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Analysis on the Process of Ship Striking the Anti-collision Pier

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ABSTRACT: China's extensive inland navigable water system determines that inland navigation must be an important part of China's shipping industry. The collision process of ship striking the anti-collision pier is analyzed through simulation experiment in this paper. The results show that the collision process usually lasts less than 2 seconds, and the peak value of the collision force, friction and resultant force appears 0.5 after the start of the collision.

1 INTRODUCTION

China's extensive inland navigable water system determines that inland navigation must be an important part of China's shipping industry. With the implementation of the national strategy of country with strong transportation network, more bridges will be built in the navigable waters of inland rivers in the future, and the navigable safety of inland river Bridges will become an unavoidable topic in the industry. As an important bridge anti-collision facility, anti-collision pier will be widely used in navigable inland waters in the future.

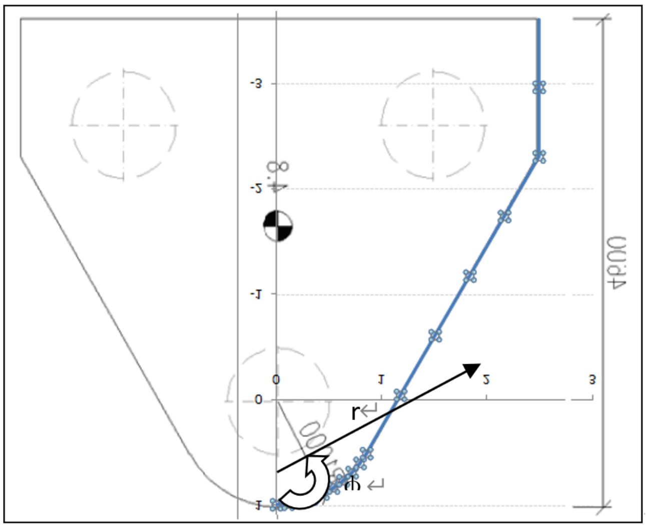

Figure 1. Shape of the anti-collision pier

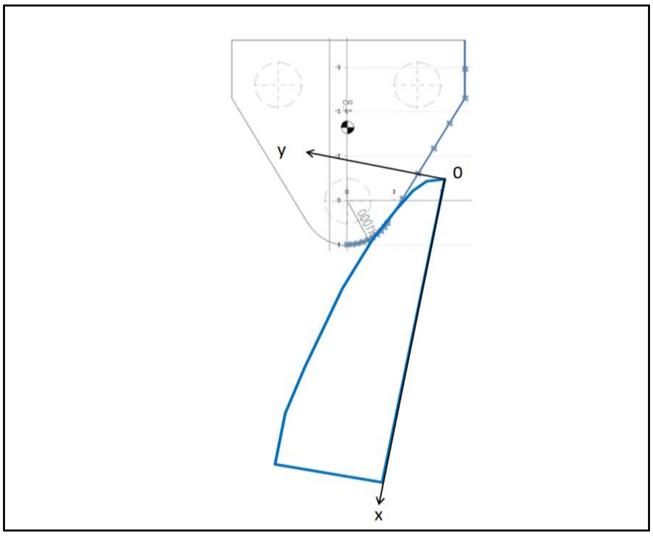

Figure 2. Ship attitude after collision

2 PLANE MODEL OF ANTI-COLLISION PIER

In this experiment, anti-collision pier with a width of 5.0 meter, a length of 4.6 meter and a thickness of 2.9 meter was adopted. as shown in Figure 1. Its plane shape was composed of a 5.0 meter×1.3-meter rectangle, and a trapezoid with a width of 5.0 meter at the bottom, 1.72 meter at the top and 2.8 meter at the top, and a chord tangent circle with a radius of 1 meter and a chord length of 1.72 meter [1-2]. The shape of one side of the bow as shown in Figure 2.

