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Numerical Simulation of Magneto Plasma Sail by using 3D Hybrid PIC Code

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A development of a propulsion system for deep space exploration is very important, especially, reduction of the mission time and high energy efficiency must be established rapidly. And it is necessary for more effective exploration to outer planets that we develop a new propulsion system alternative to chemical propulsion system. As one of the candidates, MPS (Magneto Plasma Sail) has been suggested in 2000 by Winglee, et al. [1]. MPS produces the propulsive force by interaction between the solar wind and the artificial magnetic field inflated by the plasma injection. And it is expected to have high thrust power ratio and specific impulse compared with the chemical propulsion system [2].

In order to study the feasibility of MPS, we firstly have to investigate the mechanism of thrust generation of magsail [3] system of which is basically the same idea as the MPS without injected plasma for magnetic inflation. The magsail also produces the propulsive force by interaction between the solar wind and the artificially generated magnetic field. The numerical simulations were investigated by using a hybrid simulation code about the interaction between the solar wind and the dipole magnetic field which has the representative length ranging from 800km to 400m. And it was obtained a good agreement with the experimental results which Funaki had conducted a scale-down laboratory experiment for the thrust estimation under the same dimensionless parameters in a space chamber [4].

The other issue of MPS research is the magnetic inflation by injecting plasma from the boundary of the superconducting coil. Numerical simulations of magnetic inflation for the cases with different beta value are conducted by using hybrid simulation codes. A coil which has 1.0[m] radius is located at the center of this numerical model and the coil generates the dipole magnetic field. As an initial condition, the plasma ions are located randomly and injected from a 2.mm-thick region located at 1.0 [m] from the center of the coil. The plasma has a density of $N=10^{20}[m^{-3}]$ and a velocity of v=4.0[km/s]. The strength of magnetic field in the region where plasma is injected is 0.02[T], which corresponds to the beta value of 1. Then the inflation of magnetic field is evaluated quantitatively and the configuration of magnetic field after the plasma is injected isotropically is examined. It was found that the magnetic field could be inflated by injecting plasma (beta=1) as B is proportional to $r^{-2.2}$ in the polar direction.

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[3] R. M. Zubrin, 'The Use of Magnetic Sails to Escape from Low Earth Orbit', Journal of the British Interplanetary Society, Vol.46, 3-10, 1993

[4] I. Funaki, H. Yamakawa, H. Ogawa, H. Nishida, I. Shinohara, K. Fujita and H. Otsu, 'Feasibility Study of Magnetoplasma Sail.' 29th International Electric Propulsion Conference, 115, 2005.