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Numerical Pool of Ship and Ocean Engineering Based on MFBM

Sarava Sride*

University of Anbar, Iraq

**corresponding author*

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Abstract: With the development and progress of human civilization, human beings have become more and more dependent on the ocean. Today, human beings have entered the era of marine economy. Therefore, this paper studies and analyzes the numerical pool(NP) of ship and marine engineering based on the Multiple Network Virtual Boundary Method (MFBM). This paper firstly expounds the related theory of grid technology and NP wave making, and then analyzes the current situation of NP wave making and wave elimination, and finally analyzes the variation law of slamming load and the sensitivity analysis of surge period.

1. Introduction

Rich and diverse marine resources have always been the focus of human attention [1]. With the ever-changing science and technology and the growing population, various resources and available space on land have been unable to meet the needs of human social and economic development [2]. In order to survive, oceanic rivers must be developed. Over the years, ocean engineering has quietly become a rising star in research disciplines [3]. The acquisition and development of marine resources is a strategically important part that has emerged and developed rapidly in recent decades [4]. Water transportation is one of the three major transportation systems. Compared with land transportation and air transportation, it has the advantages of less economic cost investment, less floor space, and large cargo transportation volume. It plays an irreplaceable role in economic development. The research on NP of ship and marine engineering is of great significance to the exploitation of marine resources [5-6].

At present, many scholars have carried out research on NP in ship and ocean engineering, and have achieved good research results. For example, researchers such as Kim J developed a 3D numerical wave pool model based on CFD tools, which combined the improved VOF method to track the free surface and solved the turbulence with the LES model, and for different incident wave heights, offshore water depths, adjacent The space between the piles and the beach slope was subjected to a series of numerical experiments for this numerical model to analyze the wave breaking force [7]. Zwaginga J et al. have proposed a method to improve the production process of offshore factory modules by analyzing process mining data obtained from the shipbuilding industry. Data mining uses information accumulated from event logs provided by the system to generate process models and identify hidden The value in the process, the discovered process is visualized as a process model, this method can improve the productivity and realize the effective management of the production process [8]. Experts and scholars such as Kumar R discussed a nonlinear controller based on saturation function with variable parameters for setpoint adjustment and trajectory tracking control of autonomous underwater vehicles (AUV), considering the underwater The characteristic operation of the aircraft LIRMIA2, a mathematical model is obtained, and Lyapunov parameters are used to perform the stability analysis of the closed-loop system for the proposed nonlinear controller [9]. In recent years, with the development of marine resources, the research on NP of ship and marine engineering has become more and more in-depth, but the research on NP of ship and marine engineering based on MFBM is relatively rare [10].

Based on the MFBM, this paper studies the NP of ship and ocean engineering. The structure of this paper can be divided into three parts: the first part is a brief introduction to the relevant basic concepts. This paper introduces the two basic concepts of numerical network technology and numerical wave making. Introduction; the second part is the analysis of the research status, which analyzes the current situation of wave generation and wave elimination and grid convergence of the NP; the third part is the analysis of the research results, in this part, the slamming load is mainly analyzed. Change law and surge cycle sensitivity are analyzed.

2. Related Overview

2.1. Grid Technology

In the solution of hull motion, MFBM is usually used to discretize the computational domain, so that the relative position between each grid remains unchanged, only the shape and absolute position of the grid are changed, based on the tension-compression operation and torsional deformation of the grid, etc. process to ensure that the grid can always fit the hull surface well when the hull moves [11]. When the hull moves in a small range, the stretching and deformation of the mesh will not cause the mesh quality to be too poor to affect the calculation accuracy or make the calculation diverge [12]. MFBM is used to solve small-amplitude wave motion and ship six-degree-of-freedom motion problems. The amount of mesh deformation is calculated by solving the Laplace equation [13].

2.2. NP Wave Generation

Ocean engineering pools are equipped with special wave generators and wave elimination devices. The wave maker can produce regular waves and more complicated irregular waves according to the needs of the experiment, and some specific wave generators, such as the L-shaped wave maker mentioned in this paper, can produce multi-directional mixed waves. According to the wave propagation characteristics, it can be known that the wave will reflect when encountering obstacles, so the corresponding wave-making device should be equipped with a wave-absorbing device, so that the wave energy generated by the wave-making machine in the pool can stably meet the test requirements [14-15]. Therefore, both wave-making and wave-dissipation are processes that cannot be ignored in the NP simulation.

