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SPACE PROPULSION SYMPOSIUM (C4)
Advanced and Combined Propulsion Systems (8)

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TWO- AND THREE-DIMENSIONAL PARTICLE-IN-CELL SIMULATION OF MAGNETO PLASMA SAIL

Abstract

The magnetic sail is a spacecraft propulsion system using the interaction between the magnetic field and the solar wind. An artificial magnetosphere is formed and the solar wind flow will lose its momentum. Due to this interaction, a corresponding repulsive force would exert on the coil to accelerate the magnetic sail spacecraft in the anti-sun direction. Magnetic sail is expected to provide an efficient orbital transfer in interplanetary space since it directly converts the momentum of the solar wind into thrust by using a superconductive coil without consuming fuels. In addition, MPS (Magnetic Plasma Sail) inflates the original magnetosphere by a small amount of plasma injection from the spacecraft and MPS is expected to be able to provide a large thrust with a small coil size. In the present study, we conduct a two- and three-dimensional Full-PIC (Particle-In-Cell) simulation for a very small magnetosphere (several 100 m to several 1000 m) generated by MPS since the thrust characteristics of such a small MPS remains uninvestigated. Particularly, we analyze the MPS in terms of how the thrust is affected by the charge separation and what injection plasma parameters enhance the thrust efficiently. As a result, it is revealed that the charge separation and the electron Larmor motion affect the thrust of the magnetic sail depending on the magnetospheric size. In addition, the structure of the magnetosphere changes according to the angle between the solar wind and the magnetic moment of the onboard coil, and the thrust also changes. MPS simulations also revealed that the low-beta plasma injection enable the efficient thrust generation. Approximately, 3 times efficient thrust generation was obtained in MPS compared to the ideal electric propulsion corresponding to the plasma injection. Thrust level of MPS becomes up to 7.5 times larger than the original thrust of magnetic sail by the optimization of the plasma injection parameters. Finally, the realistic three-dimensional simulation assuming the design parameters of MPS demonstrator spacecraft obtained the mN-class MPS thrust.