

跨音轴流压气机设计中落后角的确定

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【摘要】 对轴流压气机设计中落后角的选取作了分析,并对影响落后角的气动和几何因素进行了讨论。通过归纳总结,提出了一个新的落后角估算公式,通过对压气机轴流级的验算表明,该公式能较准确地确定落后角的分布规律。

主题词: 跨音速压气机 轴流式压缩机 落后角

分类号: V 245 TH 453

1 影响落后角的气动及几何因素

NA SA - L E W I S 中心为研究跨音压气机转子叶尖稠度对级性能影响而设计了叶尖稠度分别为 1.3、1.5 和 1.7 的跨音压气机。这 3 台压气机试验结果表明叶尖稠度为 1.3 和 1.5 的压气机满足了设计要求,效率点比设计值高,而叶尖稠度为 1.7 的压气机最高效率值比设计值低。究其原因,这 3 台压气机设计压比、流量、效率和展弦比都相同,只有稠度不同。

在大展弦比下,气流流动接近二维流动,因而大展弦比压气机落后角按 Carter 公式计算。小展弦比压气机的扩散因子 (D 因子) 比较高,若按 Carter 公式估算落后角往往偏高。在其它参数比较接近的条件下,展弦比不同,其落后角也是不同的。

在压气机设计中,落后角的经验选取通常是参考压比、展弦比、稠度和绝热效率等比较接近的已经成功设计的压气机落后角分布,一般情况下结果还是满意的。但是,参考所查阅的跨音压气机的设计和试验报告,发现简单地参考压比、展弦比和稠度等参数来确定落后角的分布是不完全正确的。对于轴流压气机转子槽道流动来说, D 因子与稠度 σ 有关。因此, D 因子、损失系数分布隐含着稠度、展弦比、叶型对落后角的影响。 D 因子越大,叶片负荷越大,气流转角大,叶片附面层厚,落后角也大;损失系数 $\bar{\omega}$ 大,落后角也大。 D 因子和损失系数反映了沿叶高各基元叶栅的负荷以及气流流过各基元叶片的“通畅”能力。所以,落后角的选取应综合考虑 D 因子和损失系数分布对落后角的影响。

2 跨音轴流压气机设计落后角的确定问题

由于超跨音压气机内气流流动的复杂性及激波的干扰作用,如何确定落后角分布至关重要。从以往的设计报告和有关文献可知^[1],落后角的估算式为:

$$\delta = \delta_{\text{Carter}} + X \quad (1)$$

δ_{Carter} 为由大量叶栅试验得出的与叶栅几何参数有关的经验公式计算, X 为三维修正系数^[1]

$$\delta_{\text{Carter}} = m \varphi \sqrt{\sigma}, \quad m = 0.92(a/b)^2 + 0.002(90 - \beta_2) \quad (2)$$

根据公式(1)、(2), 验算文献[1]中的第 1 级转子。修正系数 X 数据取值于文献[1]提供的曲线。结果见图 1。

考虑二次流影响的落后角计算关系式:

$$\delta = \delta_{\text{Carter}} + X_s \quad (3)$$

式中 δ_{Carter} 仍然用公式(2)计算, 而 X_s 是文献[2]中的二次流模型, 具体考虑到压气机内通道涡、叶片表面附面层径向迁移、泄漏涡和端壁附面层等因素而得出的。该模型的最大特点是能经验地描述叶尖漏流对落后角的影响。由于该模型建立在低速、小扰动基础上, 为了能在设计中经验地确定超跨音压气机端部流动特点, 对模型中的附面层发展的有关系数进行了修正, 以考虑超跨音流的特点, 并用公式(3)验算了文献[1]中的转子落后角, 结果如图 1。

由于公式(1)、(3)中落后角 δ 的估算必须已知叶型的有关参数, 其本质上是建立二维基础上的三维修正。在前面分析的基础上, 根据各设计和试验报告提供的数据, 通过归纳总结, 提出了一个直接与叶栅关键参数关联的经验公式:

$$\delta = K \pi A_r (D + \bar{\omega}) \quad (4)$$

式中, π 为压比, σ 为叶栅稠度, A_r 为转子平均展弦比, D 为扩散因子, $\bar{\omega}$ 为损失系数, $n = A_r / \sigma$, $K = 3.0$, 经验系数, 由大量数据统计得出。公式(4)考虑到了高负荷、大转角的情况, 式中把落