The realization of numerical wave generation is an indispensable step for the follow-up work of the NP [16]. In recent years, through continuous efforts, researchers from various countries have either imitated the wave-making method of physical pools, or have developed new numerical wave-making methods. , mainly including the rocking plate wave making method, the velocity inlet wave making method, and the source wave making method [17].

3. Research Status Analysis

3.1. Construction of the Numerical Pool

The wave generation method used in this paper is the velocity inlet method, and the wave elimination method is the damping wave elimination method. Linear regular waves and fifth-order Stokes waves are simulated in three working conditions, respectively, and the specific wave parameters of each working condition are shown in Tables 1 and 2. The initial water depth of the pool in Example 1 and Example 4 is 0.6m, the initial water depth of the pool in Example 2, Example 3 and Example 5 is 1.2m, and the initial water depth of the pool in Example 6 is 2.3m. The reference coordinate system is set at the center of the free liquid surface at the initial moment of the front of the pool, and the coordinate axis satisfies the right-hand spiral rule, where the X axis points to the length of the pool, the Z axis points to the height of the pool, and the waves propagate along the positive direction of the X axis. In this paper, the gas-liquid two-phase flow is used for calculation, that is, air above the free liquid surface and water below the free liquid surface, where the density of water is 997.561kg/m3, the dynamic viscosity is 8.8871×104Pas, and the free liquid surface capture method is VOF Law.

Table 1. Linear Regular Wave Wave Parameters Table

Calculation example	Wave height	Period	Water depth
Example 1	0.006	2.2	0.6
Example 2	0.012	2.2	1.2
Example 3	0.022	1.5	1.2

Table 2. Fifth-order Stoke wave parameter table

Calculation example	Wave height	Period	Water depth
Example 4	0.070	1.6	0.6
Example 5	0.120	1.6	1.2
Example 6	0.160	1.0	2.3

3.2. Mesh Convergence of Numerical Wavemaking

In order to consider the influence of the calculation grid on the numerical simulation results, numerical verification work was carried out on the incident short wave. A numerical wave pool is established to simulate the propagation process of regular waves, and the first-order Stokes regular wave is simulated by numerical wave making method, which is realized by setting the moving speed with time on the wave making boundary. The waveform of the inlet boundary is given according to the first-order Stokes wave theory.

This section simulates a first-order regular wave with x=3.879m and H=0.079m. Figure 1 shows the wave pool built for the regular wave. The left side of the pool is the inlet boundary, the top boundary is set as the pressure inlet, and the right side is the outlet boundary And a long enough wave-absorbing area is arranged on the right side to ensure sufficient wave-absorbing, and the bottom of the pool is set as the wall boundary. Waves are introduced from the wave-making entrance and propagate toward the exit on the right. In order to record the change of wave height, set the wave height meter at x=0 (the bow). For this regular wave, verification of the grid arrangement is performed.

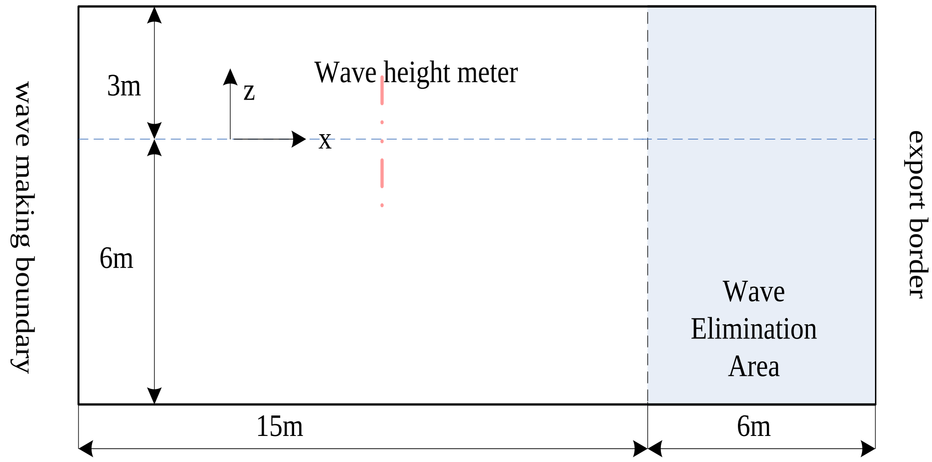

Figure 1. Structure diagram of numerical wave pool

The grid layout in the numerical simulation is based on the following considerations: along the wave propagation direction, in order to accurately capture the wave surface motion and reduce the numerical dissipation generated in the wave simulation, the horizontal and vertical directions at the free surface need to be finely meshed. Make the mesh size meet the numerical simulation accuracy requirements.

