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流体力学与飞行力学

基于系统辨识技术的叶轮机非定常气动力建模方法

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An Unsteady Aerodynamic Modeling for Turbomachinery Based on System Identification

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摘要 为了快速获得不同刚度的叶轮机叶片颤振特性,提出了一种基于系统辨识技术的叶片排非定常气动力建模方法,分析了叶片气动阻尼随叶间相角差和固有频率的变化特性.该方法通过对多叶片通道的某一叶片单独施加一个扫频振动信号,求解一次非定常流场,得到叶片排上每个叶片的气动力响应,通过系统辨识,获得每个叶片的气动力频率响应.根据小扰动流的叠加原理,得到扫频范围内各固有频率下的叶片排所有叶片共同激励的气动力模型,由此进一步得到各个不同固有频率的所有叶间相角差下的气动阻尼.针对STCF4(Standard Test Configuration 4)算例,该方法的计算结果与直接采用计算流体力学(CFD)方法和直接采用谐振信号的降阶方法(ROM)得到的气动阻尼系数吻合得很好.该方法只需进行一次非定常CFD计算就能得到扫频范围内不同固有频率下的气动阻尼特性曲线,极大地提高了计算效率,方便了叶轮机设计初期的气动弹性稳定性参数分析.

关键词： 颤振 计算流体力学 降阶模型 系统辨识 叶轮机 气动弹性

Abstract: This paper presents an efficient and fidelity-oriented unsteady aerodynamic modeling method that can investigate flutter for turbomachinery. A certain blade of multiple blade passages is specified vibrating at a swept-frequency signal instead of harmonic one, and forced aerodynamic responses of the blade row can first be calculated. Identify form the aerodynamic responses data, so that the frequency responses of the system for muti-passages are acquired, and the aerodynamic coefficient of every blade for different natural frequencies within swept-frequencies can be obtained immediately. Following the superposition principle of small disturbance flow, aerodynamic damping coefficients changing with inter blade phase angles as well as frequencies are acquired only by an unsteady computational fluid dynamics(CFD)computation. The aeroelastic characteristics of STCF4 (Standard Test Configuration 4) are analyzed by using this method. The results for different na- tural frequencies are agreed well with that of reduced order model(ROM)method as well as direct CFD method, and the computational efficiency is improved obviously, as a result, this method is useful to analyze stability during preliminary design of turbomachinery.

Keywords: flutter computational fluid dynamics reduced order model system identification turbomachinery aeroelasticity

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