3 ANALYSIS OF COLLISION FORCE BETWEEN SHIP AND ANTI-COLLISION PIER

The force perpendicular to the surface in the process of collision is an elastic force. The relationship between the force F(t) changing with time and the change rate of ship's normal momentum (M·δV) theorem is:

$$F(t)\cdot\delta t = M\cdot\delta v$$

During the collision process, the velocity vector of the ship is not parallel to the tangent plane. Besides the normal velocity perpendicular to the tangent plane, there is also a tangent velocity parallel to the tangent plane. The ship has a tendency to slip along the surface of the anti-collision pier. Affected by the positive pressure, there is a friction prevents the slip movement.

$$F_f(t) = \mu F(t)$$

$$\delta v_r = \frac{F(t)\delta t}{M}$$

The changing of course is:

$$\delta T = \frac{180\cdot\left[F(t)\left(\sin(T+\varphi)\cdot(0.5L - x_b) - \cos(\varphi+T)\cdot y_b\right)\right]}{I_z\cdot\delta t\cdot\pi} + -\frac{F_f(t)\left(\cos(T+\varphi)\cdot(0.5L - x_b) + \sin(T+\varphi)\cdot y_b\right)}{I_z\cdot\delta t\cdot\pi}$$

The changing of collision point is:

$$\delta\varphi = \frac{180\cdot\delta v_r}{\pi r}$$

$$\delta r = r(\varphi+\delta\varphi) - r(\varphi)$$

The polar coordinates of the bow position changing with time during collision are as follows:

$$r_b = \sqrt{\left(r + \frac{y_b}{\sin(T+\varphi)}\right)^2 + \left(x_b + y_b{*}ctg(T+\varphi)\right)^2 - 2\left(r + \frac{y_b}{\sin(T+\varphi)}\right)\left(x_b + y_b{*}ctg(T+\varphi)\right)\cos(T+\varphi)}$$

$$\varphi_b = \varphi + \arccos\left\{\frac{\left(x_b + y_b{*}ctg(T+\varphi)\right)^2 - \left(X_b + y_b{*}ctg(T+\varphi)\right)^2 + r_b^2}{2r_b\left(x_b + y_b{*}ctg(T+\varphi)\right)}\right\}$$

4 COLLISION ANALYSIS BASED ON SIMULATION TEST

At the initial moment of collision, the hull moves towards the anti-collision pier with a certain radial velocity. The hull and the side of the anti-collision pier contact and continue to move, the anti-collision pier and the surface of the hull resulting in elastic force [4].

MSC. Dytran was used to analysis the structure of the ship [5,6]. The results of vertical collision between bow and anti-collision pier are as shown in Figure 3 and Figure 4.

The maximum collision force and damage effect are produced by vertical frontal collision of bow. The collision velocity vector can be decomposed into the direction perpendicular and parallel to the collision plane. The component perpendicular to the collision plane is the collision velocity and the collision force is generated. The component parallel to the collision plane is the slip velocity, which forms the friction force. The normal momentum consumption process of the bow under the collision as shown in Figure 5.

