Research on Maneuverability of Ships in Port Based on MMG Separation Modeling

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Abstract: In order to effectively use experimental data to detect ship maneuverability and improve the standardization of ship prediction, a mathematical model based on ship maneuvering motion is proposed. This paper takes the model test data as the research sample, constructs the mathematical simulation model through hydrodynamic coefficients, and verifies it by comparing the actual ship with the model, so as to explore the maneuverability of the ship in the port. The experimental results show that the MMG method can accurately predict the ship maneuverability, which is helpful to promote the convenience of ship maneuvering in port, and has important application value.

1. Research background

1.1 Literature review

According to the existing literature, ship maneuverability mainly includes four aspects, namely, turning, course stability, turning and stopping performance. In the course of navigation, the ability of a ship to change or maintain speed, position and course is the maneuverability of the ship (Hou, et al, 2012). Generally speaking, the communication with good maneuverability can change course rapidly when turning, or keep moving direction when going straight, and has the capability of navigating according to the predetermined course and stopping properly (Wei, et al, 2018). At present, ship maneuverability tools mainly include active rotating device, rotating duct, rudder, and translational propeller. These tools cooperate with each other to maximize ship performance. The specific contents of ship manoeuvring mainly involve manoeuvring in wind and waves, emergency collision avoidance, navigation in narrow channels, etc. (Zhang and Li, 2010). Because the seakeeping and maneuverability of ships belong to unsteady motion, inertia should be considered. In the existing literature, many scholars have discussed it in detail. Some scholars have pointed out that ship maneuvering inertia mainly involves additional inertia force. In addition to the acceleration of the hull itself, the inertial force acts on the surrounding water, thus boosting the ship's acceleration. According to the principle of action and reaction of force, the reaction force of water body to hull is additional inertia force (Mo, 2018). Some scholars point out that the additional inertia force is proportional to the acceleration of the ship, and the proportion coefficient formed by it is the additional mass. The additional mass has a certain relationship with the shape and direction of motion of the object itself. Literature studies have shown that when the hull moves along the coordinate axis, the inertia action takes the form of an example, while when the ship rotates around the coordinate axis, the inertia expression is the force rectangular form (Liu, et al, 2011). Some scholars point out that the additional mass and moment of inertia are both the reaction forces of fluid on ships, so this element is a function of the hull, which is determined by model tests or empirical formulas. There will be a good application scenario (Liu, et al, 2014) when calculating. Separate Modeling (MMG) is a commonly used method for ship maneuvering motion modeling. According to the concept of MMG model, the model can be used in ship's specific hydrodynamic performance, maneuverability and simulation, and has good application effect.

1.2 Purposes of research

With the development of the strategy of “one belt and one road” and “ocean power”, the shipping

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industry is developing rapidly, but at the same time, it brings some maritime traffic risks. In the course of ship maneuvering, there are usually several common steps. For example, the Maneuvering Simulation model, the hydrodynamic characteristic model test, the hydrodynamic coefficients in the simulation model, the maneuvering performance research and so on. Today, the MMG simulation model has been widely used, mainly because the MMG model can obtain hydrodynamic coefficients, modify the corresponding coefficients according to the scale effect, and carry out underwater direct navigation simulation experiments according to the mathematical model, and test the propagation maneuverability in the experimental process. From this, the final simulation results and test results are tested, and finally effective data are obtained. Therefore, this paper will use MMG model to analyze ship maneuverability in port, and give the corresponding results, in order to provide some suggestions for shipping development.

2. Gmm-based simulation model of ship maneuvering in port

In port, the MMG model is needed for ship motion model. It decomposes the whole force process of ship into separate forces of ship, rudder and slurry, and interacts with each other. This model has strong universality and clear physical meaning, and can be applied to other ships of the same type (Liu, et al, 2011). Therefore, based on the actual needs of ship motion control and maneuvering, this paper establishes a more reasonable and moderately complex mathematical model of ship maneuverability on the basis of MMG model.

2.1 Manipulation simulation model

The coordinate system of this study is shown in Figure 1. In space $o_0 - x_0 y_0$, $x_0 - y_0$ is a plane coincident with the still water surface. O is in the boat, X and Y point to the bow and starboard respectively. This coordinate system is the coordinate system of the ship's bow motion, considering that the ship may sail at different draft depths. If the origin is set in the center, the rudder and slurry will change with the different coordinates of the underwater center, it is necessary to select the bow as the origin, so as to avoid the above problems.

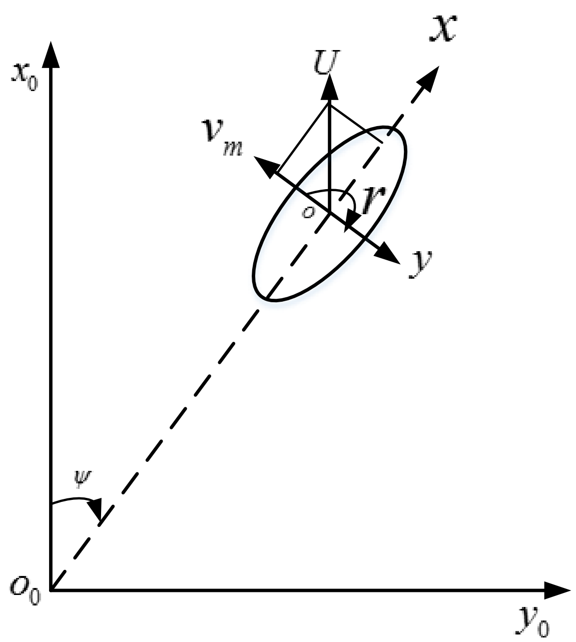

Fig 1. Coordinate System

2.2 MMG mathematical model

According to the momentum moment theorem and Newton's rigid body mechanics momentum theorem, the following mathematical models are set up:

$$\begin{cases}(m+m_x)\dot{u}-(m+m_y)vr = X_H + X_P + X_R \\ (m+m_y)\dot{v}-(m+m_x)ur = Y_H + Y_P + Y_R \\ (I_{ZZ} + J_{ZZ})\dot{r} = N_H + N_P + N\end{cases}$$

