设计与试验

文章编号: 1001－2060(2000)02－0122－03

同心反切燃烧方式的气固两相流动特性实验研究

(哈尔滨工业大学, 黑龙江　哈尔滨　150001)
王春刚　朱群益　李争起　孙绍增　吴少华　秦裕琨
(黑龙江省北安热电有限责任公司)　刘国军

摘　要: 针对切向燃烧锅炉燃用劣质煤时的稳燃及水冷壁高温腐蚀等问题, 采用 PDA 测量系统, 对四角切圆锅炉中一、二次风同心反切和同心同向燃烧方式进行了气固两相流动特性的实验研究。结果表明, 与同心同向燃烧方式相比, 同心反切燃烧方式的气固两相流动特性使其在稳燃、低 NOx 排放、防结渣、防高温腐蚀等方面具有较优良的性能。

关　键　词: 同心反切; 同心同向; 气固流动特性; PDA
中图分类号: TK16　　文献标识码: A

1　问题的提出

采用同心反切燃烧技术(CFS－II)可以起到加强水冷壁氧化气氛及消弱炉膛出口残余旋转的作用, 在近几年取得了良好的工程应用效果, 如上海吴泾电厂 1025 t/h 锅炉采用的一、二次风同心反切 CFS－II 型燃烧系统具有良好的防结渣、低 NOx 排放、变负荷宽等效果[1,2]。本文采用 PDA(Particle Dynamic Analyzer)分别对同心反切和同心同向燃烧技术在炉膛中的颗粒浓度场、速度场进行了实验研究, 以期深入了解煤粉气流在炉膛中的气固两相混合机理, 为工程设计和运行提供指导。

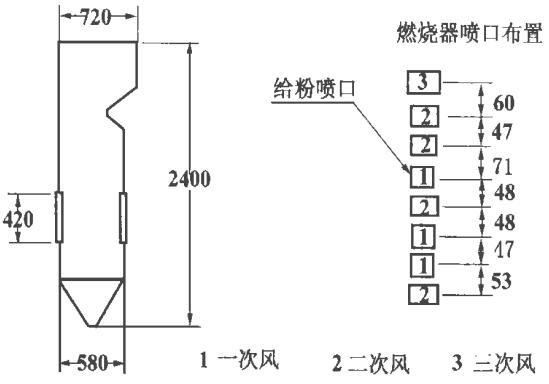

图 1　实验台简图

2　实验系统及实验方法

图 1 为以 1:14 比例根据相似模化原理建成的冷态实验台[3], 冷态模化条件为: 一、二次风动量比相等(1.1:1), 炉膛进入自模化区($Re_{min}=4\times10^4$), 燃烧器进入自模化区($Re_{min}=1.4\times10^4$)。基于斯托克斯准则相似的气固模化原则, 计算出实验物料玻璃微珠的平均直径为 42 μm, 在实验所用物料的平均直径范围内(35 ~ 45 μm)。本实验中单只燃烧器给粉, 给粉浓度 2.62 kg/kg。实验参数见表 1, 同心反切方式下之时给粉喷口所在层一次风反切, 其他层一、二次风正切, 图 2 为切圆示意图。测量时以给粉喷口的中心截面为测量截面, 同时以侧墙为 x 轴, 前墙为 y 轴, 炉膛高度为 z 轴。相应方向速度为 u、v、w。

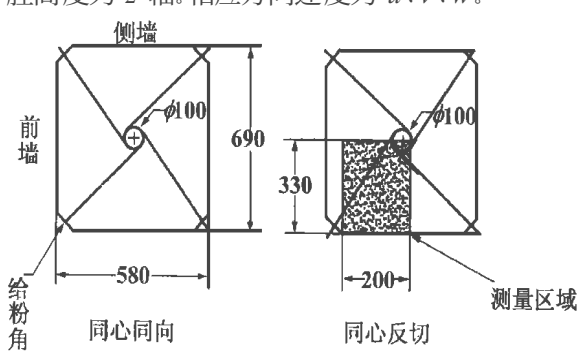

图 2　切圆示意图

表 1　实验参数

	一次风	二次风	三次风
风速/m·s^{-1}	5.1	7.7	11
截面(宽×高)/mm^2	34×38	40×36	40×50

3　实验结果及分析

图 3 ~ 8 分别为同心反切和同心同向燃烧方式下测量截面上的颗粒数密度图(单位立方厘米内颗

收稿日期: 1999－05－27; 修订日期: 1999－06－09
基金项目: 国家"九五"重点科技攻关项目(96－A19－01－01)及清华重点实验室开放基金资助课题
作者简介: 王春刚(1972－), 男, 黑龙江杜尔伯特县人, 哈尔滨工业大学能源科学与工程学院博士研究生