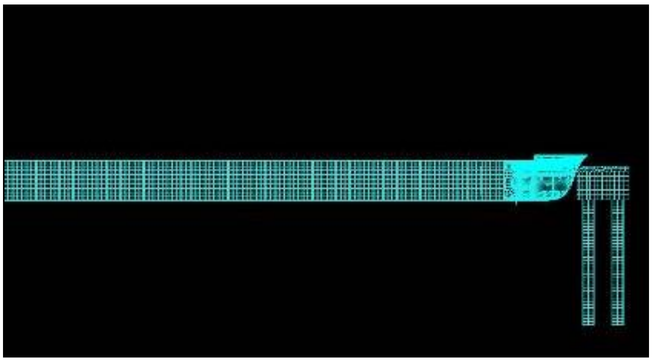

Figure 3. Calculation model

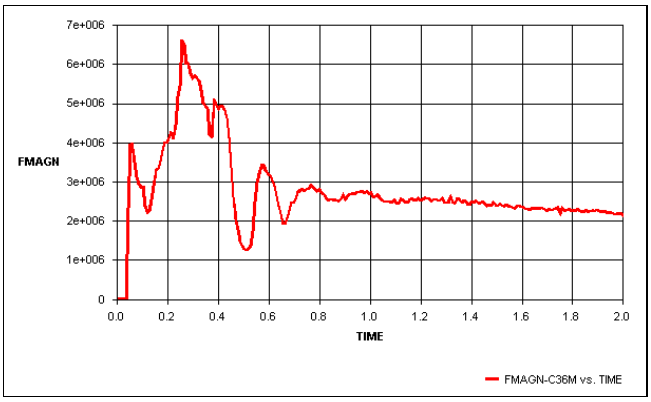

Figure 4. The change of collision force with time

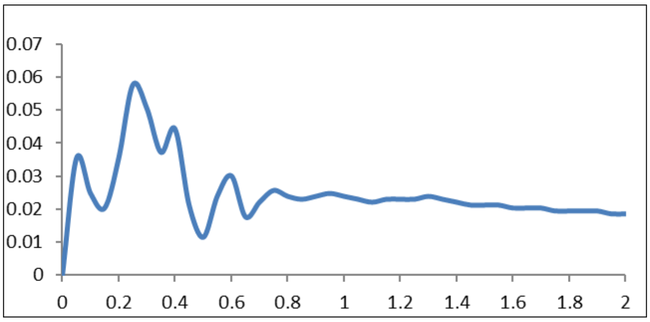

Figure 5. The changing of impulse coefficient variation with time

The front of the bow of the test ship struck the anti-collision pier vertically at a speed of about 4m/s, the collision time is about 2 seconds. The ratio of impulse to initial normal vector at any time during collision is defined as impulse coefficient C(t):

$$C(t)=\frac{F(t)dt}{\int_0^2 F(t)dt}=\frac{F(t)dt}{Mv_0}$$

When the bow of the ship struck the anti-collision pier, the collision force is:

$$F(t)=\frac{C(t)\cdot Mv_0}{dt}\approx\frac{C(t)\cdot Mv_0}{\delta t}$$

5 ANALYSIS OF THE RESULTS OF SIMULATING

The test conditions as shown in Table 1, the collision force, friction and resultant force changing with time as shown in Figure 6 to 8, the Collision velocity and slip velocity with time as shown in Figure 9 to 11.

Table 1. Test conditions

No.	Wind D	Wind S	Water flow D	Water flow S	Angular velocity of rotation	Ship speed	Heading
1	N	4	300	1.4	2.8	6.2	302.9
2	N	5	300	1.4	7.5	5.9	307.7
3	N	6	300	1.4	8.3	5.8	309.4

