

一种新畸变屏及其应用

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紊流发生器是一种进气畸变模拟器,七十年代国外已在新机研制中应用。美国 SAE S-16 航空空间技术委员会编制的军用飞机进气道/发动机相容性评定规范中紊流发生器列为重要试验设备。在紊流发生器上常用不同开度的金属丝网制成的畸变网来模拟稳态总压畸变图谱。美国海军喷气推进中心 (NAPC) 在二元紊流发生器上试验 F404 发动机时曾使用过模拟板。通用电气公司 (GE) 在二元紊流发生器喉道和出口设置畸变网。常规畸变屏是畸变网和模拟板,在运用得当时虽能达到满意的精度,但是调试工时长、能耗及成本高。因此发展一种既能有满意的模拟精度、又省工时、节能的畸变屏是很有实际意义的。

本文提出了一种新畸变屏—模拟棒,可用于畸变流场中调整稳态总压畸变图谱。它是由一定数量、相同直径的杆组成,其插入流场的深度可以在试验过程中进行无级调节。1988 年设计了用在轴对称紊流发生器缩尺模型出口的模拟棒,并且于 1989 年进行了模拟图谱的考核实验。实验表明,这种模拟棒远比常规畸变屏好,它具有结构简便、省工时、模拟精度高又节能的优点。实验测量方法见参考文献 [1]。

一、实验概况和结果分析

在紊流发生器上模拟图谱的过程是将一个有一定稳态和动态畸变的非均匀流场转变成符合模拟图谱所要求的流场。

这一转变要通过畸变屏来实现,由此可见畸变屏的设计技术至关重要。众所周知,畸变网使来流面平均紊流度 Tu 严重衰减。为了摸清这种影响,作者曾做过一系列实验^[1]。在二元紊流发生器上保持波前马赫数为 1.25,开度为 76% 的畸变网使来流 Tu 下降达 40%,开度相同的模拟板要好得多。可是它的总压损失超过畸变网的一倍以上。因此,在用了畸变屏后,对来流的 Tu 和总压损失都不要变化太大的思想指导下,

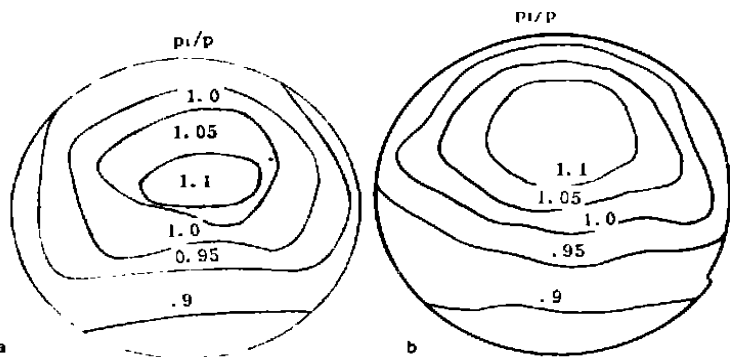


图 1 图谱模拟 (a. 目标图谱; b. 模拟图谱)

设计了一系列网和板的组合畸变屏。用来模拟参考文献 [2] Fig. 8 的稳态总压畸变图谱, 见图 1a, 模拟结果见图 1b。通过这一图谱模拟实验体会到常规畸变屏的制作、安装十分费时, 又不能在试验过程中进行, 能耗大。国外设计畸变屏有成熟的经验, 对于选定的畸变图谱, 通常只要经过二至四次网格制作的反复实验, 就能达到目标。但是由于压力损失取决于网格的开度和来流速度, 要进行若干个图谱的模拟就需要随时更换畸变网, 从而引起实验时间的浪费。

在一般情况下, 畸变屏的实验可以在缩尺模型上进行, 比在全尺寸实物上进行相同试验, 其经费可降低两个数量级, 这是一种通常采用的办法。但是, 对于紊流发生器的畸变屏来说情况特殊, 其畸变流场无法预测, 也不能在缩尺模型上再现。因为这种流场来自有分离的管道流动, 在同一设备上稳定的, 对同样设计的不同设备是随机的。因而, 要求畸变屏能在试验过程中进行调节尤为重要, 显然, 选用常规畸变屏就难以实现, 必须设计一种新畸变屏 “模拟棒”。