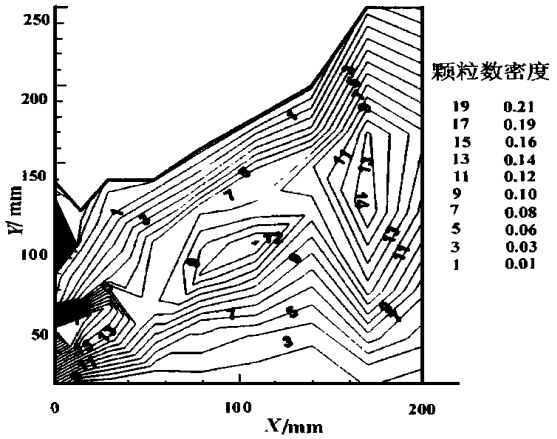

图 3　同心反切颗粒数密度图

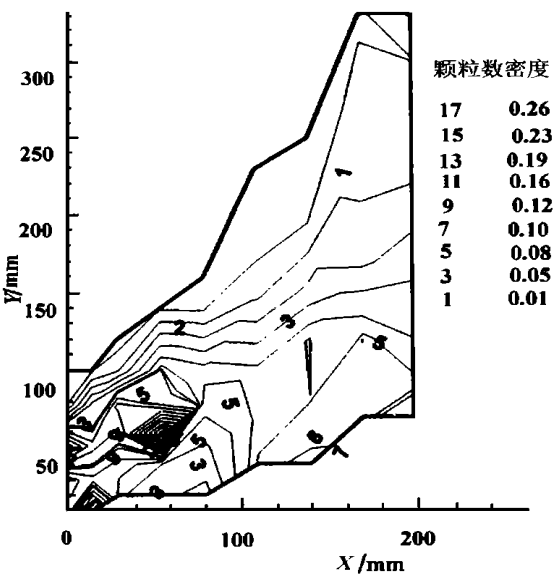

图 4　同心同向颗粒数密度图

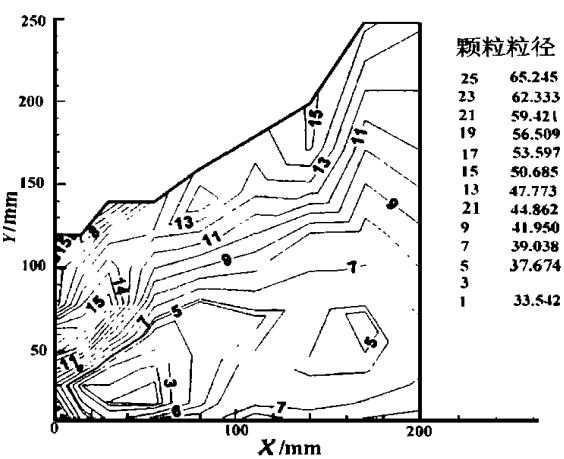

图 5　同心反切颗粒粒径分 布

粒个数, $10^4/cm^3$)、颗粒粒径图及速度矢量图。由等值线图 3 ~ 6 可见, 对于同心反切燃烧方式, 由于一次风反切, 含粉射流离开喷口一定距离后, 在主流场的作用下发生偏转, 由于滞止作用, 使颗粒聚积, 从而形成一个高浓度区, 同心反切颗粒数密度图表示出了射流中心部分在炉膛中心出现反常增大的情况, 同时颗粒粒径分布也表示出只有较少的小颗粒流向背火侧。另外, 由速度矢量图表示的射流流动过程可见, 同心同向燃烧方式与同心反切方式相比, 一次风射流向壁面的偏转趋势增强, 较多并较大的颗粒扩散到壁面, 显然同心反切燃烧方式的气固流动特性在实际燃烧过程中使其在稳燃、低 NOx 排放、防结渣、防高温腐蚀等方面具有较优良的性能。

