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# Numerical Simulation of Green Water Incidents Based on Parallel MPS Method

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## ABSTRACT

In this paper, 2D and 3D green water on fixed ship in head-sea condition without forward speed are investigated numerically based on a parallel MPS solver, MLParticle-SJTU, developed in Shanghai Jiao Tong University. Two cases are considered: first, green water on 2D FPSO exposed to regular wave is analyzed. The shipping wave and impact pressure on a deck mounted structure are calculated and compared with experimental results obtained by Greco (2001) and numerical results computed by Nielsen (2004). Qualitatively and quantitatively, the agreement is good. Second, a 3D green water case is considered, where the incoming wave is a solitary wave with a large height, representing an extreme sea condition. Evolution of wave shipping on the deck is analyzed. Severe shipping water is observed. Under such circumstance, the structure on the deck is largely wetted and endures a large impact pressure. This 3D simulation suggests that the MLParticle-SJTU solver is capable of handling such 3D green water incident.

KEY WORDS: Green water; parallel MPS; MLParticle-SJTU solver; impact pressure; free surface flow

## INTRODUCTION

In severe sea condition, the waves may exceed the freeboard of sailing ship or moored offshore platform and wet the deck. It is known as green water incident. The shipping water can cause large damage to the superstructure of ship when it flows along the deck and impact against the structure in way. Therefore, green water has received some attention in the hydrodynamic community.

In the last decades, many researchers have investigated green water problem, both experimentally and numerically. Buchner (2002) conducted experimental studies on the physics of shipping water on FPSOs in which the effect of bow geometry on the flow of shipping water was discussed. Greco (2001) experimentally analyzed the green water flow, focusing on the early stage of wave overtopping and plunging onto the deck. For numerical study, Wan and Wu (1999) investigated solitary wave induced green water on 2D ship based on a Navier-Stokes solver combined with volume of fluid (VOF) method for free surface capturing. Nielsen and Mayer (2004) developed a 3D Navier-Stokes solver based on finite volume method (FVM), and simulated 2D and 3D green water on a moored FPSO. Their numerical results are compared with experiment and show good agreement.

Recent years, Lagrangian particle methods, such as Smoothed Particle Hydrodynamics (SPH) and Moving Particle Semi-implicit (MPS) methods, have received much research attention and are seen as promising numerical approaches for violent free surface flows. Differently to grid based method, particle methods solve flow field based on a set of Lagrangian particles without using grid system for discretization of spatial domain. Simulation of the evolution of flows is achieved by tracing these Lagrangian particles. Due to the Lagrangian nature, particle method shows great flexibility in dealing with large deformed free surface flows. By now, there have been many studies on application of particle methods in the field of ocean engineering, such as liquid sloshing (Delorme et al., 2009; Colagrossi et al., 2010; Zhang et al., 2011a), ship-wave interaction (Marrone et al., 2012), water entry(Oger et al., 2006). For green water, Go´mez-Gesteira (2005) analyzed wave overtopping on a fixed horizontal deck based on SPH method, where the wave profiles were discussed and compared with experimental data. Touze et al. (2010) applied a parallelized SPH code, SPH-flow, to predict fluid behavior in 2D and 3D green water flows, and compare their numerical wave elevations with experimental data. Unfortunately, impact pressure induced by shipped water on the deck mounted structure is not discussed. Shibata et al. (2012) developed an overlapping particle technique, and applied it to simulate green water. However, they focused on the computational cost. No comparison investigation is conducted against their numerical results.

The investigations mentioned above, both experiments and numerical simulations, have significantly advanced our knowledge about the physics of green water. However, the fundamental nature of flows in green water incident is still unknown. The aim of the presented study is to make some useful contribution on the prediction of green water incident. To achieve this, a particle solver, MLParticle-SJTU, is used in this paper. The MLParticle-SJTU is a parallel C++ program, developed in Shanghai Jiao Tong University based on two meshless methods, SPH and MPS, with the purpose of providing a valuable numerical tool for ocean engineering. The parallel computation in MLParticle-SJTU is