航空学报
ACTA AERONAUTICA ET ASTRONAUTICA SINICA
ISSN 1000-6893
CN 11-1929/V

航空学报 » 2013, Vol. 34 » Issue (12) :2682-2691 DOI: 10.7527/S1000-6893.2013.0181

轴流压气机转子叶尖泄漏堵塞特性的试验研究

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Experimental Investigation on Characteristics of Tip Leakage Blockage in an Axial Compressor

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摘要

在低速大尺寸压气机试验台上，利用体视粒子图像测速（SPIV）技术详细测量了不同气动负荷水平的叶片、不同转子叶尖间隙大小和不同工作状态时转子通道内部的流场结构。定量分析了不同测量条件下转子通道内堵塞分布特点，讨论了影响堵塞发展的物理机制，旨在为转子尖部流动控制和模化研究提供必要的理论帮助。结果表明：在本文的各种测量条件下，叶尖泄漏堵塞均呈现非线性、非单调性的特征，通常在叶片通道内出现堵塞峰值；叶片通道内的逆压梯度是堵塞增长的重要物理机制，在逆压梯度环境下，堵塞起始区域的流量越大，堵塞增长得越迅速，堵塞起始区域流体的总压损失越高，堵塞越容易引起失速；泄漏流与主流之间存在较强的湍流掺混，在这个物理过程中，黏性和湍流脉动所带来的主流与泄漏流之间的动能输运是使得堵塞衰减的主要物理机制。

关键词： 叶尖泄漏涡 端壁堵塞 逆压梯度 湍流掺混 体视粒子图像测速 压气机

Abstract:

Rotor passage flow fields are measured by stereoscopic particle image velocimetry (SPIV) in a large-scale low speed axial compressor test facility. The measurements are conducted in conditions of stages with different aerodynamic loading levels, different rotor tip gap sizes and different operating conditions. The variations of blockage inside the rotor passage are analyzed by a quantitative method. The results show that: in the test conditions the distribution of blockage by the tip leakage vortex has the characteristics of non-linearity and non-monotonicity, which means the peak blockage occurs inside the rotor passage; the adverse pressure gradient is the most important physical mechanism for the growing of the blockage; in an environment of adverse pressure gradient the higher the initial mass flow rate in the blockage region,the faster is the growth of blockage, and the higher the initial total pressure deficit, the easier it is to cause stall; intensive turbulent mixing occurs between the tip leakage flow and the mainstream, and the transport of kinetic energy between the mainstream and tip leakage flow by the viscosity and turbulent fluctuation in the turbulent mixing is the main mechanism for blockage decay.

Keywords: tip leakage vortex endwall blockage adverse pressure gradient turbulent mixing stereoscopic particle image velocimetry compressor

Received 2013-01-30;

Fund:

国家自然科学基金（51136003，51006007，50976009）

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引用本文:

刘宝杰, 张志博, 于贤君. 轴流压气机转子叶尖泄漏堵塞特性的试验研究[J]. 航空学报, 2013, 34(12): 2682-2691.DOI: 10.7527/S1000-6893.2013.0181

LIU Baojie, ZHANG Zhibo, YU Xianjun. Experimental Investigation on Characteristics of Tip Leakage Blockage in an Axial Compressor[J]. Acta Aeronautica et Astronautica Sinica, 2013, 34(12): 2682-2691.DOI: 10.7527/S1000-6893.2013.0181