Variables and definitions in the formula are shown in Table 1:

Table 1. Variables and Definitions

Variable	Definition	Variable	Definition
m	Ship quality	X_H, X_P, X_R	Longitudinal forces of viscous fluids, Slurry and Rudder
m_x, m_y	Longitudinal and lateral additional mass of ships	Y_H, Y_P, Y_R	Lateral forces of viscous fluids, Slurry and rudder
I_{ZZ}, J_{ZZ}	Moment of inertia and additional moment of inertia	N_H, N_P, N	Viscous fluids, Slurries and bow moments
u, v, r	Longitudinal velocity vector, Lateral velocity vector, Stern angular velocity		

2.3 Hydrodynamic maneuvering model of ship hull

Because the simulation experiment only aims at the design of ship's rapidity, forces other than X need to be omitted and XH retained, as shown in formula (1):

$$X_H^{'}(v_m^{'}, r^{'}) = X_{vv}^{'} v_m^{'2} + X_{vr}^{'} v_m^{'} r^{'} + X_{rr}^{'} r^{2'} + X_{vvvv}^{'} v_m^{'4} \tag{1}$$

2.4 Model test and data analysis

Based on the above model, the parameters of different underwater draft vessels are established, as shown in Table 2.

Table 2. Parameters under Different Draughts

	Structural draught		Ballast draught		Draft design	
Parameter	Solid ship	Model	Solid ship	Model	Solid ship	Model
L_{pp}(m)	186.0	5.2214	186.0	5.2214	180.2	6.1285
B(m)	20.1	0.8524	20.1	0.8524	26.8	0.8034
T_A(m)	10.6	0.2841	10.6	0.2841	10.2	0.7143

On this basis, it is necessary to discuss the open water characteristics of pulp in dimensionless form. M and S are models and solid ships respectively.

$$X_{Ym} = \frac{Y_m}{\rho_m N_m^2 u_{pm}^4}$$

$$X_{Nm} = \frac{N_m}{\rho_m N_m^2 u_{pm}^5}$$

Next, the coefficient of ship grouping is discussed. The concrete formulas are as follows:

$$I_{os}^{'} = \frac{J + J_{WBK}}{J}[(1+k)C_F + C_A] + C_W + C_{AA}$$

Among them, the frictional resistance coefficient, the wave-making resistance coefficient, the correction coefficient and the air resistance coefficient, respectively.

2.5 Ship Maneuverability and Maneuvering Methods

For a specific ship, the first stability evaluation is performed by rolling parameters to determine whether the design meets the requirements. Ship pilots should understand the evaluation incentives of the first stability criterion of parameter rolling, and then grasp the maneuvering characteristics of ships in practical applications (Chang, et al, 2008). In practical application, it should not only be considered that the first stability criterion of parameter rolling will play a practical role. In fact, the minimum requirement of formula (1) for stability only considers ship form parameters with square coefficients, and does not consider draft, captain and other parameters. Statistical analysis of accidents shows that most container ships and ro-ro ships are greatly affected by parameters. Relatively speaking, bulk carriers are not prone to parametric roll (Xiong, et al, 2013).

Now, it is necessary to set up specific methods of ship maneuvering. Firstly, the rolling standard of parameters is realized by stowage of goods. In this case, the ratio of stability can be reduced by increasing the ship stability height, thus effectively avoiding the occurrence of parameter rolling. In stowage of cargo, the possibility of ship rolling is reduced by adjusting the height of cargo detention. In addition, in order to prevent the damage caused by the shift of goods, the stability of goods needs to be further fixed (Ning, et al, 2017).

At the same time, in order to meet the specific parameters setting under wave conditions, it is necessary to change the yaw stability parameters. Due to the obvious pitching motion of ships with large variation, the draft range changes within a certain range, which leads to instability. Therefore, the ship needs to change course adjustment while sailing. When encountering waves, the ship can reduce rolling by adjusting the sailing time. When the ship encounters large roll and heave phenomena, it is necessary to avoid the secondary harmonic roll zone.

In addition, according to the existing research and analysis, ships with lower speed are prone to generate acceleration in the condition of crosswave. In order to prevent the occurrence of transitional acceleration, the ship's speed should be wider than the contents of your payroll cargo stowage. At the same time, the appropriate initial value of the ship is guaranteed and the transition acceleration is controlled from the source. When a ship is sailing in a rolling wave, if conditions permit, the rolling acceleration of the ship can be reduced by increasing the speed of the ship. Before the arrival of strong winds and waves, the ship's maneuverability should be adjusted in the harbor to inform the personnel concerned to take care to prevent damage. In principle, the roll transition acceleration is mainly due to the contradictory stable failure modes. Therefore, when loading water, we can consider the factors such as wind wave, wave period that may encounter and so on, adjust the relevant factors in time to prevent the generation of transition acceleration.

3. Simulation experiments and conclusions

Based on the platform of MATLAB, the above model is validated by programming. When the main probability is fixed, the simulation direct navigation tests of ships in different draft states are carried out, and the longitudinal velocity changes of ships are obtained by MMG model. At the same time, in the simulation direct navigation test, the error between the steady speed result and the experimental ship is smaller. The experimental results show that the MMG method is used to analyze the ship model, establish the simulation mathematical model, and verify it by MATLAB programming. The results show that the algorithm has a good application prospect for the detection of ship maneuverability, and has a great application value for the actual operation.

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