Astrophys Space Sci (2014) 349:181–195
DOI 10.1007/s10509-013-1638-4

ORIGINAL ARTICLE

Shock jump relations for a dusty gas atmosphere

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Received: 9 July 2013 / Accepted: 16 September 2013 / Published online: 5 October 2013

Abstract This paper presents simplified forms of jump relations for one dimensional shock waves propagating in a dusty gas. The dusty gas is assumed to be a mixture of a perfect gas and spherically small solid particles, in which solid particles are continuously distributed. The simplified jump relations for the pressure, the temperature, the density, the velocity of the mixture and the speed of sound have been derived in terms of the upstream Mach number. The expressions for the adiabatic compressibility of the mixture and the change-in-entropy across the shock front have also been derived in terms of the upstream Mach number. Further, the handy forms of shock jump relations have been obtained in terms of the initial volume fraction of small solid particles and the ratio of specific heats of the mixture, simultaneously for the two cases viz., (i) when the shock is weak and, (ii) when it is strong. The simplified shock jump relations reduce to the Rankine-Hugoniot conditions for shock waves in an ideal gas when the mass fraction (concentration) of solid particles in the mixture becomes zero. Finally, the effects due to the mass fraction of solid particles in the mixture, and the ratio of the density of solid particles to the initial density of the gas are studied on the pressure, the temperature, the density, the velocity of the mixture, the speed of sound, the adiabatic compressibility of the mixture and the change-in-entropy across the shock front. The results provided a clear picture of whether and how the presence of dust particles affects the flow field behind the shock front. The aim of this paper is to contribute to the understanding of how the shock waves behave in the gas-solid particle two-phase flows.

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Keywords Shock waves · Dusty gas · Solid particles · Shock jump relations · Mach number · Two phase flow

1 Introduction

It is well-known that the gas-particle two-phase flow is a rapidly developing field of research. The gas-solid particle two-phase flows are involved in many industrial processes and occur in a variety of natural phenomena. The natural phenomena accompanied by the gas-particle flows are typified by explosion of supernova, sand storms, moving sand dunes, aerodynamic ablation, cosmic dusts, etc. The formation of shock in astrophysical situations is very important, particularly in the evolution or death of the stars. For example, when the pressure in the central region of a star increases, the disturbance can steepen to form a shock as it propagates. This shock wave travels from the central region to the periphery and emerges at the surface. Since in outer surface of the star, the density of gas decreases to zero, the propagation of shock wave results in the concentration of energy near the surface of the star. This process is relevant to the problem of the origin of cosmic ray during the explosion of supernova. Shock formation and propagation is also important during the formation of the atmosphere around a celestial body. For example, the downfall of gas onto a neutron star causes the propagation of unsteady disturbance when the gas particles strike the solid surface. The gas-particle flows are encountered in pneumatic conveying of particulates commonly used in pharmaceutical, food, coal, and mineral powder processing. In addition, gas-particle mixtures with gases heavily laden with small solid particles occur frequently in the industrial processes such as plastics manufacturing, flour milling, coal-dust conveying, powder metallurgy and powdered-food processing.