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ORIGINAL ARTICLE

Investigation of non-isothermal electron effects on the dust acoustic waves in four components dusty plasma

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Abstract The time fractional modified KdV, the so-called TFMKdV equation is solved to study the nonlinear propagation of the dust acoustic (DA) solitary waves in unmagnetized four components dusty plasma. This plasma consists of positively charged warm adiabatic dust, negatively charged cold dust, non-isothermal electrons and Maxwellian ions. The TFMKdV equation is derived by using semi-inverse and Agrawal's method and solved by the Laplace Adomian decomposition method (LADM). The effects of the time fractional order (β), the ratio of dust to ion temperature (δ_d), the time (τ), the mass and charge ratio (α), the non-isothermal parameter (γ) and wave velocity (υ) on the DA solitary wave are studied. Our results show that the variations of the amplitude of DA solitary wave versus (γ) are in agreement with the results obtained previously. Moreover, the time fractional order plays a role of higher order perturbation in modulating the soliton shape. The achievements of this research for the DA solitary waves may be applicable in space plasma environments and laboratory plasmas.

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Keywords Dust acoustic waves · Riemann-Liouville fractional derivative · Laplace transform · Adomian decomposition method · Time fractional modified KdV equation

1 Introduction

A dusty plasma is a multi-component system consisting of electrons, ions, charged microscopic particles (dust grains) and neutral atoms or molecules (Shukla and Eliasson 2009; Morfill and Ivlev 2009). The collective behavior of dust particles may lead to propagation of either new or modified waves in the dusty plasmas. The dust acoustic (DA) wave is normally categorized amongst low-frequency and longitudinal waves. For the excitation of the DA solitary wave, the dynamics of the dust grains has to be considered because inertia is provided by the mass of the dust particles. Rao et al. (1990) were the first to report theoretically the existence of the low phase velocity DA solitary waves in multi-component dusty plasma. Subsequently, Barkan et al. (1995) have experimentally observed DA solitary waves in laboratory experiments.

Some attentions have been paid to investigate the electrostatic structures in four-component dusty plasmas (Sayed and Mamun 2007). The positively and negatively dust particle distribution functions in such plasmas are considered to be Non-Maxwellian by authors (Sayed and Mamun 2007; Shahmansouri and Tribeche 2013). The presence of positively charged dust particles has also been observed in different regions of space; viz., cometary tails (Horanyi 1996; Mendis and Horanyi 1991), upper mesosphere (Havnes et al. 1996), Jupiter's magnetosphere (Horanyi et al. 1993). Moreover, the experimental observations indicate that the astrophysical and space plasmas have non-Maxwellian particle distribution functions (Vasyliunas 1968; Leubner 1982).