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ABSTRACT

A theoretical investigation has been made to explore the behavior of nonplanar (cylindrical and spherical) electrostatic shock waves in a dusty plasma system that consists of arbitarily charged dust particles, negatively charged heavy ions following Cairn's distribution, positively charged ions with two different temperatures, and nonextensive electrons. The reductive perturbation technique is used to derive a modified Burgers equation analytically. Analytical analysis shows that the characteristics of the nonplanar shock waves, including their polarity, amplitude, width, and phase speed, undergo significant alterations due to factors such as the charges on dust particles, the number density of particles, the temperatures of heavy and light ions, nonextensive electron behavior, and dust kinematic viscosity. Furthermore, this study found shock structures with either a positive or negative potential, depending on the critical value of the proportion of ions to the density of dust particles. The findings maybe useful in understanding the characteristics of shock waves both in space plasma environments and laboratory plasmas.

I. INTRODUCTION

Dusty plasmas have been introduced as an exciting area of scientific exploration, primarily owing to their crucial role in enhancing the comprehension of collective phenomena within both space environments[1–4] and laboratory plasmas.[5–7] Dust particles become negatively charged as they accumulate electrons[2,8] due to significantly higher speeds than ions, resulting in an excess of electrons being gathered by the dust grains. Conversely, these particles can acquire a positive charge through various mechanisms, such as the emission of photoelectrons caused by UV photons,[8] thermionic emission resulting from radiative heating,[2,9] and secondary electron generation.[10] Hence, positively or negatively charged dust particles have been identified in diverse settings, ranging from space environments to controlled laboratory dusty plasmas.[2,11–13] Nonetheless, it has been discovered that randomly charged dust within plasmas not only alters the characteristics of the wave spectra but also brings forth various new eigenmodes. In recent times, nonlinear dust-acoustic waves (DAWs),[14–17] including solitary waves and shock waves, have also gained significant interest in understanding the characteristics of localized electrostatic disturbances in dusty plasmas. Recently, Tanisha *et al.*[18] analyzed cylindrical and spherically DA modified Gardner solitons (GSs) in a five-component dusty plasma systems. In 2022, Rajib and Sultana[19] studied the nonlinear electromagnetic wave phenomena by investigating compressive and rarefactive electron–positron (EP) magnetoacoustic modes in an EP plasma medium.

However, the influence of two-temperature ions[20] or electrons[21–23] on dust acoustic shock waves (DASHWs) in both space environments[24–26] and laboratory plasmas[25] has been investigated extensively by various researchers.[27,28] Hatami and Niknam[29] studied the propagation of ion-acoustic double layers with arbitrary amplitudes in a nonlinear plasma system containing hot fluid ions and nonextensive electrons at two temperatures (cold and hot). Recently, Rajib *et al.*[30] explored the nonlinear propagation of dust-ion-acoustic rogue waves within a three-component dust-ion-electrons system employing the standard nonlinear Schrödinger equation framework.

This paper studies the characteristics of nonplanar DASHWs in a dusty plasma system. The formation of DASHWs arises from a delicate equilibrium between nonlinearity and dissipation mechanisms. The dissipation, crucial for shock formation,[11] stems from various sources, such as Landau damping, kinematic viscosity among plasma constituents, and wave–particle interactions. The primary aim of this study is to investigate the characteristics of cylindrical and spherical electrostatic shock formations using the modified Burgers equation (mBE). These phenomena have been observed in a variety of environments, including Saturn's E ring, Earth's mesosphere, Halley's comet tails, Jupiter's magnetosphere, solar active regions,[31] and laboratory dusty plasmas.[32] The manuscript is structured as follows: the governing equations are provided in Sec. II. In Sec. III, we derive the mBE by employing the reductive perturbation technique. A brief analytical analysis is presented in Sec. IV. Finally, a summary is given in the conclusion Sec. V.

II. GOVERNING EQUATIONS

We examine the propagation of nonplanar (cylindrical and spherical) DASHWs in an unmagnetized dusty plasma medium containing arbitrarily charged mobile dust, electrons following q nonextensive distribution, nonthermal ions following Cairn's distribution, and negatively charged heavy ions at two distinct temperatures. Therefore, at equilibrium, we have $n_{i10} + n_{i20} + jZ_d n_{d0} = n_{h0} + n_{e0}$, where $j = \pm 1$ (+ for positively charged dust and − for negatively charged dust); Z_d is the number of electrons or protons present on the surface of the dust grain; and n_{i10}, n_{i20}, n_{h0}, n_{e0}, and n_{d0} are the equilibrium number density of ion with lower temperature, ion with higher temperature, heavy ion, electron, and dust particles, respectively. The nonlinear dynamics of low-frequency DASHWs in a dusty plasma system, where the phase speed is significantly slower than the thermal speeds of electrons and ions, but faster than that of dust particles, is described by the following equations:

$$\frac{\partial n_d}{\partial t} + \frac{1}{r^\nu}\frac{\partial}{\partial r}\left(r^\nu n_d u_d\right) = 0, \tag{1}$$

