Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2022, 9(9):87-93

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Large Amplitude Ion-Acoustic Compressive Solitons in Plasmas with Presence of Positrons and Two Superthermal Electrons

J. K. Chawla[1], P. C. Singhadiya[2]

[1]Department of Physics, Govt. Raj Rishi College Alwar, Rajasthan, India-301001
Email: jitendra123chawla@yahoo.co.in
[2]Govt. College Jaipur, Rajasthan, India-302004
Email: prakashsinghadiya82@gmail.com

Abstract Study of the large amplitude of ion-acoustic solitons in plasma consisting of ions, positrons and cold and hot superthermal electrons. Find the energy integral equation for the system has been derived with the help of the pseudo-potential method (SPM). It is found that only compressive solitons exist in the plasma system for selected set of plasma parameters. The effects of the spectral indexes of hot electrons (k_h), spectral indexes of cold electrons (k_c), temperature ratio of two species of electron (σ_1), positron concentration (α), ionic temperature ratio (σ), positron temperature ratio (γ) and Mach number (M) on the characteristics of the large amplitude ion-acoustic solitons are discussed in details. The investigation of this manuscript may be helpful in space and astrophysical plasma system where positrons and superthermal electrons are present.

Keywords Ion-acoustic soliton, Positrons, superthermal electrons, Pseudo potential method.

1. Introduction

Many researchers study the large amplitude of ion-acoustic waves with two distinct groups of hot electrons [1,5], negative ion [2], EPI [3,5], charge dust grains [4,6], superthermal electrons [7] in plasmas with using the SPM. Bharuthram and Shukla [1] investigated the effect of two distinct groups of hot electrons on large amplitude ion-acoustic waves in plasmas. Jain et al. [6] studied the effect of charge dust grains on large amplitude ion-acoustic waves in plasmas.

The super thermal electrons observed in space environment deviates from Maxwellian distribution and found to obey kappa distribution. Hellberg et al. [8] investigated that the kappa distribution should be greater than (3/2) for superthermal electrons and reduces to maxwellian distribution as the value of kappa distribution approaches to ∞. Boubakour et al. [9] investigated the effect of superthermal electrons and positrons on ion-acoustic waves in an unmagnetized plasma. El-Tantawy and Moslem [10] studied the large amplitude ion-acoustic waves in unmagnetized plasma with superthermal electrons and founs that the characteristics of solitary and shock waves. El-Tantawy et al. [11] have studied the small amplitude ion-acoustic structures in dusty plasmas with superthermal electrons and found the effect of superthermal electrons and positrons on the characteristics (amplitude and width) of nonlinear structures. The propagation of ion acoustic cnoidal waves in two temperature superthermal electrons in magnetized plasma by Panwar et al. [12]. El-shamy [13] studied the ion-acoustic waves in magnetoplasma with superthermal electron and positron and found that characteristic of the solitary waves (e.g., amplitude and width) increases with increase in the kappa distribution. Saha et al. [14] studied the ion-acoustic waves in magnetoplasma with superthermal electrons and positrons and found that effect of kappa distribution on the amplitude of ion-acoustic wave. Saini et al. [15] derived the ZK equation with hot and cold superthermal electron on ion-acoustic wave in a magnetoplasmas. Bains et al. [16] examined the low frequency ion acoustic shock waves in magnetoplasma with hot and cold superthermal electrons and found that the superthermal parameters affect drastically the nature and properties of the solitons. Singhadiya et al. [17] studied the small amplitude of ion-acoustic solitary waves in plasma consisting of ions, positrons and superthermal electrons and found that the effect of spectral indexes on the basic properties i.e., amplitude and width as well as on their nature.

In the present paper, my goal is to study the effects of superthermal electrons and positrons on the large amplitude of ion-acoustic compressive solitons in plasmas. To the best of my knowledge the large amplitude of ion-acoustic compressive solitons in plasmas with positrons and superthermal electrons has not been studied so far. The paper is arranged in the following manner. In section 2, the normalized fluid basic equations for the system have been presented and derive the Sagdeev potential. Using SPM the large amplitude solitons solution has been derived in section 3. In section 4, numerical analysis is presented and main conclusions have been summarized in section 5.

