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The electron dynamics in relation to a rapid nonlinear saturation process of plasma instabilities in a high Mach number

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The numerical simulation of a collisionless shock wave is reported under high Mach number and high frequency ratio condition (MA = 174, electron plasma frequency/electron gyro-frequency=120) similar to shock waves generated by the strong blast wave of supernovae. We focus on the electron dynamics through the nonlinear particle-field coupling process. Nonlinear evolution of the plasma instabilities between the ions and electrons and following the ion-ion instability causes strong particle energization. At the moment of the nonlinear saturation of the instability, strong mixing occurs between the incoming and reflected ion component in the velocity phase space as well as some considerable change in the field structures, for example, from the magnetic leading packet to the magnetic solitary humps. The magnetic leading packet consists of a series of large-amplitude negative-positive magnetic fields. Since the each component of the leading packet and the magnetic humps are converging, some electrons scattered and bouncing between these two structures gain energy rapidly by the 1st-order Fermi type process. Some electrons around magnetic humps also gain energy in a rather stochastic manner. There is still non-zero bulk flow variation due to the ion gyro-motion. Depending on the gyro-phase, energetic electrons gain energy when its gyro-motion couples with the motional electric field variation of the ion-scale.

Keywords: shock wave, plasma instability, nonlinear plasma dynamics, electron dynamics, particle acceleration