Numerical Investigation of Regular Wave Impact on a Square Column-Deck-Pontoon Structure

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ABSTRACT

In recent years, the damage to marine structures caused by wave impact has attracted extensive attention in the industry, and more studies of the wave impact on geometry-simplified structures have also appeared in the laboratory. However, compared with the numerical simulation, it is difficult to give detailed flow field data in the previous model tests on the wave impact. In this paper, by developing a numerical wave tank (NWT), the hydrodynamic characteristics of wave impacts on the square column-deck-pontoon structure were studied, and the influence of pontoon configuration on the impact pressure was discussed. Euler overlay method (EOM) and additional damping terms were used for numerical generation and absorption of fifth-order Stokes waves, respectively. The free surface was handled by the volume of fluid (VOF) method. The accuracy of the numerical model was verified by being compared with the experimental results. The research showed that the slamming coefficient of impact pressure varies significantly with wave steepness and presents obvious spatial differences. Furthermore, it was found that properly increasing the height and length of the pontoon is beneficial to the overall safety of the structure from the view of engineering design.

KEY WORDS: Wave impact; computational fluid dynamics (CFD); numerical wave tank (NWT); volume of fluid (VOF); impact pressure; square column.

NOMENCLATURE

\[ \begin{align*}
    a_0 & : \text{Initial air gap} \\
    A_c & : \text{Wave crest amplitude} \\
    B & : \text{Width of the NWT} \\
    b_s & : \text{Width of the square column} \\
    d & : \text{Draft of the square column-deck-pontoon structure} \\
    F_t & : \text{Total wave force in the horizontal direction} \\
    F_r & : \text{Total wave force in the vertical direction} \\
    H & : \text{Wave height} \\
    h_s & : \text{Height of the square column} \\
    h_d & : \text{Height of the deck} \\
    h_p & : \text{Height of the pontoon} \\
    h_w & : \text{Water depth in the NWT} \\
    l_d & : \text{Length of the deck} \\
    l_p & : \text{Length of the pontoon} \\
    P & : \text{Total wave pressure} \\
    P_d & : \text{Wave impact pressure} \\
    P_{q_0} & : \text{Quasi-static pressure} \\
    T & : \text{Wave period} \\
    v_i & : \text{Wave impact velocity} \\
    v_w & : \text{Wave celerity} \\
    z_i & : \text{Vertical position of the impact load cell relative to the SWL} \\
    \lambda & : \text{Wavelength}
\end{align*} \]

INTRODUCTION

Wave impact usually occurs in breaking waves or high sea states, with large energy transfer and strong nonlinearity. The impact pressures caused by wave slamming have severe implications for the integrity and safety of structures, such as the topside and the columns of a semi-submersible platform, the deck of a fixed platform, an offshore bridge, etc. Accurate estimation of impact loads is of great significance for the design of marine structures. Meanwhile, a thorough understanding of the characteristics of impact pressure will be beneficial to the prediction of impulsive load.

The wave impact pressure is characterized by a very high peak and extremely short duration. Its properties significantly depend on the wave parameter, breaker type, wave celerity, and structural configuration (Wienke and Oumeraci, 2005). Nonlinear regular waves with large wave steepness can lead to unexpected impact pressure in some situations. Besides, the single-frequency unidirectional incident wave reduces the complexity of the impact process and makes it easier to clarify the physics of the impact load. There have been many correlative studies on