氙气与多种示漏气体漏率转换关系研究*

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摘　要: 电推进技术是我国航天卫星未来重要的推进系统技术, 具有比常规化学推进比冲高、推力小、推进剂利用率高等优点, 其中离子推进器主要使用氙气作为推进剂。常规的推进系统密封性测试采用氦气作为示漏气体, 检漏结果与实际工质氙气的真实漏率存在换算关系, 为了能够准确评估电推进系统的实际泄漏状态和漏率数值, 亟需开展相关研究。本文通过搭建多种示漏气体测试系统, 验证了氙气原位检漏技术的可行性, 并由理论分析和实验研究初步获得氙气与氦气、氪气之间的漏率转换关系, 以及转换系数理论上下限数值, 为后续电推进的检漏工作提供参考依据。

关 键 词: 电推进系统; 检漏; 氙气; 转换关系; 漏率

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Research of the Leak Rate Conversion for Xenon and Tracer Gas

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Abstract: The electric propulsion technology is an important propulsion system technology for Chinese satellites in the future. It has the advantages of higher specific impulse, lower thrust and higher propellant utilization compared to the conventional chemical propulsion. The ion thrusters mainly use xenon as propellant. Helium is used as the leakage gas in the conventional sealing test of the propulsion system. There is a conversion relationship between the leakage detection result and the actual leakage rate of the xenon. In order to accurately evaluate the actual leakage state and leakage rate of the electric propulsion system, it is urgent to carry out relevant research. In this paper, the feasibility of xenon in-situ leak detection technology is verified by building a several tracer gases testing system. Through theoretical analysis and experimental research, the leak rate conversion relationship between xenon, helium and krypton, as well as the theoretical upper and lower limits of the conversion coefficient, are preliminarily obtained. It will provide a reference for the leak detection of the electric propulsion system.

Key words: electric propulsion system; leak test; xenon; conversion relationship; leak rate

常规的卫星推进系统采用化学燃料推进, 与之对应的电推进技术[1-2]也有 70 多年的历史, 后者在欧美等航天大国空间任务中应用普遍[3-6], 是一种先进高效的推进系统技术。电推进技术利用供配电系统提供的电能电离推进剂, 产生比化学推进高很多的推进速度, 有效减少推进剂的需求量, 具有比冲高、推力小、推进剂利用率高等特点, 可显著提高航天器的有效载荷, 降低卫星推进系统质量, 提高卫星寿命, 是未来卫星的重要配置。

电推进系统离子推进器主要使用氙气作为推进剂[2, 7-8], 而目前检漏使用的工质普遍为氦气[9-13], 氙气与氦气之间的漏率关系亟需研究, 否则无法准确评估氙气的实际泄漏状态和漏率数值。氙气工质的总漏率测试技术亦能够有效避免电推进系统的重复充卸过程, 提高电推进系统的检漏准确度。本文通过开展氙气检漏技术和氙气与检漏工质间漏率转换关系的研究, 从理论分析

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