管道断面外形对亚音速真空管道磁浮系统气动特性的影响 *

宋嘉源, 李 田, 张继业, 张卫华

(西南交通大学牵引动力国家重点实验室, 四川 成都 610031)

摘 要: 亚音速真空管道磁浮系统内部流场复杂,研究管道断面外形对气动效应的影响至关重要。基于计算流体力学,考虑流体粘性与列车悬浮间隙建立了三维亚音速真空管道列车空气动力学模型,数值模拟并对比分析了四种不同断面外形管道内的气动力、流场和气动热效应。4 种典型的管道外形为圆形、马蹄形、矩形和拱形。研究结果表明:当阻塞比一定时,列车在拱形管道中受到的气动阻力最小,其次为圆形管道,矩形管道内的列车气动阻力最大;圆形管道内垂直方向的压力梯度最小,管道表面压力最低;亚音速真空管道磁浮系统中最高温度分布在列车鼓包两侧,最低温度分布在管道表面;不同断面外形对温度分布的影响较小。在管道断面面积一定的情况下,优先推荐选用拱形管道,其次为圆形管道。

关 键 词: 真空管道列车;管道断面外形;气动力;压力;气动热

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Effect of Tube Cross-Section Shape on Aerodynamic Characteristics of Subsonic Evacuated Tube Maglev System

SONG Jia-yuan, LI Tian, ZHANG Ji-ye, ZHANG Wei-hua

(State Key Laboratory of Traction Power, Southwest Jiaotong University, Chengdu 610031, China)

Abstract: The internal flow field of a subsonic evacuated tube train is complex, and it is important to study the effect of the tube cross-section shape on the aerodynamic properties. Based on computational fluid dynamics (CFD), considering the fluid viscosity and train suspension gap, a three-dimensional aerodynamic model of subsonic evacuated tube train is established. The aerodynamic drag, flow field characteristics and aerodynamic heating effect in 4 different cross-sectional tube are numerical simulated and compared. The results show that when the blockage ratio is constant, the aerodynamic drag of the train in an arched tube is the smallest, and then the circular tube, the largest in the rectangular tube. The pressure gradient in the vertical direction of the circular tube is the smallest, and the pressure on the upper surface of the tube is also the smallest. In the subsonic evacuated tube maglev system, the maximum temperature is shown on both sides of the train bump, and the minimum temperature is on the tube surface. Tube cross-section shape has few effects on the temperature distribution. When the area of the tube cross-section is chosen, the arched tube is prior recommended, and next choice is the circular tube.

Key words: evacuated tube train; tube cross-section shape; aerodynamic forces; pressure; aerodynamic heating

真空管道磁浮系统采用低真空环境与悬浮制式手段降低运行阻力,是一种高效快捷的交通运输方式。随着速度不断提升,管道列车周围流场更加复杂,运行时受到的阻力以及气动热变化明显。作为未来交通发展的趋势,国内外不少学者对真空管道磁浮系统的气动特性开展了研究。

沈志云[1]提出发展 600km/h 真空管道列车的设想,并分析了真空管道磁浮系统的可行性与必要性。张耀平[2]、谢元华等[3]介绍了真空管道的基本构成并分析了行业未来发展的机遇。MUSK[5]提出 Hyperloop Alpha 管道列车的概念,并指出气动特性是系统设计中的关键问题。KIM 等[6]、CHOI

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作者简介: 宋嘉源(1999-),男,四川省乐山市人,硕士生。 **通讯作者:** 李田,副研究员,硕士生导师。

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