Shock Wave Interaction with a Loose Dusty Bulk

Baochun Fan, Xiaohai Jiang
National Key Laboratory of Transient Physics, Nanjing University of Science and Technology, Nanjing, Jiangsu 210094, China

Corresponding author, B. C. Fan: bcfan@mail.njust.edu.cn

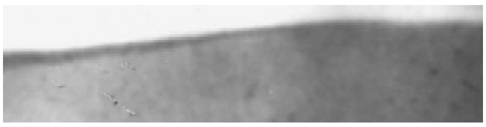
Introduction

Many phenomena occurring in nature and industrial production runs are related with the loose dusty bulks or the granular materials, e.g. production of ultra-fine particles, fluidized bed, pneumatic transport and dust explosion etc(Rayevsky 1991, Milton 1992, Fan 1995, Fan 1996). In this paper, the interaction of a moving planar shock wave over a surface of a loose dusty bulk was investigated experimentally and numerically.

Experimental and Numerical

The experiments were carried out in a horizontal shock tube consisting of a driver section, a driven section and a test section fitted with two optical glass windows. When the shock wave generated by the rupture of the diaphragm passes through the dusty bulk in the test section, transmitted shock waves are induced inside the dusty bulk and a dust cloud is formed above it. The flowfields both in gas and granular phase were recorded by means of shadow graphs and pulsed X ray shadow graphs with trace particles. The typical pictures were shown in Fig1, where the characteristic angles, i.e. incident angle, transmitted shock oblique angle and turning angle, were able to be measured. The pressure transducers were used for shock velocity measurements just before entering the test section and the Malvern particle sizer was employed for measurements of mean diameter of particles.

a) Shadow Photograph



b)X-ray Shadow Photograph

Fig 1. Typical shadow photograph of interaction of shock wave and starch dusty bulk with shock velocity q_0 = 650m/s, mean diameter of starch d_p=15 μ m and initial bulk density of particles ρ_p = 520kg/m^3

The particle motion in the dusty bulk, defined as the granular flow, is strongly controlled by particle-particle collision. It is common to identify the fluctuation kinetic energy of particles associated the particle-particle collision as "granular temperature". Based on kinetic theory approach, the conservation equations together with constitutive relations including for "granular temperature", collision granular viscosity and collision granular conductivity etc were derived and the subgrid scale model was used for the turbulence in gas phase. Solution of the set of partial differential equations was performed numerically by using AUSM (Advection Upstream Splitting Method) scheme with the advantages of both the efficiency of Flux-Vector Splitting and the accuracy of Flux-Difference Splitting and easy to treat more complicated hyperbolic system due to no matrix operations(Lion 1995). The simulated results of shock wave interaction with a loose dusty bulk were shown in Fig 2.

The velocity vectors are shown in Fig 3, where a) gas velocity vectors and b) particle velocity vectors. Measured and calculated results were in a good agreement as shown in Fig4.

