

# 煤粉气流强迫点火特性试验研究

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**摘 要:** 在一座小型煤粉燃烧试验台上, 对不同条件下, 两种煤粉气流的强迫点火特性进行了试验研究。结果表明, 用火炬引燃煤粉气流, 存在一个对应于最低煤粉浓度的最佳点燃速度; 煤粉气流的着火界限主要受初始温度、点火源温度、煤种和煤粉细度的影响; 提高煤粉气流的初始温度、点火源温度和煤粉细度均可使着火范围变宽, 挥发份含量高的煤种点火容易。在相同条件下, 直流煤粉气流比旋转煤粉气流容易点燃。

**关 键 词:** 煤粉气流; 点火; 着火界限

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## 1 引言

尽管各种燃烧设备的特点不尽相同, 但它们都有一个共同的要求, 即迅速而稳定地将燃料点燃。对于煤粉气流, 不论是直接点火, 还是间接点火, 都可归结为利用火焰火炬的强迫点火问题, 其实质就是点火源为一股高温气体射流(例如燃烧产物射流)。因此, 研究煤粉气流的火炬点火规律, 对于燃烧室和预燃室点火参数的选择以及点火枪的设计, 都有重要的指导意义。为此, 在一座小型煤粉燃烧试验台上, 用氧—乙炔火炬作为点火源, 对煤粉气流的火炬点火特性进行了试验研究, 重点考察了煤粉气流初始温度、点火源温度、点火方式、煤种以及煤粉细度等因素对着火界限的影响。

## 2 试验系统和试验方法

### 2.1 试验装置

试验装置如图 1 所示, 本系统主要包括试验台本体、供粉系统、热风系统、点火系统和测量系统。煤粉斗中的煤粉由绞龙输送至风粉混合器, 供粉量

由调速电机控制供粉绞龙的转速加以调节。压缩空气经电加热器加热后, 在风粉混合器内引射从输粉绞龙落下的煤粉并与其混合, 然后由旋流器喷入点火室中被高温氧—乙炔火炬点燃。为便于直接观察点火过程, 点火室由一个长 1 300 mm, 内径 100 mm, 壁厚 4 mm 的透明石英管所做成。

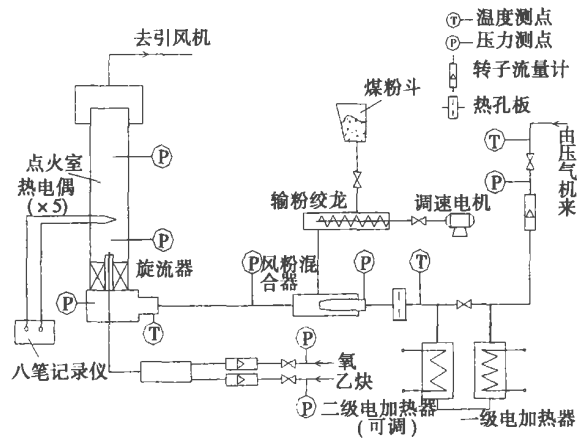


图 1 试验装置系统图

空气电加热器分为两级, 额定加热功率各为 25 kW, 其中第二级由一个调压器控制其加热功率的大小, 以调节热风的温度。为便于点燃煤粉气流, 氧—乙炔火炬为富燃料燃烧所形成的扩散火焰, 点火源温度用双铂铑热电偶测量, 点火室内部的温度和压力分别用铠装热电偶和 U 型管差压计测定。为提高温度测量的准确性, 各支热电偶的结点均裸露, 使其对温度的变化更加敏感, 各点温度的变化用一台 XWT-864 型八笔记录仪自动记录。