2. Basic equations

We consider a collisionless plasma consisting of ions, positrons and superthermal electrons. The dynamics of the plasma is given by the continuity equation, equation of motion and Poisson's equation:

$$\partial_t n + \partial_x (nv) = 0 \tag{1}$$

$$\partial_t v + v\partial_x v = -\partial_x \phi - \sigma n \partial_x n \tag{2}$$

$$\partial_x^2 \phi = n_h + n_c - \alpha n_p - (1-\alpha) n \tag{3}$$

The superthermal electrons having two distinct temperatures follow kappa distribution and positrons may be given by

$$n_c = \nu \left(1 - \frac{\phi}{k_c - 3/2}\right)^{-(k_c - 1/2)} \tag{4}$$

$$n_h = \mu \left(1 - \frac{\sigma_1 \phi}{k_h - 3/2}\right)^{-(k_h - 1/2)} \tag{5}$$

$$n_p = e^{-\gamma\phi} = \left(1 - \gamma\phi + \frac{\gamma^2\phi^2}{2} - \frac{\gamma^3\phi^3}{6} + \dots\right) \tag{6}$$

Where,

$$\mu = \frac{n_{c0}}{n_{e0}}, \qquad \nu = \frac{n_{h0}}{n_{e0}}, \qquad \alpha = \frac{n_{p0}}{n_{e0}}, \qquad \alpha_1 = \frac{(1-\mu)(2k_c - 1)}{(2k_c - 3)} + \frac{\sigma_1 \mu (2k_h - 1)}{(2k_h - 3)},$$

$\alpha_2 = \dfrac{(1-\mu)(4k_c^2 - 1)}{2(2k_c - 3)^2} + \dfrac{\sigma_1^2 \mu (4k_h^2 - 1)}{2(2k_h - 3)^2}$ and $k_{c,h}$ is the k-distribution corresponding to cold and hot species of electrons.

In the above equations n, n_p, n_c and n_h and v are denote the normalized density of ions, positron, cold and hot electrons, fluid velocity of the ion respectively. The ion-acoustic speed $C_s = \sqrt{\dfrac{T_e}{m}}$ and $\phi = \dfrac{T_e}{e}$ is the normalized electrostatic wave potential. The space variable (x) and time variable (t) have been normalized by Debye length $\lambda_D = \sqrt{\dfrac{T_e}{4\pi n_0 e^2}}$ and inverse of the ion plasma frequency in the mixture $\omega_{pi}^{-1} = \sqrt{\dfrac{m}{4\pi n_0 e^2}}$, respectively. $\gamma = T_p / T_e$, $\sigma = T_i / T_e$, and $\sigma_1 = T_c / T_h$ are the ratio of positron and electron temperature, the ratio of ion and electron temperature, the ratio of cold to hot electron temperature respectively.

3. Stationary Soliton Solution

Let us find out the Sagdeev pseudopotential from basic equations (1) – (3) with introduce the usual transformation

$$\eta = x - Mt \tag{7}$$

where M is the Mach number of DLs.

Using the equation (7) in Eqs. (1) – (3), the fluid equations be written as

$$-M\partial_\eta n + \partial_\eta (nv) = 0 \tag{8}$$

$$-M\partial_\eta v + v\partial_\eta v = -\partial_\eta \phi - \sigma n \partial_\eta n \tag{9}$$

$$\partial_\eta^2 \phi = n_e - \alpha n_p - (1-\alpha) n \tag{10}$$

Using the Eqs. (4) – (6), in the equation (10) and integrating Eqs. (8) - (9) with using appropriate boundary conditions for the unperturbed plasma at $|\eta| = \infty,$ n = 1, v = 0, $\phi(\eta) = 0$ and $d_\eta \phi = 0.$

