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Cross-scale coupling at a perpendicular collisionless shock

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A full particle simulation study is carried out on a perpendicular collisionless shock with a relatively low Alfven Mach number (MA = 5). Recent self-consistent hybrid and full particle simulations have demonstrated ion kinetics are essential for the non-stationarity of perpendicular collisionless shocks, which means that physical processes due to ion kinetics modify the shock jump condition for fluid plasmas. This is a cross-scale coupling between fluid dynamics and ion kinetics. On the other hand, it is not easy to study cross-scale coupling of electron kinetics with ion kinetics or fluid dynamics, because it is a heavy task to conduct large-scale full particle simulations of collisionless shocks. In the present study, we have performed a two-dimensional (2 D) electromagnetic full particle simulation with a "shock-rest-frame model". The simulation domain is taken to be larger than the ion inertial length in order to include full kinetics of both electrons and ions. The present simulation result has confirmed the transition of shock structures from the cyclic self-reformation to a turbulent shock front. During the transition, electrons and ions are thermalized in the direction parallel to the shock magnetic field. Ions are thermalized by low-frequency electromagnetic waves (or rippled structures) excited by strong ion temperature anisotropy at the shock foot, while electrons are thermalized by high-frequency electromagnetic waves (or whistler mode waves) excited by electron temperature anisotropy at the shock overshoot. Ion acoustic waves are also excited at the shock overshoot where the electron parallel temperature becomes higher than the ion parallel temperature. We expect that ion acoustic waves are responsible for paralleldiffusion of both electrons and ions, and that a cross-scale coupling between an ion-scale mesoscopic instability and an electron-scale microscopic instability is important for structures and dynamics of a collisionless perpendicular shock.