

带有防咬死铜镀层的标准螺纹紧固件放气率测试*

卯 鑫^{1,2}, 冯思庆^{1,2,3}, 刘 鹏¹, 彭学兵¹, 吴 欢¹

(1. 中国科学院合肥物质科学研究院等离子体物理研究所, 安徽 合肥 230031;
2. 中国科学技术大学, 安徽 合肥 230026; 3. 合肥科烨电物理设备制造有限公司, 安徽 合肥 230088)

摘 要: 铜镀层是防止聚变堆运行时真空室内标准螺纹紧固件咬死的主要手段之一。针对带有铜镀层标准螺纹紧固件在高真空下的放气现象, 本文简要介绍了铜镀层工艺及麻点缺陷的解决方法, 采用小孔流导法测试了其放气率, 分析了铜镀层及环境温度等对放气率的影响。结果表明: 脱附气体由氢、水、氮气和 CO₂ 组成; 含氢放气率未达到要求, 这与铜镀层工艺、放气率测试环境及测试时间等因素有关, 需对试验影响因素加以控制, 以达到聚变堆真空室内材料的放气率要求。

关 键 词: 标准螺纹紧固件; 咬死; 电镀铜; 放气率

中图分类号: TB74

文献标识码: A

文章编号: 1002-0322(2024)04-0080-05

doi: 10.13385/j.cnki.vacuum.2024.04.15

Test of Outgassing Rates of Threaded Fasteners with Copper Anti-seize Coating

MAO Xin^{1,2}, FENG Si-qing^{1,2,3}, LIU Peng¹, PENG Xue-bing¹, WU Huan¹

(1. Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences, Hefei 230031, China; 2. University of Science and Technology of China, Hefei 230026, China;
3. Hefei Key Electrical Physical Equipment Manufacturing Co., Ltd., Hefei 230088, China)

Abstract: Copper coating is one of the main means to solve the anti-seize problem of threaded fasteners in vacuum vessel during the running of fusion reactor. This work briefly introduces the coating copper procedure and the solution to pitting-attacks on the copper coating. Meanwhile, to satisfy the high vacuum requirement, the orifice conductance method was used to test the outgassing rates of threaded fasteners with copper coating. The impact of copper coating, environmental temperature, and other factors on the material outgassing rate was analyzed in detail. The results show that the desorption gas is composed of hydrogen, water, nitrogen, CO₂, and the contained hydrogen rate does not meet the relevant requirements. This is bound up with coating copper process, test environment, test time and so on. It is necessary to control the test influential factors to achieve the anticipated outgassing rate requirements of material in vacuum vessel of fusion reactor.

Key words: standard threaded fastener; seizing; copper coating; outgassing rate

高真空环境是保证聚变堆稳态长脉冲运行的关键因素之一。因此, 聚变堆真空室内部部件均需满足一定放气率要求。托卡马克聚变装置的内部部件主要包括包层和偏滤器。包层和偏滤器由于包络高温等离子体需承受高能粒子的轰击, 所以有损坏的风险, 这就要求包层和偏滤器具备可更换性。标准螺纹紧固件易于购买、安装和拆卸, 是包层和偏滤器维护的首选连接件, 其同样存在于聚变堆真空室内部, 需承受电磁、

热等循环交变应力。为防止交变应力可能产生的振动, 通常对标准螺纹紧固件施加很大的预紧力。同时, 聚变装置内部部件要求具备整体性和无磁性等, 故内部部件和标准螺纹紧固件均采用无磁 316 L 不锈钢。但复杂的运行环境、大的预紧力和相同的材料, 使得标准螺纹紧固件易产生咬死现象。

标准螺纹紧固件咬死表现为装置运行后紧固件和真空室内部件的粘接, 使内部部件难以拆

收稿日期: 2023-11-10

作者简介: 卯鑫 (1984-), 男, 安徽阜阳人, 博士生, 工程师。 通讯作者: 冯思庆, 工程师。

* 基金项目: 中国科学院青年创新促进会项目偏滤器强化传热技术研究 (Y15YZ51293)