$$\frac{\partial u_d}{\partial t} + u_d\frac{\partial u_d}{\partial r} = -j\frac{\partial \phi}{\partial r} + \frac{\eta}{r^\nu}\frac{\partial}{\partial r}\left(r^\nu \frac{\partial u_d}{\partial r}\right), \tag{2}$$

$$\begin{aligned}\frac{1}{r^\nu}\frac{\partial}{\partial r}r^\nu\frac{\partial \phi}{\partial r} &= \mu\left[1 + (q-1)\sigma_2\phi^{\frac{(q+1)}{2(q-1)}}\right] \\ &\quad + \mu_h\left(1 + \beta\sigma_h\phi + \beta\sigma_h^2\phi^2\right)e^{-\sigma_h\phi} \\ &\quad - \mu_{i1}\left(1 + \beta\phi + \beta\phi^2\right)e^{-\phi} \\ &\quad - \mu_{i2}\left(1 + \beta\sigma_1\phi + \beta\sigma_1^2\phi^2\right)e^{-\sigma_1\phi} - jn_d,\end{aligned} \tag{3}$$

where $\nu = 0$ for 1D planar geometry and $\nu = 1$ (2) for nonplanar cylindrical (spherical) geometry, n_d is the density of dust particles normalized by its equilibrium value n_{d0}, u_d is the dust fluid speed normalized by $C_d = (Z_d k_B T_{i1}/m_d)^{1/2}$, η is the viscosity coefficient normalized by $m_d n_{d0}\omega_{pd}\lambda_{Dm}^2$, and ϕ is the electrostatic wave potential normalized by T_{i1}/e. The parameters raised in Eq. (3) are defined as $\sigma_1 = T_{i1}/T_{i2}$, $\sigma_2 = T_{i1}/T_e$, $\sigma_h = T_h/T_e$, $\mu_{i1} = n_{i10}/Z_d n_{d0}$, $\mu_{i2} = n_{i20}/Z_d n_{d0}$, $\mu_h = n_{h0}/Z_d n_{d0}$, and $\mu = n_{e0}/Z_d n_{d0} = \mu_{i1} + \mu_{i2} - \mu_h + j$, where T_{i1} (T_{i2}) is the lower (higher) ion temperature, T_e is the electron temperature, and T_h is the heavy ion temperature. The time variable t is normalized by $\omega_{pd}^{-1} = (m_d/4\pi n_{d0}Z_d^2 e^2)^{1/2}$, and the space variable x is normalized by $\lambda_{Dm} = (T_{i1}/4\pi n_{d0}Z_d e^2)^{1/2}$. The number densities of two-temperature nonthermal ions, nonthermal heavy ions, and nonextensive electrons are

$$n_{i1} = n_{i10}\left[1 + \beta\left(\frac{e\phi}{T_{i1}}\right) + \beta\left(\frac{e\phi}{T_{i1}}\right)^2\right]e^{-\left(\frac{e\phi}{T_{i1}}\right)}, \tag{4}$$

$$n_{i2} = n_{i20}\left[1 + \beta\left(\frac{e\phi}{T_{i2}}\right) + \beta\left(\frac{e\phi}{T_{i2}}\right)^2\right]e^{-\left(\frac{e\phi}{T_{i2}}\right)}, \tag{5}$$

$$n_h = n_{h0}\left[1 + \beta\left(\frac{e\phi}{T_h}\right) + \beta\left(\frac{e\phi}{T_h}\right)^2\right]e^{-\left(\frac{e\phi}{T_h}\right)}, \tag{6}$$

$$n_e = n_{e0}\left[1 + (q-1)\frac{e\phi}{T_{i1}}\right]^{\frac{q+1}{2(q-1)}}, \tag{7}$$

where $\beta = 4\alpha/(1 + 3\alpha)$ and α is the combined population of nonthermal ions and negatively charged heavy ions.

III. DERIVATION OF MODIFIED BURGERS EQUATION

To formulate the mBE for the electrostatic DASHWs, we initially introduce the stretched coordinates as

$$\zeta = \varepsilon(r - V_p t), \quad \tau = \varepsilon^2 t, \tag{8}$$

where V_p expresses the phase speed of the DASHWs and ε ($0 < \varepsilon < 1$) represents a parameter indicating the weakness of the dispersion. We then expand n_d, u_d, and ϕ in power series of ε[33] as

$$n_d = 1 + \varepsilon n_d^{(1)} + \varepsilon^2 n_d^{(2)} + \varepsilon^3 n_d^{(3)} + \cdots, \tag{9}$$

$$u_d = 0 + \varepsilon u_d^{(1)} + \varepsilon^2 u_d^{(2)} + \varepsilon^3 u_d^{(3)} + \cdots, \tag{10}$$

$$\phi = 0 + \varepsilon\phi^{(1)} + \varepsilon^2\phi^{(2)} + \varepsilon^3\phi^{(3)} + \cdots, \tag{11}$$

and formulate equations using different powers of ε. At the smallest magnitude of ε, Eqs. (9)–(11) give

$$u_d^{(1)} = \frac{j}{V_p}\phi^{(1)}, \tag{12}$$

$$n_d^{(1)} = \frac{j}{V_p^2}\phi^{(1)}, \tag{13}$$

$$V_p = \frac{1}{\sqrt{\frac{1}{2}\mu\sigma_2(1+q) + t_1(\beta - 1)}}, \tag{14}$$

where $t_1 = \mu_h\sigma_h - \mu_{i1} - \mu_{i2}\sigma_1$.