Find the quadratic equations

$$\sigma n^4 - (M^2 + \sigma - 2\phi) n^2 + M^2 = 0 \tag{11}$$

From equation (11) the ion density (n) is given by

$$n = \frac{\sqrt{2}M}{\left[\left(M^2 + \sigma - 2\phi\right) + \left\{ \left(M^2 + \sigma - 2\phi\right)^2 - 4\sigma M^2 \right\}^{1/2} \right]^{1/2}} \tag{12}$$

Integrating equation (10) with respect to $\eta,$ we obtain

$$\frac{1}{2}\left(d_\eta \phi\right)^2 + V(\phi) = 0 \tag{13}$$

where $V(\phi)$ is the Sagdeev potential which is given by

$$\begin{aligned} V(\phi) = {} & \frac{\mu}{\sigma_1}\left[1 - \left\{1 + \frac{2\sigma_1 \phi}{3 - 2k_h}\right\}^{\frac{3}{2} - k_h}\right] + \nu\left[1 - \left\{1 + \frac{2\phi}{3 - 2k_c}\right\}^{\frac{3}{2} - k_c}\right] + \frac{\alpha}{\gamma}\left(1 - e^{-\gamma\phi}\right) \\ & - \frac{M(1-\alpha)}{\sqrt{2}}\left[\sqrt{\left(M^2 + \sigma - 2\phi\right) + \sqrt{\left((M^2 + \sigma - 2\phi)^2 - 4\sigma M^2\right)}} + \frac{4\sigma M^2}{3\left[\left(M^2 + \sigma - 2\phi\right) + \sqrt{\left((M^2 + \sigma - 2\phi)^2 - 4\sigma M^2\right)}\right]^{3/2}}\right] \\ & + (1-\alpha)\left(M^2 + \frac{\sigma}{3}\right) \end{aligned} \tag{14}$$

For the existence of large amplitude solitons, the Sagdeev potential must satisfy the following conditions

$$V(\phi) = 0, \text{ and } d_\phi V(\phi) = 0, \text{ at } \phi = 0 \tag{15}$$

$$V(\phi)\big|_{\phi=\phi_m} = 0, \text{ and } d_\phi V(\phi)\big|_{\phi=\phi_m} < (>) 0 \text{ for } \phi_m < (>) 0 \tag{16}$$

$$V(\phi) < 0 \text{ for } 0 < |\phi| < |\phi_m|, \tag{17}$$

Here ϕ_m, represents the maximum value of potential.

$$\begin{aligned} & \frac{\mu}{\sigma_1}\left[1 - \left\{1 + \frac{2\sigma_1 \phi_m}{3 - 2k_h}\right\}^{\frac{3}{2} - k_h}\right] + \nu\left[1 - \left\{1 + \frac{2\phi_m}{3 - 2k_c}\right\}^{\frac{3}{2} - k_c}\right] + \frac{\alpha}{\gamma}\left(1 - e^{-\gamma\phi_m}\right) \\ & - \frac{M(1-\alpha)}{\sqrt{2}}\left[\sqrt{\left(M^2 + \sigma - 2\phi_m\right) + \sqrt{\left((M^2 + \sigma - 2\phi_m)^2 - 4\sigma M^2\right)}} + \frac{4\sigma M^2}{3\left[\left(M^2 + \sigma - 2\phi_m\right) + \sqrt{\left((M^2 + \sigma - 2\phi_m)^2 - 4\sigma M^2\right)}\right]^{3/2}}\right] \\ & + (1-\alpha)\left(M^2 + \frac{\sigma}{3}\right) < 0 \end{aligned} \tag{18}$$

……. for $-\phi_m$ ……….. and …>0 …….. for $+\phi_m$

4. Numerical Analysis

In the present investigation, it is found that for the selected set of plasma parameters, the system supports only IACSs depending upon the spectral indexes of hot electrons (k_h), spectral indexes of cold electrons (k_c), temperature ratio of two species of electron (σ_1), positron concentration (α), ionic temperature ratio (σ), positron temperature ratio (γ) and Mach number (M).

