the damage deformation of side structure are obtained. The simulation results indicate that changing the impact position and initial velocity will obtain the different form and degree deformation. In addition, the critical ship speed of ship shell ruptured is insured, which can offer the theoretical basis for maritime security management.

Introduction

With the development of shipping, the ship traffic density is increasing, also bring continuous marine pollution. Data shows [1], a large amount of marine environment pollution come from ship marine accidents, and more than 40% marine accidents are ship collision [2]. So studying the ship collision will help to prevent the marine pollution, protect life and property, and also can offer the theoretical basis to resolve the maritime disputes in the increasingly busy shipping area.

The ship collision effect of side structure has been studied a lots [3, 4]. Xiao Taoyun etc. [5] studied the energy loss in the Sanxia Reservoir, but didn't consider the quality of the struck ship and the cargo. Ma Jun etc. [6] studied the effect of initial velocity on structure. Reference 7 studies the general process of side structure deformation during ship collision, but the collision situation is single, which used a rigid bow with an initial velocity to collide the side structure, so the conclusions were limited.

In the actual ship to ship collision, there are many impact parameters (position, velocity, etc.), and the different parameters will lead to different damage effect. So, it is very necessary to deeply study the effect of the collision position and initial velocity. This paper uses the ANSYS/LS-DYNA to build the ship to ship collision model to study the collision characteristics by changing these parameters.

Finite Element Model

In order to study the oil tanker leakage, a 159,000 tonnage of tanker at full load condition (load 95%) is simulated. The rigid bow is a bulbous bow of 31,000 tonnage of tanker, with 5 meters diameter, and by changing the density of the rigid bow to make the initial kinetic energy same as the entire ship's [8]. The influence of the fluid to the collision is considered by using additional water mass [9]. The quality of the cargo is added to the inner shell by using the additional density [10].

The side structure is simulated by SHELL163, and applying the refinement grid to the collide area. The Cowper-Symonds is applied which is suitable by experiment to treat the relation between the yield stress and strain rate, and the failure strain is taken to 0.3. The finite element model is shown in Fig. 1.

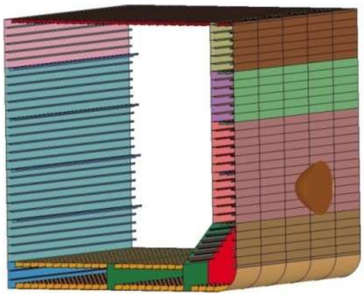


Fig.1. Finite element model of collision

Collision Situation

As the combination of the collision parameters are varying and complicating, so in the paper only studying the effect of impact position and initial velocity on structure of collided ship. The collision situations are shown in Tab. 1.

Tab1. Collision situations

Number	Impact angle	Impact position	Initial velocity(m/s)	Whether consider the friction effect
1		A		
2		B	7	yes
3	90°	C		
4			7	
5		C	5	yes
6			3	

Three impact positions are considered, as shown in Fig. 2. In the Fig., A means the rigid bow impact between two side longs, B means the rigid bow impact at the transverse web frame, and C means the rigid bow impact the cross of the side stringer and the transverse web frame.

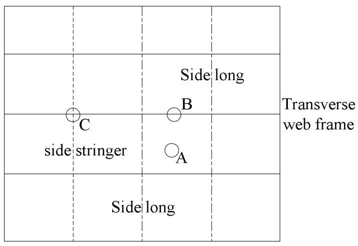


Fig.2. Impact position

Analyses of Simulation Results

Effect of Impact Position

The effect of impact position to the collision force is shown in Fig. 3. From the figure it can be seen: The collision force has very stronger nonlinear features. Each curve has different peak values, which illustrates that the different impact position have different damage process. The whole collision process can be divided into three sections. The first one, the penetration is in 0~1.14m, when the impact position is in point C, the collision force is obviously higher than others. The reason is the side stringer and the transverse web frame resistance action. The second one, the penetration is in 1.14~2.4m, in this stage the collision forces are the same basically. As the rigid bow is located between the inner shell and the outer shell, the side components collided by the rigid bow are nearly the same. The third one, the penetration is in longer than 2.4m, with the rigid bow going deeply, the sizes of the contact area are further increasing, which leads the collision force increase continuously, until the inner shell starts to ruptured.

Fig. 4 implies that the effect of impact position to the absorbing energy. It can be seen from the figure: At the same penetration, different impact position has different absorbing energy. At impact position A, the absorbing energy of the struck ship is the least. Due to the transverse web frame and the side stringer hadn't fully absorbed energy and the energy was mainly absorbed by the deformation of the outer shell. That is very dangerous for the struck ship. It is noteworthy that the inner shell ruptured is nearly at the same time for impact position at B and C. That implies the inner shell will ruptured easier when the impact position is at the higher strength side structure.

