Interaction of a Planar Shock with a Dense Field of Particles

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1 Introduction

Understanding the particle-particle and shock-particle interactions that occur in dense gas-solid flows is limited by a lack of knowledge of the underlying phenomena. Gas-solid flows are characterized by the particle volume fraction $\phi_p$ of the flow \[1\]. For particle volume fractions less than about 0.1%, flow is considered dilute and the effects of particle collisions are negligible \[2\]. For packed particles, where the $\phi_p$ is greater than about 50%, the flow regime is said to be granular. The dilute and granular regimes have been well studied, but conversely, a substantial knowledge gap exists for dense gas-solid flows, which have intermediate particle volume fractions of about 0.1 to 50%. This regime exists at microsecond time scales during blast-induced dispersal of material when the shocked particles are closely spaced.

Very little experimental data exist for the interaction of a shock wave with a dense gas-solid field of particles, with rare exceptions such as Rogue et al. \[3\]. Though they provided useful observations of particle trajectories and pressures following the impingement of a shock on a granular bed of particles, much remains unknown regarding the interactions that are involved in the dense gas-solid flow regime. Without data specifically acquired for such flows, simulations of energetic material detonation in the early-time expansion will continue to suffer from limited physical fidelity. To fill the gap in data for shock-particle interactions with initial volume fractions residing between the dilute and granular limits, a multiphase shock tube was recently constructed \[4\]. The unique facility uses a gravity-fed seeding method to generate a dense, spatially isotropic field of 100-micron diameter particles into which a planar shock is driven. High-speed schlieren imaging and pressure data are used to provide insight into the flow and particle behavior in the dense gas-solid regime.
2 Experimental Program

A schematic of the multiphase shock tube is shown in Fig. 1. The driver section is a 2.1 m long stainless steel pipe with an inner diameter of 88.9 mm and a wall thickness of 12.7 mm, supplied by high-pressure compressed nitrogen. Cruciform scored, nickel alloy burst disks are used as diaphragms. Three disk thicknesses yield shock Mach numbers $M_s$ of $1.66 \pm 0.02$, $1.92 \pm 0.02$, and $2.01 \pm 0.02$. The driven section is 5.2 m long and consists of square aluminum tubing with an inner width of 79 mm. The driven gas is air at an initial temperature of about 300 K and an initial atmospheric pressure of about 84.1 kPa. Pressure measurements have shown that the shock is well planar by the time it reaches the ‘particle curtain’ test section [5]. The unique aspect of this shock tube is its ability to provide multiphase flows

Fig. 1 Schematic and photo of the multiphase shock tube

Fig. 2 Particle curtain test section