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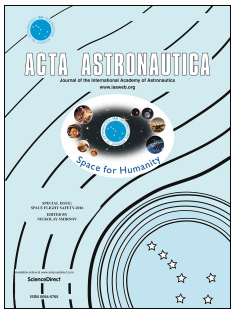

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PII: S0094-5765(17)31266-3

DOI: 10.1016/j.actaastro.2018.07.007

Reference: AA 6988

To appear in: *Acta Astronautica*

Received Date: 8 September 2017

Revised Date: 17 June 2018

Accepted Date: 3 July 2018

Please cite this article as: G. Cai, H. Zheng, L. Liu, X. Ren, B. He, Three-dimensional particle simulation of ion thruster plume impingement, *Acta Astronautica* (2018), doi: 10.1016/j.actaastro.2018.07.007.

Three-dimensional particle simulation of ion thruster plume impingement

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Abstract

The interaction between the high-energy particles in the plume and the spacecraft surfaces will produce interference torque that affects the operating state of the spacecraft in orbit. The thrust of an electric propulsion system is quite small, so it is difficult to be measured directly. The Vacuum Plume Laboratory (VPL) measured the LIPS-200 type ion thruster plume force in an order of 10^{-3} N using a fully elastic micro thrust measuring device. In this paper, the particle in cell (PIC) method and the direct simulation Monte Carlo (DSMC) method are employed to analyze the three-dimensional plasma environments under specified experimental conditions. The Maxwell model is used to calculate the plume force on a 300 mm diameter plate. Simulation results of the plume force give good agreements with the experimental data. Moreover, the effects of the 300 mm diameter aluminium plate on the flow field in vacuum conditions are analyzed. The results show that the number density of atoms is greatly increased before the plate, which has a further impact on the distribution of charge exchange ions (CEX). The enhanced CEX ions moving towards the solar battery panels or sensitive optical components may cause possible damage or interference, which should be avoided by the designers.

Key words: electric propulsion; PIC-DSMC method; plume impingement; plume force

1. Introduction

Electric propulsion thruster is a device converting electrical energy into the kinetic energy of the propellant [1, 2]. It has the advantages of higher specific impulse, longer lifetime and higher control precision. The application of electric propulsion technology in north-south station keeping, resistance compensation, orbital maneuver, deep space exploration and other space tasks can significantly reduce the fuel weight and improve satellite life [3, 4]. At present, ion thruster and Hall thruster have been applied in deep space exploration. They ionize the inert gas, then accelerate the charged particles by the electric field and magnetic field to obtain thrust.

The main composition of the electric propulsion plume is the plasma produced by the ionization of propellant. The speed of particles is very high, which normally reaches tens of