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ORIGINAL ARTICLE

Observing the effects of the polarization force in strongly coupled dusty plasmas with suprathermal electrons

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Abstract Our objective here is to investigate a strongly coupled dusty plasma system with the presence of polarization force (PF). This plasma consists of superthermal electrons, Maxwellian ions, and negatively charged dust grains. The nonlinear propagation of dust-acoustic (DA) waves in such dusty plasma system has been theoretically investigated by employing the reductive perturbation method. The Burgers' and K-dV equations have been derived to and numerically analyzed. It has been found that the dust-acoustic shock and solitary waves exist associated with a negative potential only, and that the effect of the dust fluid temperature significantly modifies the basic properties (amplitude and width) of such nonlinear waves' potential structures. We hope that the results of our present investigation should help us in understanding the localized electrostatic disturbances in space and laboratory strongly coupled dusty plasmas with superthermal electrons and polarization force.

Keywords Strongly coupled dusty plasma · Superthermal electrons · DA waves · Polarization force · Reductive perturbation method · Negative potential · Shock and solitary waves

1 Introduction

Dust-acoustic (DA) wave (Rao et al. 1990) and it's arbitrary amplitude have also been rigorously investigated theoretically by many authors for different dusty plasma systems (Mamun et al. 1996; Mamun 1999; Shukla and Mamun 2001; Mamun and Shukla 2001) during past two decades. However, all of these works are on nonlinear DA waves (Mamun and Shukla 2009a, 2009b) and mainly based on the most commonly used dusty plasma model that assumes negatively charged dust. There are some important charging processes through which dust grains become positively charged (Rosenberg et al. 1999). The principal mechanisms by which dust grains become positively charged are photoemission in the presence of a flux of ultraviolet photons (Rosenberg and Mendis 1995), thermionic emission induced by the radiative heating (Rosenberg and Mendis 1995), secondary emission of electrons from the surface of the dust grains (Mendis and Horanyi 1990; Mendis and Rosenberg 1994). Recently, motivated by these theoretical predictions and satellite/experimental observations (D'Angelo 2001; Mamun and Shukla 2002; Shukla 2004), a large number of authors (Mamun 2008a, 2008b) have considered a dusty plasma system with dust of opposite potential, and have investigated linear (D'Angelo 2001) and nonlinear (Shukla 2004; Shukla and Rosenberg 2005) DA waves. However, all of these studies are limited to weekly coupled dusty plasmas and are valid as long as $\Gamma \ll 1$ ($\Gamma = (q_d^2/a_d T_d)\exp(-a_d/\lambda_D)$, the coupling parameter, q_d is the dust grain charge, a_d is the inter-grain distance, T_d is the dust temperature in units of the Boltzmann constant, and λ_D is the dusty plasma Debye radius).

Generally the polarization force arises due to the interaction between electrons and highly positively charged dust grains. It's importance in dusty plasma physics have been explained by Hamaguchi and Farouki (1994a, 1994b), and the effects of polarization force on linear propagation of the dust-acoustic (IA) waves have been investigated by Khrapak et al. (2009). The polarization force ($\mathbf{F}_p$) acting on a dust grain is, mathematically, defined as (Hamaguchi and

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