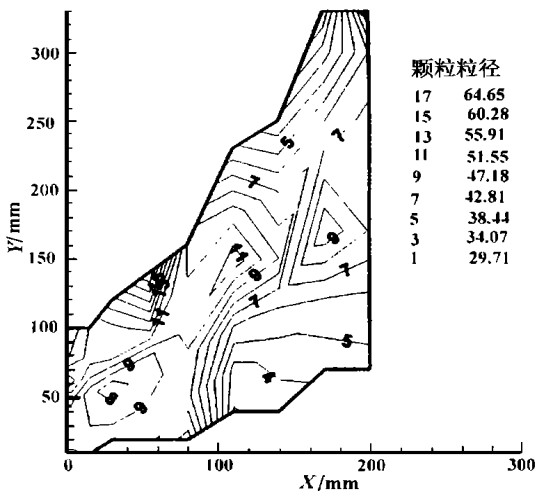

图 6　同心同向颗粒粒径分 布图

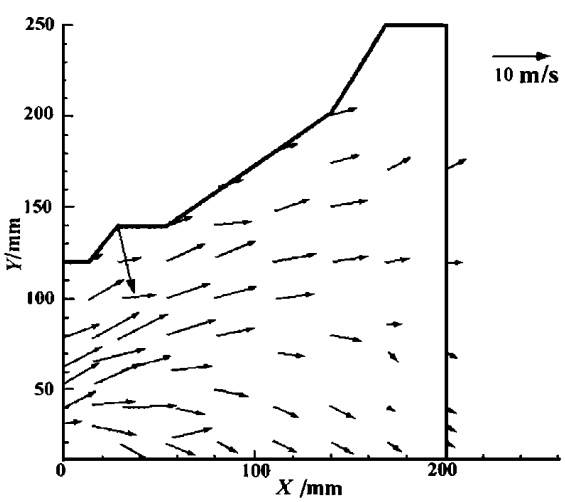

图 7　同心反切颗粒速度矢量图

图 9 ~ 12 为两种方式下不同方向的气相雷诺切应力图。这里以两个方向脉动速度的乘积 $u'v'$、$u'w'$ 来表征雷诺切应力, 显然这与雷诺切应力 $-\rho u'v'$ 相差 $-\rho$, 这里 $u'v'$ 的绝对值越大, 表示流体之间的混合越强。可见, 对于同心反切方式, 由于反切风与主流场相互作用较为强烈, 由 $u'v'$、$u'w'$ 对表示出了较大的雷诺切应力, 一次风射流与上游来流之间的混合较强; 同时由于一次风射流与壁面(侧

