Investigation on the wave characteristic inside the well dock of LPD ship in open ocean

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ABSTRACT

Landing Platform Docks (LPDs) are able to carry a large number of vehicles and vessels. A floodable well dock is required to launch and recover vehicles and vessels. The outboard end of the well dock is built into the stern of the ship and is open to the sea. Initial CFD study shows that very complicated wave motion appears in the wake and well dock of the LPD ship. The wave motion involves wave diffraction, wave radiation and vortex shedding behind the dock gate. As the first stage, numerical simulations were performed by utilizing a commercial CFD software STAR-CCM+ to investigate the relationship between the waves inside and outside the well dock. To simplify this problem, the ship is assumed to be fixed. Laminar model was applied in the CFD simulation and free surface is captured by VOF method. Initial numerical results show that wave motions inside a well dock are caused by relative wave motions at the dock gate. Also, wave height in some certain positions in the well dock is higher than the incident wave height due to superposition of the wave crests of propagating-in and propagating-out waves.

KEY WORDS: Ship with well dock; numerical wave tank; CFD (Computational Fluid Dynamics).

INTRODUCTION

Landing Platform Docks (LPDs) play a significant role in launching and recovering vessels and amphibious vehicles on the sea. Usually, LPD ships are designed to have a well dock, whose outboard end is constructed into the stern of the ship, and can be floodable by ballasting the ship. A well dock gate is installed at the stern, a little lower than the well dock floor. And it separates the well dock and the outside ocean. When sailing on the sea, the dock gate is usually closed to avoid sloshing inside the well dock. When launching or recovering operations are carried out, the gate can be opened, then vessels are able to get off from the LPD ship, or get aboard.

Operations under ocean waves can be difficult for LPD ships, and can be risky when sea state gets severe. Because when operating with well dock, the water inside the well dock is connected to the open sea, and ocean waves in the open sea can propagate inside the well dock, causing wave motions inside. Besides, motions of LPD ship can also cause wave motions inside the well dock. Under this situation, vessels are hard to be controlled to get in or out of the well dock, and the risk of accidents like collision raises. Thus, to guarantee safety of operations, the characteristic inside the well dock of LPD ship should be studied.

The problem of wave motions inside the well dock was studied by CFD (Computational Fluid Dynamics) method and experimental method previously by other researchers. Hopman et al. (1994) set up a typical model test to study the wave motions inside the well dock of two ship models (with good performance and newly designed), in a series of wave directions and speeds under two irregular spectral conditions, and a self-propelled landing craft model was utilized to study the embarking and disembarking operation. Bass et al. (2004) used a commercial CFD code (Flow-3D) with a ship motion code (MOTSIM) to simulate the wave interaction in the wetted well dock and verified the numerical simulation result with the model test that carried out by Hopman. Cartwright et al. (2007) used SPH (Smoothed Particle Hydrodynamics) method to simulate 2D landing craft entering well dock and explore the influence of well dock design on landing craft movement. Yoon and Seo (2012) conducted model tests in landing craft with different well dock positions and studied their seekeeping and safety. Xu et al. (2020) used commercial software FLUENT to establish a linear numerical wave tank and studied the hydrodynamics performance of original Wigley-III ship and modified Wigley-III ship with well dock, and the hydrodynamics effect of the floating body in the well dock were also investigated.

In this work, a simplified LPD ship model with a well dock is established according to Hopman’s script in his paper. We presently set the LPD ship to be stationary, thus only diffraction problem will be involved. The incoming wave is set to be first-order linear wave. The direction of incoming wave is 180°, the value of wavelength/length of the ship is set to be 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, and 1.8, and the wave steepness is 1%. Wave height monitors are set inside the well dock to have a clear view of the evolution of the waves inside.

NUMERICAL METHOD

Governing equation

Continuous equation and momentum equation (Navier-Stokes equation) for incompressible flow are as follows:

\[ \nabla \cdot \mathbf{U} = 0 \]
\[ \rho \frac{\partial \mathbf{U}}{\partial t} = \mathbf{f} + \nabla p + \mu \nabla^2 \mathbf{U} \]

where \( \mathbf{U} \) is the velocity, which has three components in three directions \( x, y, \) and \( z \), \( \rho \) is the density, \( p \) is the pressure, \( \mu \) is the dynamic viscosity, and \( g \) is the acceleration due to gravity.

In STAR-CCM+, the velocity and pressure in the governing equation are decoupled by SIMPLE method. As the LPD ship is set to be stationary, which means zero speed is applied, and also we focus on the evolution of the waves and the interaction between waves and structures, the laminar model is selected for this problem.

Free surface capturing

The problem involves wave generating and evolution, and also interaction between free surface and ship hull, so multi-phase conditions should be issued. The Eulerian multi-phase model in STAR-CCM+ is selected, and VOF (Volume of Fluid) method is applied to capture the free surface. VOF method is realized by defining a variable, which is the ratio of one fluid (water or air) to the volume of a cell. The