To the next higher order of ε, we obtain a set of equations as

$$\frac{\partial {n_d}^{(1)}}{\partial \tau} - V_p\frac{\partial {n_d}^{(2)}}{\partial \zeta} + \frac{\partial {u_d}^{(2)}}{\partial \zeta} + \frac{\partial p}{\partial \zeta} + \frac{{u_d}^{(1)}\nu}{V_p\tau} = 0, \tag{15}$$

$$\frac{\partial u_d^{(1)}}{\partial \tau} - V_p\frac{\partial u_d^{(2)}}{\partial \zeta} + u_d^{(1)}\frac{\partial u_d^{(1)}}{\partial \zeta} + j\frac{\partial \phi^{(2)}}{\partial \zeta} = \eta\frac{\partial^2 u_d^{(1)}}{\partial \zeta^2}, \tag{16}$$

$$\begin{aligned}
&\frac{1}{4}\mu{\sigma_2}^2(5+q)(3-q){\phi^{(1)}}^2 + \frac{1}{2}\mu\sigma_2(1+q)\phi^{(2)} \\
&+\mu_h\beta\sigma_h\phi^{(2)} - \mu_h\sigma_h\phi^{(2)} + \frac{1}{2}\mu_h\sigma_h^2{\phi^{(1)}}^2 - \mu_{i1}\beta\phi^{(2)} \\
&+\mu_{i1}\phi^{(2)} - \frac{1}{2}\mu_{i1}{\phi^{(1)}}^2 - \mu_{i2}\beta\sigma_1\phi^{(2)} + \mu_{i2}\sigma_1\phi^{(2)} \\
&-\frac{1}{2}\mu_{i2}\sigma_1^2{\phi^{(1)}}^2 - j{n_d}^{(2)} = 0,
\end{aligned} \tag{17}$$

where $p = n_d^{(1)}u_d^{(1)}$. Now combining Eqs. (15)–(17), we obtain an equation in the form,

$$\frac{\partial \psi}{\partial \tau} + A\psi\frac{\partial \psi}{\partial \zeta} + \frac{\nu}{2\tau}\psi - C\frac{\partial^2 \psi}{\partial \zeta^2} = 0. \tag{18}$$

Equation (18) represents the modified Burgers equation, where $\phi^{(1)} = \psi$, A is the nonlinear coefficient, and C is the dissipative coefficient are given by

$$A = \frac{V_p^3}{2}\left[\mu_{i1} + \mu_{i2}\sigma_1^2 - \frac{1}{4}\sigma_2\mu(1+q)(3-q) - \mu_h\sigma_h^2 + \frac{3j}{V_p^4}\right], \tag{19}$$

$$C = \frac{\eta}{2}. \tag{20}$$

The stationary shock wave solution of Eq. (18) in planar geometry ($\nu = 0$) is obtained by the normalized quantity $\xi = \zeta - U_0\tau$ and $\tau' = \tau$ as

$$\psi = \psi_m[1 - \tanh(\xi/\Delta)], \tag{21}$$

where $\psi_m = U_0/A$ is the DASHWs amplitude and $\Delta = 2C/U_0$ is the DASHWs width. It is obvious from $\psi_m = U_0/A$ that $\psi_m \to \infty$ as $A \to 0$. This means that our theory is not valid when $A \sim 0$, which makes the amplitude extremely large and breaks down the validity of the reductive perturbation method. We can get the time evolution of the shock wave solution by modifying Eq. (21) as $\psi(\xi \neq 0, \tau') = \psi_m[1 - \tanh(\xi/\Delta)]$.[34]

IV. ANALYTICAL ANALYSIS

From Eq. (21), the nonlinear coefficient A is a function of μ_{i1}, μ_{i2}, μ_h, σ_1, σ_2, σ_h, β, and q. Therefore, to identify the parametric regions where $A = 0$, we express the parameter μ_{i1} in terms of the others (μ_{i2}, μ_h, σ_1, σ_2, σ_h, β, and q). Thus, the critical value of μ_{i1} (denoted as μ_c) at $A = 0$ can be represented as

