IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
6th National Conference on Science, Technology and Communication Skills – NCSTCS 2K23
Narula Institute of Technology, Agarpara, Kolkata, India
Vol. 10, Special Issue 3, September 2023

The Influence of Secondary Electron Emission on the Dust Ion Acoustic Wave Propagation in Lorentzian Dusty Plasma

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Abstract: In this paper, characteristics of linear dust ion-acoustic waves are investigated in the presence of suprathermal primary and secondary electrons. A simplified model for dusty plasmas is adopted, whose constituents are suprathermal inertialess primary electrons, secondary electrons, inertial ions, and charged immobile dust grains. The suprathermal primary electrons and secondary electrons are assumed to follow Lorntzian kappa velocity distribution. The effect of dust charge variation due to secondary electron emission is also investigated on the dust ion-acoustic waves. The dispersion relation is derived considering both the negative as well as the positive potential of dust grains. The damping rate of the dust ion-acoustic waves is determined from the dispersion relation. It is seen that the secondary electron population as well as the suprathermal electron population has a destabilizing effect on the dust ion-acoustic wave propagation.

Keywords: Dust ion-acoustic wave, Secondary emission, Lorentzian plasma

I. INTRODUCTION

Space and astrophysical plasmas are made of ions, and electrons along with small dust grains. These small dust grains are very large comparing ions and electrons and they may accumulate charge by attachment or emission of electrons and ions. It is also observed that when small dust grains come to exposure of ultraviolet rays, they emit electrons from the dust grain surface[1-4]. Similarly, the electrons emit due to the excited hitting of electrons on the dust grains surface. This is the secondary electron emission. The secondary emission of electrons is one of the emission processes that may play an important role in dust grain charging because electron emission acts as a positive current to the dust particle [5-14]. The electron and ion plasma charging current densities and secondary electron current density have been previously presented [1,8,15] with the Maxwellian distribution. Jingyu Gong and Jiulin Du discussed the dust charging process with nonextensive power law distribution and the effect of secondary electron emission on this charging process[16,17].

The effect of secondary electron emission on dust acoustic wave propagation has been investigated considering the Maxwellian and Lorentzian Kappa distribution of electrons and ions [18-20]. Similarly, dust ion-acoustic waves are also investigated in the Maxwellian plasma. M. R. Gupta et al studied the effect of secondary electron emission on dust ion-acoustic wave propagation in combination with variations of ion and electron number density [21]. The effect of secondary electron emission on dust ion-acoustic wave propagation in the plasma with positively charged dust grains has been investigated by B Roy et al [22]. They have shown that these waves are purely damped for the positively charged dust grains. All these work are carried out in Maxwellian plasma. In recent years, physicists have studied the dust ion-acoustic wave propagation considering Kappa velocity distribution. Baluku and Hellberg [23] studied the dust ion-acoustic waves using a kinetic theory approach, in an unmagnetized collisionless plasma with kappa-distributed electrons and ions, and Maxwellian dust grains of constant charge. M. Lazar et al represented a new realistic interpretation of the population of suprathermal particles to investigate DIA using suprathermal tail with Maxwellian core [24]. However, these investigations have not considered the effect of secondary electron emission on dust ion-acoustic wave propagation. The effect of secondary electron emission on the dust ion-acoustic wave is yet to be studied in Lorentzian dusty plasma.

In this article, we investigate the characteristics of dust ion-acoustic wave propagation in the presence of both the suprathermal primary and secondary electrons. As an application of variable charged dust grain, we investigate the dust ion-acoustic waves in unmagnetized dusty plasma considering suprathermal electrons, inertial ions, and static dust grains. The effect of both the population of secondary electrons and the population of suprathermal electrons in Lorentzian dusty plasma are studied numerically. The analysis shows that these two types of electrons have a destabilizing effect on the wave frequency and the damping rate of the dust ion-acoustic wave.

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II. MATHEMATICAL METHODS

It is well known that the dust charging currents depend on the nature of the equilibrium dust charge. Our main objective is the application of the charge variation due to secondary electron emission on dust ion-acoustic waves in unmagnetized Lorentzian dusty plasma. So we assume a simple dusty plasma containing primary and secondary electrons along with positive ions and negatively charged dust particles. In equilibrium condition, these charged particles satisfy the quasineutrality condition

$$n_{i0} = n_{e0} + n_{s0} + n_{d0} z_{do} \tag{1}$$

where n_{io}, n_{eo}, n_{s0} and n_{d0} are equilibrium number densities of ions, primary electrons, secondary electrons, and dust grains respectively, and z_{d0} is the number of electron charges on the dust grains in equilibrium.

