Electron dynamics at the shock transition layer

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We discuss the problem how the bulk flow energy converts electron heating and acceleration at the shock transition layer by using particle simulation. At a given Mach number non-thermal electrons tend to be generated more with larger plasma beta and shocked electrons tend to be hotter with smaller plasma beta. When beta is too large waves can not grow to make non-thermal electrons, so that the beta value for the most effective acceleration can be found at a given Mach number. When the electron gyro-motion synchronizes with their hole dynamics, the electrons are accelerated about ten times by motional electric field during several plasma oscillation.

We discuss the problem how the bulk flow energy converts electron heating and acceleration at the shock transition layer by using particle simulation. Recently, observational data at the shock transition layer indicates the relationship between electron dynamics and local nonlinear waves. Indeed, simulations for the (quasi) perpendicular shocks illustrate that two-stream instability between electrons and ions grows at the shock transition region where reflected ions exist. Electrostatic waves due to the instability evolve into electron holes which result strong electron heating and acceleration. The generation rate of non-thermal electron and the rate of thermal heating are determined by three physical quantities, the ion bulk energy, plasma temperature and magnetic field (or usual two parameters, Alfven Mach number and plasma beta). Simulation results indicate that at a given Mach number non-thermal electrons tend to be generated more with larger plasma beta and shocked electrons tend to be hotter with smaller plasma beta. Larger beta condition suppresses wave growth so that the bulk flow is partially trapped and modified, and the rest part of the bulk population is converted into non-thermal electrons. Smaller beta condition results large amplitude waves which modify almost all part of the bulk flow. When beta is too large waves can not grow to make non-thermal electrons, so that the beta value for the most effective acceleration can be found at a given Mach number. Electron holes contribute to the generation of non-thermal electrons. When the electron gyro-motion synchronizes with their hole dynamics, the electrons are accelerated about ten times faster by motional electric field during several plasma oscillation. This process is interesting as a rapid acceleration mechanism at the shock transition layer. The ratio of the typical hole dynamics time to the electron gyration time controls also electron dynamics at the shock transition layer. When the latter time is larger than the former electron holes are not formed properly and dose not lead effective heating.

Since electrostatic waves carrying electron holes initially propagate to the upstream direction, they can not contribute to the dissipation at the shock. However, as the temperature of reflected ions and electrons are raising (or large velocity dispersion), the group velocity points to the downstream region and dissipates there. Velocity dispersion of the reflected ions is amplified by the rapid deviation (time scale of the electron dynamics) of the ion reflection points. This fact indicates the magnetic field profile is changing during the time scale of the electron dynamics. It relates shock cyclic behavior in the micro scale.