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叶顶凹槽形态对动叶气动性能的影响

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Effect of Squealer Tip Geometry on Rotor Blade Aerodynamic Performance

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摘要

应用数值方法联合标准k-ω两方程湍流模型求解雷诺平均Navier-Stokes方程组,研究了GE-E^{3}发动机第1级动叶片顶部凹槽、凹槽内布置流向肋条以及凹槽内布置横向肋条3种不同的涡轮叶顶结构对动叶顶部泄漏流动以及动叶气动性能的影响。首先详细分析了不同叶顶结构间隙内泄漏流场以及损失分布,接着研究了不同间隙下不同叶顶结构对动叶总体性能的影响,最后对凹槽内布置横向肋条叶顶结构的变工况特性也进行了分析。数值研究结果表明:叶顶凹槽内布置肋条增加了间隙泄漏流动阻力,减小了间隙泄漏流量,其中,凹槽内布置正对着泄漏流方向的横向肋条显著降低了叶顶间隙泄漏流量,从而获得最好的气动性能,尤其在大间隙时更为明显;凹槽内布置横向肋条也具有较好的变工况性能;适当的叶顶结构可以在不影响转子叶片做功能力的前提下使得泄漏流利用凹槽和肋条的侧壁向叶片额外输出有用功。

关键词: 涡轮 凹槽 间隙高度 叶顶泄漏流 肋条 攻角

Abstract:

Numerical investigation is performed to simulate the effects of three different tip configurations (cavity tip, cavity tip with streamwise rib, and cavity tip with crosswise rib) on tip leakage flow and aerodynamic performance for the first stage rotor blade in GE-E^3 engines, by solving Reynolds-averaged Navier-Stokes equations in conjunction with the standard k-ω two-equation turbulence model. The leakage flow field and loss distribution for the different tip configurations are analyzed; so are the effects of the different tip configurations on rotor overall performance for different tip clearance heights. Also, the off-design characteristics of the cavity tip with crosswise rib are analyzed in detail. Numerical results show that cavity tip with ribs increases the resistance to tip leakage flow, which can reduce the leakage flow rates. Cavity tips with crosswise ribs normal to the local leakage flow direction provide the best off-design performance and exhibit significantly the lowest tip leakage and the best aerodynamic performance, especially for larger tip clearance heights. In addition, the tip leakage flow could do extra work to blades through the sidewall surfaces of the cavity and ribs on condition that it shall not affect the main blade work.

Keywords: turbines squealer tip tip clearance height tip leakage flow rib angle of attack

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