The equilibrium charge of dust grains is the balanced condition of different types of charge flux. If the negative charge flux is more than the positive one, the dust grain becomes negative. Here we consider the equilibrium dust charge to be negative. Using the orbit-limited motion approach, the charging current for electrons and ions can be calculated if the radius of the dust grain is smaller than the Debye radius [25].
Now we consider that electrons and ions obey the following Lorentzian kappa energy distribution function [26]

$$f_{\alpha 0}(E) = n_{\alpha 0}\left(\frac{m_\alpha}{2\pi\kappa_\alpha E_0}\right)^{3/2} \frac{\Gamma(\kappa_\alpha+1)}{\Gamma(\kappa_\alpha-1/2)}\left[1+\frac{E}{\kappa_\alpha E_0}\right]^{-(\kappa_\alpha+1)}, \qquad \alpha = e, i \tag{2}$$

where $E_0 = \left[\frac{(2\kappa_\alpha - 3)T_\alpha}{\kappa_\alpha}\right]$. $m_\alpha, n_{\alpha 0}, T_\alpha$ are respectively the mass, number density, temperature, and E is the energy of the corresponding particles, Γ is the Gamma function. κ_α is the kappa index. $\alpha = e, i$, e and i indicates the electrons and ions respectively. Using this velocity distribution function, the electron, ion, and secondary electron charging currents are already been derived in Lorentzian dusty plasma [15]:

$$I_e = -\pi r_0^2 e n_e \left(\frac{8T_e}{\pi m_e}\right)^{\frac{1}{2}} \left(\kappa_e - \tfrac{3}{2}\right)^{\frac{1}{2}} \frac{\Gamma(\kappa_e - 1)}{\Gamma(\kappa_e - \frac{1}{2})}\left(1 - \frac{e q_d}{r_0(\kappa_e - \frac{3}{2})T_e}\right)^{-(\kappa_e - 1)} \tag{3}$$

$$I_s = 4\pi r_0^2 e n_e \left(\frac{1}{2\pi\kappa_e^3 E_0^3}\right)^{1/2} \frac{\Gamma(\kappa_e+1)}{\Gamma(\kappa_e-1/2)} \int_0^\infty E\delta(E)\left[1+\frac{E-e\phi}{\kappa_e E_0}\right]^{-\kappa_e - 1} dE \tag{4}$$

Here E is the impact energy and ϕ is the dust surface potential. The dust grain surface potential $\phi = q_d / r_0$, where q_d and r_0 are charge and radius of the dust grains. T_s is the temperature of the secondary electrons. Here we assume the uniform spherical shape of the dust grains. To derive the current due to secondary electron emission from the equation (4), we consider that the expression of the secondary yield due to electron impact is [1]

$$\delta(E) = 7.4\delta_M \frac{E}{E_M}\exp\left(-2\sqrt{E/E_M}\right) \tag{5}$$

where δ_M is the maximum value of δ. The quantities δ_M and E_M are determined by the materials of dust grains. It is clear from the above equations the expression of current depends on the nature of the surface potential of dust grains (ϕ). Using the yield function from equation (5), we obtain the current expressions due to secondary electron emission, when $\phi < 0$, as follows:

$$I_e^s = 3.7\pi r_0^2 \delta_M e n_e \left(\frac{8T_s}{\pi m_e}\right)^{\frac{1}{2}} \frac{\Gamma(\kappa_e+1)}{(\kappa_e - \frac{3}{2})^{\frac{3}{2}}\Gamma(\kappa_e - \frac{1}{2})} F_\kappa^-(U, x) \tag{6}$$

Where

$$F_\kappa^-(U,x) = x^2 \int_0^\infty u^5 e^{-u}\left\{1 + \frac{xu^2 - U}{(\kappa_e - \frac{3}{2})}\right\}^{-(\kappa_e+1)} du \tag{7}$$

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Here $U=\frac{eq_d}{r_0T_e}$ and $x=\frac{E_M}{4T_e}$.