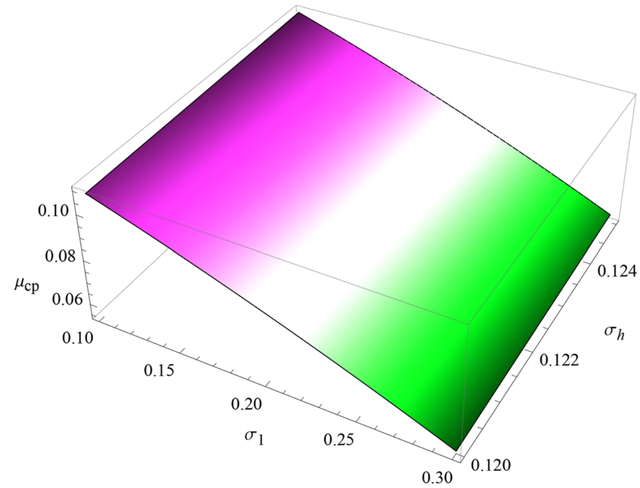

FIG. 1. μ_{cp} vs σ_1 and σ_h when $A = 0$.

$$\begin{aligned}
\mu_{i1} = \mu_c = &\frac{1}{6p_1^2}\left[-6\mu_{i2}p_1p_2\right. \\
&\left. + j\left(-4 - (1+q)\sigma_2p_3 + 6\mu_hp_1p_4 + \sqrt{D}\right)\right],
\end{aligned} \tag{22}$$

where $D = [j(j(16 + (1+q)\sigma_2(96 - 96\beta + 8(21+q)\sigma_2 - 48(q-3)(\beta-2)\beta\sigma_2 + 24p_5(\beta-1)\sigma_2^2 + (q-3)^2(1+q)\sigma_2^3)) + 24(2(\beta-1) - (1+q)\sigma_2)(\mu_{i2}(-4(\beta-1)(\sigma_1-1)\sigma_1 + 2(1+q)(\sigma_1^2-1)\sigma_2 + p_5(\beta-1)(\sigma_1-1)\sigma_2^2) + \mu_h(-p_5(\beta-1)\sigma_2^2(\sigma_h-1) + 4(\beta-1)(\sigma_h-1)\sigma_h - 2(1+q)\sigma_2)(\sigma_h^2-1)))]$, $p_1 = (2 - 2\beta + \sigma_2 + q\sigma_2)$, $p_2 = (2\sigma_1 - 2\beta\sigma_1 + \sigma_2 + q\sigma_2)$, $p_3 = (12 - 12\beta + 3\sigma_2 + 7q\sigma_2)$, $p_4 = (\sigma_2 + q\sigma_2 + 2\sigma_h - 2\beta\sigma_h)$, and $p_5 = (q-3)(1+q)$.

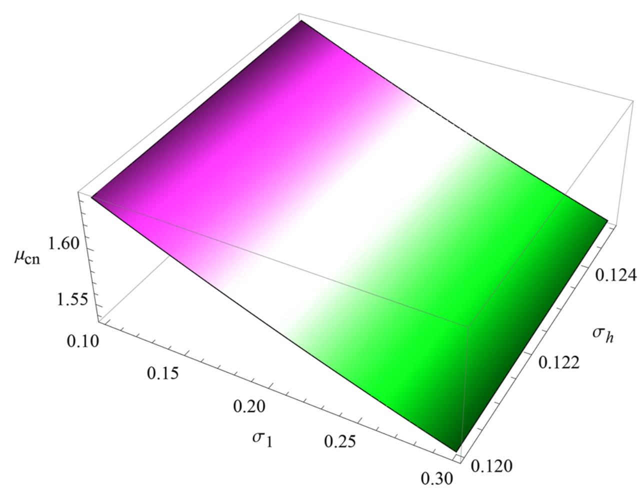

FIG. 2. μ_{cn} vs σ_1 and σ_h when $A = 0$.

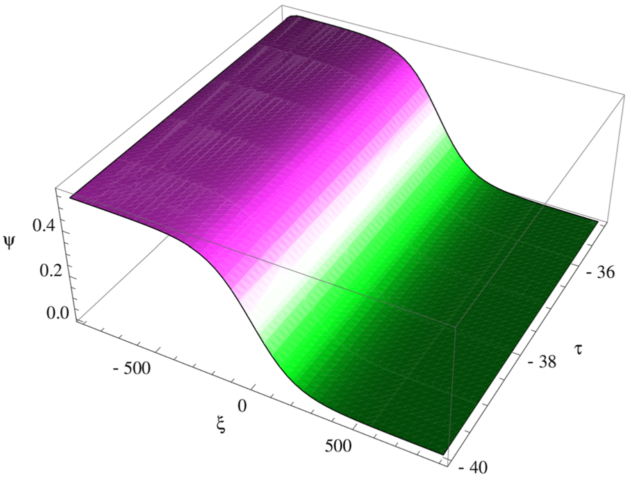

FIG. 3. ψ vs ξ and τ for μ_{i1} = 0.3, ν = 1, μ_{i2} = 0.5, μ_h = 1.1, σ_1 = 0.2, σ_2 = 1, σ_h = 0.125, β = 0.6, q = 0.3, η = 0.5, and j = 1.

