任军学,顾左,郭宁,仇钎,汤海滨.离子发动机羽流特性的数值模拟[J].航空动力学报,2013,28(6):1372~1379

离子发动机羽流特性的数值模拟

Numerical simulation of characteristics of ion thruster plume

投稿时间： 2012-06-14

DOI：

中文关键词： 离子发动机 羽流 单元内粒子 交换电荷离子 数值模拟

英文关键词:ion thruster plume particle in cell charge-exchange(CEX) ion numerical simulation

基金项目:国家自然科学基金(10805004)

作者	单位
任军学	北京航空航天大学宇航学院，北京 100191
顾左	兰州物理研究所真空低温技术与物理重点实验室，兰州 730000
郭宁	兰州物理研究所真空低温技术与物理重点实验室，兰州 730000
仇钎	北京航空航天大学宇航学院，北京 100191
汤海滨	北京航空航天大学宇航学院，北京 100191

中文摘要：

离子发动机羽流中产生的交换电荷(CEX)离子返流会影响航天器的正常工作.建立离子发动机羽流模型,采用单元内粒子方法(PIC)对羽流场进行数值模拟计算.结合DS-1探测器飞行实验的测量结果,分析了卫星电势、电子温度、卫星几何尺寸、推力器工作特性等对相关因素对CEX离子返流特性的影响.结果表明:从推力器出口附近到卫星背面,CEX离子密度为10^{8}~$10^{12}m^{-3}$.当卫星电势从-15V变化到27V,测量点位置处CEX离子密度从$0.65\times10^{12}m^{-3}$变化到$1.5\times10^{12}m^{-3}$.羽流中CEX离子密度和电势结构随电子温度变化不大,但电势大小随电子温度成比例地变化.同一位置处不同工况下CEX离子的密度可根据CEX离子生成率与工作点参数间的关系式准确地估计.卫星安装推力器的表面起着对CEX离子返流屏蔽和降低的作用.

英文摘要：

The back flow of charge-exchange (CEX) ions in the ion thruster plume affects normal operation of the satellite.The ion thruster plume model was established and a numerical simulation using particle-in-cell (PIC) method was adopted to obtain CEX ions distribution in the plume.The simulation results agree well with the flight measurement results of deep space one spacecraft.Influential factors to the distribution characteristic of CEX ions surrounding the spacecraft were analyzed,including:spacecraft potential,electron temperature,thruster operation parameter and size of spacecraft.It shows that CEX ion density surrounding the spacecraft varies from $10^{8}m^{-3}$ to $10^{12}m^{-3}$.The CEX ion density in the measurement point varies from $0.65\times10^{12}m^{-3}$ to $1.5\times10^{12}m^{-3}$ when the spacecraft potential varies from -15V to 27V.The distribution of CEX ion density and electrical potential structure varies slightly with the electronic temperature.However,the magnitude of the electrical potential is proportional to the electronic temperature.The CEX ion density at different thruster operation points can be induced accurately according to the relationship between the CEX ion generation rate and the thruster's operation parameter.The surface of the spacecraft onto which the thruster is installed in fact shields the backflow of CEX ions.