For simplicity, we consider the ion distribution to be Maxwellian. So the positive current due to ions, considering the Maxwellian distribution is obtained,

$$I_i=\pi r_0^2 en_i\left(\frac{8T_i}{\pi m_i}\right)^{\frac{1}{2}}\left(1-\frac{eq_d}{r_0T_i}\right)=\pi r_0^2 en_i\left(\frac{8T_e}{\pi m_e}\right)^{\frac{1}{2}}\sqrt{\frac{\sigma_i}{\mu_i}}\left(1+\frac{Z}{\sigma_i}\right) \qquad (8)$$

where $\mu_i=m_i/m_e, Z=\frac{z_{d0}e^2}{r_0T_e}$ and $\sigma_i=T_i/T_e$. Here we have used $q_d=-ez_{d0}$ due to negative dust grain.

From the current balance equation, we can obtain the expression of ion density. Now arranging the current balance equation $\left(I_e+I_i+I_e^s=0\right)$ we obtain,

$$\frac{n_{i0}}{n_{e0}}=\delta_i=\sqrt{\frac{\mu_i}{\sigma_i}}\frac{\Gamma(\kappa_e-1)}{\Gamma(\kappa_e-\frac{1}{2})}\frac{\left\{(\kappa_e-\frac{3}{2})-Z(\kappa_e-1)\right\}}{\sqrt{\kappa_e-\frac{3}{2}}\left\{1+Z/\sigma_i\right\}}A_1 \qquad (9)$$

where $A_1=1-\frac{3.7\delta_M\sigma_s\kappa_e(\kappa_e-1)^2}{(\kappa_e-\frac{3}{2})^2(\kappa_e+1)}\left(\frac{(\kappa_e-\frac{3}{2})-Z(\kappa_e+1)}{(\kappa_e-\frac{3}{2})-Z(\kappa_e-1)}\right)F_\kappa^-(U,x),\ Z=\frac{z_{d0}e^2}{r_0T_e},\sigma_i=\frac{T_i}{T_e},\mu_i=\frac{m_i}{m_e},\sigma_s=\frac{T_s}{T_e}$

This condition helps us to determine the type of dust surface potential. Since we have considered that the equilibrium dust surface potential is negative. So, δ_i must be greater than one.

To describe the fluid nature of ions, we have considered the continuity and momentum equations for ions. Considering n_i and v_i as instantaneous ion number density and ion fluid velocity respectively, the one-dimensional continuity equation of ion fluid is presented as follows,

$$\frac{\partial n_i}{\partial t}+\frac{\partial}{\partial x}(n_iv_i)=0 \qquad (10)$$

The first term on the left-hand side of Equation (10) expresses the time change of the fluid density. The second term on the left-hand side is the fluid volume, which flows out from a unit volume per unit time. The equation of motion for the ion along with the electrostatic force and a pressure force term as follows,

$$m_in_i\frac{\partial v_i}{\partial t}+m_in_iv_i\frac{\partial v_i}{\partial x}=-n_ie\frac{\partial\varphi}{\partial x}-\frac{\partial P}{\partial x} \qquad (11)$$

Rearranging the above equation, we obtain,

$$\frac{\partial v_i}{\partial t}+v_i\frac{\partial v_i}{\partial x}=-\frac{e}{m_i}\frac{\partial\varphi}{\partial x}-\frac{T_i}{m_in_i}\frac{\partial n_i}{\partial x} \qquad (12)$$

where we have used $P=n_iT_i$. The electrostatic plasma potential φ can be expressed using the Poisson equation considering e as electron or ion charge and q_d as dust grain charge respectively.

$$\frac{\partial^2\varphi}{\partial x^2}=-4\pi(en_i-en_e-en_s+q_dn_d) \qquad (13)$$

Here n_i, n_e, n_s and n_d are the number density of ion, electron, secondary electron, and dust grain respectively. In equilibrium condition, the dust charge is $q_d=-z_{do}e$, where z_{do} is the number of electrons on the dust grain. The number density for the inertialess electrons is [27]

$$n_j=n_{j0}\left(1-\frac{2e\varphi}{m_e\kappa_e\theta_j^2}\right)^{-\left(\kappa_e-\frac{1}{2}\right)} \qquad (14)$$

Here $j(=e,s)$ indicates the primary electron (e) and the secondary electron (s) respectively.

