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Heating and Acceleration by Microinstabilities in the Quasi-Perpendicular Shock Transition Region

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The physics of particle acceleration at collisionless shocks has attracted considerable attention. The main reason is that so-called galactic cosmic rays (cosmic rays below the knee energy 10^{15} eV) are believed to be produced by supernova remnants shocks. In the heliosphere, interplanetary shocks and planetary bow shocks have been extensively studied as a laboratory of particle acceleration theory. Now, it is known that collisionless shock waves can indeed produce nonthermal ions with the power law energy spectra via diffusive shock acceleration process. However, our understanding of the physics of electron acceleration at shocks is still limited. The well-known difficulty is that thermal electrons cannot be scattered by low frequency Alfven waves. In order to produce nonthermal electrons, we require either (1) the presence of high frequency whistler waves, (2) preacceleration of low energy electrons to mildly relativistic energy, so that the preaccelerated electrons can be scattered by Alfven waves.

We have recently found that the preacceleration of electrons occurs in the transition region of quasi-perpendicular shocks through shock surfing acceleration followed by shock drift acceleration. The energy of injected electron is large enough to be accelerated by subsequent diffusive shock acceleration process at shocks with Alfven Mach number typical of supernova remnants (Amano & Hoshino, ApJ in press). However, the nonlinear evolution of the shock structure including the back-reaction from energetic particles, which is closely related to the problem of maximum attainable energy by diffusive shock acceleration process, is not yet fully understood. This is because their study was based on one dimensional particle-in-cell simulations.

In order to understand the issue, we think that multidimensional effects will become important; namely, the energetic electrons injected by the above mentioned mechanism may excite plasma instabilities both in the shock transition region and the upstream if we use two or three dimensional simulation box. In addition to this, the anomalous resistivity in the transverse direction by plasma microinstabilities (lower hybrid drift instability, modified two stream instability, etc.) might be important for further dissipation and the production of energetic particles at high Mach number shocks. We have started to investigate two dimensional shock structures using particle-in-cell simulations. In this report, we would like to discuss the impact of the transverse nonuniformity on electron shock surfing acceleration. The dissipation due to the anomalous resistivity caused by, for instance, lower hybrid drift instability will also be investigated.