墙)的角度增大, 由 $u'v'$、$u'w'$ 对表示出的较大的雷诺切应力区靠近角部, 并且作用区域较小, 这样使得一次风射流与背火侧流体之间的混合减弱。

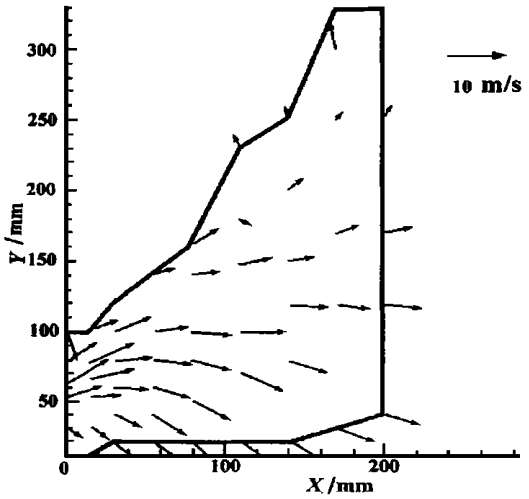

图 8 同心同向颗粒速度矢量图

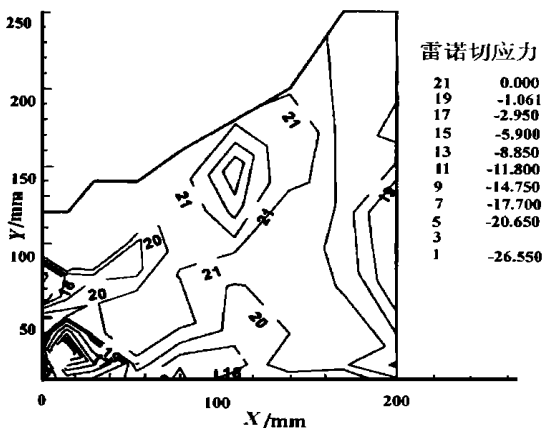

图 9 同心反切 $u'v'$ 雷诺切应力图

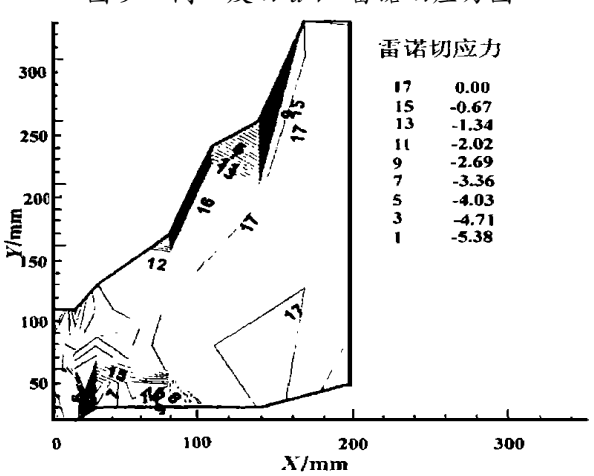

图 10 同心同向 $u'v'$ 雷诺切应力图

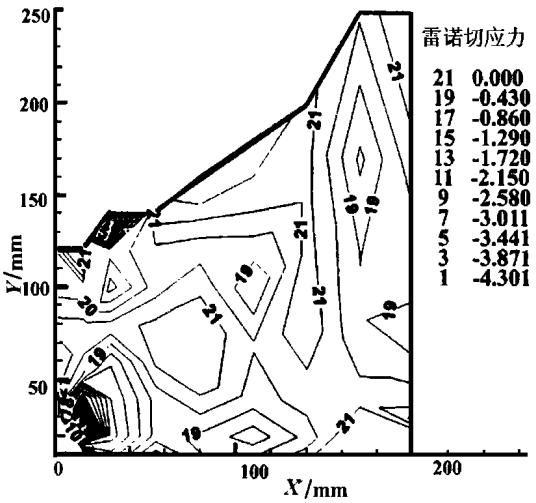

图 11 同心同向 $u'w'$ 雷诺切应力图

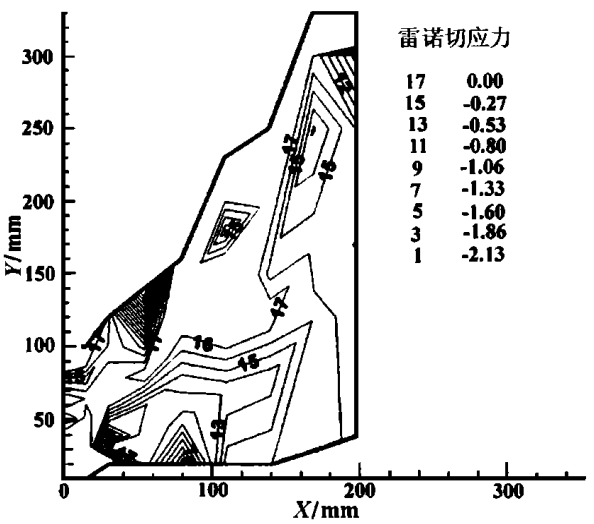

图 12 同心反切 $u'w'$ 雷诺切应力图

4 结论

与同心同向燃烧技术相比, 同心反切燃烧技术有以下的气固两相流动特性: 主颗粒流在炉膛主旋流区内强烈混合, 一次风射流与向火侧来流有强烈的质量交换, 背火侧颗粒少, 并且混合弱。这保证了同心反切燃烧技术在稳燃、低 NO x 排放、防结渣、防高温腐蚀等方面具有优良的性能。

参考文献

〔1〕 谢幼铭. 同心反切圆燃烧器设计和运行实绩. 锅炉技术, 1993, 9: 16~23.

〔2〕 吴生来. 电站锅炉四角切圆燃烧技术刍议. 中国电力, 1999, 32(1): 15~21.