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Considering a small perturbation $\left(\approx e^{i(kx-\omega t)}\right)$ about equilibrium we obtain linearised number densities of primary electrons and secondary electrons from the equation (14), in the form,

$$\frac{\delta n_e}{n_{e0}}=\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\frac{e\varphi}{T_e},\frac{\delta n_s}{n_{s0}}=\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\frac{e\varphi}{T_e}\frac{1}{\sigma_s} \tag{15}$$

Similarly, linearising the continuity equation (10) and the momentum equations (12) , we obtain the ion velocity perturbation as

$$\delta v_i=\frac{\omega}{K}\frac{\delta n_i}{n_{i0}} \tag{16}$$

$$\omega\delta v_i=\frac{eK}{m_i}\varphi+Kv_{thi}^2\frac{\delta n_i}{n_{i0}} \tag{17}$$

where ω is wave frequency, K is wave number, and $v_{thi}=\sqrt{T_i/m_i}$ is the ion thermal speed. Combining the equation and we obtain the perturbed ion number density

$$\frac{\delta n_i}{n_{i0}}=\frac{K^2v_{thi}^2}{\omega^2-K^2v_{thi}^2}\frac{e\varphi}{T_i}=\frac{1}{\sigma_i}\frac{K^2v_{thi}^2}{\omega^2-K^2v_{thi}^2}\frac{e\varphi}{T_e} \tag{18}$$

Collecting perturbed terms from the grain charging equation, we obtain,

$$\frac{\partial q_1}{\partial t}=-v_1q_1+v_2\left\{\frac{\delta n_i}{n_{i0}}-\frac{\delta n_e}{n_{e0}}\right\} \tag{19}$$

Substituting the expression of electron density and perturbed ion density from the equation (15) and (18) we have from the above equation (19),

$$\frac{\partial q_1}{\partial t}=-v_1q_1+v_2\left\{\frac{1}{\sigma_i}\frac{K^2v_{thi}^2}{\omega^2-K^2v_{thi}^2}-\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\right\}\frac{e\varphi}{T_e} \tag{20}$$

Here terms on the right-hand side are

$$v_1=\frac{r_0\omega_{pi}}{\sqrt{2\pi}\lambda_{Di}}\left[1+\frac{\sigma_i\left(\kappa_e-1\right)\left(1+\frac{Z}{\sigma_i}\right)-\frac{3.7\delta_M\sigma_s\left(\sigma_i+Z\right)\kappa_e\left(\kappa_e-1\right)^2}{\left(\kappa_e-\frac{3}{2}\right)^2}F_\kappa^-(U,x)}{A_1\left(\kappa_e-\frac{3}{2}\right)-Z\left(\kappa_e-1\right)}\right],v_2=\frac{r_0\omega_{pi}}{\sqrt{2\pi}\lambda_{Di}}\left(\frac{\sigma_i}{Z}+1\right) \tag{21}$$

where r_0 dust grain radius, $\omega_{pi}=\sqrt{\frac{4\pi e^2n_{i0}}{m_i}}$ ion plasma frequency, $\lambda_{Di}=\sqrt{\frac{T_i}{4\pi n_{i0}e^2}}$.

Linearization of the equation (20) gives the perturbed dust charge as,

$$q_1=v_2\left\{\frac{1}{\sigma_i}\frac{K^2v_{thi}^2}{\omega^2-K^2v_{thi}^2}-\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\right\}\frac{e\varphi}{T_e}\frac{1}{v_1-i\omega} \tag{22}$$

Using, (15),(18) and (22) in the linearized Poisson equation for plasma potential we get

$$K^2\lambda_{De}^2=\frac{\delta_i}{\sigma_i}\frac{K^2v_{thi}^2}{\left(\omega^2-K^2v_{thi}^2\right)}-\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\left(1+\frac{\delta_s}{\sigma_s}\right)+\frac{v_2\left(\delta_i-\delta_s-1\right)}{\left(v_1-i\omega\right)}\left\{\frac{1}{\sigma_i}\frac{K^2v_{thi}^2}{\left(\omega^2-K^2v_{thi}^2\right)}-\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\right\} \tag{23}$$

where $\lambda_{De}=\sqrt{\frac{T_e}{4\pi n_{e0}e^2}}$, $\delta_i=\frac{n_{i0}}{n_{e0}}$ and $\delta_s=\frac{n_{s0}}{n_{e0}}$. From, using the large wavelength approximation $\left(K\lambda_{De}\approx 0\right)$, we obtain the general expression of the dispersion function,

$$\varepsilon(\omega,K)=\frac{\delta_i}{\sigma_i}\frac{K^2v_{thi}^2}{\left(\omega^2-K^2v_{thi}^2\right)}-\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\left(1+\frac{\delta_s}{\sigma_s}\right)$$
$$+\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\left\{\frac{1}{\sigma_i}\frac{K^2v_{thi}^2}{\left(\omega^2-K^2v_{thi}^2\right)}-\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\right\}\left(1+\frac{i\omega}{\nu_1}\right)=0 \tag{24}$$

