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剪刀式尾桨悬停状态气动力及噪声特性计算研究

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Computational Research on Areodynamic and Aeroacoustic Characteristics of Scissors Tail-rotor in Hover

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摘要

建立了一个基于计算流体力学(CFD)/FW-H(Ffowcs Williams-Hawkings)方程的预测剪刀式尾桨悬停状态气动性能和噪声特性的分析方法。该方法首先采用CFD方法对尾桨流场进行求解,并应用嵌套网格技术对流场空间进行离散。控制方程采用非惯性坐标系下的Navier-Stokes方程,空间方向采用二阶迎风格式(Roe格式)进行求解,时间方向采用隐式LU-SGS(Lower-Upper Symmetric Gauss-Seidel)格式进行推进。在此基础上,采用FW-H方程将尾桨噪声声压扰动传播至远场,以获得尾桨的噪声特性。应用该方法对两种剪刀式尾桨构型("L"构型和"U"构型)进行了计算研究,对比分析了剪刀式尾桨在气动力和噪声方面与常规尾桨的差别,以及两个重要构型参数(剪刀角和轴向间距)对剪刀式尾桨气动力和噪声的影响规律。计算结果表明,构型参数对剪刀式尾桨气动力和噪声特性影响很大,合理地选择构型参数可以降低尾桨噪声水平。

关键词： 剪刀式尾桨 气动特性 噪声特性 FW-H方程 计算流体力学

Abstract:

A comprehensive analysis method is established to predict the aerodynamic force and aeroacoustic characteristics of a scissors tail-rotor in hover based on computational fluid dynamics (CFD)/FW-H (Ffowcs Williams-Hawkings). In the present method, the CFD method is first employed to simulate the flowfield around the tail-rotor by solving the Reynolds-averaged Navier-Stokes equations which are formulated at the blade-attached reference frame, and a second-order upwind scheme (Roe scheme) and an implicit LU-SGS (Lower-Upper Symmetric Gauss-Seidel) scheme are used for space and time discretization respectively. Secondly, based on the flowfield solved by the present CFD method, the FW-H equation is used to transfer acoustic disturbance to the far field. Finally, comprehensive calculations on two different configurations of scissors tail-rotor, i.e., L configuration and U configuration, are performed based on the method developed. The differences are studied between a scissors tail-rotor and a conventional tail-rotor in terms of aerodynamic force and aeroacoustic characteristics. Meanwhile, the influence is analyzed of the two important parameters of scissors angle and vertical space on the aerodynamic force and acoustic characteristics. It is demonstrated that the configuration parameters have significant effects on the aerodynamic force and aeroacoustic characteristics of the tail-rotor, and reasonable configuration parameters can decrease its acoustic level.

Keywords: scissors tail-rotor aerodynamic performance aeroacoustic characteristic FW-H equation computational fluid dynamics

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