In fig. (1), Sagdeev potential $V(\phi)$ curves have been plotted to investigate the effect of spectral indexes of hot electrons (k_h). The graphical representation reveals that for decreasing the value of k_h, the amplitude of the IACSs increases. In fig. (2), Sagdeev potential $V(\phi)$ curves have been plotted to investigate the effect of spectral indexes of cold electrons (k_c). The graphical representation reveals that for decreasing the value of k_c, the amplitude of the IACSs increases.

In figure 3 the Sagdeev potential $V(\phi)$ against potential ϕ for different values of Mach number (M). It is found that increasing values of M results increases in amplitude of the SP of the IACSs. In figure 4 the Sagdeev potential $V(\phi)$ against potential ϕ for different values of ionic temperature ratio (σ). It is found that increasing values of σ results increases in amplitude of the SP of the IACSs. In figure 5 the Sagdeev potential $V(\phi)$ against potential ϕ for different values of temperature ratio of two species of electron (σ_1). It is found that increasing values of σ_1 results decreases in amplitude of the SP of the IACSs. In figure 6 the Sagdeev potential $V(\phi)$ against potential ϕ for different values of positron temperature ratio γ. It is found that increasing values of γ results increases in amplitude of the SP of the IACSs. In figure 7 the Sagdeev potential $V(\phi)$ against potential ϕ for different values of positron concentration (α). It is found that increasing values of α results increases in amplitude of the SP of the IACSs.

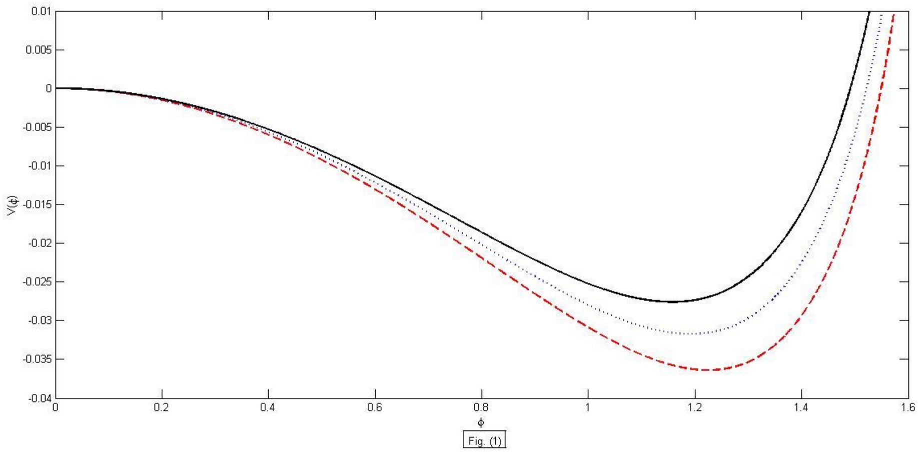

Figure 1: Variation of the SP $V(\phi)$ with potential ϕ of the IACSs for M = 2.1, k_c = 8, σ = 0.1, σ_1 = 0.1, ν = 0.01, α = 0.001 and γ = 0.001 having different values of k_h = 2.0 (red color dashed line), 2.01 (blue color dotted line) and 1.9259 (black color solid line).