This dispersion relation of the dust ion-acoustic wave propagating in a Lorentzian dusty plasma in the presence of secondary electron emission is used to determine the real and the imaginary frequency of the wave. Separating the real and imaginary part of the above expression, we obtain

$$\varepsilon_r(\omega,K)=\left\{\frac{\delta_i}{\sigma_i}+\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\frac{1}{\sigma_i}\right\}K^2v_{thi}^2-\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\left\{1+\frac{\delta_s}{\sigma_s}+\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\right\}\left(\omega^2-K^2v_{thi}^2\right) \tag{25}$$

$$\varepsilon_i(\omega,K)=\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\frac{K^2v_{thi}^2}{\sigma_i}\frac{\omega}{\nu_1}-\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\frac{\omega}{\nu_1}\left(\omega^2-K^2v_{thi}^2\right) \tag{26}$$

Considering low decay or growth rate i.e. $\omega=\omega_r+i\omega_i$ where $\omega_r>>\omega_i$. The real frequency of the wave is obtained making the real part of the dispersion relation equal to zero. So from the equation (25), we obtain,

$$\left\{\frac{\delta_i}{\sigma_i}+\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\frac{1}{\sigma_i}\right\}K^2v_{thi}^2-\frac{\left(\kappa_e-\frac{1}{2}\right)}{\left(\kappa_e-\frac{3}{2}\right)}\left\{1+\frac{\delta_s}{\sigma_s}+\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\right\}\left(\omega_r{}^2-K^2v_{thi}^2\right)=0 \tag{27}$$

From this equation, a normalized form of the real frequency $W_r=\frac{\omega_r}{Kv_{thi}}$ is then obtained as,

$$W_r^2=1+\frac{\left(\kappa_e-\frac{3}{2}\right)\left\{\frac{\delta_i}{\sigma_i}+\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\frac{1}{\sigma_i}\right\}}{\left(\kappa_e-\frac{1}{2}\right)\left\{1+\frac{\delta_s}{\sigma_s}+\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\right\}} \tag{28}$$

The imaginary frequency or the decay rate is determined by the relation [28]

$$\omega_i=-\left.\frac{\operatorname{Im}\varepsilon(\omega,K)}{\frac{\partial}{\partial\omega}\operatorname{Re}\varepsilon(\omega,K)}\right|_{\omega=\omega_r} \tag{29}$$

So, the normalized decay rate $W_i=\frac{\omega_i\nu_{D1}}{K^2v_{thi}^2}$ takes the form

$$W_i=\frac{\frac{\kappa_e-\frac{3}{2}}{\kappa_e-\frac{1}{2}}\frac{\left(\delta_i-\delta_s-1\right)}{\sigma_i}\frac{\nu_2}{\nu_1}-\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\left(W_r^2-1\right)}{2\left\{1+\frac{\delta_s}{\sigma_s}+\left(\delta_i-\delta_s-1\right)\frac{\nu_2}{\nu_1}\right\}} \tag{30}$$

Here the expression of W_r^2 is to be taken from the equation (28). This is the analytical form of the growth or decay rate of dust ion-acoustic waves. Equations (28) and (30) depict the expression of wave frequency and damping rate of the dust ion-acoustic wave

III. NUMERICAL RESULTS AND DISCUSSIONS

To obtain a better insight into the role of the secondary electrons on the dust charging procedure and the dust ion-acoustic wave propagation in the Lorentzian plasmas, we have performed an analytical derivation of the charging currents and the dust ion-acoustic wave frequency considering both the negative and positive dust grain in equilibrium. To assess the analytical results in a physical situation, we have considered the space plasmas containing suprathermal electrons e.g. solar wind, interplanetary space, cometary tails, etc. [29-31]. We have considered the value of the Kappa index between 2 and 6, as this range has been found to fit the observations in the astrophysical plasma [31]. For numerical estimation, we have considered the plasma parameters [17,20,23] $\sigma_i = 0.01-1, \sigma_s = 1-1.5, \delta_s = 0.1-1, r_0/\lambda_{De} \approx 5\times10^{-4}$. Our main focus is on the effect of secondary electron emission and suprathermal electrons on the dust charging process and the influence of this charge variation on dust ion-acoustic wave propagation characteristics.