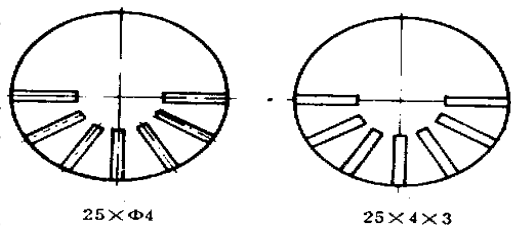


图 2 模拟棒和模拟板

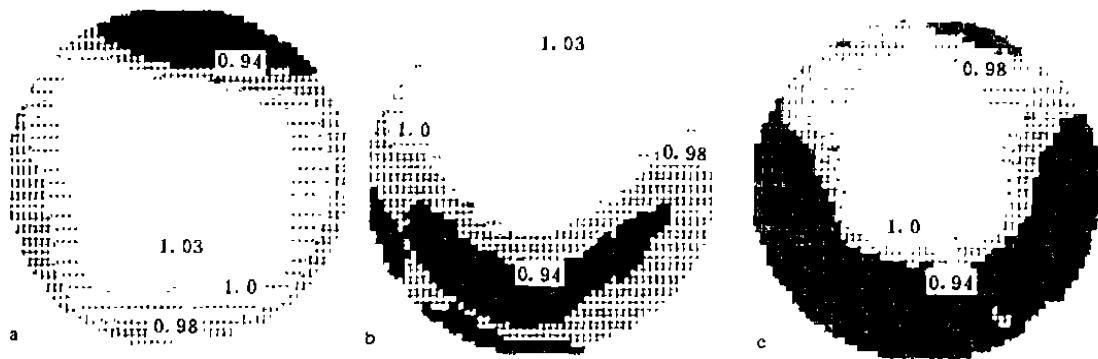


图 3 图谱比较 (a. 原始流场图谱; b. 用模拟板的图谱; c. 用模拟棒的图谱)

在二元紊流发生器出口, 管道直径为 80mm 截面的第 3、4 象限设计了如图 2 所示开度为 0.86 的模拟棒和模拟板进行对比实验。实验结果见图 3 (a. 原始流场图谱, $\sigma=0.8493$, $DC60=0.2269$, $Tu=0.0361$; b. 用模拟板的图谱 $\sigma=0.8175$, $DC60=0.3534$, $Tu=0.0315$; c. 用模拟棒的图谱, $\sigma=0.8158$, $DC60=0.1710$, $Tu=0.0403$)。以上实验马赫数 $Ma \approx 0.5$, 同样开度的模拟棒和模拟板压力损失几乎相同, 约 4%。模拟板使来流畸变指数 $DC60$ 增大 55.8%, Tu 衰减 12.7%, 模拟棒使来流 $DC60$ 减少 24.6%, Tu 增大 11.6%。这就表明, 两者对来流 $DC60$ 和 Tu 的影响恰好相反, 并且在这种特定畸变流场条件下, 模拟棒比同开度的模拟板在气流中产生的紊流度要大, 稳态畸变要小。稳态畸变小对图谱模拟有利, 紊流度大正是设计所指望的, 因此模拟棒很有实用价值。

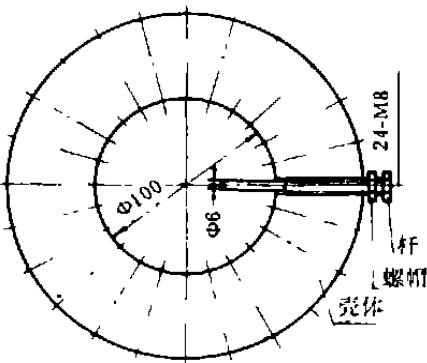


图 4 手动模拟棒

1988 年为轴对称紊流发生器缩尺模型设计了手动调节的模拟棒装置, 见图 4。航空燃气轮机研究所现已完成这一装置全尺寸的设计和制造, 正在着手做图谱模拟的试验。这种装置是由 24 根带螺纹的杆组成, 杆的直径 6mm, 沿圆周均匀分布, 管道直径为 100mm。杆的数量和直径大小取决于模拟棒的开度和模拟图谱所要求的精度。数量多有利于提高模拟精度, 因此在模拟棒允许开度范围内, 杆多一些为好。杆的数量选定后, 唯一可以调节的参数是杆插入流场的深度, 只要深度一定, 模拟棒布局就就绪。各杆深度的调节是根据原始流场分布和目标图谱的特征在试验过程中进行。实验还表明, 这种模拟棒装置对不同非均匀流场的影响具有良好一致的规律性。

二、图谱模拟举例

将图 4 所示模拟棒联接在紊流发生器上, 就能进行多个图谱的模拟。下面列举一个真实图谱模拟实例。图 5a 是进气道稳态压力畸变图谱, 以此为目标进行模拟。首先选好紊流发生器模态, 获得相近的流场, 然后调节各杆的深度, 进行追捕目标的模拟。调节模拟棒一次, 就实时采集和处理一次图谱, 并与目标进行比较。当掌握了调节模拟棒对图谱的变化规律后, 精心调节若干次, 就能达到目标。图 5b 是模拟结果。比较图 5 (a. 真实图谱, $Ma = 0.520$, $DC90 = 0.050$, $Tu = 0.022$; b. 模拟结果, $Ma = 0.522$, $DC90 = 0.507$, $Tu = 0.024$), 模拟图谱令人满意。

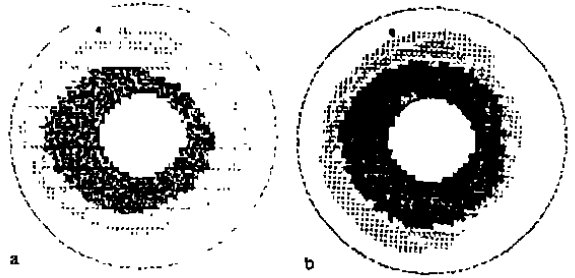


图 5 进气道及其模拟图谱
(a. 真实图谱; b. 模拟结果)