本装置可进行变工况试验, 研究各种点火条件下煤粉气流的火炬点火规律。试验煤种为南京下关电厂燃用的劣质烟煤和福建加福无烟煤, 其有关参

数见表 1。

表 1 试样的工业分析和细度

煤 种	Wad ( $\times 10^2$ )	Aad ( $\times 10^2$ )	Vad ( $\times 10^2$ )	Cad ( $\times 10^2$ )	$Q_{ad}$ $\text{kJ} \cdot \text{kg}^{-1}$	$R_{90}$ ( $\times 10^2$ )
加福无烟煤	2.0	24.13	3.58	70.29	22 920	9.95
南京下关电厂烟煤	1.25	22.95	40.96	34.84	17 050	28.14

## 2.2 试验方法

试验时,先用电子点火枪点燃氧—乙炔混合气体,然后保持点火源工况不变,在给定的煤粉气流初始温度和流速条件下,调节供粉量直到煤粉气流被火炬点燃为止。煤粉气流一旦着火,八笔记录仪上的温度曲线便会向上突跃,同时观察点火室内火焰的变化即可判断点火是否成功。

## 3 试验结果与分析

### 3.1 煤粉气流初始温度的影响

图 2 给出了下关电厂烟煤采用直流点火方式时,不同初始气流温度条件下的着火界限。由此可见,在一定的工况条件下,煤粉气流速度存在一个最佳值,在该流速下,较低的煤粉浓度便可使点火成功。提高煤粉气流初始温度  $T_0$  对着火界限有两方面的影响:

(1) 着火界限的范围变宽,即着火界限左移。这是因为提高煤粉气流初始温度,点燃时所需的着火热量大为减少,因而有利于点火。换句话说,如果着火热保持不变,则允许煤粉气流在更低的煤粉浓度下被点燃,因此其点燃范围变宽。

(2) 对应于最低煤粉浓度的最佳煤粉气流点燃速度变大。这是因为煤粉气流同点火源之间的湍流热质交换对煤粉气流的着火界限起着决定性的作用,而湍流热质交换系数  $A$  与煤粉气流的密度  $\rho$  和速度  $V$  成正比,  $T_0$  提高会使得  $\rho$  减小,从而造成  $A$  下降,不利于点火,此时为了保持  $A$  的数值不变,就必须增加煤粉气流的实际速度  $V$ ,因而使得整个着火界限上移,最佳煤粉气流点燃速度也随之增大。

从图 2 还可以发现,提高煤粉气流初始温度  $T_0$ ,使得整个着火界限向左上方移动,这是由于上述两个因素综合作用所致。

### 3.2 点火源温度的影响

图 3 给出了不同点火源温度下下关电厂烟煤的着火界限。由此可以看出,提高点火源温度对煤粉气流的点火极为有利,这一点不难理解。

### 3.3 煤粉细度的影响

图 4 对两种不同平均粒径的下关电厂烟煤煤粉气流的着火界限进行了比较。从图中可以看出,提高煤粉细度可使煤粉气流的着火范围变宽,这是因为煤粉气流的着火温度随着煤粉细度的提高会明显下降。

