低温绝热气瓶真空寿命模拟试验研究 *

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摘 要:提出了对绝热气瓶真空夹层逐次充入模拟气体进行绝热气瓶漏气和材料放气的真空寿命模拟试验评价方法。试验实例表明:低温绝热气瓶静态蒸发率在低温下夹层压力 >5×10^{-2}Pa 后迅速上升,即 5×10^{-2}Pa 可视为夹层真空寿命终结的拐点(或阈值)。5A 分子筛在液氮温度下对氮具有巨大的吸附潜力,对氢表现出弱的吸附能力。真空绝热夹层的材料放气对真空寿命的影响远远大于漏气的影响,提高绝热气瓶真空寿命的技术途径是减小夹层材料的放气率和改善内置吸附剂对氢的吸附能力。模拟试验能直观、实际、准确地研究漏气和放气对真空寿命诸因素的影响,为确定切合实际的设计参数和工艺提供参考数据,进而推广用于各类真空绝热型低温容器的真空寿命评价和应用。

关 键 词:低温绝热气瓶;漏气率;放气率;真空寿命;吸附等温线

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Simulated Experimental Study on Vacuum Life of Cryogenic Insulated Cylinders

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Abstract: The method of filling simulated gases into the vacuum interlayer of insulated cylinder is successively put forward to evaluate the vacuum life of insulated cylinder for leakage and material outgassing. The test result shows that the static evaporation rate of cryogenic insulated cylinder rises rapidly after the interlayer pressure is greater than 5×10^{-2}Pa at low temperature, that is to say, 5×10^{-2}Pa can be regarded as the inflection point (or threshold) of the interlayer vacuum life termination. 5A molecular sieve has great adsorption potential for nitrogen at liquid nitrogen temperature, however, with weak adsorption capacity for hydrogen. The effect of material outgassing on vacuum life of vacuum insulating sandwich is far greater than that of leakage. The technical way to improve vacuum life of insulating cylinder is to reduce the outgassing rate of sandwich material and improve the adsorption capacity of built-in adsorbent for hydrogen. This test can directly, practically and accurately study the influence of leakage and outgassing on vacuum life, provides reference data for determining practical design parameters and process, and then promotes the application and evaluation of vacuum life of various vacuum insulated cryogenic vessels.

Key words: cryogenic insulated cylinders; leakage rate; outgassing rate; vacuum life; adsorption isotherm.

氢能的开发和利用技术已经成为新一轮世界能源变革的重要方向,也是汽车产业未来发展的战略制高点,发展氢能对新时代能源转型具有重大意义。“十三五”国家战略性新型产业发展规划提出推动车载储氢系统以及制氢、储运和加注技术发展, 实现燃料电池汽车规模化生产及应用[1]。在车载储氢应用中,氢以高压气体、低温液体、金属氢化物形式储运。其中高压气体储氢是传统的储氢方式,存在储存质量密度低、安全性差的缺点; 金属氢化物储运尚在试验研究阶段,低温液体储氢是目前最理想的储氢方式,具有储存质量密度大、安全性高的优点,其低温绝热技术是液体储氢要解决的关键技术[2]。高真空多层绝热是车载储氢容器关键技术之一,尤其是近年

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