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Full particle-in-cell simulation study on the solar wind interactions with small scale dipole field

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We have been investigating the solar wind interaction with small-scale dipole magnetic fields comparable to or less than the ion inertial length by performing full particle-in-cell simulations. Such micro-scale magnetosphere would be used for the next-generation interplanetary flight system called Magneto Plasma Sail (MPS) which has been proposed as one of the innovative interplanetary flight systems by JAXA. In the current paper, we focus on the analysis of current layer caused by the interaction of the solar wind at the boundary of the dipole field. The current layer is very important for the MPS thrust which can be evaluated with the Lorentz force obtained with the magnetic field component induced by the current layer and the current by a superconducting coil at the satellite. In a situation where the ion inertia length is larger than the dipole field region, electron interaction with the magnetic field becomes important. The ions, which are basically unmagnetized in such as situation, can be indirectly influenced by the presence of the dipole field due to the electrostatic force cause by the difference from the electron dynamics. We will examine the formation of a small-scale magnetosphere in such a situation as well as the features of the current layer in terms of location, location and width for modeling the current layer.

In addition, IMF effect such as the formation of shock structure and magnetic field reconnection can affect the formation of the current layer. In the preliminary two dimensional PIC simulations, magnetic reconnection takes place at the night side of the magnetosphere even in the northward IMF case. A current density peak is formed inside the magnetosphere due to the electron backflow from the reconnection region, in addition to the induced current density at the front boundary layer where the solar wind momentum is primarily diverted. Consequently, when we consider the IMF effect, we could observe expansion of the dipole field structure and the increase of the MPS thrust at the satellite. We will perform a multi-scale three dimensional PIC simulation to understand the detailed process of the solar wind interaction with a small scale dipole field and point out the difference from those obtained with two dimensional model.

Keywords: dipole magnetic fields, solar wind interactions, particle simulation, magnetoplasma sail