Particle Contact Laws and their Properties for Simulation of Fluid-Sediment Interaction with Coupled SPH-DEM Model

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ABSTRACT

Particle methods are a promising approach for the simulation of fluid-structure interaction, especially when complex object geometries and moving boundaries have to be considered. The main advantage of this approach is that there is no need for costly grid generation and interface tracing or capturing techniques. The interaction of fluid and structure are treated as particle-to-particle contact rather than as boundary condition at the object interface. Therefore, contact laws are used to capture the collision process and to ensure balancing of collision forces. In the present study we model the fluid phase by smoothed particle hydrodynamics (SPH) using the classical approach where the fluid is assumed to be weakly compressible. The sediment, in terms of solid spheres made of granite, is modelled by the discrete element method (DEM). Both of them are meshfree particle methods but SPH is a continuum approach and DEM describes the motion and interaction of discrete physical objects. This implies that basically three different contact types, i.e. sediment-sediment, fluid-fluid and fluid-sediment, have to be modelled. The approach and properties of the first and the latter contact type will be discussed in detail.

In this work we test different particle contact laws and study the effect of certain properties on the considered interaction. It will be shown for the sediment-sediment interaction that the interaction force in relation to time step size and its error may vary among different contact laws and contact constellation, i.e. the interaction with fixed particle or among freely movable particles. Particularly, the linear and Hertz contact laws are discussed. A related issue, that is typical for the combination of SPH and DEM, concerns the size of computational time step, which is usually determined by the latter. To overcome this discrepancy, the properties of the contact law may be adjusted but only by making a compromise with regard to accuracy. For the fluid-sediment interaction, the classical Lennard-Jones potential is modified considering only repulsive forces depending on the distance of fluid particle to sediment surface. For this contact type, the importance of an appropriate parametrisation of the contact law and the role of fluid- to sediment-particle ratio is demonstrated by two numerical experiments, namely the simulation of buoyancy and the settling velocity of a sphere.