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某单级跨声速轴流压气机失稳过程试验

Experiment on the instability process in a one-stage transonic axial compressor

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中文摘要:

为了深入认识高负荷单级跨声速轴流压气机的失稳过程,揭示其不稳定流动现象的发生、发展及其诱导压气机失稳的物理本质,针对某单级跨声速轴流压气机开展试验研究,对整个失稳过程进行了稳态和动态试验测量.通过对原始信号进行低通滤波和FFT(fast Fourier transform)分析,结果表明:在失稳过程中,静子叶根区域首先出现大幅值、轴对称的轴向低频扰动,此时,该压气机50%叶高以下的加功能力有所下降,但整机并未完全失稳.由于该扰动具有频率低、轴对称、幅值大等典型特征,因此,将这一现象定义为局部喘振.随着流量进一步降低,该扰动会沿轴向和径向传播,最终发展到全叶高,此后,该扰动在转子叶尖区域诱发出旋转失速团,最终导致压气机完全失稳.

英文摘要:

To fully understand the instability process and reveal the occurrence, development and essence of the unstable flow phenomena of one-stage transonic axial compressor with high loading, test investigation was carried out with both steady and dynamic measurements. The analysis was performed by the original signal, the low pass filtering and the FFT (fast Fourier transform) method. The results show that the large amplitude, low frequency axisymmetric axial disturbance appears firstly at the stator hub during the instability process. At that time, there is a decrease in the performance below 50% span of the compressor. But the compressor can still be operated. Meanwhile, considering the features of this disturbance such as low frequency, axisymmetricity, large amplitude, this kind of unstable flow phenomena, named as partial surge, is identified. Then, this disturbance spreads axially and radially with the further decrease of the mass flow. Next, this disturbance extend to the full span. Finally, it leads to the rotating stall cells at the rotor tip region, and the indicating the compressor reached the instability boundary.

参考文献(共18条):

[1] Paduano J D,Epstein A H,Valavani L,et al.Active control of rotating stall in a low-speed axial compressor[J].Journal of Turbomachinery,1993,115(1):48-56.

[2] Emmons H W,Pearson C E,Grant H P.Compressor surge and stall propagation[J].Transactions of the ASME,1955,77(3):455-469.

[3] Greitzer E M.Surge and rotating stall in axial flow compressors:Part Ⅰ theoretical compression system model[J].Journal of Engineering for Power,1976,98(2):190-198.

[4] Greitzer E M.Surge and rotating stall in axial flow compressors:Part Ⅱ experimental results and comparison with theory[J].Journal for Engineering for Power,1976,98(2):199-211.

[5] Moore F K,Greitzer E M.A theory of post-stall transients in axial compressor systems:Part Ⅰ development of equations[R].ASME Paper 85-GT-171,1985.

[6] Epstein A H,Ffowcs Williams J E,Greitzer E M.Active suppression of compressor instabilities[R].AIAA 86-1994,1986.

[7] McDougall N M,Cumpsty N A,Hynes T P.Stall inception in axial compressors[J].Journal of Turbomachinery,1990,112(1):116-125.

[8] Garnier V H,Epstein A H,Greitzer E M.Rotating waves as a stall inception indication in axial compressors[J].Journal of Turbomachinery,1991,113(2):290-301.

[9] Greitzer E M.Some aerodynamic problems of aircraft engines:fifty years after the 2007[R].ASME Paper GT2007-28364,2007.

[10] Day I J.Active suppression of rotating stall and surge in axial compressors[J].Journal of Turbomachinery,1993,115(1):40-47.

[11] Day I J.Stall inception in axial flow compressors[J].Journal of Turbomachinery,1993,115(1):1-9.

[12] Day I J,Freeman C.The unstable behavior of low and high-speed compressors[J].Journal of Turbomachinery,1994,116(2):194-201.

[13] Camp T R,Day I J.A study of spike and modal stall phenomena in a low-speed axial compressor[J].Journal of Turbomachinery,1998,120(3):393-401.

[14] Mailach R,Sauer H,Vogeler K.The periodical interaction of the tip clearance flow in the blade rows of axial compressors[R].ASME Paper 2001-GT-0299,2001.

[15] 陆亚钧,张顺林.跨音压气机旋转失速机理及实验研究[J].航空学报,1982,3(2):61-71. LU Yajun,ZHANG Shunlin.Flow mechanism experimental investigation of rotating stall in transonic compressors[J].Acta Aeronautica et Astronautica Sinica,1982,3(2):61-71.(in Chinese)

[16] Day I J,Breuer T,Escuret J,et al.Stall inception and the prospects for active control in four high-speed compressors[J].Journal of Turbomachinery,1999,121(1):18-27.