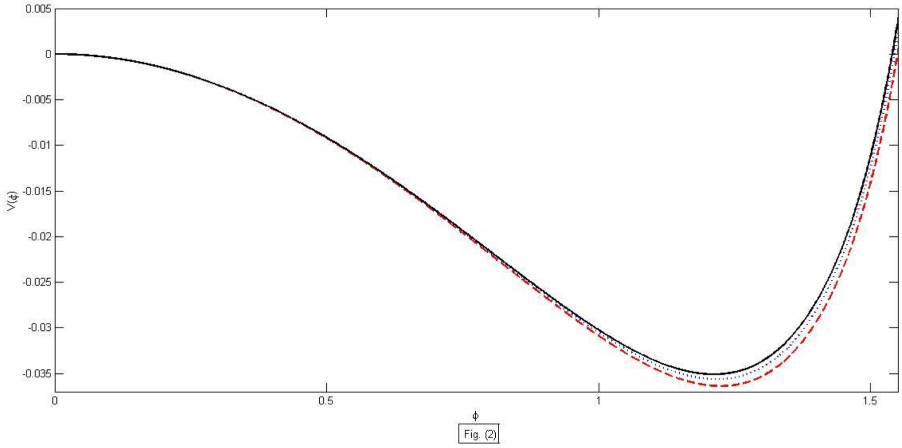

Figure 2: Variation of the SP $V(\phi)$ with potential ϕ of the IACSs for M = 2.1, k_h = 2, σ = 0.1, σ_1 = 0.1, ν = 0.01, α = 0.001 and γ = 0.001 having different values of k_c = 8.0 (red color dashed line), 9.0 (blue color dotted line) and 1.9259 (black color solid line).

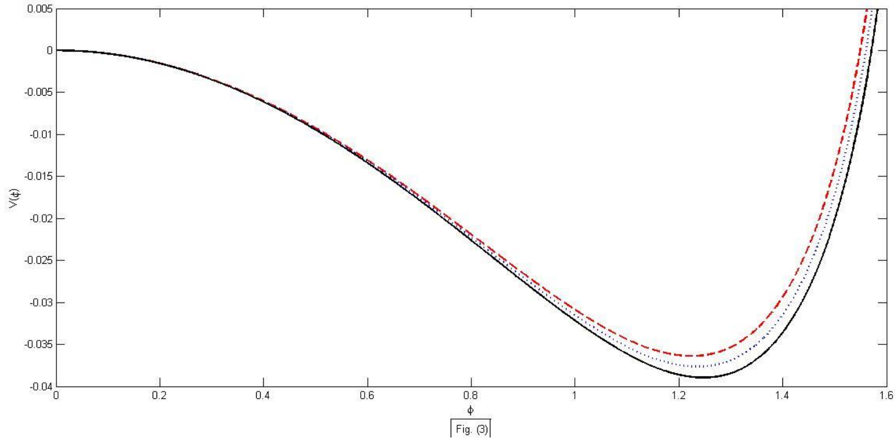

Figure 3: Variation of the SP $V(\phi)$ with potential ϕ of the IACSs for k_h = 2.0, k_c = 8, σ = 0.1, σ_1 = 0.1, ν = 0.01, α = 0.001 and γ = 0.001 having different values of M = 2.1 (red color dashed line), 2.103 (blue color dotted line) and 1.9259 (black color solid line).

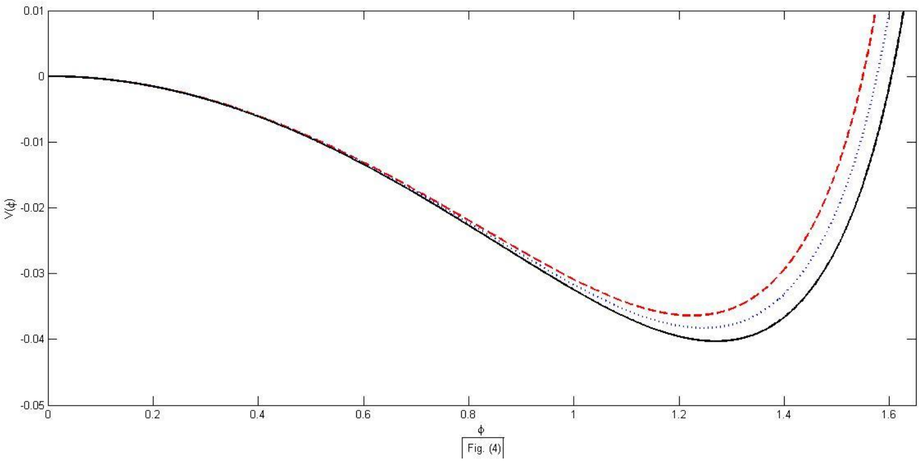

Figure 4: Variation of the SP $V(\phi)$ with potential ϕ of the IACSs for k_h = 2.0, k_c = 8, M = 2.1, σ_1 = 0.1, ν = 0.01, α = 0.001 and γ = 0.001 having different values of σ = 0.1 (red color dashed line), 0.09 (blue color dotted line) and 0.08 (black color solid line).

