**Numerical Simulation of a Damaged Ship Flooding with a Three-Dimensional SPH Method**

F.R. Ming, H. Cheng, A.M. Zhang  
College of Shipbuilding Engineering, Harbin Engineering University  
Harbin, Heilongjiang, China

**ABSTRACT**

The flooding process of a damaged ship is a vital problem which is related to the survivability of the ship and the safeties of human life and property. It is always a complicated process accompanied with sloshing, wave breaking, air-liquid mixing and other nonlinear problems, thus it is difficult to solve with traditional methods. Therefore, the smoothed particle hydrodynamics (SPH) known as a meshfree method is adopted in the paper to simulate the flooding of a damaged ship. Firstly the basic idea of SPH and some numerical treatments such as solid wall boundary are presented in the paper. Furthermore, the influences of the crevasse size and position relative to the ship hull are considered. Then, the wave maker is incorporated in the SPH code to study the responses of the damaged ship to different waves. Through the above studies, the dynamic responses of the damaged ship flooding can be reproduced and the revealed laws will provide a reference for the maritime disaster rescue, the decision-making and further the ship manufacture.

**KEY WORDS:** damaged ship flooding; SPH; fluid-structure interaction; wave

**INTRODUCTION**

The flooding of a damaged ship is a typical problem of fluid-structure interaction involving the coupling between the fluid and the ship. When a ship subjected to server environmental loads, the crevasse might be generated on the outer plates followed with the cabin flooding. The ship will sink when the flooding water is overwhelming to the point that the buoyancy of the ship becomes less than the overall gravity. A damaged ship flooding is a long-time course which may take as long as a few minutes or even hours. The process is related to many external factors, such as the size and the position of the crevasse, the incident wave, the air captured in the cabin and so on.

The complex motion of the fluid and the ship is coupled in the flooding process. At the beginning of the flooding, the waterspout can be formed under the action of the pressure difference. Then, the waterspout will spread, crush and impact the internal face of ship. Thus the floating state of the ship will change with the flooding water increasing and the ship may lose its balance. Inversely, the ship motion also affects the motion of the internal water by changing the water flow. The coupling process will exist throughout the process of the ship flooding. It is hard to analyze and predict the ship motion during the flooding by theoretical methods. The quasi-static analysis method is only suitable for forecasting some specific cases, e.g. the very slow flooding. It is inadequate for the ship design and rescue (Zhang et al., 2013). While the model experiment is an efficient method to study the process of the damaged ship flooding, the solution is always restricted to the scale effect (Manderbacka et al., 2015). With the development of the computer technology, more and more numerical approaches are applied to solve the fluid-structure interaction problem. Generally, there are two sorts of numerical methods, i.e., the grid-based method and the meshless method. Because the process of ship flooding covers the phenomena of large deformation, breaking and splashing of free surface, which bring great challenges to the grid-based method due to mesh distortions or the tracking of the interface (Gao et al., 2011). Smoothed particle hydrodynamics (SPH) is a meshfree method characterized by the Lagrangian property. In this method, the computational domain is modeled as a series of particles which have mass and carry some information, such as pressure, velocity, etc. Different from the grid-based method, the Lagrangian particles in SPH method are independent of each other. Thus it has natural advantages in simulating the violent fluid deformation (Zhang et al., 2013). In recent years, the SPH method has been improved a lot in terms of accuracy and efficiency. But there are few papers addressing the flooding of damaged ships using SPH method. Those rare studies mainly focus on the green water and the sinking of simplified ship model (Le et al., 2010; Zhang et al., 2013) .

The work like this is not enough and some key factors of the real environment are not taken into account, e.g. waves. Therefore, the main idea of this paper is to apply the SPH method for the numerical simulation of a damaged ship flooding under the real environment. The major work is organized as follows. Firstly, the SPH theory and some numerical treatments adopted in the simulation are introduced. Secondly, the flooding of a damaged ship in the still water is simulated. The influences of the crevasse size and position on the ship flooding are discussed. Furthermore, the wave maker is incorporated into the SPH program and the flooding process of a damaged ship in waves is simulated. Finally, some conclusions are drawn and future works are expected.