Theoretically, we have derived the dispersion frequency of dust ion-acoustic waves considering negative and positive charged dust grain in two separate models. Now to analyze the dust ion-acoustic wave propagation, we plot the imaginary frequency of the dust ion-acoustic wave with respect to Z. The range of Z is chosen in a way that this must satisfy the quasineutrality conditions. First, we analyze the dust ion-acoustic waves containing a negative equilibrium dust charge. We plot the imaginary frequency as a function of $Z\left(=\frac{z_{d0}e^2}{r_0T_e}\right)$ to see the effect of the suprathermal electron population (κ_e) and the secondary electron population (δ_M). Figure (1) shows that the rate of damping decreases with decreasing kappa index. Thus, increasing the population of suprathermal electrons decreases the damping rate of the dust ion-acoustic wave. Figure (2) shows that the imaginary frequency (ω_i) or damping rate increases with increasing Z. It also depicts that increasing δ_M decreases the damping effect. So it is clear that the increasing population of secondary electrons minimizes the stability of the wave.
In the above discussion, all these figures imply that the increasing population of suprathermal electrons and secondary electrons both minimizes the wave stability of dust ion-acoustic waves. This destabilization occurs due to wave-particle interaction. Waves obtain energy from the high-energy particles. Thus damping rate decreases with an increasing population of suprathermal electrons and secondary electrons in the permissible range of Z.

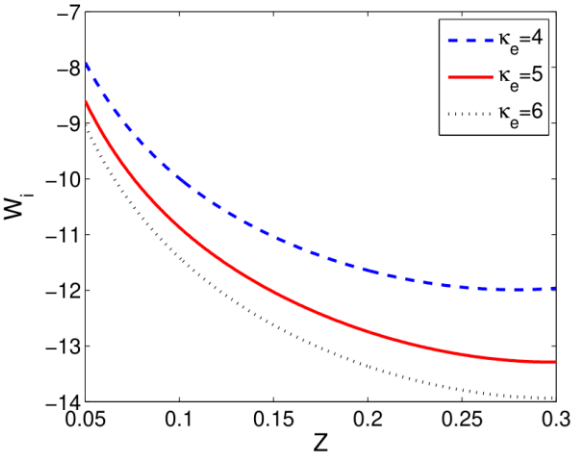

Fig. 1 Plot of W_i versus Z of dust acoustic waves for different kappa index(κ_e) considering $\sigma_i = 1, \sigma_s = 1, \delta_M = 3$ and $E_M / 4T = 45$.

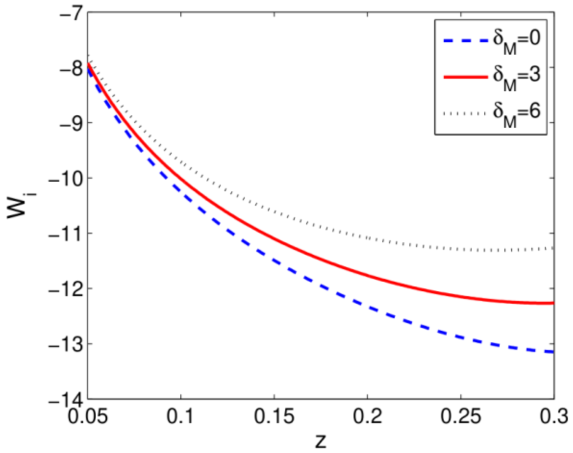

Fig. 2 The plot of W_i versus Z of dust acoustic waves for different δ_M considering $\sigma_i = 1, \sigma_s = 1, \kappa_e = 4$ and $E_M / 4T = 45$.

IV. CONCLUSION

In the above theoretical analysis, the effect of the population of suprathermal electrons and secondary electrons on the dust ion-acoustic waves is discussed. The numerical study indicates that the suprathermal primary and secondary electrons greatly influence dust ion-acoustic waves in these plasmas. Suprathermal electrons may increase the probability of secondary electron emission. This investigation shows that the increasing population of suprathermal electrons and secondary electrons both minimize the stability of dust ion-acoustic waves. This theoretical analysis can be applicable to the complex plasma that shows non-Maxwellian behavior such as solar wind, Saturn E ring, etc. secondary emission is important.

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