文章编号: 1001－2060(2006)04－0383－04

多孔介质内往复流动超绝热燃烧的简化解

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摘　要: 通过与稳态的逆流燃烧器类比, 得到了一个简化的理论解, 并与实验结果进行了对比。该解适用于绝热的惰性多孔介质内往复流动下的超绝热燃烧。简化的理论解包括两个常微分方程, 方程中包含所有的控制参数, 因此有助于深入理解这些控制参数对燃烧器的影响。与数值模拟的结果相比, 多孔介质固体的温度曲线可以用简化解的分段线性函数很好的估算, 利用简化的理论解求得的燃烧器内温度的最大值与实验值取得了相同的趋势, 但是通常比实验值大, 二者的误差大约是 20%。

关　键　词: 理论解; 超绝热燃烧; 多孔介质; 往复
中图分类号: TK16　　文献标识码: A

1　引　言

近年来, 能够实现自我内部热回流的预混合往复式多孔介质燃烧器, 由于其不仅能够在不需外加热源的情况下处理低热值的废气, 而且可以回收部分热量且具有可控的污染物排放, 正受到越来越广泛的研究和关注。基于上述燃烧器的优良特性, 随着计算机的发展, 研究者应用完整的数值模型对往复式燃烧器进行了深入的研究。而模拟瞬时和准稳态平衡的往复式燃烧器特性, 需要选择合适的半周期、初始预热温度和燃烧器长度等等, 因此即使是应用了简单燃烧模型, 计算时间也相当可观, 因为系统达到准稳态平衡, 当填充床为惰性多孔介质时, 需要往复 20 多个周期, 而应用在化工领域的催化燃烧器, 甚至需要 200 个以上的周期[1]。

因此, 为了简化模型, Boreskov and Martos 等人提出了高切换频率的简化模型[2]; Nieken 等人分析了往复半周期为无限大和无限小的两种极限情况[3]。通过简化一个准稳态平衡模型, 得到了一个与重要的控制参数相关联的简化的表达式。模型可以预测燃烧区域的最大温度, 以及燃烧器两侧的温度梯度; Marco Cittadini 等人在文献的基础上, 通过进一步简化推导, 可以预测燃烧器的最小长度、最大半周期、最大和最小的气流入口速度等等[1]。以上模型都是以化工领域的往复式催化燃烧器为基础进行的研究。而作为预混合往复式超绝热燃烧的惰性多孔介质燃烧器简化解的研究, 目前见到的报道很少。

本文通过往复式惰性多孔介质燃烧器与稳态逆流燃烧器的类比, 推导适合于燃料为单一预混合的、填充床为材料单一的惰性多孔介质的燃烧器, 在达到准稳态平衡时的简化理论解, 并应用理论解推导的分段线性函数来构建燃烧器内多孔介质固体的温度曲线, 最后讨论工况参数对固体温度最大值的影响。

2　简化理论解的建立

图 1 为逆向反应器示意图。与往复式惰性多孔介质燃烧器相比, 前者的燃烧器中的多孔介质是催化剂, 不仅参与了热量的蓄积和释放过程, 而且参与了化学反应, 而后者是惰性的, 只进行热量的传递; 其次, 前者新鲜混合气气流分为两股, 等量永久地同时分别从两端流入, 每一端的预热都是通过另一端的尾气, 借助于多孔介质固体来完成的。而后者的预热是通过上半个周期气体蓄积在燃烧器出口的热量来进行的, 因此, 在往复式惰性多孔介质燃烧器气流方向的快速翻转的极限情况下, 由于固体的热容很大, 在每个半周期内, 固体温度几乎不变, 只是气体温度在固相温度线的上下周期变化。因此, 这两类燃烧器的结构和温度分布非常类似, 图 2 中 T_1 与 T_s、T_2 与 T_s 分别相当于往复式惰性多孔燃烧器系统在达到准稳态平衡时, 正向(从左到右)和逆向流动半周期结束时的气体与多孔介质固体的温度曲线, 因此, 通过二者的类比, 可以推导出后者的简化理论解。

收稿日期: 2005－09－06;　修订日期: 2006－03－10
基金项目: 国家自然科学基金资助项目(50076005　50476073)
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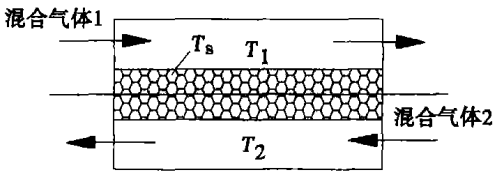