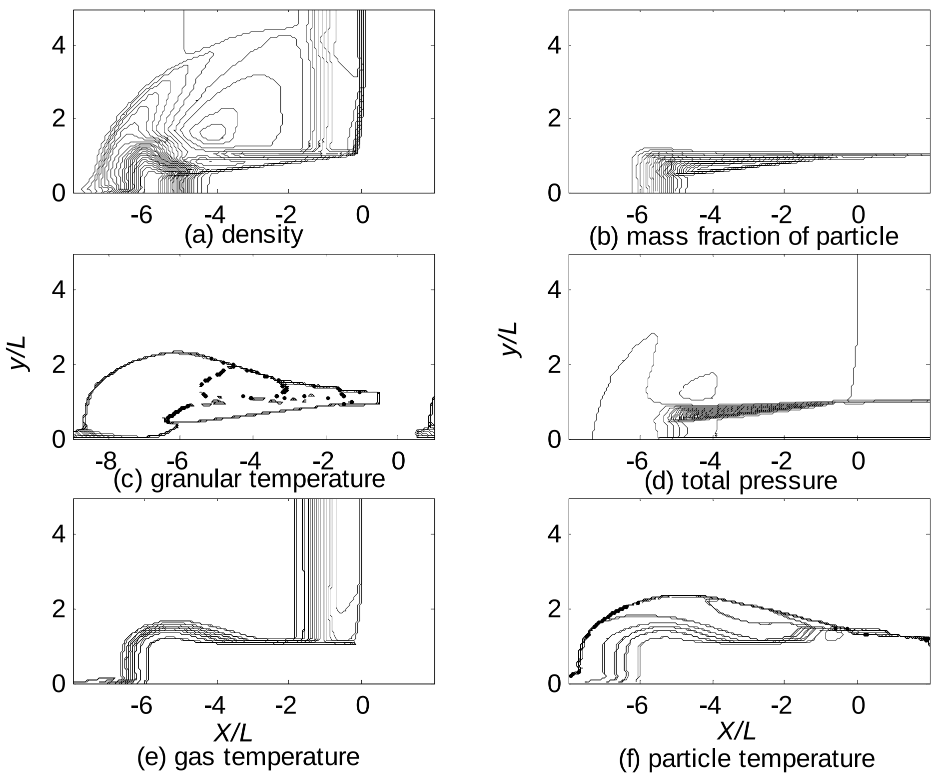


Fig 2 calculated contours

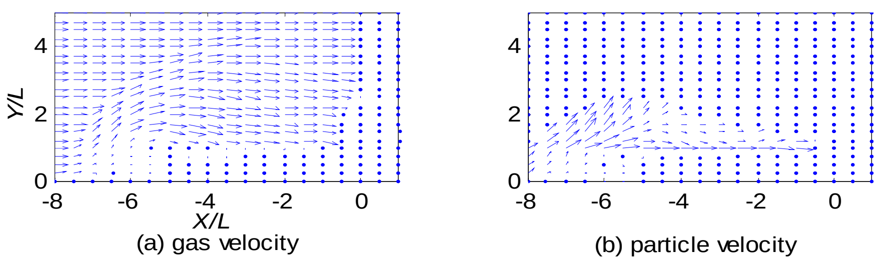
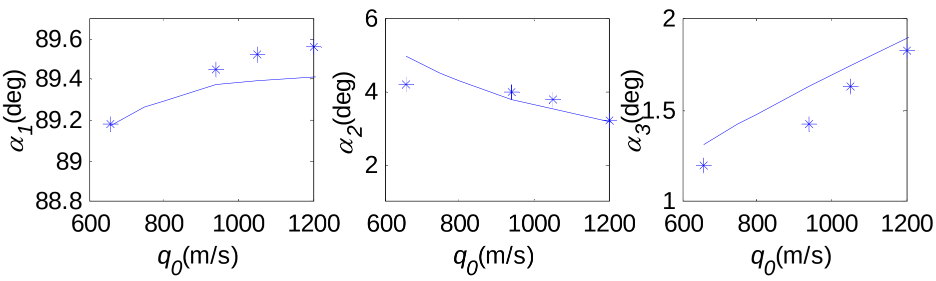


Fig 3 Velocity Vectors



(a) Incident angle (b) Transmitted angle (c) Turning angle

Fig 4.Variations of incident angle α_1, transmitted shock oblique angle α_2 and turning angle α_3 with shock velocity q_0

solid line – calculated; *-measured

Conclusion

When a shock wave passes over a surface of a dusty bulk, the front of incident shock wave is curved toward the down stream near the surface, the dust clouds are distributed above the surface and deformation of the particle bulk and particle-particle collisions are induced under the action of shock waves.

The specific experimental setup and measuring technology developed in the paper are reliable to study this phenomenon experimentally. The flowfield both in gas and granular phases can be recorded by means of shadow graphs and pulsed X -ray shadow graphs with trace particles.

The extended AUSM scheme employed in the paper is suitable to solve the partial differential equations of dense two-phase flow. According to the calculated results, the wave patterns in the gas and particle bulks, the dust cloud, and the interface are described in the detail. Calculated results show good agreement with the measurements.

Acknowledgments

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