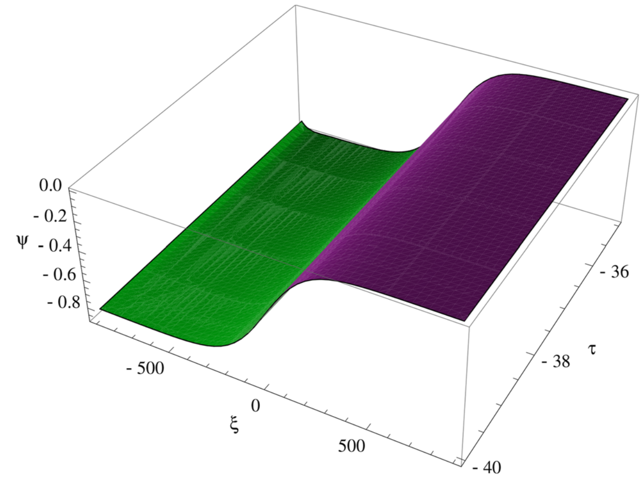

FIG. 5. ψ vs ξ and τ for μ_{i1} = 0.02, ν = 1, μ_{i2} = 0.5, μ_h = 1.1, σ_1 = 0.1, σ_2 = 1, σ_h = 0.125, β = 0.6, q = 0.3, η = 0.5, and j = +1.

Equation (22) expresses the critical value of μ_{i1}, denoted as μ_{cp} for positively charged particles and μ_{cn} for negatively charged particles. It is observed that shock waves exist with positive potential for $\mu_{i1} > \mu_{cp}$ and $\mu_{i1} < \mu_{cn}$ and with negative potential for $\mu_{i1} < \mu_{cp}$ and $\mu_{i1} > \mu_{cn}$. Notably, the nonlinear coefficient A reaches zero at its critical point, $\mu_{i1} = \mu_{cp} \simeq 0.08$ for positively charged dust $(j = 1)$ and $\mu_{i1} = \mu_{cn} \simeq 1.58$ for negatively charged dust $(j = -1)$. Equation (22) is calculated for a set of plasma parameters, $\mu_{i2} = 0.5$, $\mu_h = 1.1$, $\sigma_1 = 0.1 \sim 0.3$, $\sigma_2 = 1$, and $\sigma_h = 0.125$ for $j = 1$ and $\mu_{i2} = 0.8$, $\mu_h = 1.1$, $\sigma_1 = 0.1 \sim 0.3$, $\sigma_2 = 0.41$, and $\sigma_h = 0.125$ for $j = -1$[13,14,26,35] using Mathematica 13.

The certain ranges of the dusty plasma parameters $\sigma_1 = 0.1 \sim 0.3$, $\sigma_2 = 1$ for $j = 1$; $\sigma_2 = 0.1 \sim 0.7$ for $j = -1$; and $\sigma_h = 0.120 \sim 0.125$, $\beta = 0.1 \sim 0.9$, and $q = 0.3$ are used in this analytical analysis.[13,14,35,36] The parametric range considered for this dusty plasma model is shown in Figs. 1 and 2. Our main results are in the following.

1. The small amplitude shock waves exist with a positive potential for $\mu_{i1} > \mu_{cp}$ and $\mu_{i1} < \mu_{cn}$ and with a negative potential for $\mu_{i1} < \mu_{cp}$ and $\mu_{i1} > \mu_{cn}$ (shown in Figs. 3–10).
2. The time evolution of the nonplanar DASHWs significantly differs from the 1D planar DASHWs. In addition, the properties of shock waves are observed to change over time in both cylindrical and spherical cases.
3. Equation (18) shows that the term $\frac{\nu}{2\tau}\psi$ exhibits singularity at $\tau = 0$ and goes to infinity as τ approaches zero. As τ becomes large, this term diminishes, yielding the Burgers equation. Considering the temporal dimension, we may

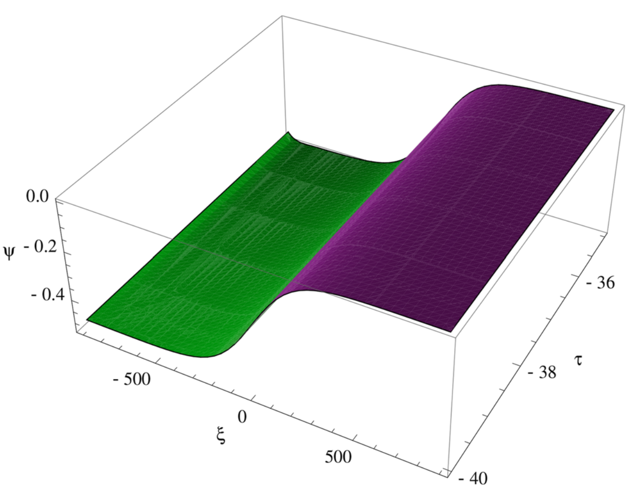

FIG. 4. ψ vs ξ and τ for μ_{i1} = 2.3, ν = 1, μ_{i2} = 0.5, μ_h = 1.1, σ_1 = 0.1, σ_2 = 1, σ_h = 0.125, β = 0.6, q = 0.3, η = 0.5, j = −1.

