A PARTICLE-DISCRETE-FINITE ELEMENT METHOD FOR ANALYSIS OF PARTICULATE FLOWS AND THEIR INTERACTION WITH STRUCTURES

Eugenio Oñate, Miguel A. Celigueta, Guillermo Casas, Riccardo Rossi
F. Zarate, Pablo Becker and Sergio R. Idelsohn,
International Center for Numerical methods in Engineering (CIMNE)
Technical University of Catalonia (UPC), Barcelona, Spain
www.cimne.com
onate@cimne.upc.edu

ABSTRACT

We present recent developments in the integration of the Particle Finite Element Method (PFEM, www.cimne.com/pfem) [1] and the Discrete Element Method (DEM, www.cimne.com/dempack) [2] for analysis of coupled problems in mechanics involving particulate flows and their interaction with structures. The so called PDFEM uses a unified updated Lagrangian description to model the motion of material points in a domain containing a fluid and a variety of solids (such as particles of different sizes and rigid or deformable structures) [1,3]. A mesh connects the material points defining the discretized domain where the governing equations for each of the constituent materials are solved as in the standard FEM. Both a moving mesh and a fixed mesh PFEM procedure the can be used for solving the equations of continuum mechanics for both fluids and solids using the FEM. For the fixed mesh approach the information of the material points is mapped at each time step onto the nodes of the mesh where the governing equations are solved with the FEM [4].

For free-surface flows a moving mesh technique is used where the mesh is regenerated at every time step in order to obtain good quality meshes accounting for large distortions in the fluid domain. We use a new parallel mesh generation procedure that reduces considerably the computational time of the overall solution process

Large discrete particles within the fluid are treated as rigid or deformable bodies which interact with each other "a la DEM" via adequate frictional contact laws. A boundary-fitted fluid mesh is generated around each discrete particle at each time step. The motion of large discrete particles is governed by the particle weight, the fluid force and the contact forces. Smaller discrete particles are immersed in the fluid mesh and their motion and coupled interaction with the fluid is modeled using standard techniques for particulate flows.

We describe the procedures to model frictional contact conditions between the interacting bodies within the fluid and material erosion at fluid-solid and solid-solid interfaces.

We present several examples of application of the PDFEM to fluid-soil-structure interaction problems such as the motion of small and large particles in water streams, the erosion, transport and deposition of soil particles in fluids, the stability of breakwaters under sea waves, the falling of landslides on houses and into reservoirs, underwater excavation and drilling problems in tunneling and oil and gas engineering, the failure of rockfill dams in overspill situations and a number of industrial problems involving particulate flows.

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