10th International Congress on Civil Engineering, 5-7 May 2015
University of Tabriz, Tabriz, Iran

A 3D Eulerian-Lagrangian Model for the Motion of the Multiple Non-cohesive Sediment Grains in Water

Reza Barati[1] Seyed Ali Akbar Salehi Neyshabouri[2] Goodarz Ahmadi[3]

1- Ph.D. candidate, Faculty of Civil and Environmental Engineering, Tarbiat Modares University, Tehran, Iran.

2- Prof., Water Engineering Research Center, Department of civil Engineering, Tarbiat Modares University, Tehran, Iran.

3- Prof., Department of Mechanical and Aeronautical Engineering, Clarkson University, Potsdam, New York, USA.

E-mail: r88barati@gmail.com

Abstract

The numerical simulation of a group of sediment grains is important for the bedload estimation. The present treatise deals with the development of a 3D Eulerian-Lagrangian model by considering the non-linear drag force, the shear lift force, Magnus force, the buoyancy force, the added mass force, the Basset history force and torque. A sub-model for particle-particle interaction of bed sediment-laden flows is also included. By using the developed model, the effect of particle– particle collision on the trajectories of saltating grains in open-channel flows can be investigated. The analyses of the simulation results indicated that inter-particle collisions introduce several effects on the sediment transport including changing length and height of the sediment saltation and its lateral diffusion. Therefore, the use of such model can increase the accuracy of the bed-load transport estimation.

Keywords: 3D model, Group of particles, Particle– particle collision, Bedload transport.

1. INTRODUCTION

The sediment transport is one of the most common and the most important processes in the human environment [1, 2]. This phenomenon is naturally stochastic because of the fluctuation of the turbulent fluid field, presentation of irregular bed surface and inter-particle interactions (i.e. particle– particle collision) between sediment grains.

While bed-load grains from a flow is transferred predominately by the bed-particle collisions at low shear stress, the inter-particle interactions is the dominant mechanisms of the bedload transport at medium shear stress [3, 4]. By increasing shear stress, the sheet-flow regime occurs, where the shearing of adjacent granular sheets is the main mechanism of the transport.

The use of an Eulerian-Lagrangian model for the simulation of the motion of sediment grains is an effective approach for the bed-load simulation [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15] and [16]. However, most of them were focused on single-jump of a single sediment grain or multi-jump of a single grain in 2D vertical plan. Such assumptions tend to overestimate the experimental values of the bed-load transport. On one hand, 2D model cannot capture the lateral diffusion of the sediment movement which yields to increase the saltation features (i.e. length and height of the saltation). On the other hand, inter-particle collisions have important effects on the motion of the sediment grains, which can increase or decrease the values of the characteristics of the movement. For example, Niño and García [12] and [13] developed a 2D Lagrangian model for the numerical simulation of the movement of the sand and gravel sediments, which have been widely used (e.g. [14] and [15]). Although the results of the model is agree with typical bed-load equations, they overestimate experimental measurements. Therefore, a more realistic is need to simulate the bed load transport by considering the simulation of multiple sediment grains moving at the same time and colliding with the bed surface and among them.

To elaborate the aforementioned problem, a 3D Eulerian-Lagrangian model for the motion of the multiple non-cohesive sediment grains in water was developed. Several important hydrodynamic forces were used to increase the accuracy of the model. For the modeling of the flow field, the logarithmic law was applied. The