8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

ADVANCES IN THE PARTICLE FINITE ELEMENT FOR FLUID-SOIL-STRUCTURE INTERACTION

Eugenio Oñate , Sergio R. Idelsohn and Miguel A. Celigueta

International Center for Numerical Methods in Engineering (CIMNE)
Technical University of Catalonia
Campus Norte UPC, 08034 Barcelona, Spain
Email: onate@cimne.upc.edu; Web page: http://www.cimne.com

Key Words: *Lagrangian formulation, fluid-structure interaction, particle finite element method, bed erosion, free surface flows*

ABSTRACT

The analysis of problems involving the interaction of fluids and structures accounting for large motions of the fluid free surface and the existence of fully or partially submerged bodies which interact among themselves is of big relevance in many areas of engineering. Examples are common in ship hydrodynamics, off-shore and harbour structures, spill-ways in dams, free surface channel flows, environmental flows, liquid containers, stirring reactors, mould filling processes, etc.

Typical difficulties of fluid–multibody interaction analysis in free surface flows using the FEM with both the Eulerian and ALE formulation include the treatment of the convective terms and the incompressibility constraint in the fluid equations, the modelling and tracking of the free surface in the fluid, the transfer of information between the fluid and the moving solid domains via the contact interfaces, the modeling of wave splashing, the possibility to deal with large motions of the bodies within the fluid domain, the efficient updating of the finite element meshes for both the structure and the fluid, etc.

Most of the above problems disappear if a Lagrangian description is used to formulate the governing equations of both the solid and the fluid domains. In the Lagrangian formulation the motion of the individual particles are followed and, consequently, nodes in a finite element mesh can be viewed as moving material points (hereforth called ‘‘particles’’). Hence, the motion of the mesh discretizing the total domain (including both the fluid and solid parts) is followed during the transient solution.

The authors have successfully developed in previous works a particular class of Lagrangian formulation for solving problems involving complex interaction between fluids and solids. The method, called the *particle finite element method* (PFEM)[1,2], treats the mesh nodes in the fluid and solid domains as particles which can freely move and even separate from the main fluid domain representing, for instance, the effect of water drops. A finite element mesh connects the nodes defining the discretized domain where the governing equations are solved using a stabilized FEM based in the Finite

Calculus (FIC) approach[1]. An advantage of the Lagrangian formulation is that the convective terms disappear from the fluid equations. The difficulty is however transferred to the problem of adequately (and efficiently) moving the mesh nodes. We use a mesh regeneration procedure blending elements of different shapes using an extended Delaunay tesselation with special shape functions [1,2].

The aim of this paper is to describe recent advances of the PFEM in two specific areas: a) the analysis of the interaction between a collection of bodies which are floating and/or submerged in the fluid stream, and b) the modeling of fluid-soil-structure interaction in open channel flows. Both problems are of great relevance in many areas of civil, marine and naval engineering, among others. It is shown in the paper that the PFEM provides a general analysis methodology for treat such a complex problems in a simple and efficient manner.

The layout of the paper is the following. First the key ideas of the PFEM are outlined. Next the basic equations for an incompressible flow using a Lagrangian description and the FIC formulation are presented. Then a fractional step scheme for the transient solution is briefly described. Details of the treatment of the coupled FSI problem in the PFEM are given. The methods for mesh generation and for identification of the free surface nodes are outlined. The procedure for treating at mesh generation level the contact conditions at fluid-wall interfaces and the frictional contact interaction between moving solids in water is explained. A methodology for modeling fluid-soil-structure interaction following the ideas presented in [3] is described. The method is particularized to the study of bed erosion in open channel flows. Finally, the efficiency of the PFEM is shown in its application to a number of problems in civil and marine engineering involving large flow motions, surface waves, moving bodies in water , bed erosion and other fluid-soil-structure interaction situations.

REFERENCES

[1] E. Oñate, S.R. Idelsohn, F. Del Pin and R. Aubry, "The particle finite element method. An overview", *Int. J. Comput. Methods*, Vol. **1** (2), 267–307, 2004.

[2] S.R. Idelsohn, E. Oñate, F. Del Pin and N. Calvo, "Fluid–structure interaction using the particle finite element method", Comput. Meth. Appl. Mech. Engrg., Vol. **195**, 2100–2113, 2006.

[3] E. Oñate, S.R. Idelsohn, M.A. Celigueta and Riccardo Rossi, "Advances in the particle finite element method for the analysis of fluid-multibody interaction and bed erosion in free surface flows", *Comput. Methods Appl. Mech. Engrg.*, Vol. **197**, pp1777–1800, 2008.