

展弦比对叶栅性能影响的研究

西北工业大学 李 立 严汝群

70 年代发展起来的飞机发动机风扇和压气机较明显的变化是叶片展弦比 AR 有了明显的减小。这使叶片数目大为减少, 改善了强度和气动弹性稳定性^[1]。早期所做的改变 AR 的工作, 从未离开叶片设计点应由叶栅数据确定的概念, 其中大多数采用高 AR 以保持基元流动的二元性。而新的设计思想, 本质上是取低 AR 工作范围较宽的优点, 将叶栅的设计点取在高得多的负荷范围^[1]。这样, 低展弦比对压气机设计体系是一个有力的冲击。关于 AR 对压气机性能影响的文献 [2、3] 阐述了 AR 对压气机单级或多级性能的影响, 文献 [4] 从理论上研究了端壁附面层的计算和预测方法。但有关 AR 对叶栅性能影响方面的研究比较缺乏, 有待于进行大量的理论和实验研究。本文对压气机在不同小展弦比 (AR) 条件下的叶栅性能进行了实验研究。结果表明: 展弦比对叶栅损失、气流转折、压比及叶栅负荷等均有较大影响。本文还推导了叶栅性能参数与 AR 、叶栅几何参数及气动参数之间的关联式。计算结果与实验数据的对比分析表明, 关联式给出了叶栅性能参数随 AR 变化的明显规律。本文涉及到的叶栅总压损失系数 $\bar{\omega}$ 、增压比 Π 和扩散因子 D 的推导及表达式见文献 [5、6]。

1. 实验研究 叶栅吹风实验是在我校亚音速开式平面叶栅风洞设备上完成的。实验段装有七片叶片, 气源由一台罗茨鼓风机提供, 进口气源马赫数 Ma 由进气阀门调节。实验中通过在叶栅通道中上、下端加垫块的办法来改变 AR , AR 及垫块厚度见表 1; 为了保证加垫块时通道的平滑连续, 又在叶片排进口前垫入倾角为 20° 的楔形垫块; 为保证栅后测量的有效性, 在栅后上、下端垫入厚度与槽道中垫块厚度相同的矩形垫块。随着冲角的变化, 栅前风洞通道的宽度以及叶栅额线的倾斜度都将变化, 对应栅前楔形垫块的形状也将随之变化。因此, 在实验中, 每改变一次冲角, 必须将叶片全部拆掉, 才能将栅前上、下端壁的楔形垫块粘在壁面上, 然后再将叶片安装好, 接着粘好通道中的垫块, 最后粘栅后的矩形垫块。

实验中所用的叶栅叶型参数见文献 [6]。实验测量的参数有: 栅前总温 T_1^* 、总压 P_1^* 和静压 P_1 ; 栅后总压 P_2^* 、出口气流角 β 和静压 P_2 ; 端壁附面层厚度及尾迹附面层总厚度 δ_{ull} 。实验中进口气流参数取

表 1 AR 垫块厚度及截面位置

AR	垫块厚度 (m)	测量截面离上端壁的距离 (m)		
		0.005	0.03	0.05
1.8	0.0	0.005	0.015	0.025
0.9	0.0255	0.005	0.0125	
0.45	0.0375	0.005		

为冲角 $i = 0^\circ + 5^\circ + 8^\circ$ 和 12° ; Ma 从 0.2 变化到 0.6。为研究 AR 减小时二次流和端壁附面层的影响, 在半个叶高范围内选择了三个测量截面, 截面位置见表 1。

本文于 1990 年 10 月收到。

2. 理论值与实验值的对比分析 (1) 总压损失系数 $\bar{\omega}$

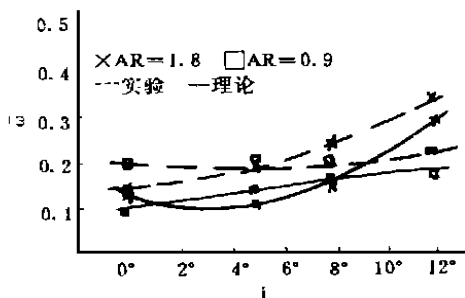


图 1 $\bar{\omega}-i$ 曲线 ($Ma=0.5$)

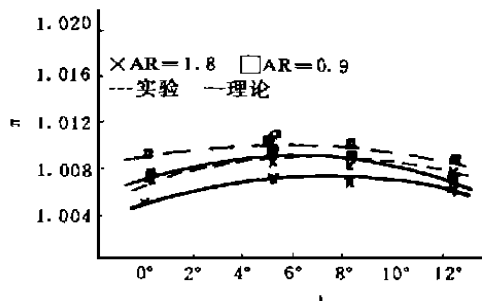


图 2 $\Pi-i$ 曲线 ($Ma=0.2$)

