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用激光多卜勒风速仪研究畸变模拟器的三元速度场*

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一、测 量 方 法

作者用同点双测法，藉一台 55X 二维激光多卜勒风速仪（LDA）对多种畸变模拟器的三元速度场进行了研究。试验布置见图 1。图 1a 为侧视图，1b 为上视图。当三束激光从侧面射入玻璃窗，可以测出轴向分速 V_x 及切向分速 V_s。当激光束从进口沿轴向射入，则可测出径向分速 V_r 及 V_s。畸变模拟器可绕轴转动，激光束交点藉位移机构可沿径向移动，再使用各种长度的直管，就可获得任意截面的三元速度场。前透镜焦距应选大些，以防影响模型的进口流场。

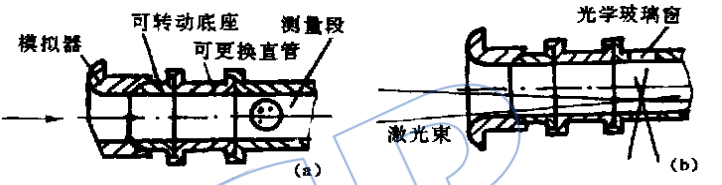

图 1　同点双侧法试验布置图

二、典型结果与讨论

图 2 例示 90 扇形圆环畸变模拟器的速度矢量场（a. 90 扇形圆环模拟器；b. 三元速度矢量场沿轴向的变化；c. 进口缺口处 V_r 与 V_s 的合速度场）。图 3 是其合速度均值图谱及速度紊流图谱（a. 距进口 1.6D 处；b. 距进口 3.6D 处）。由图可见，气体从两个缺口被沿径向吸入（图 2c），造成唇口分离。在中心区相遇后，向管内流去。形成鲜明集中的

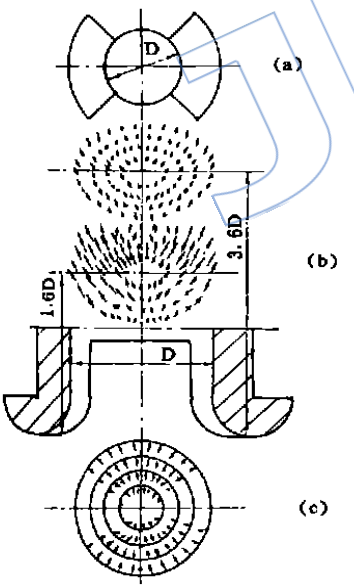

图 2　速度矢量图

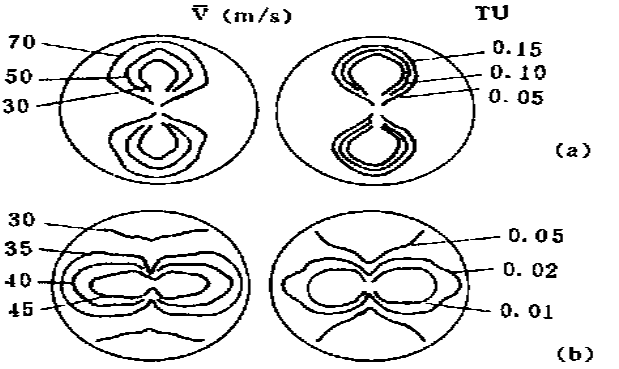

图 3　合速度均值图谱及速度紊流图谱

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低速大紊流度区域 (图 3a)。然后分离涡旋逐渐减弱, 低速大紊流度区域逐渐弥散, 却形成了集中的高速低紊流度区(图 3b), 总的速度值减小。气流方向从进口处的向心变成离心 (图 2)。流速对轴线的夹角, 在进口截面最大约为 70°, 在 1.6D 截面最大约为 20°, 到 3.6D 减为 15°左右。图 4 和图 5 均为 20°斜切圆环。由此可见斜切唇口分离的发生与发展过程 (a. 20°斜切圆环; b. 三元速度矢量场沿管长的变化; c. 进口截面 V_r 与 V_s 的合速度场)。作者还对环形挡板、扇形挡板以及一些组合式模拟器的速度场进行了研究。实验所揭示现象均属前所未见。