3.3. Numerical Wave Clipping

Wave elimination corresponds to wave making. Whether it is a physical pool or a NP, because the pool has boundaries, once the waves propagate to the pool boundary, they will inevitably form reflections, which will interfere with the normal operation of the waves in the work area. Therefore, corresponding measures are taken in the pool. Wave elimination treatment is very necessary [18].

At present, there are two main wave elimination methods when using numerical software to build a NP for simulation, one is wave elimination by setting up a damping layer, and the other is active absorption wave elimination. The main principle of damping layer wave elimination is to add a damping term, so that the governing equations and boundary conditions of the flow field change to a certain extent, so the wave energy can be attenuated to a certain extent, and finally the effect of wave elimination is achieved. The text adopts the damping layer wave elimination method, and the change of the momentum equation in the damping layer elimination band is as follows:

$$\frac{\partial v}{\partial a}+v\frac{\partial v}{\partial b}+w\frac{\partial v}{\partial c}=-\frac{1}{\rho}\frac{\partial p}{\partial b}+\mu\left[\frac{\partial^2 v}{\partial b^2}+\frac{\partial^2 v}{\partial c^2}\right]-\mu v \tag{1}$$

$$\frac{\partial w}{\partial a}+v\frac{\partial w}{\partial b}+w\frac{\partial w}{\partial c}=k-\frac{1}{\rho}\frac{\partial p}{\partial c}+\mu\left[\frac{\partial^2 w}{\partial b^2}+\frac{\partial^2 w}{\partial c^2}\right]-\mu w \tag{2}$$

The momentum equation at this time needs to satisfy the continuity equation:

$$\frac{\partial v}{\partial b}+\frac{\partial w}{\partial c}=0 \tag{3}$$

4. Analysis of Research Results

4.1. Analysis of the Variation Law of Slamming Load

Figures 2 and 3 are the comparison diagrams of the maximum slamming pressure and the maximum slamming pressure at the bottom of the plate under various working conditions.

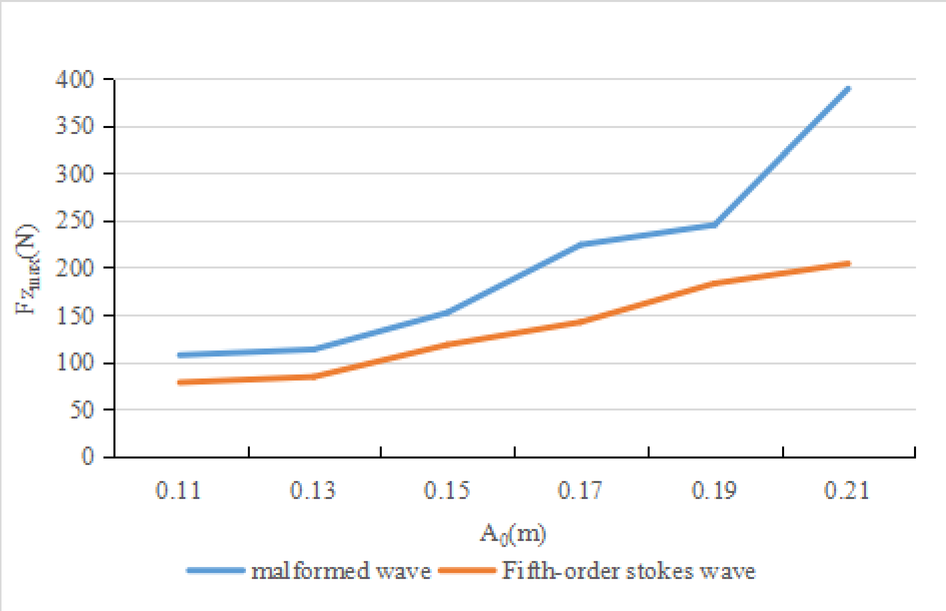

Figure 2. Graph of the maximum value of the slamming pressure at the bottom of the plate

