THE INTERACTION BETWEEN SHOCK WAVES AND SOLID SPHERES
ARRAYS IN A SHOCK TUBE

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ABSTRACT: When a shock wave interacts with a group of solid spheres, non-linear aerodynamic behaviors come into effect. The complicated wave reflections such as the Mach reflection occur in the wave propagation process. The wave interactions with vortices behind each sphere’s wake cause fluctuation in the pressure profiles of shock waves. This paper reports an experimental study for the aerodynamic processes involved in the interaction between shock waves and solid spheres. A schlieren photography was applied to visualize the various shock waves passing through solid spheres. Pressure measurements were performed along different downstream positions. The experiments were conducted in both rectangular and circular shock tubes. The data with respect to the effect of the sphere array, size, interval distance, incident Mach number, etc., on the shock wave attenuation were obtained.

KEY WORDS: shock wave, spheres arrays models, schlieren visualization, pressure measurement, compressible multiphase flow

1 INTRODUCTION

The interaction of shock waves with a solid sphere is a fundamental aerodynamic phenomenon[1]. The problem of the shock wave interaction with a single particle has been solved by experimental investigations and numerical simulations[2]. Britan et al.[3] studied an anti-blast wave structure using a group of small spheres. Purygin and Buzanov[4] reported an application of shock wave impact on solid metal balls, by which the metal surface can be hardened. Though Skews[5] showed a flow visualization of the shock propagation through matrix, the aerodynamics of the shock wave interaction with multiple spheres was not well understood. For example, the experimental data of the shock attenuation by spheres are not sufficient.

The shock interaction with a group of spheres is much more complicated than the interaction with a single sphere because of the nonlinear nature. Firstly, there exist multiple shock wave reflections among spheres; secondly, there exists the shock wave interaction with vortices in the wake behind each sphere. It was because of lack of the aerodynamic knowledge, in their study of particles with diameters from a few micro to a few hundred micro, Rogue et al.[6] did not show clearly how to treat the drag coefficient for the particles in a dense cloud. Sichel et al.[7] also indicated that in the study of shock wave ignition of dusts, both experiments and analyses involve too many difficulties and approximations. In this paper we present an experimental study on the shock interaction with spheres, whose diameters are 10 mm and 20 mm, respectively, because they can be easily framed by using...
smaller diameter rods. It is believed that the present experiment may shed some light into the study on particles with smaller diameters.

2 EXPERIMENTS

The experiment was done in the φ80 shock tube\cite{8,9}. For the flow visualization, a rectangular section of 730 mm in length and 55 mm × 53 mm in cross sectional area is connected to the end of the circular driven section of the shock tube (Fig.1). The total length is increased to 6.12 m. Photos of Figs.2(c) and 2(d) show the structure of the rectangular section. The test model is shown in Fig.2(a) (front view) and Fig.2(b) (side view), respectively. The frames are constructed with aluminum spheres of 10 mm and 20 mm in diameters and stainless rods of 3 mm in diameter. There are three arrays of particles that are separated at different distances of 10 mm, 15 mm, 20 mm, 25 mm and 30 mm, respectively. The pressure signals when shock waves passing through the spheres were measured by pressure transducers (Qianfang Type). The positions of the spheres and pressure transducers are shown in Figs.2(c) and 2(d). Sensor 2 is in front of the frame and sensor 1 is behind it. The end wall pressure is

![Diagram of the circular/rectangular shock tube](image_url)

**Fig.1** Schematic of the circular/rectangular shock tube

![Diagram of the square frame of solid spheres models](image_url)

**Fig.2** Square frame of solid spheres models