[17] 脱伟,陆亚钧,袁巍,等.处理机匣激励频率对跨声速压气机性能的影响[J].推进技术,2009,30(4):430-433. TUO wei,LU Yajun,YUAN Wei,et al.Effect of exciting frequency of casing treatment on transonic compressor performances[J].Journal of Propulsion Technology,2009,30(4):430-433.(in Chinese)

[18] 宋浩飞.新型处理机匣对跨音压气机影响的实验和数值模拟研究[D].北京:北京航空航天大学,2010. SONG Haofei.The experiment and numerical simulation research on the influence of an innovative casing treatment on transonic compressor[D].Beijing:Beijing University of Aeronautics and Astronautics,2010.(in Chinese)

相似文献(共20条):

[1] 周敏,王如根,白云,王学德,武卫.低雷诺数下跨声速压气机转子失速工况时流动失稳触发过程研究[J].航空动力学报,2009,24(6):1379-1384.

[2] 胡加国,王如根,李少伟,甘甜.跨声速轴流压气机径向涡现象与失稳机理[J].航空动力学报,2014,29(9):2239-2246.

[3] 刘小华,周燕佩,孙大坤,马云飞,孙晓峰.基于特征值理论的轴流跨声速压气机失稳预测[J].航空学报,2014,35(11):2979-2991.

[4] 王卓奇,袁巍,宋西镇,李茂义,陆亚钧.跨声速压气机转子失速过程的实验[J].航空动力学报,2012,27(7):1456-1463.

[5] 黄旭东,陈海昕,符松.跨音速压气机中的涡结构与失速机理分析[J].空气动力学学报,2007,25(Z1):75-79.

[6] 杨剑华,赵远征,刘国库,祝剑虹.跨音轴流压气机转子失稳机理研究[J].沈阳航空工业学院学报,2007,24(4):13-16.

[7] 夏钦斌,王如根,李勇,郭飞飞.低雷诺数下跨声速转子流动失稳及周向槽处理机匣扩稳[J].推进技术,2010,31(3):340-344.

[8] 钟勇健,滕金芳,徐玺,羌晓青,吴亚东,欧阳华.跨声速轴流压气机失速边界预测方法[J].航空动力学报,2014,29(8):1838-1845.

[9] 胡加国,王如根,李坤,董鑫.跨声速压气机叶尖开槽射流扩稳策略探究[J].推进技术,2014,35(11):1475-1481.

[10]阳诚武,赵胜丰,韩 戈,卢新根,朱俊强.跨声速压气机多圆柱孔式处理机匣设计与扩稳机理研究[J].推进技术,2015,36(3):385-391.

[11]郑新前,张扬军,郭宫达,张继忠.车用跨声速离心压气机设计[J].航空动力学报,2008,23(10):1903-1907.

[12]李泯江,祁祎,邓宝洋,敬荣强,桂幸民.高负荷跨音压气机转子ATS-3气动设计[J].航空动力学报,2002,17(2):193-187.

[13]徐全勇,侯安平,李绍斌,周盛.轮毂曲线对跨声速压气机转子性能的影响[J].工程热物理学报,2009,30(5).

[14]王卓奇,陆利蓬,袁巍,宋西镇.驻涡式处理机匣对跨声速压气机扩稳的数值模拟[J].航空动力学报,2014,29(12):2948-2956.

[15]谢芳,楚武利,李相君,刘传乐.叶尖间隙对跨声速轴流压气机近失速的影响[J].航空动力学报,2014,29(10):2417-2423.

[16]付磊,袁巍,宋西镇,周盛,陆利蓬.跨声速压气机转子叶尖流场旋转不稳定现象的数值研究[J].航空动力学报,2014,29(5):1145-1153.

[17]吴虎,孙娜,杨金广.跨声速轴流压气机特性预测的损失模型研究[J].航空发动机,2007,33(4):8-11,29.

[18]徐全勇,侯安平,周盛.跨声速轴流压气机转子叶片的掠形优化研究[J].工程热物理学报,2007,28(Z1):109-112.

[19]刘一操,杨化动,范孝良.跨声速单级轴流压气机试验台设计[J].机械设计与制造,2014(11).

[20]杨策,老大中,蒋滋康.求解跨声速压气机叶栅粘性流动反问题的数值解[J].推进技术,1999,20(4):57-60.