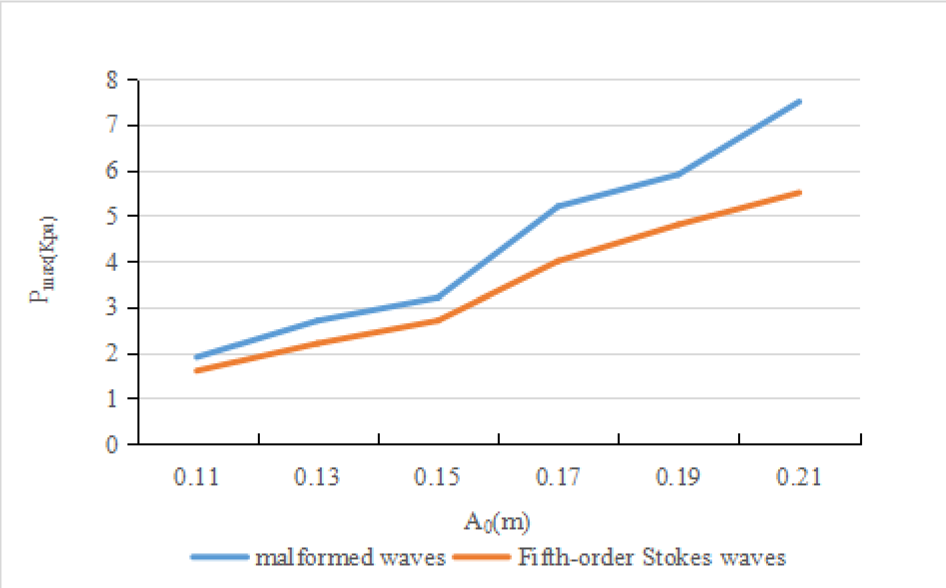

Figure 3. Variation of the maximum value of the slamming pressure at the bottom of the plate

Through the analysis of Fig.2 and Fig.3, it can be seen that under the action of the deformed wave and the fifth-order Stoke wave, the maximum slamming pressure and the pressure value at the bottom of the plate increase with the rise of the peak height, and the deformity can also be seen from the two figures. The maximum slamming pressure and slamming pressure at the bottom of the wave plate are always higher than those of the fifth-order Stokes wave. When the peak height reaches 0.21 m, the maximum pressure values of the deformed wave and the fifth-order Stoke wave reach the highest values, which are 389 and 204, respectively, and the maximum pressure of the deformed wave is 1.9 times that of the fifth-order Stoke wave. The maximum value of the slamming pressure at the bottom of the plate of the above two waves is also the maximum at 0.21 m, the deformed wave is 7.5, and the fifth-order Stoke wave is 5.5, the difference between the two is 1.3 times. The reason why the attack pressure and the maximum pressure change with the height of the wave crest is that as the height of the wave crest increases, the water body it carries will also increase, and the vertical velocity of the water quality point at the same height within the wave crest range also increases accordingly. The corresponding slamming force also increases when a large wave acts on the plate.

4.2. Sensitivity Analysis of Surge Cycle

In order to explore the influence of swell on ship motion, a sensitivity analysis of swell period was carried out. The combined action of wind, wave and swell is simulated by superimposing long-period irregular waves with short-period irregular waves. The parameters of wind, wave and swell are shown in Table 3. Changes in ship motion response are analyzed by changing the swell period.

Table 3. Surge parameter table

Sea state	HS(m)	Tp(s)
Wind sea	0.85	8.2
Swell	0.81	22.0

Fig. 4 and Fig. 5 are graphs of calculation results of the motion 1/3 meaningful amplitude calculated by the numerical simulation software.

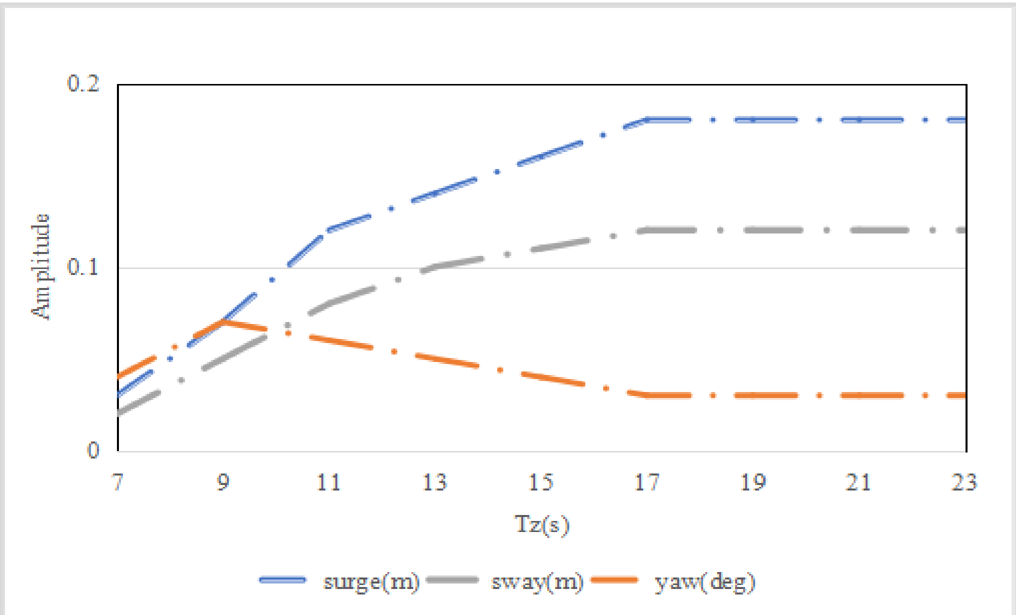

Figure 4. Calculation result of 1/3 meaningful amplitude of horizontal low-frequency motion

