Particle heating and acceleration process around high Mach number shock front

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Full particle simulation for high Mach number shock (Ma = 10 - 20) with quasi-perpendicular geometry and with non-relativistic velocity is carried out to investigate electron dynamics around shock front. Electrons begin to heat up strongly at ramp region and its heating process is non-adiabatic (T_perpendicular/B = 10 or more).

We sometimes observe electron phase holes in the ramp and just upstream region while ion phase holes in the just downstream region as well as in the region electron holes are observed. We think such strong heating can be caused by nonlinear phase holes interaction. Phase holes are created by non-linear stage of Buneman instability and behave like super-particles with anti-charge to reflect another species.

Above critical Mach number (2-3) we familiar with the fact that ion kinematics play a crucial role in shock dissipation process. We wonder if something interesting will occur for particle, especially electron, dynamics in the region of higher Mach number. One of the highest Mach number shock directly observed is the Uranus bow shock (Ma ~ 20) by Voyager 2 (1986). We investigate such high Mach number shocks (Ma = 10 ~ 20) with quasi-perpendicular geometries by means of full-particle simulation. Strong overshoot (~ ten times larger than upstream magnetic field magnitude) and strong heating are obtained as observed at the Uranus bow shock. At the foot point ions are rapidly heated up to several hundreds times as large as upstream temperature, at the ramp electron temperature increases at most to hundred times as large as upstream value. Since the value of perpendicular temperature divided by magnetic field strength (T_perpen/B) is about 10 or larger, electrons are heated non-adiabatically. Results from our simulation show that electron phase holes are often observed in the ramp and foot region while ion phase holes in just downstream region as well as in the region electron holes are observed. Packets with micro-scale and large-amplitude potential structures are observed accompanied with the phase hole and phase vortex structures. These structures are created by non-linear stage of Buneman instability caused by strong ion reflection. We think interaction between the electron (ion) phase holes and ions (electrons) play an important role for particle heating and shock dissipation process.