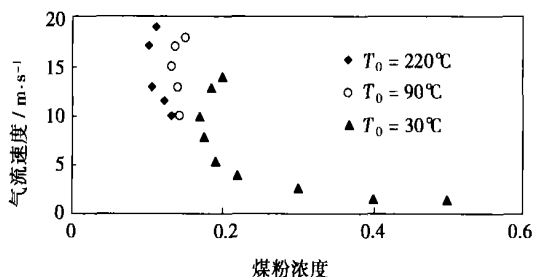


图 2 初始气流温度对着火界限的影响

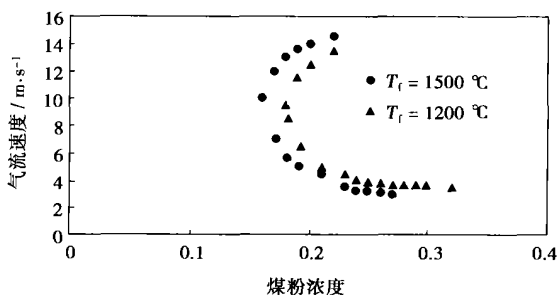


图 3 点火源温度对着火界限的影响

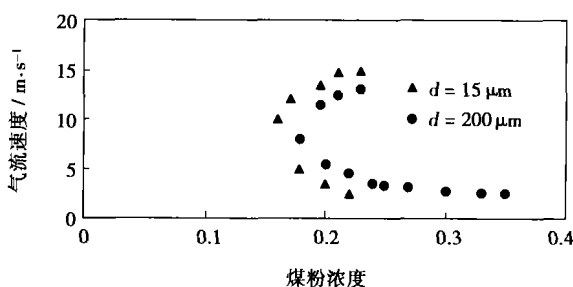


图 4 煤粉细度对着火界限的影响

### 3.4 煤种的影响

对福建加福无烟煤和南京下关电厂烟煤两种煤粉气流的点火试验发现,下关电厂烟煤煤粉气流在初始温度为  $220^\circ\text{C}$ ,甚至在常温下即可被点燃,而加福无烟煤粉气流直到初始温度达到  $315^\circ\text{C}$ 时才可能被点燃,低于此温度均不能被点燃,即使在这样高的初始温度下,也只是局部着火,而且与下关电厂烟煤煤

粉气流相比,着火区域要小得多,见图 5。这是由于前者的挥发份含量较后者小得多,因而着火温度较高,所需的着火热也较大,着火区域自然变小。

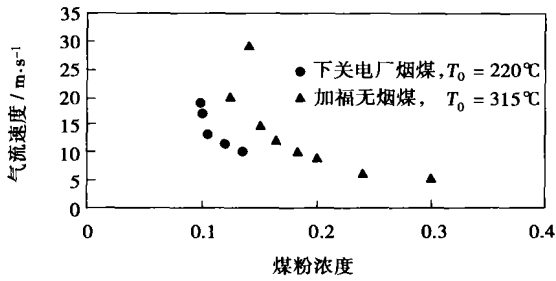


图 5 煤种对着火界限的影响

### 3.5 旋流点火与直流点火的比较

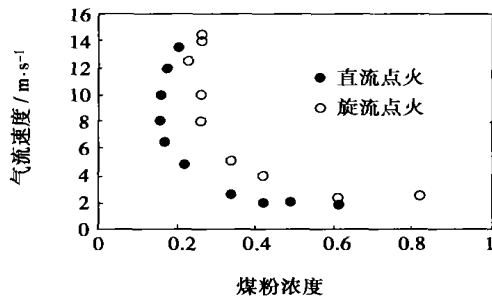


图 6 点火方式对着火界限的影响

对直流( $\alpha=0^\circ$ )和旋流( $\alpha=30^\circ$ )两种点火特性进行了试验研究,结果见图 6。由图可见,直流点火比

旋流点火容易。这是因为旋流点火时,煤粉气流具有一定的周向和径向速度,大量的煤粉被甩至点火室内壁而旋转上升,从而造成点火室中煤粉分布不均匀,点火源火炬附近混合区内的煤粉浓度大幅度降低,对着火极为不利。因此,在工况条件相同的情况下,与直流煤粉气流相比,旋转煤粉气流必须在较高的平均煤粉浓度下才能被点燃,即着火范围变窄。

## 4 结 论

(1) 用火炬引燃煤粉气流时,存在一个对应于最低煤粉浓度的最佳点燃速度,其值随煤粉气流初始温度的升高而增加;

(2) 提高煤粉气流的初始温度和点火源温度,提高煤粉细度,均可使着火范围变宽;

(3) 不同煤种,其点火特性也有所区别,挥发份含量越高,对点火越有利;

(4) 在相同的工况条件下,旋转煤粉气流比直流煤粉气流难以点火。

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的不均匀度变小。

(2) 回流区的形状受湿度影响不大,回流区的扩张角,回流区的最大直径以及回流区最大直径截面的位置变化不大,但在回流区中回流速度随着湿度的增大而减小,回流区长度有所缩小。加湿燃烧将有利于燃烧室轴向尺寸的缩短。

(3) 随着湿度的增加,燃烧区的温度以及 O 原子浓度降低,导致 NO 浓度的显著降低。

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abatic combustion.

