SPH Simulation of Water Waves and Impact with a Rigid Offshore Structure in a 2D Flume

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ABSTRACT

Reliable offshore structural design deserves proper definition of the loads that a structure must bear during the life cycle. The characterization of the wave-induced action plays a key role in this context. Wave-wave interaction can cause non-linear phenomena leading to occasional wave heights much greater than the mean wave height in a sea state. When sea waves interact with an offshore structure, breaking and water sprays occur as well as two-phase flow due to air entrainment. Particle-based methods have been proven to be particularly suitable to mimic these phenomena.

This work illustrates the application of the Free/Libre and Open-Source Software (FOSS) code SPHERA v.9.0.0 (RSE S.p.A.) for the generation of regular waves, non-linear waves, and the wave impact with a fixed rigid offshore structure in a 2D wave flume. Obtained results are compared against laboratory experiments and results from other numerical models. The main advantages of the proposed modelling approach are pointed out and the aspects that deserve further improvement are discussed.

KEY WORDS:

SPH; Experimental Validation; Non-Linear Wave Generation; Offshore Structures; Wave Impact; Wave Load.

INTRODUCTION

The wave load is a key parameter in the design process to ensure reliability and longevity of offshore structures. Wave-structure interaction, is a highly complicated phenomenon as the impacting wave forces a movement to the structure which being partially constrained, generates an interference wave field. Furthermore, in the impact, wave breaking and large deformation of the continuum occur. Eulerian grid-based methods have been soundly adopted to simulate wave-structure interaction. Examples can be found in Stansberg et al. (2005) with the commercial code Flow-3D; Pákozdí et al. (2005) using the commercial code STAR CCM+; Yan et al. (2019) with a Navier-Stokes solver and Yan et al. (2020) using OpenFOAM. These highly non-linear phenomena are well estimated by means of Lagrangian particle-based methods, among which the Smoothed Particle Hydrodynamics (SPH) seems to be particularly well suited (Liu and Liu, 2003) and has therefore been recently applied to these phenomena. Gómez-Gesteira et al. (2005) analyzed green water overtopping a deck, finding the utilized SPH model to be quantitatively suitable for one-to-one comparison between numerical and experimental results. Lo and Shao (2002) adopting an Incompressible SPH (ISPH) method together with a Large Eddy Simulation (LES) successfully reproduced wave profiles of solitary wave against a vertical wall and running up a plane slope. In the matter of ISPH Liu et al. (2014) used a non-reflection internal wave maker to simulate waves and interaction with a solid wall and a submerged trapezoid backwater; the authors found that the non-reflection internal wave maker can be a quite robust tool for long time simulation of waves and wave-structures interaction. More recently Sun et al. (2019) simulated a freak wave impacting a fixed structure focusing on the suction stage. Altomare et al. (2020) simulated real sea wave impacting a large-scale structure with the open-source code DualSPHysics in a real-word engineering application. In order to test the capability of a numerical code and its accuracy, before simulating non-linear waves and wave-structure impact, it may be convenient starting with the generation of regular waves in a flume using the wavemaker theory (Biésel and Suquet, 1951). Ursell et al. (1960) investigated the regular wave generation in a flume adopting wavemaker theory for flap-type and piston-type wavemakers. Laboratory experiments focused on the wave steepness affecting the non-linear behavior of regular waves. The study results showed that the wavemaker theory is quite suitable to describe the height of small steepness generated waves whilst the amplitude is slightly overestimated for high steepness waves (non-linear effect). The experiments of Ursell et al. (1960) were reproduced adopting numerical codes in Huang et al. (1998) and in Anbarsooz et al. (2013), Huang et al. (1998) focused on the piston-type wavemaker for the simulation of non-linear wavefields. They developed a finite difference numerical method for solving the unsteady 2D Navier-Stokes equations where a modification of the SUMMAC method for treating the free-surface unknown variables was implemented. Their results are in good agreement for the low steepness waves whilst high steepness wave heights are slightly underestimated with respect to the experimental results. Anbarsooz et al. (2013) focused on laboratory experiments and numerical non-linear generation of regular waves for both piston-type and flap-type wavemaker. The used