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Water aerosol formation: Transient process induced by shock waves

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ABSTRACT

The formation of aerosols artificially is an interesting topic nowadays. This paper studied the interaction between water sheets and shock waves experimentally to seek the interaction mechanism and simulate the formation processes of water aerosol. Optical instruments like normal high speed camera and multiple-spark high speed camera were employed in the experiments and the data obtained was solved with common statistics software Statistical Product and Service Solutions (SPSS). Phase Doppler Particle Analyzer (PDPA) was also used to give a description of the water aerosol shown with diameter and velocity parameters. After the analysis of typical photos and data obtained, results showed that once past through by shock waves, the water sheet faced a surface stripping and breaking progress. The shock-wave induced in the layer of water is a compressive elastic-wave, whose magnitude is related to the ratio of acoustic impedance of the two media. Shock propagates through the thickness of the water-wall and when it reaches the next water/air interface is nearly totally reflected as a tensile wave. Such tensile wave will induce cavitation in the water-wall. Subsequent to cavitation, water keeps moving with uniform velocity and undergoes tensile strain, with small vapor bubbles forming while the water keeps moving in the direction of the blast. Finally, based on the dispersal mechanism, dimensionless parameters calculated were brought in to build the water dispersal model.

1. Introduction

Aerosol technology is widely used in many fields, including atmospheric radiation detection, fire protection, medical science and military field. Over the last decades, many investigations were done to find out the phenomenon and laws for aerosol particles placed in the flow field. Particle size and distribution, as well as optical properties, were the main topics that experts focused on. Based on the aerosol mechanics and aerosol dynamics put forward by Fuchs (1964) and Fuchs and Sutugin (1971), lots of theoretical investigations were proposed and aerosol models were established (Batchelor, 1972, Batchelor and Wen, 1982; Russel et al., 1989). For aerosol particles generated or distributed in the flow field, two main problems were placed to the investigators: one is about the atmospheric aerosol and the other is for artificial aerosols. In common condition, aerosols generate in the air, and how to make aerosols for different applications becomes interesting for lots of experts. Artificial aerosols developed for different aims always catch attentions of investigators all over the world (Junge, 1995; Kaufman et al., 1997; Qiu, 2001, 2003, Qiu, Zong & Zhang 2005; Lipsky & Robinson 2006; Rissler, 2004, Rissler, Vestin, Swietlicki, Fisch & Zhou, 2006).

There are two main methods to generate artificial aerosols: one is dispersion by external forces and the other is decomposition and

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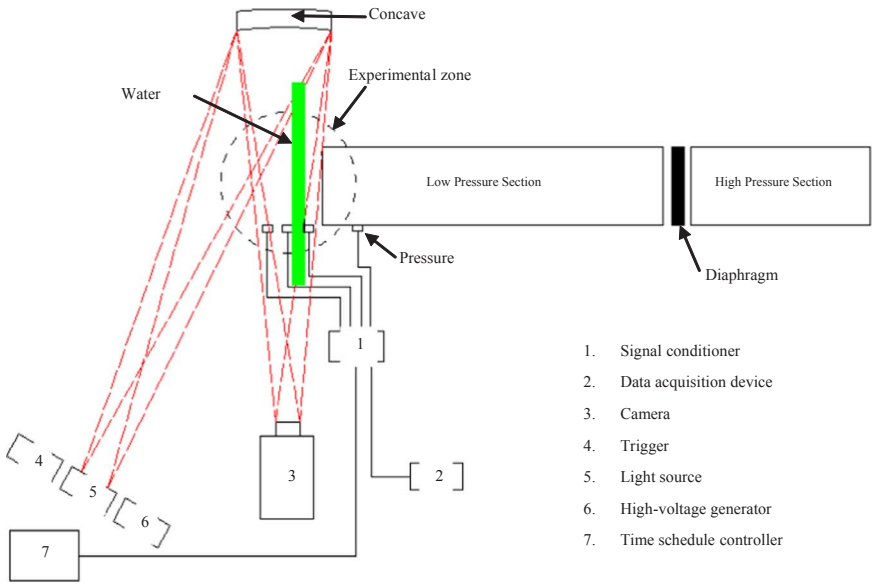

Fig. 1. Layout of the whole experimental system (shock wave generator, water sheet generating system and measuring apparatus used).

coagulation. While the latter method is not easy to carry out and its objects are of great limitation, the formation of aerosols through external forces, like spray systems, are focused on by lots of Labs (Cheremisin, Vassilyev & Kushnarenko 2003; Cheremisin, Vassilyev & Horvath 2005; Cheremisin & Kushnarenko 2010; Delichatsios & Probstein 1975; Smirnov, Nikitin & Tyurenkova 2012; Betelin, Nikitin, Kushnirenko, Nerchenko & Smirnov 2011; Betelin et al., 2012). Although size distributions and optical properties of different aerosol particles were investigated a lot, the detailed phenomenon happened in the flow field, like the driven process of aerosol particles by gas flow, was less mentioned. This paper employed optical instruments and data processing software to capture the transient phenomenon of aerosol water droplets in the turbulent flow field and establish dimensionless model to illustrate the laws during the dispersal process of water sheet.

2. Experimental

2.1. Samples

To make water aerosol, water is the main sample. Pure water was used in the experiments. A container is used to hold water, the bottom of which linear holes with different widths are set up. When the container is filled with water, the water will fall down through the linear hole and a continuous water sheet is formed.

2.2. Conditions and devices

Self-designed device, which is consisting of shock wave generating system and water sheet laying system, was used to carry out the experiments. The layout of system is shown in Fig. 1 in which shock wave is generated using high pressure air blasting method and the actual set-up photo of the system is shown in Fig. 2. The length of shock tube used is 4.84 m and it has a square cross section with the size of 0.06 m × 0.06 m. In the whole tube, the high pressure section is 1.34 m long and the driven section is 3.50 m long.

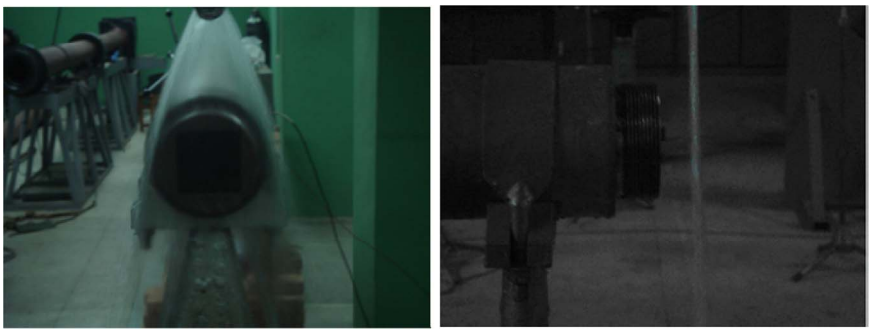

Fig. 2. Actual photos of the experimental system (with shock tube and the water sheet).