图 1 逆向反应器示意图

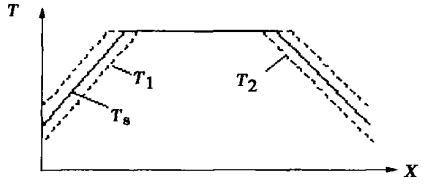

图 2 逆向反应器多孔介质固体、气体温度

多孔介质能量守恒方程:

$$(1-\varepsilon)\lambda_{se}\frac{d^2T_s}{dx^2}+\frac{1}{2}h_p(T_{g1}-T_s)+\frac{1}{2}h_p(T_{g2}-T_s)=0 \quad (1)$$

其中: ε—孔隙率; λ_{se}—包括导热、辐射在内的多孔介质固体有效导热系数; h_p—气固两相间的对流换热系数。

混合气 1 和 2 能量守恒方程:

$$-\varepsilon\rho_g u_g c_g\frac{dT_{g1}}{dx}+\varepsilon\lambda_g\frac{d^2T_{g1}}{dx^2}-h_p(T_{g1}-T_S)+h_0\varepsilon\gamma W_{g1}=0 \quad (2)$$

$$\varepsilon\rho_g u_g c_g\frac{dT_{g2}}{dx}+\varepsilon\lambda_g\frac{d^2T_{g2}}{dx^2}-h_p(T_{g2}-T_S)+h_0\varepsilon\gamma W_{g2}=0 \quad (3)$$

式中: λ_g—气体的导热系数; h_0—甲烷低热值; γ—反应物中甲烷的质量分数; W_{g1}—混合气体 1 反应物消耗速度; W_{g2}—混合气体 2 反应物消耗速率。

混合气体 1 和 2 组分守恒方程:

$$-\rho_g u_g\frac{dY_{g1}}{dx}+D\frac{d^2Y_{g1}}{dx^2}+W_{g1}=0 \quad (4)$$

$$\rho_g u_g\frac{dY_{g2}}{dx}+D\frac{d^2Y_{g2}}{dx^2}+W_{g2}=0 \quad (5)$$

假设燃烧反应是一级反应, 反应物消耗速率(气体混合物看作由反应物、生成物组成)为:

$$W_{g1}=\rho_{g1}Y_{g1}Ke^{-E/(RT_{g1})} \quad (6)$$

$$W_{g2}=\rho_{g2}Y_{g2}Ke^{-E/(RT_{g2})} \quad (7)$$

式中: E—甲烷活化能; R—气体通用常数; K—指数前因子。

式(1)~式(7)构成了逆流反应器的计算模型。为了使问题简化, 做下列假设:

(1)气体、固体的物性参数均为常数;

(2)忽略气体组分扩散, 即忽略式(4)和式(5)中的二阶项;

(3)与固体相比, 气体的导热系数很小, 忽略混合气体的导热项, 即忽略式(2)和式(3)中的二阶项。

式(1)~式(3)相加, 同时式(2)和式(3)相减后对其求导, 分别得到式(8)和式(9):

$$2(1-\varepsilon)\lambda_{se}\frac{d^2T_S}{dx^2}+\varepsilon\rho_g u_g c_g\left(\frac{dT_{g2}}{dx}-\frac{dT_{g1}}{dx}\right)+h_0\varepsilon\gamma(W_{g1}+W_{g2})=0 \quad (8)$$

$$\varepsilon\rho_g u_g c_g\left(\frac{dT_{g2}}{dx}-\frac{dT_{g1}}{dx}\right)-\frac{h_0\gamma\rho_g u_g c_g\varepsilon^2}{h_p}(W_{g2}-W_{g1})'=\frac{(\varepsilon\rho_g u_g c_g)^2}{h_p}\left(\frac{d^2T_{g2}}{dx^2}+\frac{d^2T_{g1}}{d^2x}\right) \quad (9)$$

取近似值:

$$T_S=(T_{g1}+T_{g2})/2 \quad (10)$$

将式(10)带入式(9)中, 得:

$$2\lambda_{eff}\frac{d^2T_S}{dx^2}+\frac{h_0\gamma\rho_g u_g c_g\varepsilon^2(W_{g2}-W_{g1})'}{h_p}+h_0\gamma\varepsilon(W_{g2}+W_{g1})=0 \quad (11)$$

