

交叉射流特性的试验研究*

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【摘要】 本文研究了稳燃腔中交叉射流两相流动。使用三维激光粒子动态分析仪(PDA)测量了正三角形截面副射流与主射流速度比为 2.5 时的交叉射流流动, 获得了粒子湍流脉动强度及粒子在交叉射流尾迹中的浓度分布。

关键词: 交叉射流 回流流动 湍流

1 前 言

交叉射流即是将一小股射流射入横向气流中的运动。国内外对纯气相的圆形交叉射流(如图 1)已作了较多研究, 得出射流轨迹及射流中颗粒的浓度和温度分布, 射流的穿透深度及射流尾迹中的速度分布, 回流流动, 湍流特性等等^[1]。采用一股高速副射流取代刚性钝体, 即交叉射流稳燃技术已成功地在煤粉热态试验中得到证明。本文对稳燃腔中正三角形高速射流与含颗粒主气流垂直相交后气流及颗粒的运动规律进行了研究, 其目的是探讨正交叉射流尾迹冷态气固两相流动与混合的规律, 为这种新型煤粉稳燃方式提供理论根据。

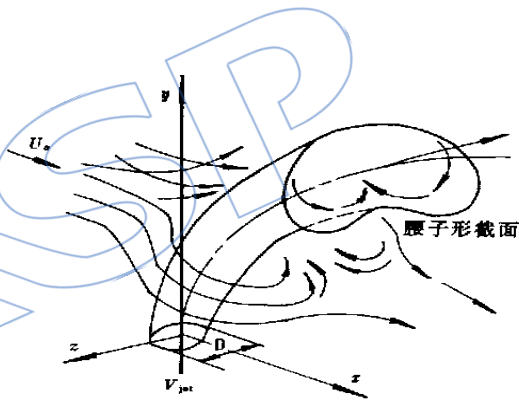


图 1 圆形交叉射流流动

2 试验装置与测量系统

试验是在华中理工大学煤燃烧国家重点实验室的环形风洞上进行的, 试验中主气流速度 U_0 为 18.5m/s, 其雷诺数为 1.43×10^5 , 副射流速度为 V_{jet} , 它与主流速度之比 R 为 2.5。主流喷口以及稳燃腔截面的高宽比均为 0.7; 稳燃腔出口面积为进口面积的 3 倍; 正三角形副射流边宽 b 为稳燃腔进口边宽的 1/3。试验段具体尺寸如图 2。

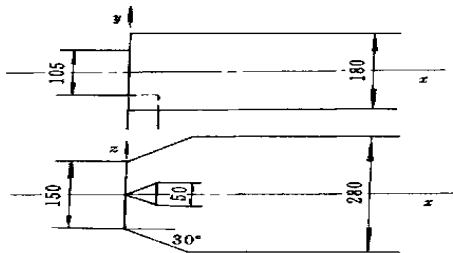


图 2 试验段尺寸

三维激光粒子动态分析仪是 LDA 技术的发展。PDA 利用多普勒频移测速度, 多普勒相移测粒

径, 它能对粒子速度及其脉动、尺寸和浓度等进行同时测量。试验所采用的粒子为聚氯乙烯塑料粉末, 其筛分尺寸为 $50\sim 120\mu\text{m}$, 显微结构与煤粉相似, 比重为 $1.4\sim 1.6$, 亦为煤粉相同。

3 试验结果与分析

3.1 湍流强度分布

文献[2]测量了稳燃腔交叉射流尾迹三维速度场; 本文给出了交叉射流尾迹湍流强度 u'/U_0 的分布(如图3)。从图中可看出, 由于交叉射流中主、副射流强烈的相互撞击、卷吸, 使其尾迹湍流脉动强烈, 而峰值出现在回流区边界附近。同时交叉射流回流区内的湍流强度仍然保持较高的水平, 说明交叉射流尾迹回流区内仍存在着强烈的动量交换。