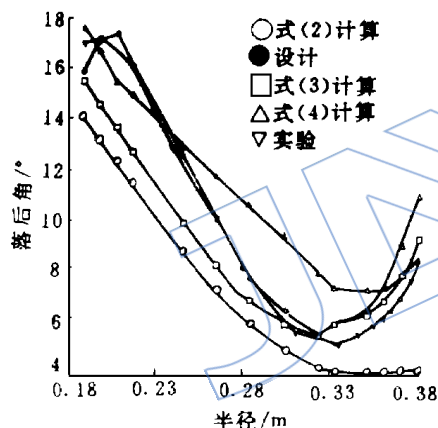


图 1 第 1 级转子^[1]落后角计算结果对比

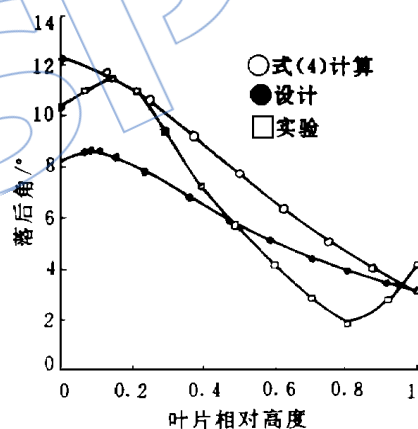


图 2 转子^[3]落后角计算结果对比

后角与叶栅关键参数相关联来确定落后角。利用该公式计算文献[1, 3]中的转子, 发现计算值与设计值和试验值相差 $2 \sim 3^\circ$, 计算结果见图 1、图 2。

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EXPERIMENTAL INVESTIGATION ON SWIRL CONTROL IN AN S-SHAPED DIFFUSER BY VORTEX REDUCED DEVICE

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ABSTRACT

An experimental investigation on swirl control in an S-duct has been completed by the aid of a so-called vortex reduced device (VRD) which is made of a metallic frame and placed upwards near the throat of the diffuser. Effects of geometric sizes of the VRD and its angle of attack on the flow in the duct were investigated in a wind tunnel. The flow parameters, including wall static pressure, total pressures and 3-D velocity field at the duct exit were measured. The optimum geometry shape and size ($W_{\text{in}} = 0.0595$) are found. The VRD with optimized geometry can effectively reduce the swirling range and improve the average total pressure coefficient at the exit.

Key words Air intake Flow field Distortion

DEVIATION ANGLE DETERMINATION IN TRANSONIC AXIAL FLOW COMPRESSOR DESIGN

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ABSTRACT

The deviation angle determination in transonic axial compressor design is analyzed in detail. In addition, the aerodynamic and geometrical parameters acting on deviation angle distribution are discussed. A new deviation angle calculation formula is provided and applied to redesigning of an axial compressor stage. The results show that the aerodynamic and blade design is quite satisfactory.

Key words Transonic compressors Axial flow compressors Deviation angles

EXPERIMENTAL INVESTIGATION ON PERFORATED ACOUSTIC LINER IN A SINGLE TRANSONIC AXIAL COMPRESSOR INLET DUCT

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ABSTRACT

Some experimental results and analyses from the measurements of the sound field in a single transonic axial compressor inlet duct with single plastic glass lining are presented. The plastic glass linings are designed and made by ourselves (two kinds of perforate rating, $\sigma_1 = 2.85\%$ and $\sigma_2 = 5.85\%$). The experimental results are firstly obtained in China from the real sonic fields in a single transonic axial compressor at high sound pressure conditions ($> 150\text{dB}$). The experimental results and conclusions provide some reference for the further investigation on design of the acoustic treatment assemblies in aeroengine nacells and turbomachinery duct.

Key words Perforated linings Noise control Noise reduction systems