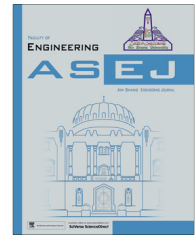




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Cylindrical shock waves in rotational axisymmetric non-ideal dusty gas with increasing energy in presence of conductive and radiative heat fluxes



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Rotating medium

Abstract The propagation of a cylindrical shock wave in a rotational axisymmetric non-ideal dusty gas in the presence of conductive and radiative heat fluxes with increasing energy, which has variable azimuthal and axial fluid velocities, is investigated. The dusty gas is assumed to be a mixture of non-ideal (or perfect) gas and small solid particles, in which solid particles are continuously distributed. Similarity solutions are obtained and the effects of the variation of the heat transfer parameters, the parameter of non-idealness of the gas, the mass concentration of solid particles in the mixture and the ratio of the density of solid particles to the initial density of the gas are investigated. It is shown that the heat transfer parameters and the parameter of non-idealness of the gas, both, decrease the compressibility of the gas and hence there is a decrease in the shock strength. © 2015 Faculty of Engineering, Ain Shams University. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Marshak [1] studied the effect of radiation on the shock propagation by introducing the radiation diffusion approximation. He solved both the cases of constant density and constant pressure fields without invoking conditions of self similarity. Using the same mode of radiation, Elliott [2] discussed the conditions leading to self-similarity with a specified functional form of the mean free path of radiation and obtained a solution for self-similar spherical explosion. Wang [3], Helliwell [4] and

Nicastro [5] treated the problems of radiating walls, either stationary or moving, generating shocks at the head of self-similar flow fields. Ghoneim et al. [6] obtained the self-similar solution for spherical explosions taking into account the effects of both conduction and radiation in the two limits of Roseland radiative diffusion and Planck radiative emission.

The formation of self-similar problems and examples describing the adiabatic motion of non-rotating gas models of stars, is considered by Sedov [7], Zel'dovich and Raizer [8], Lee and Chen [9], and Summers [10]. The experimental studies and astrophysical observations show that the outer atmosphere of the planets rotates due to rotation of the planets. Macroscopic motion with super-sonic speed occurs in an interplanetary atmosphere and shock waves are generated. Shock waves often arise in nature because of a balance between wave breaking non-linear and wave damping dissipative forces [8]. Collisional and Collisionless shock waves can

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Nomenclature

A	angular velocity	U	non-dimensional radial component of fluid velocity
A_a	initial angular velocity	U_m	internal energy per unit mass of the mixture
a_m	speed of sound in the mixture	u	radial component of fluid velocity
a_{iso}	isothermal speed of sound in the mixture	V	shock velocity
B	constant	V_{sp}^*	volume of solid particles
b	internal volume of the molecules of the gas	V^*	total volume of the mixture
$\bar{b}$	parameter of non-idealness of the gas	v	azimuthal component of velocity
C_p	specific heat of the perfect gas at constant pressure	W	non-dimensional axial component of fluid velocity
C_v	specific heat of the perfect gas at constant volume	w	axial component of fluid velocity
C_{sp}	specific heat of solid particles	X	similarity variable
C_{pm}	specific heat of the mixture at constant pressure	X_p	value of X at inner expanding surface
C_{vm}	specific heat of the mixture at constant volume	Y	reduced pressure
D	non-dimensional density	Z	volume fraction of solid particles in the mixture
E	total energy of the flow between shock and the inner contact surface or piston	Z_a	initial volume fraction of solid particles in the mixture
E_0	constant	α_R	Rosseland mean absorption coefficient
E^*	constant	β	density ratio across the shock
F	total heat flux	β'	ratio of specific heat of the solid particles to that of perfect gas at constant volume
F_c	conductive heat flux	β_c	density variation index in thermal conductivity
F_R	radiative heat flux	β_R	temperature variation index in absorption coefficient
f	reduced total heat flux	Γ	ratio of specific heat of the mixture
G	ratio of the density of solid particles to that of the perfect gas	Γ_c	non-dimensional conduction heat transfer parameter
G_a	ratio of the density of solid particles to that of the perfect gas at initial state	Γ_R	non-dimensional radiation heat transfer parameter
g	reduced density	γ	ratio of the specific heat of the perfect gas
h	reduced azimuthal velocity	δ_c	density variation index in thermal conductivity
J	abbreviation	δ_R	density variation index in absorption coefficient
K	thermal conductivity	λ	ambient azimuthal velocity variation index
K_p	mass fraction (concentration) of the solid particles in the mixture	μ	ambient axial velocity variation index
L	abbreviation	π	ratio
l_r	non-dimensional radial component of vorticity	ρ	density of the mixture
l_θ	non-dimensional axial component of vorticity	ρ_{sp}	density of solid particles
l_{z^*}	non-dimensional azimuthal component of vorticity	ρ_{g_a}	density of the perfect gas in the initial state
M	shock-Mach number	$\bar{\rho}_g$	partial density of the gas in the mixture
M_e	effective shock-Mach number	σ	Stefan-Boltzman constant
m	total mass of the mixture	ϕ	reduced radial velocity
m_{sp}	mass of solid particles	ψ	reduced axial velocity
N	abbreviation	ξ	non-dimensional azimuthal component of fluid velocity
P	non-dimensional pressure	$\vec{\xi}$	vorticity vector
p	fluid pressure	ξ_r	radial component of vorticity vector
p_g	partial pressure of the gas in the mixture	ξ_θ	axial component of vorticity vector
Q	non-dimensional total heat flux	ξ_{z^*}	azimuthal component of vorticity vector
$\vec{q}$	fluid velocity		
R	shock radius		
R^*	gas constant		
r	space coordinate		
r_p	radius of inner expanding surface		
S	abbreviation		
s	total energy variation index		
T	absolute temperature of the mixture		
t	time coordinate		

Subscripts

a	immediately ahead of the shock
n	immediately behind the shock
S	at constant entropy
T	at constant temperature
0	reference state

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