3.2 粒子浓度分布

图4为交叉射流尾迹粒子浓度分布。其中 C_0 为主流入口粒子初始浓度。交叉射流尾迹

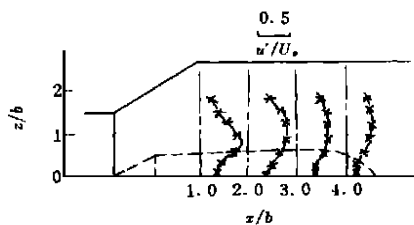


图3 交叉射流尾迹湍流强度分布

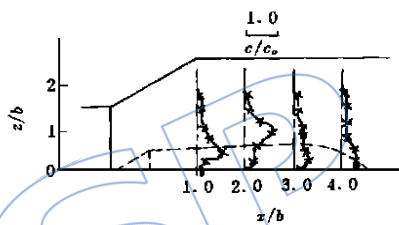


图4 交叉射流尾迹粒子浓度分布

回流区中粒子浓度存在一个较小的峰值, 原因是: ①交叉射流尾迹湍流脉动很强烈, 因而有一定数量的较小的粒子脉动进入回流区; ②副射流的速度虽然较高, 但它不是刚性物体, 因而不能完全阻挡住颗粒的运动, 大颗粒在惯性的作用下会直接穿过副射流而进入尾迹回流区中。而在回流区边界附近, 粒子浓度明显地存在着一个较大的峰值, 说明该强湍流区为粒子沉聚区。这是因为: ①主流受到副射流的阻碍后, 其中粒子由于惯性作用而变向能力较之气体要弱得多, 因而会沉聚在副射流与主流的交界面及主流的后续流线上, 这就是颗粒的惯性沉聚。②交叉射流尾迹回流区是三维, 回流区中不仅有来自后方的返流气流, 也有少量的侧向气体的卷入^[2], 于是处于正、反流动交界处的回流区边界上粒子数较大。正是由于粒子局部浓度增大发生于速度梯度大、湍流脉动强烈、剪切应力高的回流区边界上从而十分有利燃料的着火和稳燃。

以上试验结果和分析得到如下结论: (1) 交叉射流流动是一种非常复杂的三维流动, 其尾迹不仅可产生稳定的回流区, 而且其尾迹回流区边界上湍流脉动强烈, 同时也是粒子的富聚区。(2) 回流区中, 既有一定数量的小直径粒子, 又有较多在惯性的作用下直接进入的大粒子。

参 考 文 献

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shock/boundary layer interaction. Comparison has been made between the flow fields over NACA0021 airfoil with and without the flexible-wall. Since we use the time marching method to get the steady results, the main difficulty in the present case is the treatment of the flexible wall boundary which changes its shape as the solution proceeds. The deflections of the flexible wall as function of the pressure over it can be found by the mechanics of the material. We proposed a method of locally changing grids to avoid the global interpolation. The locally changed grids maintain the good quality of the original grids. The calculated results show that a strong shock splits into two weak shocks in comparison with the case without the control.

A MATHEMATIC MODEL AND A CALCULATION METHOD FOR COOLING AIR MIXING IN A TURBINE

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ABSTRACT A mathematic model is proposed for predicting the effect of injected cooling air on cooled turbine performance. The model takes the gas flow as the mainstream flow and regards the cooling air as a consecutive source with continuous distribution in the flow field. A numerical method is presented for determining the intensity of the consecutive source. According to the model, the coupled aerothermodynamic equations reflecting the effect of the cooling air mixing in general form are derived in a relative coordinate system. As an example, the model is used in the throughflow calculation for the cooled turbine and the governing equations are derived along S_2 stream surface in a non-orthogonal curvilinear coordinate system. By defining a quasi-stream function which satisfies the continuity equation, a line-relaxation calculation method is developed for the quasi-stream function. It makes full use of the existed calculation method without considering the cooling air mixing and is easy to be programed. In accordance of the mathematic model a formula of entropy variation due to the cooling air mixing is derived in the light of the second law of thermodynamics. By means of the present calculation method, an air-cooled gas turbine stage is analyzed. The results show the reasonableness of the mathematic model and the feasibility of the calculation method.

EXPERIMENTAL STUDY ON TURBULENT JET IN A CONFINED CROSSFLOW

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ABSTRACT A turbulent triangular jet issuing perpendicularly into a confined gas-particle two-phase flow was investigated experimentally. When jet-to-crossflow velocity ratio R equaled to 2.5, mean and fluctuating velocity components were measured by the Three-Dimensional Particle Dynamics Anemometry (3-D PDA). The PDA signals were evaluated to yield the turbulent intensity and the particle concentration. The measurement results show that the turbulent intensity in the wake of the crossflow is enhanced particularly on the edge of the recirculation zone. There are two particle concentration peaks, one of them is in the recirculation zone, and the other is on the edge of the zone.