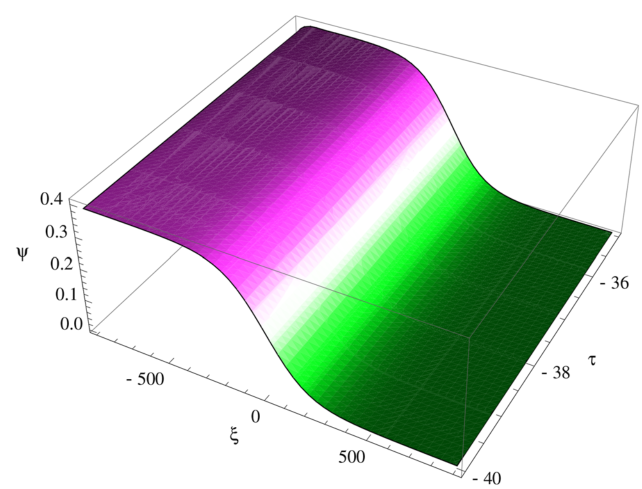

FIG. 6. ψ vs ξ and τ for μ_{i1} = 1.17, ν = 1, μ_{i2} = 0.8, μ_h = 1.1, σ_1 = 0.1, σ_2 = 1, σ_h = 0.125, β = 0.6, q = 0.3, η = 0.5, and j = −1.

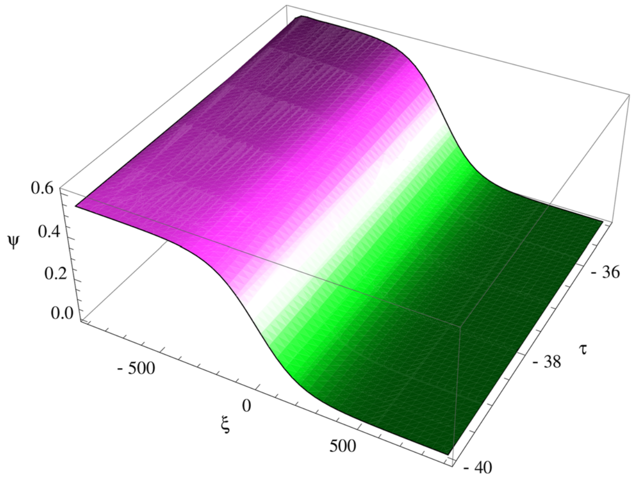

FIG. 7. ψ vs ξ and τ for $\mu_{i1} = 0.3$, $\nu = 2$, $\mu_{i2} = 0.5$, $\mu_h = 1.1$, $\sigma_1 = 0.2$, $\sigma_2 = 1$, $\sigma_h = 0.125$, $\beta = 0.6$, $q = 0.3$, $\eta = 0.5$, and $j = +1$.

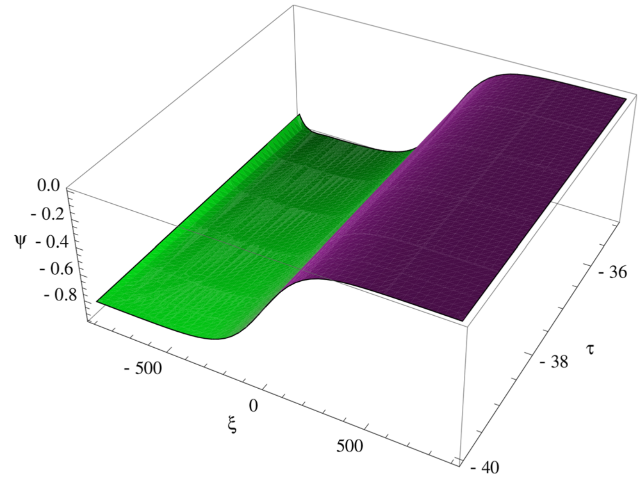

FIG. 9. ψ vs ξ and τ for $\mu_{i1} = 0.02$, $\nu = 2$, $\mu_{i2} = 0.5$, $\mu_h = 1.1$, $\sigma_1 = 0.1$, $\sigma_2 = 1$, $\sigma_h = 0.125$, $\beta = 0.6$, $q = 0.3$, $\eta = 0.5$, and $j = +1$.

initiate our initial pulse at $\tau = -40$ where the term $\frac{\nu}{2\tau}\psi$ is negligible. It is obvious from Eq. (18) that the nonplanar effect becomes prominent as τ approaches zero and diminishes for higher values of τ.

4. The height and width of the cylindrical shock wave are larger than those of the 1D shock wave but smaller than those of the spherical shock wave.
5. The Burgers equation derived in this context is valid only for the limits $A \neq 0$, $A > 0$, and $A < 0$. The ranges $0.1 \leq \sigma_1 \leq 0.3$, $0.1 \leq \sigma_2 \leq 0.6$, $0.120 \leq \sigma_h \leq 0.125$, $0.1 \leq \beta \leq 0.9$, and $-1 < q < 1$[3,35,36] of the dusty plasma parameters used in this analytical analysis are very wide and correspond to space[37,38] and laboratory plasmas.