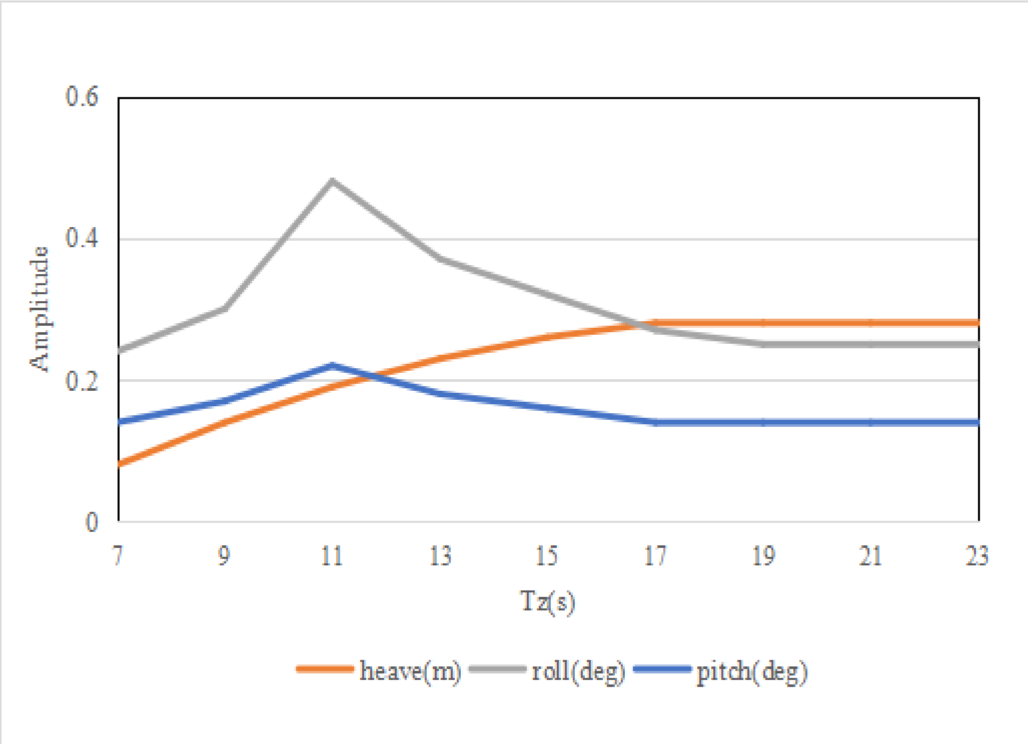

Figure 5. Calculation result of 1/3 meaningful amplitude of vertical Bourton motion

It can be seen from Figure 4 and Figure 5 that as the long-period surge period becomes larger, the ship's surge and sway gradually increase, and then stabilize around a certain value. The roll and pitch increase first, and then decrease after reaching the peak. Based on the above analysis, when analyzing the influence of swell on ship motion, it should be divided into vertical wave frequency motion and horizontal low frequency motion to be considered. The swell increases the wave frequency movement and low frequency movement of the ship to different degrees. The change of the swell period has no obvious effect on the horizontal low frequency movement, but has a certain influence on the vertical wave frequency movement. When the swell period is far from the wave frequency movement period When the wave frequency motion gradually decreases, when the surge period is close to the natural period of the wave frequency motion, a larger wave frequency motion will occur.

5. Conclusion

With the development of marine resources, the research on ship and ocean engineering becomes more and more important. Therefore, this paper studies the NP of ship and ocean engineering based on MFBM. This paper firstly analyzes the change law of the slamming load, and finds that the corresponding slamming force will also increase when the wave with a larger peak height acts on the plate. With the increase of the swell period, the ship's surge and sway gradually increased, and then stabilized around a certain value, and the roll and pitch first increased to a peak and then decreased. There are many deficiencies in this paper that need to be improved, but the research on NP of ship and marine engineering based on MFBM is a direction worthy of further research.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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