Analytical Study of Inertial Alfvén Solitary waves in an e-p-i Plasma

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Over the last many years, there has been a great deal of interest in studying the various kinds of nonlinear solitary structures under different conditions in laboratory experiments, space, and astrophysical plasma environments.The multispecies plasma mostly consists of number of particles such as ions, positrons, and electrons. The characteristics of wave propagation in e-p-i plasma is entirely different from e-i plasma. An electron-positron-ion plasma usually comprises of a fully ionized gas consisting of electrons and positrons having equal mass and opposite charge that apparently is assumed to have been existed in the early universe and has played a vital role in its evolution, in active galactic nuclei and also in pulsar magnetosphere. An e-p-i plasma can also be induced in the laboratory by the positron injection into the electron-ion system, by ultra-intense laser matter interaction and by the mechanism of relativistic heavy-ion collisions. It also occurs in many astrophysical environments like the inner region of accretion disks, solar flares, magnetosphere of neutron stars, in the vicinity of black holes, in active galactic cores[1] etc. Alfvén waves are the transverse waves which were first predicted by Alfvén[2] and experimentally in laboratory by Lundquist[3]. Alfvén waves are the low frequency waves which are formed when ions oscillate in an oscillating magnetic field. These waves are pure magnetohydrodynamics (MHD) waves which propagate when ion inertial force is balanced by the restoring force provided by tension in magnetic field. These non-dispersive waves are induced when a conducting fluid is placed in an external magnetic field. The movement of the fluid generates an e.m.f., which gives rise to electric currents which then interact with the magnetic field. Hence, mechanical forces are created and thus Alfvén waves are formed. The existence of these nonlinear structures has also been confirmed by various space observations. Among the variety of nonlinear solitary structures, kinetic Alfvén waves (KAWs) and inertial Alfvén waves (IAWs) are one of the modes that have been studied to understand the formation of coherent nonlinear soliton structures in multicomponent plasmas (e.g., in planetary rings, cometary tails, and magnetosphere of Jupiter). KAWs are the dispersive Alfvén waves which arise in a low-β_i (but finite) plasma when the finite Larmor radius effect or finite electron inertial effects modify the dispersion relation of shear Alfvén waves[4]. Inertial Alfvén waves are also a class of dispersive Alfvén waves which are formed when the perpendicular scale length is approximately equal to the electron inertial. In the case of IAWs, the plasma beta lies in the range $\beta \ll m_e/m_i \ll 1$. Thus, it can be seen that the electron inertia i.e., m_e dominates over plasma thermal pressure. An electric field parallel to the magnetic field is generated due to a slow parallel current of electrons. The IAWs travel slower than the usual magneto-hydrodynamic Alfvén waves. These are localized obliquely to the magnetic field. A nonlinear Korteweg-de Vries (KdV) equation describing the evolution of IAWs is derived by using the standard reductive perturbation method and hence the first order solution of KDV equation is obtained. Also, further an inhomogeneous KdV-type equation accounting for the higher order contributions of nonlinearity and dispersion is also derived. With the insertion of higher order effects, a new type of dressed soliton structures are obtained[5]. The influence of different plasma parameters on the dynamical evolution of the IAWs is examined. It is observed that these plasma parameters play significant role on the characteristics of inertial Alfvén solitary waves and dressed solitary waves. The main goal of present investigation is to study the effect of higher order contributions of nonlinearity and dispersion effects for the formation of inertial Alfvén solitary waves as well as dressed solitary waves. The findings of present investigation may be helpful to provide a new insight to understand the evolution of IAW and in the formation of various nonlinear structures in different space plasma regions.

References

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