D - direction
S - speed

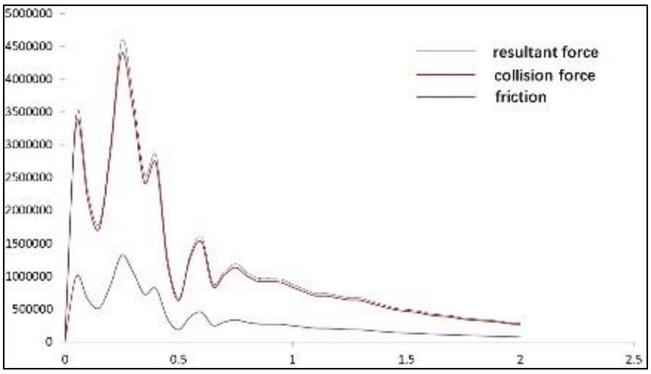

Figure 6. NO.1 test condition

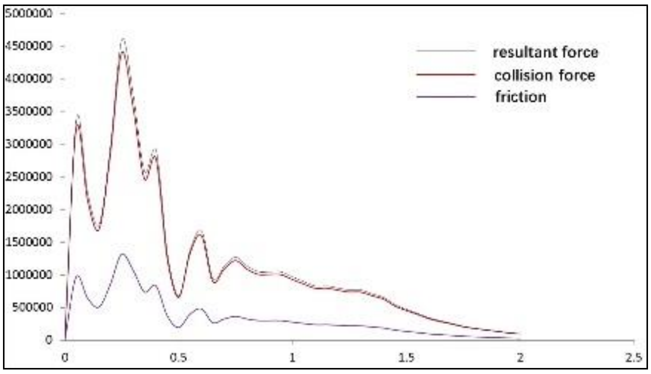

Figure 7. NO.2 test condition

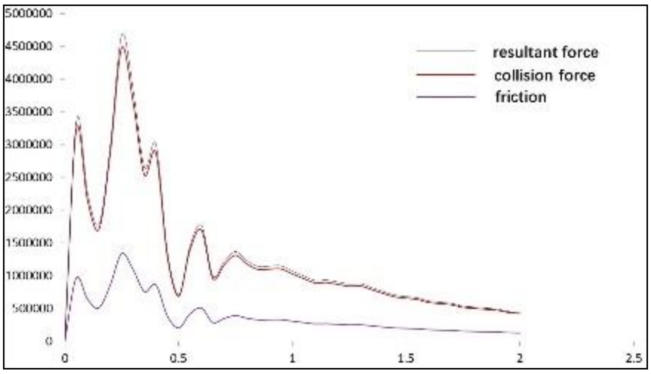

Figure 8. NO.3 test condition

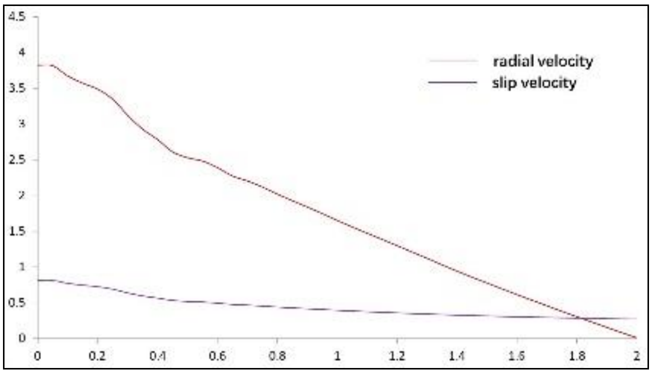

Figure 9. NO.1 test condition

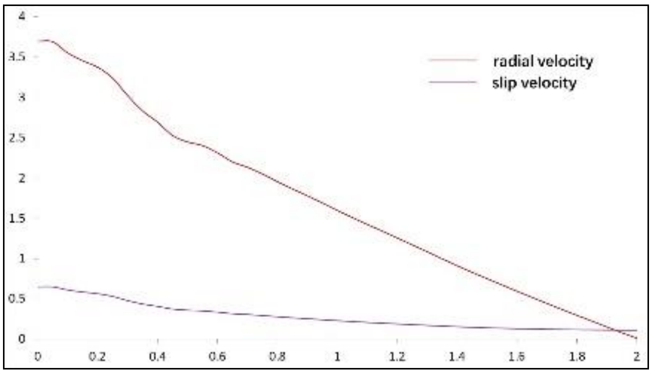

Figure 10. NO.2 test condition

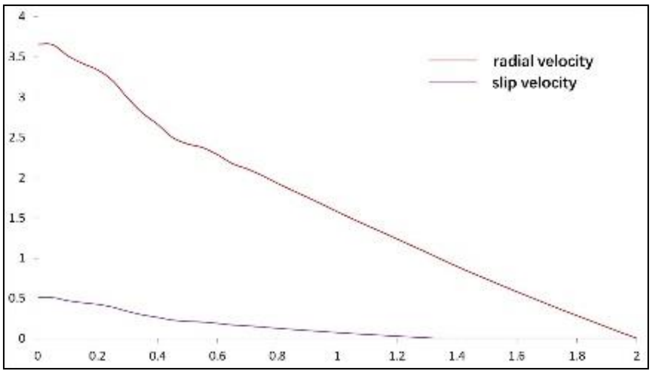

Figure 11. NO.3 test condition

6 COLLISION RANGE AND FORCE ANALYSIS

The process of the test ship struck the anti-collision pier for 2 seconds, and the peak value of the collision force, friction and resultant force appeared after 0.5 second at the beginning of the collision. During the collision, the ship's heading Angle changed a little, not more than 1°. In addition to the deformation and displacement of the anti-collision pier and hull structure, there is also a slip relative to the side of the anti-collision pier, and friction. The resultant force of friction and collision force increases slightly, but the increment is not significant.

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