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基于升力面自由尾迹的直升机旋翼悬停性能参数影响研究

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Analysis of Influence of Rotor Parameters on Rotor Hover Performance by Lifting-Surface and Free Wake Method

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摘要 最大悬停效率(FM_{max})作为衡量旋翼悬停性能的常用指标,反映了旋翼能达到的最大悬停效率,但不能反映旋翼在一定桨叶载荷范围内保持高悬停效率的能力,本文给出了旋翼悬停保持能力的定义.为更准确地反映桨叶涡量分布,建立了基于升力面理论的桨叶气动模型;考虑有弯度翼型的影响,将涡量布置于翼型中弧线,随后基于自由尾迹模型、耦合刚性桨叶挥舞运动方程、翼型动态失速模型以及二阶精度时间同步进格式建立了升力面自由尾迹方法.通过计算模型旋翼在不同桨尖马赫数下的悬停效率,并与试验数据对比,验证了方法的准确性.相比于升力线自由尾迹方法,建立的升力面自由尾迹分析方法能显著提高旋翼悬停效率计算精度.最后分析旋翼关键设计参数对悬停性能的影响,得到设计参数影响旋翼悬停保持能力的新规律.

关键词: 自由尾迹 升力面 旋翼 悬停性能 悬停保持能力

Abstract: The maximum figure of Merit (FM_{max}) is the most important index for a rotor which indicates the greatest hover efficiency the rotor can achieve. However, it cannot reflect the rotor's ability to keep a high Figure of Merit (FM) in certain blade load ranges. Therefore a new concept, the hover hold ability (HHA) of roltor is defined in this paper. In order to describe the distribution of vortices on a blade more accurately, the lifting-surface is used in the blade aerodynamic model. To take into consideration different airfoils, vortices of a blade are set on the middle line of an airfoil. Based on the free-wake model, a calculation method of rotor performance is established which includes the lifting-surface model, rigid blade flap equation, airfoil dynamics stall model and second-order time accurate algorithm. The model rotor FM with different tip Mach numbers (Ma_{tip}) is calculated and compared with test results to validate the precision of the method. Compared with the free-wake model which includes a lifting-line model, more accurate FM of rotor is attained. Finally, the influence of critical rotor design parameters on rotor hover performance is analyzed, and new laws for the effect of design parameters on rotor hover hold ability are obtained.

Keywords: free wake lifting-surface rotors hover performance hover hold ability

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