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对转压气机最先失速级的小扰动理论分析

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Prediction of Onset of Rotating Stall Using Small Perturbation Theory for Contra-rotating Compressors

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摘要

对转压气机(CRC)由于其独特的气动和结构优势而被认为是进一步提高航空发动机推重比的重要技术途径之一。在小扰动理论的基础上发展了对转压气机旋转失速的小扰动分析方法,并以实验室对转压气机为研究对象,采用小扰动理论和计算流体力学(CFD)数值模拟两种方法对不同转速匹配工况下的最先失速级位置进行了相应的研究,为对转压气机失速边界的预估探索一种快速有效的方法。研究结果表明:①旋转失速的小扰动分析方法可以较好地预估对转压气机失速边界和最先失速级位置;②小扰动分析方法和CFD计算结果均显示:转速匹配方案对对转压气机最先失速级位置存在明显的影响。当转速比大于或等于0.9时,转子2为最先失速级;当转速比小于0.9时,转子1为最先失速级;③由于小扰动分析方法进行了大量的简化,因而使得预估值同实际值之间存在相应的误差。同时,由于对转压气机级间存在较强的非定常性,进而使得相对误差进一步增大。

关键词： 对转 压气机 小扰动 旋转失速 数值模拟

Abstract:

With its structural and aerodynamic advantages, the contra-rotating compressor (CRC) is considered an important approach to further improve the thrust-weight ratio of an aircraft engine. The configuration studied in this paper is a dual-stage contra-rotating compressor in laboratory, and the onset of rotating stall of the contra-rotating compressor in different rotating speed match schemes is studied with small perturbation theory and computational fluid dynamics (CFD) numerical method. The purpose of this study is to explore a fast and efficient method for prediction of the onset of rotating stall for contra-rotating compressor. Results show: (a) the small perturbation theory is a reliable and effective method for the prediction of the onset of rotating stall. At the condition of rotating speed ratio is less than or equal to 0.9, Rotor 2 is the first stall stage. Otherwise, Rotor 1 is the first stall stage; (b) the rotating speed match scheme has a significant impact on the location of the first rotating stall stage; (c) the errors of the small perturbation method arise mainly from the simplification of the flow models, and the strong disturbance between the two rotors of the contra-rotating compressor enlarges the errors.

Keywords: contra-rotating compressor small perturbation rotating stall numerical simulation

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