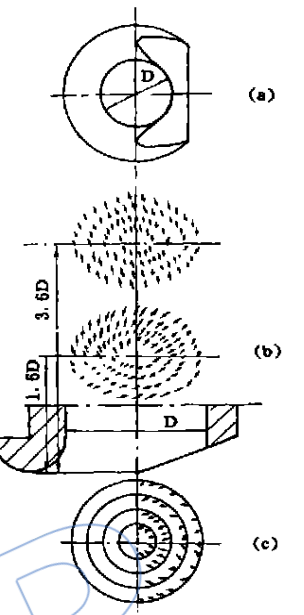

图 4 速度矢量场

用随机涡传递模型预测最大瞬时峰值畸变时, 把进气畸变流动看成是由叠加在稳态流动上的旋涡系所构成[1]。从动态总压信号求平均涡直径时, 必须作一系列假设。而涡的积分尺度与脉动速度的相关函数间有直接的关系, 它是经典定义的。用测速法容易测得, 作者依此进行了测量。测量表明, 在同一截面上紊流区与非紊流区的涡尺度有相同的量级。这是因为非紊流区相关图谱上虽显示很弱的相关性, 即相关函数中的分子很小, 但因紊流度很小, 即分母也很小, 所以涡的尺度仍与紊流区相当。表 1 例示涡的相对尺度与模拟器构造及流速的关系。

表 1 L/D 与构造及流速关系

轴向位置	平均流速 (m/s)	90°扇形圆环	20°斜切圆环
1D	20	0.12	0.21
	45	0.16	0.24
	70	0.19	0.34
3D	20	0.17	0.16
	45	0.18	0.18
	70	0.22	0.19

从表 1 可见, 不论那种构造, 涡的尺度随流速的提高均有所增加。在 1D 截面, 20°斜切圆环的涡尺度约为 90°扇形圆环的两倍。这是因为前者是一个大的集中分离区, 而后者是分立的两个的缘故。轴向位置增至 3D, 两种构造的变化趋势不同, 90°扇形圆环的涡尺度略有增加, 而 20°斜切的则减少很多。

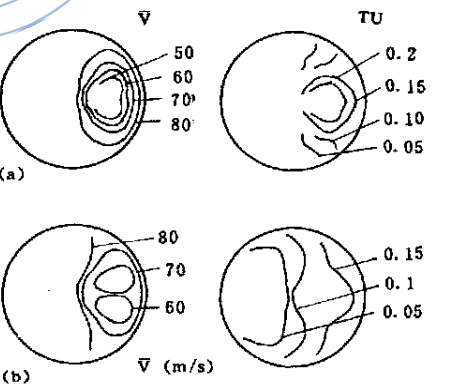

图 5 合速度均值图谱及速度紊流度图谱
(a. 距进口 1.6D 处; b. 距进口 3.6D 处)

作者一直认为应该越过只测总压之常规, 从速度的领域进行研究, 那会对模拟器设计有巨大帮助[2]。本文无疑是这种观点的又一有力佐证。

参 考 文 献

[1] Melick H. C., "Estimation Maximum Instantaneous Distortion from Inlet Total Pressure RMS and PSD Measurements", AIAA 78-970.

[2] Lin Qixun, "The Experimental Investigation of the Inlet Distortion Simulation Equipments", Proceedings of the First International Symposium of Experimental and Computational Aerothermodynamics of Internal Flows, World Publishing Corporation, 1990.

