A Fundamental Study on Two-Way Coupled Analysis of SPH and Multibody Dynamics

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ABSTRACT

In recent, some research issues of engineering in system design have been interested in multiphysics simulation which involves solving coupled system of PDE (Partial differential equation). In this study, a fundamental study on 2-way coupled analysis is investigated for interaction problems combined with hydraulic and rigid body dynamics. A smoothed particle hydrodynamics (SPH) and multibody dynamics (MBD) are employed to represent the dynamic behavior of fluids and rigid bodies, respectively. As the interfacial treatment, the contact forces acting on rigid body due to fluid motion is defined adapting Monaghan boundary force (MBF) (Monaghan et al., 2003). As a simple example of the coupled system, 1-DOF (Degree of freedom) motion in vertical of three plates linked by springs to the top of a rectangular sloshing tank being enforced inline sway motion is assumed for both experiments and simulation. From the results, it is seen that the results obtained from the present simulation are agreed well with those by experiments for time-varied free-surface elevation and vertical displacement of plates.

KEY WORDS: Multiphysics; Smoothed Particle Hydrodynamics (SPH); Multibody dynamics (MBD); Two-way coupling analysis; Sloshing loads

INTRODUCTION

When various components connected with joints and spring dampers compose a single system, multibody dynamics (MBD) can analyze dynamic behavior of the system (Schiehlen, 1997; Pogorelov, 1998). Since the '70's, lots of numerical analysis methods have been proposed to implement the MBD along with rapid increasement of computer power. And then, furthermore, these methods have been upgraded to flexible MBD (FMBD) associated with a finite-element method (Shabana, 1997).

In recent, some attempts to develop total solution system to handle not only FMBD but electricity and electronics, vibration and hydraulics revolves as a concept of multiphysics around few commercial software (SW) companies through preforming co-simulation combined with more than two SWs independently-developed. However, because the total systems for co-simulation are based on not an integrated system but the coupling system with interfacial treatment between more than two independent SW's, there exist many restricted problems, such as limitations for range of analysis, inefficiency for data transfer, inconveniences for learning how to handle all kinds of SWs consisting of the total system, so on.

Assuming that our interests are focused on only FMBD analysis coupled with fluid motion, for both hydrodynamic and structural analysis grid-based numerical methods are generally utilized to understand physical phenomena and applied for design of many industrial fields as effective tools. However such grid-based methods are based on Eulerian approach and quite difficult in analyzing energy dissipation mechanism on wave breaking, representing extremely-complex geometry and reproducing fully-nonlinear practical problems regarding to large deformation and fracture of structure in time-sequential procedure. To overcome these complicated problems, particle-based methods had been suggested instead of using mesh system, and recognized to be more feasible and effective than conventional grid-based methods (Liu and Liu, 2003). However, they had faced challenges on time-consuming for computation and turned out to be less effective. Meanwhile, a new computer technique, so-called HPC (High performance computing) using GPU (Graphics processing units), enabled mass storage data handling of particles, since 2007. With help by combination of HPC-GPU, the particle methods have been recently reevaluated and many researchers have been investigating actively on particle methods (Harada et al., 2007).

Typically there are several particle methods suggested until now, such as SPH (Smoothed Particle Hydrodynamics) by Monaghan (1992), MPS (Moving Particle Semi-implicit) method by Koshizuka and Oka (1996) and DEM (Discrete Element Method) by Cundall (1971). Especially, a lot of research using SPH have been reported on not only hydraulic analysis but structural, FSI (Fluid-Structure Interaction), multiphase and multicomponent problems in various fields. Furthermore, in recent, many researcher's interests have been changed from one-way interaction to two-way coupled analysis to analyze the interaction between distinct media. For instances, a SPH-DEM coupled analysis of slid-liquid flows (Canelas et al., 2013; Sun et al., 2013; Robinson and Ramaiali, 2011), rigid-fluid interaction (Akinci et al., 2013),...