可见, 由于低 AR 叶片的气流在叶栅通道中转折时间较长, 端部分离较大, 中间截面气流收敛较大, 所以低 AR 叶栅有助于控制气流分离, 推迟气流失速, 有较宽的小损失工作范围。由图还知, 理论值给出了 $\bar{\omega}$ 随 i 变化的较好趋势。(2) 增压比 Π 。图 2 给出了 Π 随 i 的变化曲线, 可见, AR 减小, Π 增大, 这是由于宽弦长叶片增加了气流减速增压过程。由图还知, 理论值给出 Π 随 i 变化的较好趋势。(3) 扩散因子 D 。图 3 给出了 D 随 i 的变化曲线, 由图知, 由于低 AR 叶栅有助于控制气流分离, 故 D 减小, 而且 D 随 i 的变化较平缓。由图还知, 理论值给出了 D 随 i 变化的较好趋势。

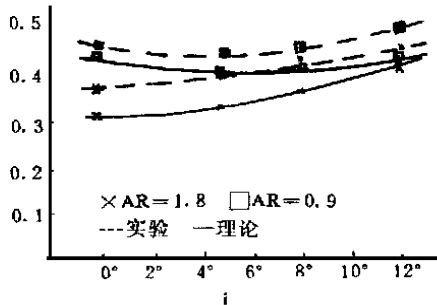


图 3 $D-i$ 曲线 ($Ma=0.5$)

3. 结论 (1) 本文对压气机尖头叶型叶栅在三种不同 AR 情况的叶栅性能进行了吹风实验, 结果表明: (a) AR 减小, $\bar{\omega}$ 随 i 的变化较平缓, 小损失工作范围增大。(b) AR 减小, Π 增大。(c) AR 减小, D 减小, 而且 D 随 i 的变化较平缓。(d) 当 AR 特别小时, 例如 $AR=0.45$, $\bar{\omega}$ 和 D 都很大, 失去了实用价值。(2) 本文中的理论值较好地反映了叶栅性能参数随 AR 的变化规律, 可用来定性估计 AR 变化时, $\bar{\omega}$, Π 和 D 的变化趋势。(3) 本文的关联曲线只是在本文研究条件下的结果, 本课题还有待于进一步的深入研究。

参 考 文 献

- [1] 蒋浩兴译, “低展弦比轴流压气机: 为什么和意味着什么”, 航空发动机参考资料, 1987 年, 第四期。
- [2] Hunter J. H., “Endwall Boundary Layer Flows and Losses in an Axial Turbine Stage”, Journal of Engineering for Power, Trans ASME January 1982, Vol 104.
- [3] Tesch W. A., and Pase R. L., “Design and Performance of a Low Aspect Ratio High Tip Speed Multi-Stage Axial Compressor”, AIAA 83-1161.
- [4] Ruyck J. De., and Hirsch C., “Investigations of an Axial Compressor Endwall Boundary Layer Prediction Method”, ASME Paper No. 80-GT-53.
- [5] 严汝群、钱肇琰, “高亚音速二元叶栅损失的理论分析和实验研究”, 工程热物理学报, 1981 年 2 月, 第二卷第一期。
- [6] 李立、严汝群, “展弦比对叶栅性能影响的研究”, 西北工业大学硕士学位论文, 1989 年 3 月。

Fang Jinyan, Yan Chuanjun and Wang Hongji (*Northwestern Polytechnical University*)

ABSTRACT

An approach, known as Edge Tracking Method, has been developed in particular, which searches out the outer edge and the central spot edge of the coherent image of a particle. The processing procedure of the digital images and its program have been worked out in detail. Finally, the outer size and the central size a particle image are determined by means of the presented technique, then the particle size and its position are calculated by means of the Three-Dimensional Judgement Technique. The results obtained are reasonable.

A DISTRIBUTED FIVE-HOLE PROBE RAKE ON STATOR BLADES FOR ROTOR EXIT MEASUREMENT OF A COMPRESSOR

Lin Qixun, Shi Chunying, Pan Gengsen (*Northwestern Polytechnical University*)

ABSTRACT

Each tube of five-holes probe will be placed at the same radius on five different blades of stator. The diameter of the probe and the wall proximity effect are decreased. The distributed five-hole probe rake has been verified experimentally. Its dynamical frequency response is enhanced seven times. Its characteristics are improved. The parameter measurement of each rotor exit in a multistage compressor becomes practicable.

EFFECTS OF ASPECT RATIO ON CASCADE PERFORMANCES

Li Ly and Yan Ruqun (*Northwestern Polytechnical University*)

ABSTRACT

An experimental research of compressor cascade performances has been completed in the conditions of varying aspect ratios (AR). The results show that AR has a significant influence on cascade losses, pressure ratios and blade loads. Furthermore, the correlations of cascade performance parameters with AR, cascade geometric and aerodynamic parameters are derived. The comparative analysis between the calculated results and the experimental data show that the correlation reveals the rules of variation of cascade performance parameters with the aspect ratio.

EFFECT OF ABRUPT INLET DISTORTION ON ENGINE STABILITY

Wang Xiaofeng (*Chinese Flight Test Establishment*)

Wang Naixing (*Northwestern Polytechnical University*)

ABSTRACT

The unsteady response of a compressor to abrupt change of inlet temperature has been calculated by numerical integration with the "actuator-volume" and the second order delay models. The calculated results are compared with flight test data favourably. The unsteady response of the compressor to abrupt change of inlet pressure (or combined with inlet temperature) has also been calculated in the same manner. The calculated results show that the effects of the abrupt inlet pressure on compressor stability cannot be ignored.