其中:

$$\lambda_{eff}=(1-\varepsilon)\lambda_{se}+\frac{(\varepsilon\rho_g u_g c_g)^2}{h_p} \quad (12)$$

$$(W_{g2}-W_{g1})'=-\rho_g u_g\left(\frac{dY_{g2}}{dx}+\frac{dY_{g1}}{dx}\right)' \quad (13)$$

$$(W_{g2}+W_{g1})=-\rho_g u_g\left(\frac{dY_{g2}}{dx}-\frac{dY_{g1}}{dx}\right) \quad (14)$$

式(13)和式(14)带入式(11)中, 并积分:

$$2\lambda_{eff}\frac{dT_S}{dx}-h_0\gamma\varepsilon\rho_g u_g(Y_{g2}-Y_{g1})=[h_0\gamma c_g(\varepsilon\rho_g u_g)^2\left(\frac{dY_{g2}}{dx}+\frac{dY_{g1}}{dx}\right)]/h_p \quad (15)$$

因为燃烧器完全对称, 为了推导多孔介质固体温度的最大值, 下面的推导只考虑燃烧器的前半部分($0\leqslant x\leqslant L/2$)。假设混合气体 2 从末端($x=L$)到达对称点时已完全反应, 即对 $0\leqslant x\leqslant L/2$ 有: $\frac{dY_{g2}}{dx}=Y_{g2}=0$, 故式(15)简化为:

$$2\lambda_{eff}\frac{dT_S}{dx}+h_0\gamma\varepsilon\rho_g u_g Y_{g1}=\left[h_0\gamma c_g(\varepsilon\rho_g u_g)^2\frac{dY_{g1}}{dx}\right]/h_p \quad (16)$$

将式(4)带入式(16)中: $\frac{dT_S}{dx}=(F-Ge^{E/RT_S})$

$$\frac{dY_{g1}}{dx} \tag{17}$$

其中：$F=\frac{h_0\gamma c_g(\varepsilon\rho_g u_g)^2}{2\lambda_{eff}h_p}$；$G=-\frac{h_0\gamma\varepsilon\rho_g u_g^2}{2\lambda_{eff}K}$

式(4)忽略 Y_{g2}的扩散源进一步简化，得：

$$\frac{dY_{g1}}{dx}=\frac{K}{u_g}Y_{g1}e^{-E/(RT_g)} \tag{18}$$

热波的传播速度[1]：

$$\omega=\frac{c_g\rho_g u_g}{c_s\rho_s(1-\varepsilon)}\left(1-\frac{\Delta T_{ad}}{T_{max}-T_0}\right) \tag{19}$$

完整的模型已经简化为单一的准稳态平衡固体温度和组分的微分方程，式(17)和式(18)构成了简化解：仅由两个常微分方程组成，与完整数值模型比较，得到了很大的简化。而热波的传播速度可以根据式(19)确定，通过与式(17)和式(18)联合求解，就可以确定给定工况的解。

应用下列边界条件对式(17)分离变量[3]，从 $x=0$ 到 $x=L/2$ 积分：

反应器入口：

$$T\mid_{X=0}=T^0+\frac{\Delta T_{ad}}{2}\left(1-\frac{Y^e}{Y^0}\right)$$

$$Y_1\mid_{X=0}=Y^0=1,\ Y_2\mid_{X=0}=Y^e$$

燃烧器的中心(对称点)：

$$Y_1\mid_{X=L/2}=Y_2\mid_{X=L/2}$$

$$\int_{T_0+\frac{1}{2}\Delta T_{ad}}^{T_{max}}\frac{1}{Ge^{E/RT_s}-F}dT_s=Y_0-Y_e=Y_0=1 \tag{20}$$

用一个简单的迭代程序就可以得到 T_{max}。对于预热段，假设没有化学反应，由式(15)直接得到：

$$\frac{dT_S}{dx}=\frac{h_0\gamma\varepsilon\rho_g u_g Y_0}{2\lambda_{eff}} \tag{21}$$

3　简化理论解的应用

3.1　往复式多孔介质燃烧器内固体温度分布

图3为建立燃烧器内温度分布的示意图。简化解的温度曲线由分段线性函数构成：首先在入口预热段(Lph1)，由于假设没有化学反应，温度梯度由式(21)直接得到。中间段为高温区域(Lhz)：点火温度由文献[4]计算：

$$T_{ign}=\left[E/R\ln\left(\frac{Y_{CH4}H_0\rho_g K}{h_p T_{med}}\right)\right]-T_{med}$$