ROTOR EXIT FLOW MEASUREMENTS IN A HIGH-SPEED MULTISTAGE FAN

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ABSTRACT A single-hole cylindrical high frequency response pressure probe characterized by high frequency, small size, high accuracy and reliability has been developed for rotor flow measurements in a high speed multistage fan. With the help of a two axes traverse mechanism and a high speed data acquisition and processing system, the periodic two-dimensional flow field at the exit of the third rotor of the fan has been successfully measured by using an on-line calibration technique to determine the pressure sensitivity and null-pressure reading (zero-offset) during the compressor measurements. The results with the high accuracy and fine resolution provide an important basis for redesign of the third stage. Furthermore, the probe, measuring method and data reduction procedure are proved simple, precise, practical and reliable.

A METHOD FOR MEASURING HIGH-SUBSONIC TWO-DIMENSIONAL PERIODIC FLOW FIELD USING A SINGLE-HOLE HIGH-RESPONSE CYLINDRICAL PRESSURE PROBE

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ABSTRACT This paper presents in detail a method for measuring high-subsonic two-dimensional periodic flow field with a single-hole cylindrical pressure probe with high-frequency response. The method normalizes the probe calibration curves at different Mach number and simplifies the compressibility correction. The probe is set in nine azimuthal angles while measuring the flow. Sampled and averaged data are used to determine flow angles by least square fitting, Mach number and stagnation pressure are then obtained from solving a set of non-linear equations. The method has been successfully applied to measuring the rotor exit flow field in a multistage compressor with high accuracy.

APPLICATION LDA TO INVESTIGATION OF 3-D VELOCITY PATTERN IN INLET DISTORTION SIMULATOR

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ABSTRACT A two-measurement-at-one-point method with a two-colour LDA (Laser Doppler Anemometer) has been used for measuring three-dimensional velocity field. Various velocity distortions of the simulator have been investigated. The velocity and turbulence patterns of 90 degree torus quadrant and of torus with 20 degree slanted cut are shown. It can be seen clearly how the low velocity and large turbulence region will be caused by the flow separation from the duct lips. In order to estimate maximum instantaneous

distortion, the vortex size must be measured. It is defined classically by velocity crelation and more directly than by total pressure. Some typical results are shown in a table. The vortex size is increased by the flow velocity. At 1D section the vortex size of torus with 20 degree slanted cut is about two times larger than the size of 90 degree torus quadrant. But at 3D section the former decreases and the later increases slightly.

EXERGY ANALYSIS OF AEROENGINE AND ITS SIGNIFICANCE

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ABSTRACT An exergy analysis method of an aeroengine is presented and compared with the traditional energy analysis method. The significance of the exergy analysis for the aeroengine engineering is considered. It must be underlined that the main part of the energy loss in the aeroengine comes out of the combustor. Therefore, to enhance of the exergy efficiency of the combustor is an essential measure to improve aeroengine performance.

STATISICAL ANALYSIS AND PREDICTION OF AEROENGINE DETERIORATION

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ABSTRACT An aeroengine deteriorates in the course of its service. Although its perfomance may be restored to some extent after overhaul, it goes down gradually in general. Based on the statistical information analysis of the test-bed performance decay of 500 engines after 0 to 3 overhauls, a concept of an overall performance index is proposed to reflect the overall performance of the engine. According to this concept, a mathematical model of the engine deterioration is presented which is established by means of the exponential smoothing theory. The prediction of the engine deterioration has been made whcih is quite consistent with the practice. The final analysis shows that it is necessary and also feasible to adopt the method of statistical and synthetic analysis for the overall engine performance decay of both randomness and regularity and, what is more, with many parameters.

A DIRECT-PROBLEM CALCULATION METHOD FOR GAS TURBINES WITH BOWED AND TWISTED BLADES

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ABSTRACT The necessity of the direct-problem calculation in aerodynamic design of gas turbines with bowed and twisted blades is discussed and a practical direct-problem calculation program is developed for the S_2 stream surface transonic flow in a multi-stage gas turbine. In the calculation, the shape of the mean S_2 stream surface is taken as that of the blade mean camber surface which is modified properly to guarantee a reasonable S_2 stream surface shape, and the circulation is specified by the stream surface shape and the axial velocity. In the supersonic region, the density is corrected by means of the artificial compressibility treatment to make the calculation stable and the velocity is solved by density.