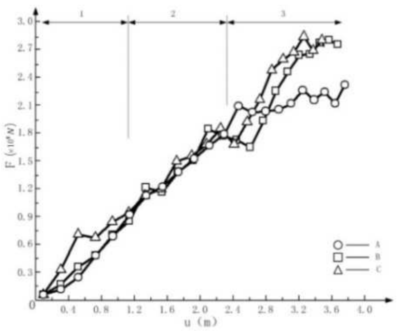


Fig.3. Collision force-displacement curve at different impact positions

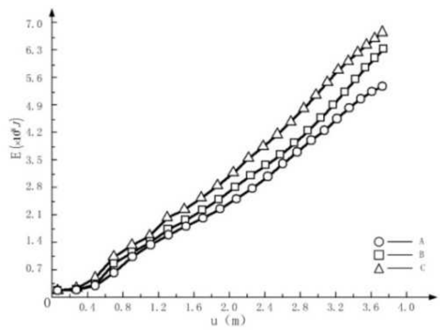
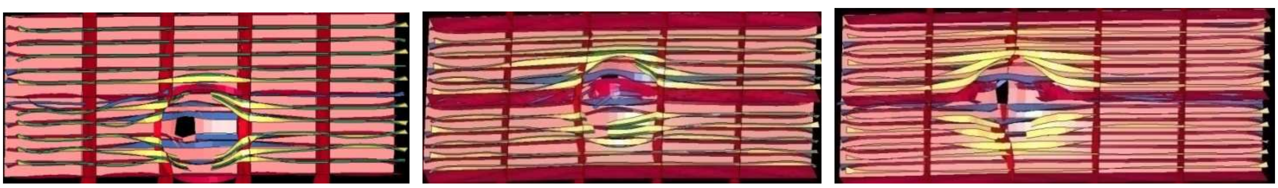


Fig.4. Energy absorbing-displacement curve at different impact positions

Fig. 5 provides the deformation of the side structure at different impact positions after the collision is finished (the inner shell was ruptured). From the figure it can be seen: The side structure deformation is small and partial. At the different impact positions, the components have the different damage situations. For impact position A or B, the side stringers mainly bear surface pressure, which presented as extrusion deformation. At C, the side stringers and the transverse web frame present crush deformation.



impact position at A impact position at B impact position at C

Fig.5. Structure damage deformation at final penetration

Effect of the Initial Velocity

Fig. 6 and Fig. 7 represent the results of the collision force and the absorbing energy at the same impact position when the rigid bow has different initial velocities. From the figures it can be seen: Different initial velocity would lead to different penetration. The changing trend of collision force and absorbing energy for different initial velocity are nearly the same.

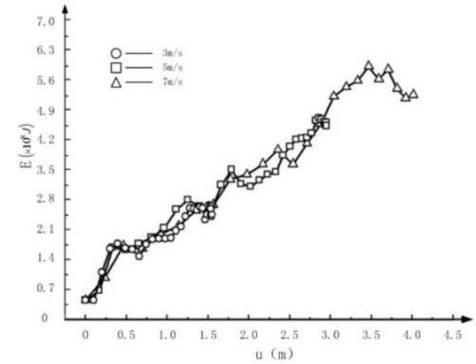


Fig.6. Collision force-displacement curve at different initial velocities

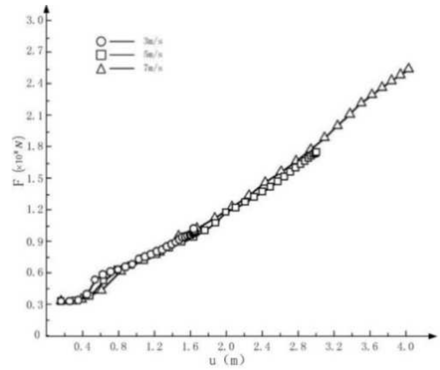


Fig.7. Energy absorbing-displacement curve at different initial velocities

Fig. 8 reflects the rigid bow's velocity-time curve. It can be seen from the figure that: The decrease trend is similar, due to the impact position and the sequence of the components that the rigid bow touched are unchanged. The rigid bow would be rebounded when the initial velocity is low (the negative velocity means the rigid bow is rebounded). That means the rigid bow does not have enough energy to entirely damage the side structure. The damaged components were occurred elastic recovery when the rigid bow is rebounded.

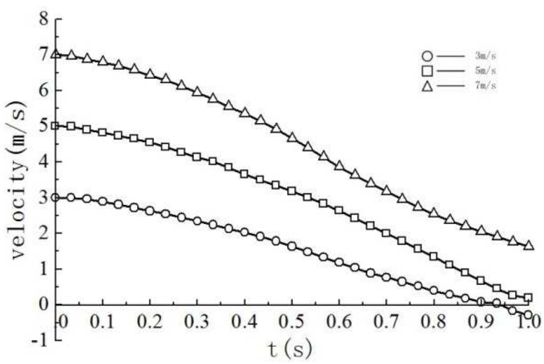


Fig.8. Velocity-time curve

Critical Ship Speed

For the double shell oil tankers, the inner shell ruptured will lead the cargo leakage, and then pollute ocean, so the critical ship speed is very important.

From above simulation, it is conducted that the critical ship speed of the outer shell is 2~3m/s (3.88~5.83kn), and the inner shell is 5~6m/s (9.72~11.66kn).

Summary

A model of ship side collision based on the software ANSYS/LS-DYNA has been successfully established, and the damage and deformation of side structure has been obtained by changing the impact position and the initial velocity. The damage of ship collision is small and partial. Different impact position will lead to different impact force, absorbing energy, penetration and structure deformation. Different initial collision velocity will lead to different penetration, when the velocity is low enough, the striking ship would be rebounded. By this simulation, the critical ruptured velocity for outer and inner shell could be conducted, and these are very important to maritime security management.

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