Hamiltonian Boussinesq simulation of wave-ship interaction above sloping bottom

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ABSTRACT

This paper describes a numerical implementation of Hamiltonian Boussinesq Wave-Ship interaction as formulated in van Groesen and Andonowati (2017) for irrotational flow, restricting to one horizontal coordinate and a cross section of the ship. As part of the HAWASSI-software, the numerical discretisation of the surface waves uses spectral methods. Non-smooth effects from the ship-fluid interaction are included in the design of a virtual wave in the ship area that is determined by the boundary conditions on the ship hull.

Except for comparison with standard cases in the literature, the performance of the code is shown in the following by comparison with measurements of an experiment on the slow-drift motion of a rectangular barge moored above a sloping beach and interacting with irregular waves, in barge beam direction, including the infra gravity waves from the run-up on the shore.

KEY WORDS: wave-ship interaction; potential flow; Hamiltonian formulation; diffraction; radiation; coastal wave run-up; slow-drift motion.

INTRODUCTION

This paper describes a numerical implementation of Hamiltonian Boussinesq Wave-Ship interaction for irrotational flow. In this paper, we restrict to one horizontal coordinate and a cross section of the ship.

Restricting to potential flows, the fluid dynamics is described with surface variables only: the surface elevation and the potential at the surface. To obtain explicit expressions, many so-called Boussinesq approximations have been developed. A subclass are approximations based on the Hamiltonian formulation described by Zakharov (1968) and independently Broer (1974). Taking an analytic or numerical approximation of the cumbersome kinetic energy in the Hamiltonian leads directly to the approximate equations for numerical codes, i.e West et al. (1987), HOS (Ducrozet et al., 2007, 2012).

Fully interaction of wave and floating or fixed structure is often modelled using CFD either mesh or mesh-free based solver that costs very long computation time, i.e. Khayyer et al, 2021. For practical use, CFD solver often uses incident waves from a potential wave kinematic solver for wave generation to make CFD domain smaller and then shorter computation time, see Bouscasse et al. 2020.

In the past years we developed software called HAWASSI that is based on the Hamiltonian formulation for the wave dynamics up to fourth order, and uses spectral methods for discretisation. Typical problems with spectral implementations, in particular dealing with varying bottoms and sharply varying structures like walls, were overcome and bottom friction and wave breaking were included.

In 1 HD and 2 HD, the pseudo-spectral implementation shows very good dispersion above varying bottom and run-up on coasts, and is relatively fast computation by using partitioned approximation of the Fourier integral operators (Kurnia and van Groesen, 2014, 2017, van Groesen et al., 2017).

Many simulation cases showed good performance when compared to results of experiments in laboratory wave tanks (Kurnia et al., 2015, 2018).

In this paper we describe the extension to include ship motions in this ‘Hamiltonian Wave-Ship-Structure Interaction’ software.

Just like potential flows, the motion of a ship as a rigid body has also a Hamiltonian structure. The challenge is to describe the correct coupled fluid-body interaction as a combined dynamical system, keeping the description of the fluid dynamics restricted to the free surface. This requires the translation of the interaction of the interior flow with the ship as an effect at the surface.