喷嘴角度对水银扩散泵抽气性能影响的 DSMC 模拟研究 *

赵长莲[1],毛世峰[1*],刘 鹏[2],覃世军[2],余 羿[1],叶民友[1]

(1. 中国科学技术大学工程与应用物理系,安徽 合肥 230027
2. 中国科学院等离子体物理研究所,安徽 合肥 230031)

摘 要:扩散泵由于其大抽速、连续稳态工作的优点,有望应用于未来聚变堆的偏滤器抽气系统中,以降低目前托卡马克装置中广泛采用的捕集式低温泵所带来的高氚存储量问题。由于氚相容性的限制,目前的商业油扩散泵无法直接应用于聚变堆中,水银将是理想的扩散泵工作介质。为了支持未来聚变堆偏滤器抽气系统的水银扩散泵设计,需要针对水银扩散泵开展设计优化研究。本文采用直接模拟蒙特卡洛方法,基于 KT-150 扩散泵结构,研究了喷嘴角度对水银扩散泵的抽气速度及水银返流率的影响。结果表明喷嘴角度为 45°时能够达到最佳的抽气速度 1.53m³/s,同时返流率没有显著提升。

关 键 词:偏滤器抽气;直接模拟蒙特卡洛方法;水银扩散泵;抽速;返流率

中图分类号:TB752⁺.3 **文献标识码**:A **文章编号**:1002-0322(2020)02-0008-05

doi:10.13385/j.cnki.vacuum.2020.02.02

DSMC Simulation Study of Influence of Nozzle Angle on Pumping Performance of Mercury Diffusion Pump

ZHAO Chang-lian[1], MAO Shi-feng[1*], LIU Peng[2], QIN Shi-jun[2], YU Yi[1], YE Min-you[1]

(1. Department of Engineering and Applied Physics, University of Science and Technology of China, Hefei 230027, China; 2.Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China)

Abstract: Due to the high pumping speed and continuous steady state operation, the diffusion pump is expected to be applied in the divertor pumping system in future fusion reactor to reduce the high tritium inventory in the cryogenic pump, which are widely used in present tokamaks. Because the requirement of compatibility with tritium, the commercial oil diffusion pump can not be directly applied in the fusion reactor. Instead, the mercury will be the ideal working fluid. For the purpose to support the mercury diffusion pump design in the divertor pumping system of future fusion reactor, the optimization study of the mercury diffusion pump design is necessary. In this work, using the direct simulation Monte Carlo (DSMC) method, influence of the nozzle angle on the pumping speed and mercury backstreaming rate are simulated based on a KT-150 diffusion pump structure. The simulation results show that the largest pumping speed of ~1.53m³/s is achieved when nozzle angle equals 45 degrees, while the backstreaming rate is not obviously increased.

Key words: divertor pumping; direct simulation Monte Carlo (DSMC); mercury diffusion pump; pumping speed; backstreaming rate

偏滤器抽气系统是未来聚变堆燃料循环的关键环节之一。聚变堆中未完全燃烧的氘氚燃料以及聚变反应产生的氦灰从芯部等离子体排出后,在偏滤器区域中性化后通过偏滤器抽气系统抽出并输送至氚工厂中进一步处理。在现有的托卡马克装置中,一般采用捕集式低温泵作为偏滤器抽气的主泵[1-5]。虽然低温泵的抽速能够满足现有装置的要求,然而其捕集式的运行模式,会在未来聚变堆的偏滤器抽气系统中导致较高的氚存储量[6]。德国卡尔斯鲁厄理工学院(KIT)的研究人员[7-8]所提出的燃料循环系统中,为了降低偏滤器抽气系统中的氚存储量,建议采用具有高抽速、稳态连续运行等优点的扩散泵取代现有的低温泵。鉴于目前商业油扩散泵中的工作介质会与

收稿日期:2019-03-05

作者简介:赵长莲(1990-),男,山东省潍坊市人,硕士。 **通讯作者**:毛世峰,副教授。

* **基金项目**:国家重点研发计划(2017YFE0301501);合肥物质科学技术中心创新项目培育基金(2016FXCX009)。