煤粉气流强迫点火特性试验研究= **Experimental Investigation of the Characteristics of Forced Ignition by Pulverized Coal-air Flows** [刊, 汉] / GU Zhong-zhu (Power Engineering Institute under the Nanjing Normal University, Nanjing, China, Post Code: 210042), WANG Zhi-bin (Jiangsu Provincial Electric Power Design Institute, Nanjing, China, Post Code: 210092), ZHANG Yong-lian (Education Ministry Key Laboratory of Clean Coal Combustion and Power Generation Technology under the Southeastern University, Nanjing, China, Post Code: 210096) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(4). — 389 ~ 391.

On a small-sized combustion test rig for pulverized coal an experimental investigation was performed of the forced ignition characteristics of two types of pulverized coal-air flow under different conditions. The results of the investigation indicate that in case of igniting pulverized coal-air flows by torches there exists an optimum ignition speed corresponding to the minimum concentration of the pulverized coal. The pulverized coal-air flow ignition limit is mainly influenced by such parameters as initial temperature, ignition source temperature, coal rank and the fineness of the pulverized coal. The enhancement of the initial temperature of the pulverized coal-air flow, the ignition source temperature and the fineness of the pulverized coal can all widen the range of ignition. It is relatively easy to ignite coal with a high volatile content. Under the same conditions it is easier to ignite a straight pulverized coal-air flow than a swirling one. **Key words:** pulverized coal-air flow, ignition, ignition limit.

燃油烟管蒸汽锅炉热力设计优化数学模型的研究= **A Study of a Mathematical Model of Optimized Thermodynamic Design for an Oil-fired Smoke-tube Steam Boiler** [刊, 汉] / SONG Zheng-chang, GAO Jian-kang (College of Electro-mechanical Engineering under the China University of Mining Engineering, Xuzhou, China, Post Code: 211672) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(4). — 392 ~ 394, 432.

To optimize the thermodynamic design of an oil-fired smoke-tube steam boiler, optimized independent variables, relevant variables and objective functions were analyzed and determined on the basis of a thermal equipment optimization theory. In connection with a thermodynamic design process the intermediate variables in the objective functions were solved. The constraint conditions of optimization were determined and a complete mathematical model of optimization was set up. Furthermore, a computer program was prepared to solve the mathematical model. The results of optimization of a typical oil-fired smoke-tube boiler indicate that the optimization model and the computer program for mathematical solution are effective and practical for engineering applications. **Key words:** oil-fired boiler, thermodynamic design optimization, mathematical model, computer program.

湿法烟气脱硫系统中 ALS 式氧化装置性能的试验研究= **Experimental Study of the Performance of a ALS (Air Lance Assembly) Type Oxidation Device Used in a Wet Flue Gas Desulfurization System** [刊, 汉] / ZHU Qun-yi, QIAN Lin-feng, DU Qian, et al (College of Energy Science & Engineering under the Harbin Institute of Technology, Harbin, China, Post Code: 150001) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(4). — 395 ~ 397.

An oxidation device composed of an agitator and air lance assembly (ALS) and installed in a wet flue-gas desulfurization system underwent a simulation by using an aeration type of stirring reactor. An experimental study was conducted of the influence on oxidation performance of the ALS type oxidation device exercised by such factors as the hole opening direction and hole diameter (0.5 - 1.5 mm) of a sparger, stirring speed (150 - 350 r/min), apparent air velocity ( $0.8 \times 10^3 \sim 5 \times 10^3$  m/s), etc. The results of the study indicate that the hole opening direction and the hole diameter of the sparger has a relatively small influence on the oxidation rate. With an increase in stirring speed and the apparent air velocity there will be an increase in oxidation speed. However, when the apparent air speed increased to a certain value, the oxidation rate increase tends to slow down. A theoretical analysis and calculation was conducted by using a two-film model. The calculation results are in relatively good agreement with test results. **Key words:** oxidation device of the air lance assembly type, oxidation performance.