〔3〕 李之光. 相似与模化. 北京: 机械工业出版社, 1983.

(复 编辑)

反切配风对大容量锅炉内流场特性影响的研究＝**The Effect of an Reverse Tangential Air Distribution on the Flow Field Characteristics in a Large-sized Boiler Furnace**[刊, 汉] Zhou Qulan, Dou Wenyu, Zhou Yuegui, et al (Xi' an Jiaotong University) //Journal of Engineering for Thermal Energy & Power. —2000, 15(2). —116 ~118

The in-furnace flow-field characteristics of a large-sized boiler were studied by way of experimental measurements and numerical simulation. The results of the experimental measurements fully agree with those of numerical simulation. In addition, in both cases the same conclusions have been reached. They are: 1. There exists at the furnace outlet of a large-sized boiler a speed excursion caused by a residual rotation; 2. There is a wall attachment tendency in the actual tangential circle at the burner zone of the large-sized boiler; and 3. The reverse tangential air-distribution mode can effectively reduce the level of rotating momentum flow rate moment in the furnace, and markedly weaken the residual rotation at the furnace outlet. **Key words**: boiler, secondary-air reverse-tangential circle, model test, numerical simulation

齿轮结构参数和误差对某动力装置主齿轮传动振动的影响＝**The effect of Gear Structural Parameters and Errors on the Main Gear Transmission Vibrations of a Marine Propulsion Plant**[刊, 汉] /Shi Huamin (Naval Engineering Academy) //Journal of Engineering for Thermal Energy & Power. —2000, 15(2). —119 ~ 121

Following the creation of a single-stage helical-gear transmission vibration model set up was a dynamics model for the main-gear transmission vibrations of a marine propulsion plant. A modal analysis method was employed to solve for the model. Analyzed and discussed was the effect of the structural parameters and errors on the main gear transmission vibrations. In addition, some pertinent conclusions were also obtained. **Key words**: gear transmission, vibration

同心反切燃烧方式的气固两相流动特性实验研究＝**An Experimental Study of the Gas-solid Duel-phase Flow Characteristics of the Reverse Tangential Firing System(CFS-II)**[刊, 汉] /Wang Chungang, Zhu Qunyi, Li Zhengqi (Harbin Institute of Technology) //Journal of Engineering for Thermal Energy & Power, 2000, 15 (2). —122 ~ 124

Low-quality coal-fired boilers operating in a tangential firing mode often suffer from such problems as a deteriorating flame stabilization and water wall high-temperature corrosion. With respect to the above-cited issues an experimental study was conducted of the gas-solid dual-phase flow characteristics of the Tangential firing system (CFS-I) and the reverse tangenfial firing system (CFS-II) with the help of PDA (particle dynamic analyzer) system. The study results show that as compared to the CFS-I system the CFS-II system enjoys a better performance as regards the flame stabilization, low NO_x emissions, heating-surface slagging and high-temperature corrosion. **Key words**: tangential firing system, reverse tangential firing system, gas-solid flow characteristics, particle dynamic analyzer

切圆燃烧流场中不同高宽比矩形喷嘴射流特性的试验研究＝**Experimental Study of Jet Characteristics of a Rectangular Nozzle with Different Height-to-width Ratios in a Tangentially-fired Combustion Flow Field**[刊, 汉] /Zhang Ze, Wu Shaohua, Yao Zheng, et al (Harbin Institute of Technology), Li Min (Harbin Power Plant Equipment Group Corp.) //Journal of Engineering for Thermal Energy & Power. —2000, 15(2). —125 ~ 127

With the help of a hot wire anemometer a detailed experimental study was performed of the rigidity and turbulence characteristics of the jet flow of a primary-air rectangular nozzle with different height-to-width ratios in a tangentially-fired combustion flow field. Furthermore, the deflection and stable combustion mechanism of the rectangular nozzle jet flow under different height-to-width ratios is also analyzed. As a result, obtained was the optimum height-to-width ratio of the rectangular nozzle in the tangentially-fired combustion flow field. The study results may serve as helpful reference data for engineering design and general applications. **Key words**: tangentially-fired furnace, jet characteristics, height-to-width ratio, experimental study, hot wire anemometer