结论 模拟棒结构简便, 调试时间少又能在试验中进行, 有满意的模拟精度, 节约能量消耗。它是紊流发生器模拟稳态图谱适用的有很大经济效益的畸变屏, 也可供别的进气畸变模拟器设计者参考。

作者对彭成一教授的指导和帮助表示感谢。

参 考 文 献

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DEVELOPMENT OF AN EFFICIENT OIL FILM DAMPER FOR IMPROVING THE CONTROL OF ROTOR VIBRATION

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ABSTRACT

An efficient oil film damper, known as Porous Squeeze Film Damper (PSFD) is developed from the normal squeeze film damper (SFD) for effective and reliable rotor vibration control. The outer race of the PSFD is made of permeable sintered porous metal materials. The permeability of PSFD under squeeze effect makes it possible for the oil to permeate through the porous outer race, so that the characteristics of squeeze film forces are improved, in particular, as the amplitude of eccentricity is rather great. The nonlinearity of squeeze film forces could be reduced due to PSFD permeability, and the relations between oil film stiffness coefficient and damping coefficient of squeeze film forces could be improved. Investigation demonstrates that: The cavitated SFD high nonlinear oil film stiffness forces, which lead to many undesirable nonlinear vibration characteristics, lessen due to the permeability of PSFD, and the damping forces are relatively enhanced by PSFD. The nonlinear vibration characteristics of SFD system such as bistable jump phenomenon are greatly improved and even eliminated at higher unbalance level with the PSFD system. The PSFD can operate effectively under greater unbalance loads as compared with the SFD system.

TECHNICAL NOTES

CORRELATION BETWEEN CONDENSED PHASE REACTION AND BURNING RATE OF AP/HTPB PROPELLANT

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ABSTRACT

The effects of transition metal oxides TMO on the thermal decomposition characteristics of AP and AP/HTPB propellants and on the burning rates of AP/HTPB and AP/Al/HTPB propellants are studied. The results show that the burning rate of AP/Al/HTPB/TMO propellant depends on the thermo-decomposition characteristics of AP/TMO and burning rate of AP/HTPB/TMO propellant depends on the thermo-decomposition characteristics of itself. The results also indicate that the aluminum decreases the burning rate of the propellant. It is suggested that the aluminum reduce the rate of condensed phase reactions and the stress effect of AP thermal decomposition properties on the burning rate of aluminized propellant.

A NEW DISTORTION SCREEN AND ITS APPLICATION

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ABSTRACT

A new distortion screen, "simulation poles", is proposed for simulation of steady state pressure distortion patterns. It is composed of a number of round poles with same diameter, the depth inserted into flow field may be adjusted steplessly during the test. The author applied it to scale simulator of an axisymmetrical random frequency

turbulence generator, in result the examinational pattern was successfully simulated. Practice of its application proves that the simulation poles are simpler, less consumptive in energy and man-hour and more accurate in simulation than the traditional distortion screen.

FUZZY CLUSTERING ANALYSIS OF GAS TURBINE ENGINE MISSION PROFILES

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ABSTRACT

In order obtain engine mission profiles from a vast amount of flight test, the fuzzy matrix of the membership function of engine mission profile samples is established according to the theory of fuzzy sets and boolean algebra behaviours. The fuzzy matrix is examined by using square method for meeting the equivalent conditions. When it meets equivalent conditions, the dynamic clustering is carried out by selecting various threshold values. The clustering analysis of the mission profiles for an actual engine has been completed by the complicated and enormous fuzzy calculation based on statistical data of the engine loads measured in flight test. The clustering method of three parameters (flight altitude, Mach number and angle of throttle lever) is first employed in the clustering analysis and the results obtained are satisfactory.

AN ACOUSTIC METHOD FOR MEASURING CHARACTERISTICS OF ROTATING STALL IN A COMPRESSOR

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ABSTRACT

According to analysis of the characteristics of frequency and propagation of the sound generated by the rotating stall, an acoustic measuring method is developed, in which the characteristic parameters, such as the number and propagation speed of stall cells, are measured. Compared with existing methods, this method is a untouched measurement so as to avoid not disturb ance of the flow field . The primary experimental results obtained on a transonic axial-flow compressor facility demonstrate the feasibility of this method.

EXPERIMENTAL INVESTIGATION ON JET NOISE

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ABSTRACT

The correlation of sound power with jet velocity is studied in this paper. It is indicated that Both Lighthill's and Lilley's formulas fit experimental data very well when Mach number of jet $Ma_j > 0.4$, but the deviation between the results obtained from the formulas and experimental data is not so negligible as $Ma_j < 0.4$. The authors propose substituting sixth power of the jet velocity instead its eighth power in the formulas. The direction sensitiveness and the frequency spectrum of jet noise have been investigated experimentally.

TECHNIQUE FOR DIGITAL PROCESSING OF COHERENT IMAGES OF PARTICLES