

Numerical Simulation of Impact Loads Using a Particle Method, MPS

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ABSTRACT

The free-surface motions interacting with structures are investigated using the Moving Particle Semi-implicit (MPS) method, which was proposed by Koshizuka et al. (1996) for incompressible flow. In the method, Lagrangian moving particles are used for solving flow field instead of Eulerian approach using grid system. Therefore the terms of time derivatives in Navier-Stokes equation can be directly calculated without any numerical diffusion or instabilities due to the fully Lagrangian treatment of fluid particles and topological failure never occur.

The MPS method is applied to the numerical study on the impact loads for incompressible flows, such as wet-drop tests and sloshing motions in a LNG tank.

KEY WORDS: Non-linear free-surface motions; MPS method; impact loads; sloshing motion; wet-drop tests; N-S equation.

INTRODUCTION

The accurate prediction of impact loads by fluid gives important information for safety of ships or maritime structures. The large deformation and dynamic behavior of free surface are one of the most difficult problems for numerical simulations because the numerical implementation of the fully nonlinear free-surface condition is in general complicated and difficult. There are several techniques to handle such kinds of problems, i.e. SOLA-VOF (Hirt and Nichols, 1981), Level-Set (Sussman et al., 1994), Marker-Density function (MDF) (Miyata and Park, 1995) etc.. Most of them are the techniques capturing the free-surface on grid system. However, there is a different approach using no-grid system, so-called particle methods by use of moving particles with the Lagrangian treatment. The particle methods seem to be more feasible and effective than conventional grid methods for solving the flow field with complicated boundary shapes or the coupling effects between fluid and structure.

In the present study, the free-surface motions interacting with structures are investigated using the Moving Particle Semi-implicit (MPS) method, which was proposed by Koshizuka et al. (1996) for incompressible flow. In the method, Lagrangian moving particles are

used for solving flow field instead of Eulerian approach using grid system. Therefore convection term in Navier-Stokes equation can be directly calculated without numerical diffusion or instabilities due to the fully Lagrangian treatment of particles and topological failure never occur. The method consists of the particle interaction models representing pressure gradient, diffusion, incompressibility and the free-surface boundary conditions. On the procedure of simulation, however, it is well known that the numerical instability in the pressure field is occurred because of insufficient incompressibility algorithm. This study includes the numerical investigation of the fluid-fluid and the fluid-solid impact loads and the impact loads due to the sloshing motion in a LNG tank.

GOVERNING EQUATION

The Governing equations for incompressible viscous flows are the continuity and Navier-Stokes equations as follows:

$$\frac{D\rho}{Dt} = 0 \quad (1)$$

$$\frac{D\vec{u}}{Dt} = -\frac{1}{\rho}\nabla P + \nu\nabla^2\vec{u} + \vec{F} \quad (2)$$

here \vec{u} is velocity vector, t the time, ∇ the gradient, P the pressure, ν the kinematic viscosity and \vec{F} the external force.

The continuity equation (Eq.1) is written with density, while velocity divergence is usually used in grid methods. The left-hand side of Navier-Stokes equation (Eq.2) denotes Lagrangian differentiation including convection terms. This is directly calculated by moving particles. The right-hand sides consist of pressure gradient, viscous and external force terms. To simulate incompressible flow, all terms expressed by differential operators of governing equations should be replaced by particle interaction models.

PARTICLE INTERACTION MODELS

Kernel Function

Continuous fluid can be represented by physical quantities of