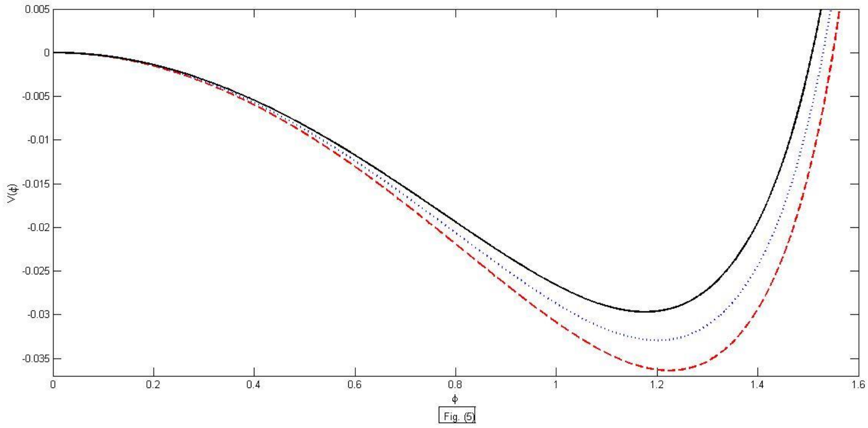

Figure 5: Variation of the SP $V(\phi)$ with potential ϕ of the IACSs for k_h = 2.0, k_c = 8, M = 2.1, σ = 0.1, ν = 0.01, α = 0.001 and γ = 0.001 having different values of σ_1 = 0.1 (red color dashed line), 0.099 (blue color dotted line) and 0.098 (black color solid line).

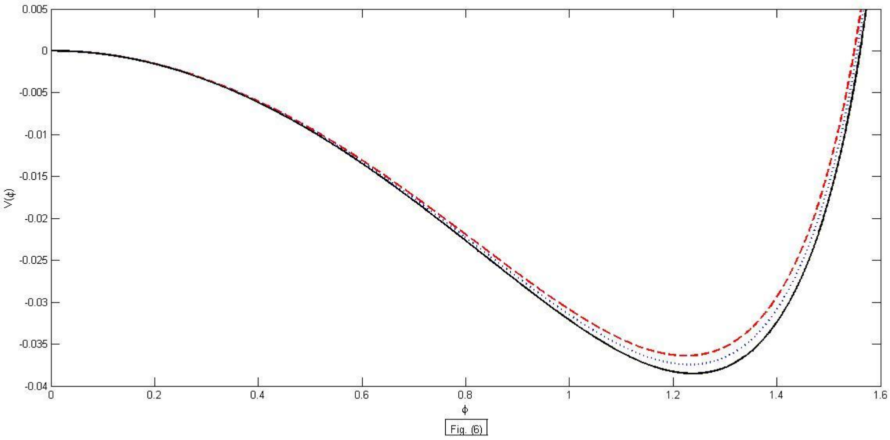

Figure 6: Variation of the SP $V(\phi)$ with potential ϕ of the IACSs for k_h = 2.0, k_c = 8, M = 2.1, σ = 0.1, σ_1 = 0.1, ν = 0.01 and γ = 0.001 having different values of α = 0.001 (red color dashed line), 0.005 (blue color dotted line) and 0.009 (black color solid line).

