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Capturing blast waves in granular flow

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Abstract

In this paper we continue the analysis of compressible Euler equations for inelastic granular gases described by a granular equation of state due to Goldshtein and Shapiro [Goldshtein A, Shapiro M. Mechanics of collisional motion of granular materials. Part 1: General hydrodynamic equations. J Fluid Mech 1995;282:75–114], and an energy loss term accounting for inelastic collisions. We study the hydrodynamics of blast waves in granular gases by means of a fifth-order accurate scheme that resolves the evolution under different restitution coefficients. We have observed and analyzed the formation of a cluster region near the contact wave using the one-dimensional and two-dimensional versions of our code.

1. Introduction

The behavior of granular material under different physical conditions is a research area of increasing interest with useful applications in industry. Fluidized granular gas is a physical state of granular media where shock wave dynamics has been observed [4,10,12].

Hydrodynamical models are the most convenient and efficient ones to describe shock wave dynamics in granular gases [3–6,8,9].

We consider fluidized granular gases modelled by means of the Euler equations for compressible granular flow described by a granular equation of state (EOS) proposed by Goldshtein and Shapiro [3], that includes both dense and inelastic effects. The main difference between a granular gas and an ideal gas is that grains lose energy with each collision, whereas elastic collision of molecules do not lose energy. Inelastic collisions between particles rule the loss of kinetic energy in granular gases in terms of the restitution coefficient, e, which is essentially the fraction of the normal component of the relative impact velocity that is kept after the collision. Thus, we shall use an energy loss term proportional to $T^{3/2}$ where T is the granular temperature [7], that takes into account the inelastic collision of particles. This model allows to describe accurately high dense clusters and shock wave dynamics in fluidized granular gases.

In [15] we analyzed the associated wave structure of the present model in terms of the volume fraction and the restitution coefficient and we showed that any consistent Riemann problem has a unique standard solution, where the characteristic fields are either genuinely nonlinear or linearly degenerate. This result allows us to use shock capturing schemes for the design of a reliable numerical approximation of the solution of the present model to describe shock wave propagation in granular gases.

In this work we study the hydrodynamics of blast waves in granular gases. Blast waves are a class of waves that occur in a natural way in any compressible gas [1,13,17]. These kind of waves can be generated by external forces as gravity or by mechanical devices (oscillatory moving walls, detonations, jets, etc.). Due to the role of inelastic collisions, the resulting dynamics of blast waves in granular flow can generate patterns of clusters observed in natural phenomena [4]. The study of blast waves in this media may help to better understand the macroscopic properties

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