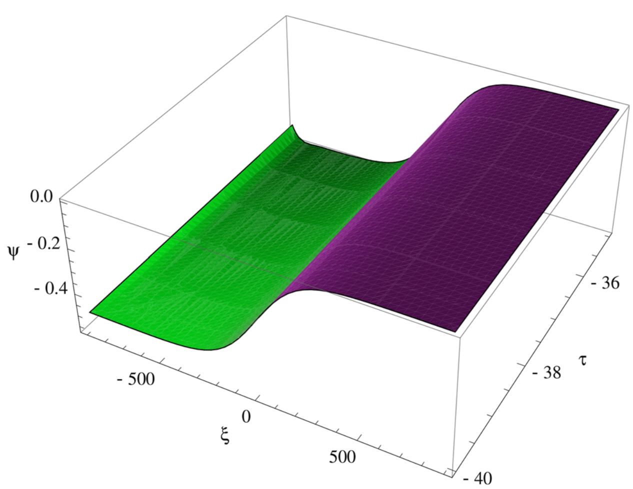

FIG. 8. ψ vs ξ and τ for $\mu_{i1} = 2.3$, $\nu = 2$, $\mu_{i2} = 0.8$, $\mu_h = 1.1$, $\sigma_1 = 0.1$, $\sigma_2 = 1$, $\sigma_h = 0.125$, $\beta = 0.6$, $q = 0.3$, $\eta = 0.5$, and $j = -1$.

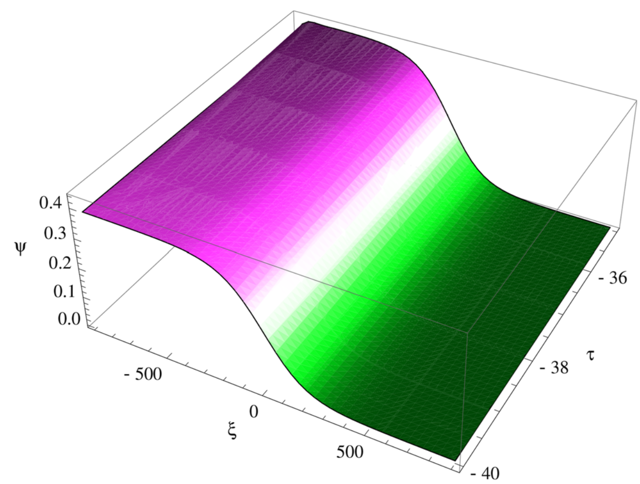

FIG. 10. ψ vs ξ and τ for $\mu_{i1} = 1.17$, $\nu = 2$, $\mu_{i2} = 0.8$, $\mu_h = 1.1$, $\sigma_1 = 0.1$, $\sigma_2 = 1$, $\sigma_h = 0.125$, $\beta = 0.6$, $q = 0.3$, $\eta = 0.5$, and $j = -1$.

V. CONCLUSION

We investigated the nonlinear propagation of cylindrical and spherical DASHWs in an unmagnetized dusty plasma consisting of arbitrarily charged mobile dust fluid, light positive ions, heavy negative ions, and nonextensive electrons. We studied the characteristics of small amplitude cylindrical and spherical DASHWs by employing the stationary solution of the modified Burgers equation. We observed that the fundamental properties of DASHWs in dusty plasmas undergo significant modifications influenced by the number densities of heavy and light nonthermal ions (n_h, n_{i1}, and n_{i2}) and the temperatures of electrons and ions (T_e, T_h, T_{i1}, and T_{i2}). Our present study contributes for understanding the key characteristics of localized cylindrical and spherical DASHWs in the space plasmas. In conclusion, we propose conducting numerical analysis to validate the theoretical findings, aiming to observe DASHWs with nonplanar geometries in both laboratory plasmas such as in pair-ion (fullerene) experiments[39] and space plasmas.[40,41]

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AUTHOR DECLARATIONS

Conflict of Interest

The authors have no conflicts to disclose.

Author Contributions

N. Y. Tanisa: Conceptualization (equal); Investigation (equal); Methodology (equal); Writing – original draft (equal). **M. Ferdousi**: Supervision (equal); Writing – review & editing (equal). **D. M. Saaduzzaman**: Writing – review & editing (equal).

DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

REFERENCES

[1] D. A. Mendis and M. Rosenberg, Annu. Rev. Astron. Astrophys. **32**, 419–463 (1994).
[2] P. K. Shukla and A. A. Mamun, *Introduction to Dusty Plasma Physics* (Institute of Physics Publishing Ltd., Bristol, 2002).
[3] F. Verheest, *Waves in Dusty Plasmas* (Kluwer, Dordrecht, 2000).
[4] P. K. Shukla, Phys. Plasmas **8**, 1791 (2001).
[5] A. Barkan, R. L. Merlino, and N. D'Angelo, Phys. Plasmas **2**, 3563–3565 (1995).
[6] R. L. Merlino, A. Barkan, C. Thompson, and N. D'Angelo, Phys. Plasmas **5**, 1607 (1998).
[7] A. Homann, A. Melzer, S. Peters, and A. Piel, Phys. Rev. E **56**, 7138 (1997).
[8] M. Rosenberg and D. A. Mendis, IEEE Trans. Plasma Sci. **23**, 177 (1995).
[9] C. K. Goertz, Rev. Geophys. **27**, 271 (1989).
[10] V. W. Chow, D. A. Mendis, and M. Rosenberg, J. Geophys. Res. **98**, 19065, https://doi.org/10.1029/93JA02014 (1993).
[11] N. Y. Tanisha, I. Tasnim, S. Sultana, M. Salahuddin, and A. A. Mamun, Astrophys. Space Sci. **353**, 137–144 (2014).
[12] O. Havnes, J. Geophys. Res. **101**, 10839, https://doi.org/10.1029/96JA00003 (1996).
[13] F. Verheest and S. R. Pillay, Nonlinear Processes Geophys. **15**, 551 (2008).
[14] M. Rosenberg and R. L. Merlino, Planet. Space Sci. **55**, 1464 (2007).
[15] M. Abd-Elzaher and A. Atteya, Sci. Rep. **12**(1), 15890 (2022).
[16] N. N. Rao, P. K. Shukla, M. Y. Yu *et al.*, Planet. Space Sci. **38**, 543 (1990).
[17] A. A. Mamun and P. K. Shukla, New J. Phys. **11**, 103022 (2009).
[18] N. Y. Tanisha, M. Ferdousi, and K. Hossain, AIP Adv. **13**, 025356 (2) (2023).
[19] T. I. Rajib and S. Sultana, AIP Adv. **12**(6), 065318 (2022).
[20] I. Tasnim, M. M. Masud, M. Asaduzzaman, and A. A. Mamun, Chaos: Interdiscip. J. Nonlinear Sci. **23**, 013147 (2013).
[21] M. S. Alam, M. M. Masud, and A. A. Mamun, Chin. Phys. B **22**, 115202 (2013).
[22] S. Sultana and A. A. Mamun, Astrophys. Space Sci. **349**, 229–238 (2014).
[23] S. Sultana, S. Islam, and A. A. Mamun, Astrophys. Space Sci. **351**, 581–589 (2014).
[24] N. Dubouloz, R. Pottelette, M. Malingre, and R. A. Treumann, Geophys. Res. Lett. **18**, 155, https://doi.org/10.1029/90gl02677 (1991).
[25] H. Derfler and T. C. Simonen, Phys. Fluids **12**, 269 (1969).
[26] S. Sarkar and S. Maity, Phys. Plasmas **20**, 084501 (2013).
[27] M. Emamuddin and A. A. Mamun, J. Korean Phys. Soc. **74**, 959–966 (2019).
[28] I. Tasnim, M. M. Masud, M. G. M. Anowar, and A. A. Mamun, IEEE Trans. Plasma Sci. **43**, 2187–2194 (2015).
[29] M. M. Hatami and A. R. Niknam, Physica A **564**, 125533 (2021).
[30] T. I. Rajib, N. K. Tamanna, N. A. Chowdhury, A. Mannan, S. Sultana, and A. A. Mamun, Phys. Plasmas **26**(12), 123701 (2019).
[31] A. Mannan and A. A. Mamun, Waves Random Complex Media **32**(5), 2396–2415 (2022).
[32] I. Tasnim, M. M. Masud, and A. A. Mamun, Plasma Phys. Rep. **40**, 723–732 (2014).
[33] N. M. Heera, J. Akter, N. K. Tamanna, N. A. Chowdhury, T. I. Rajib, S. Sultana, and A. A. Mamun, AIP Adv. **11**, 055117 (5) (2021).
[34] T. I. Rajib, "Shear Alfvenic waves in electron-positron plasma: Analysis of solitary wave properties and numerical validation," arXiv:2401.06983 (2024).
[35] A. Paul, G. Mandal, A. A. Mamun, and M. R. Amin, IEEE Trans. Plasma Sci. **39**, 1254 (2011).
[36] K. B. Zhang and H. Y. Wang, J. Korean Phys. Soc. **55**, 1461 (2009).
[37] A. A. Mamun, P. K. Shukla, and B. Eliasson, Phys. Plasmas **16**, 1145031 (2009).
[38] N. D'Angelo, J. Phys. D: Appl. Phys. **37**, 860 (2004).
[39] T. I. Rajib, AIP Adv. **12**(6), 065314 (2022).
[40] K. Xie, B. Sun, S. Guo, L. Quan, and Y. Liu, Rev. Sci. Instrum. **90**(7), 073503 (2019).
[41] U. Teubner, Y. Kai, T. Schlegel, D. E. Zeitoun, and W. Garen, New J. Phys. **19**, 103016 (2017).