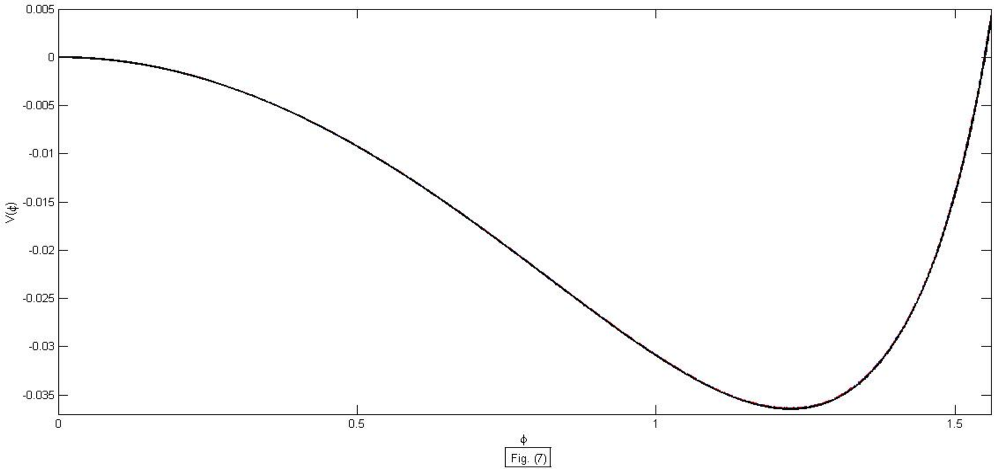

Figure 7: Variation of the SP $V(\phi)$ with potential ϕ of the IACSs for k_h = 2.0, k_c = 8, M = 2.1, σ = 0.1, σ_1 = 0.1, ν = 0.01 and α = 0.001 having different values of γ = 0.001 (red color dashed line), 0.01 (blue color dotted line) and 0.1 (black color solid line).

5. Conclusions

In the present paper, the effect of spectral indexes of cold and hot electrons, temperature ratio of two species of electron, positron concentration, ionic temperature ratio, positron temperature ratio and Mach number on the large amplitude of the IACSs are investigated in plasmas. For given set of plasma parameters on increasing indexes of cold and hot electrons and temperature ratio of two species of electron, the amplitude of IACSs decreases, but it increases with increase in ionic temperature ratio, Mach number, positron concentration and positron temperature ratio. The finding results of this paper may be useful for understanding of nonlinear ion-acoustic solitons in plasma containing positrons, ions and nonthermal electrons in space and laboratory plasmas.

References

[1]. R. Bharuthram and P. K. Shukla, Phys. Fluids 29, 3214 (1986).
[2]. S. L. Jain, R. S. Tiwari and S. R. Sharma, Can. J. Phys 68, 474 (1990).
[3]. Y. N. Nejoh, Phys. Plasma 3, 1447 (1996).
[4]. R. S. Tiwari, S. L. Jain and M. K. Mishra, Phys Plasmas 18, 083702 (2011).
[5]. (a) S. K. Jain and M. K. Mishra, J Plasma Physics 79, 893 (2013). (b) S. K. Jain and M. K. Mishra, Astrophys Space Sci 346, 395 (2013).
[6]. (a) S. L. Jain, R. S. Tiwari and M. K. Mishra, Astrophys Space Sci 357, 57 (2015). (b) S. L. Jain, R. S. Tiwari and M. K. Mishra, J. Plasma Phys 81, 1 (2015).
[7]. K. Kumar and M. K. Mishra, AIP Advances 7, 115114 (2017).
[8]. M A Hellberg, R L Mace, T K Baluku, I Kourakis and N S Saini, Phys. Plasmas 16, 094701 (2009).
[9]. N Boubakour, M Tribeche and K Aoutou, Phys. Scr. 79, 065503 (2009)
[10]. S A El-Tantawy and W M Moslem, Phys. Plasmas 18, 112105 (2011)
[11]. S A El-Tantawy, N A El-Bedwehy and W M Moslem, Phys. Plasmas 18, 052113 (2011)
[12]. A Panwar, C M Ryu and A S Bains, Phys. Plasmas 21, 122105 (2014)
[13]. E F El-Shamy, Phys. Plasmas 21, 082110 (2014)
[14]. A Saha, N Pal and P Chatterjee, Phys. Plasmas 21, 102101 (2014)
[15]. N S Saini, B S Chahal, A S Bains and C Bedi, Phys. Plasmas, 21, 022114 (2014)
[16]. A S Bains, A Panwar and C M Ryu, Astrophys Space Sci 360, 17 (2015)
[17]. P. C. Singhadiya, J. K. Chawla, S. K. Jain, Pramana J. Phys. 94, 80 (2020).