§38. Particle Acceleration due to Strong Electromagnetic Fields in Shock Waves

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By using particle simulations, we have studied 1) parallel electric fields in nonlinear magnetosonic waves [1], 2) shock formation processes in a collision of two plasmas with their relative velocity oblique to the magnetic field [2], 3) evolution of oblique shock waves in a reversed external magnetic field and associated electron acceleration [3,4], 4) effects of ion composition on the propagation of nonlinear magnetosonic waves in a two-ion-species plasma [5], and 5) detrapping of energetic electrons from curved shock front [6]. Here, we briefly describe the study of the first subject.

In the ideal MHD theory, perfect conductivity is assuemed, $\mathbf{E} + \mathbf{v}\mathrm{x}\mathbf{B}/c = 0$. Hence, the electric field parallel to the magnetic field, $E_{\|}$, is zero. The parallel electric field has been thought to be quite weak in low-frequency phenomena in high-temperature plasmas. In Ref. [1], however, we have shown that $E_{\|}$ can be strong in nonlinear magnetosonic waves.

We have analytically obtained $E_{\|}$ and the parallel quasi potential F, which is the integral of $E_{\|}$ along the magnetic field, in a small-amplitude magnetosonic wave for the low and high beta cases. When the plasma beta value is high, F and thus $E_{\|}$ are proportional to the electron temperature. When the beta value is low, they are proportional to the energy density of the external magnetic field.

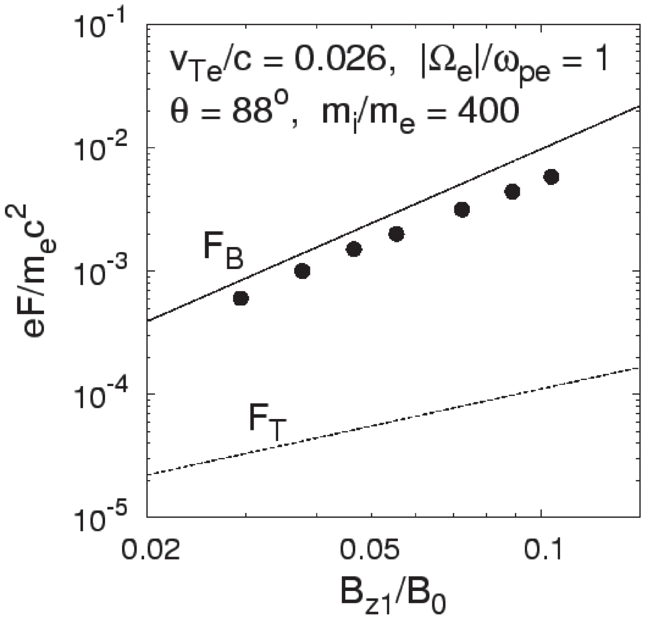

Fig. 1. Magnitude of F as a function of the amplitude for low beta case. The simulation results are close to the line F_B in this case.

We have then examined the magnitude of F by using electromagnetic particle simulations and found that the theory explains the simulation results. Figure 1 shows F as a function of the wave amplitude. Here, the lines F_B and F_T, respectively, represent the theory for low and high beta cases. The beta value is much lower than unity for the simulation parameters of Fig. 1, and the simulation results (dots) are consistent with the theory for the low beta case (F_B). (In the high beta case, F_T explains the simulation results.)

Furthermore, with particle simulations we have studied the magnitude of F in large-amplitude waves (shock waves). We have found that the simulation results of F are explained by one phenomenological relation for both low and high beta cases. Figure 2 shows the simulation results of F (closed circles and triangles), which are close to the phenomenological line (solid line). We also note that the observed F's are slightly smaller than potential ϕ (open circles and triangles).

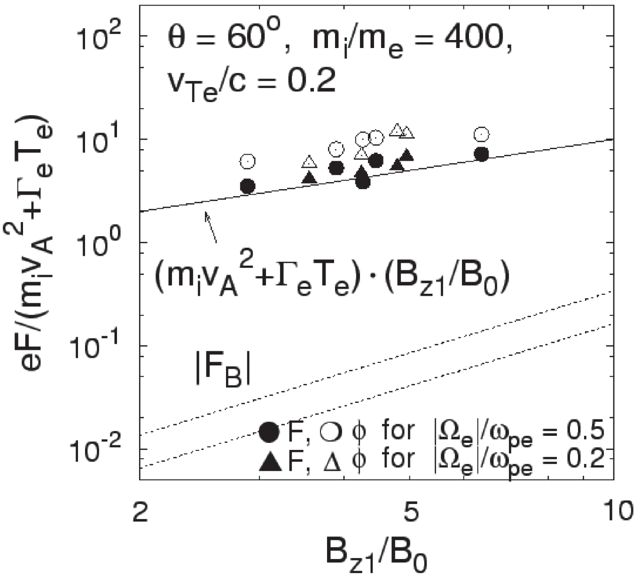

Fig. 2. F versus amplitude for shock waves. The closed circles and triangles show simulation results of F while the open circles and triangles show the potential ϕ. The phenomenological relation (represented by the solid line) explains the simulation results of F for shock waves.

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