其中：$T_{med}=\Delta T_{ad}/\left(1+\frac{h_p\lambda_{eff}}{u_g^2 c_{pg}^2\rho_g^2}\right)$

式中：T_{ad}—甲烷混合气体的绝热温升；T_{med}—为了使点火温度表达式简洁的一个中间变量。

温度最大值由式(20)得到；最后为出口段(Lph2)，固体温度在出口的值 T_{out}由热波的移动来确定。如图3所示，将温度曲线在半周期内的演变，看作从半周期初始时刻起，温度曲线(虚线)以热波的速度均匀地向下游移动，半周期结束时，已演变为半周期末的固体的温度曲线(实线)，因此出口温度：

$$T_{out}=T_{so}-\omega T_{csp}dT_s/dx$$

式中：T_{so}—正向半周期开始时燃烧器入口的固体温度；T_{csp}—半周期。

作为简化解的计算实例，本文选用的往复式燃烧器长为200 mm，填充材料为惰性的5孔/cm的氧化铝泡沫陶瓷，孔隙率为0.875。应用简化模型求解时，气体混合物的物性参数是常数，选为绝热温度下对应的属性，气固两相对流换热系数取为0.65倍[5]。数值模拟是用CFD软件包FLUENT 6.1完成的，气体的属性是随温度和组分而变化的，这与简化解的设置是不同的，而固体的物性和其它的参数设置与简化解完全相同。燃气是甲烷与空气的均匀混合物，甲烷的燃烧假设为单步总体不可逆反应，反应速率和完整的数值模拟模型见文献[6](本文没有考虑弥散效应)。

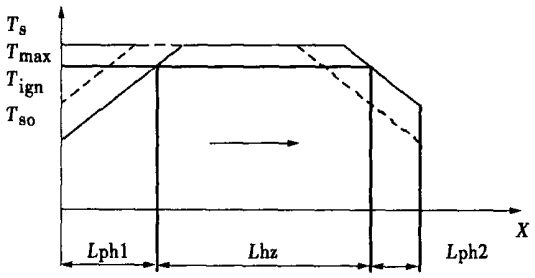

图3　建立半周期结束(实线)和开始时的温度曲线(虚线)

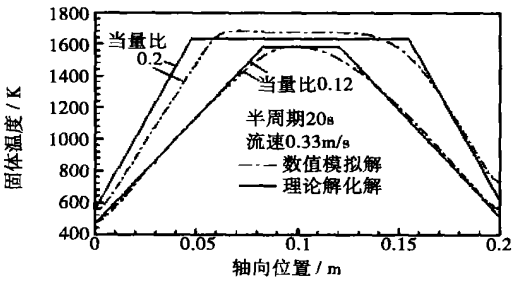

图4　简化理论解、数值模拟解温度比较图

图4为应用简化的理论解得到的温度分布曲线

与完整的数值模型解的比较，可以看出，理论解与数值模拟解吻合的很好。而入口处温度、理论解和数值模拟的结果都显示，当预混合气 $\phi = 0.12 \sim 0.2$，$u_g = 0.33$ m/s，固体温度入口值 $T_{so} = 1650 - T_{ign}$，该值是一个较好的估算值。

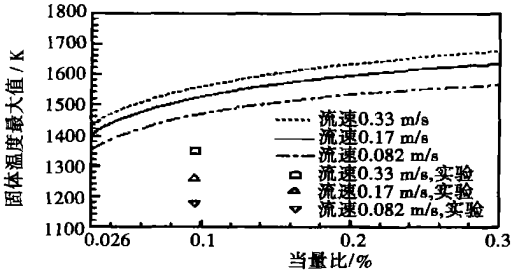

图 5 流速对多孔介质固体最大温度的影响

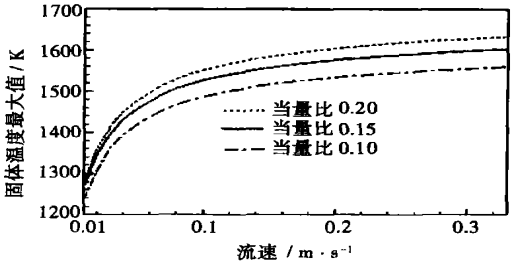

图 6 当量比对多孔介质固体最大温度的影响

3.2 工况参数对最高温度的影响

图 5 和图 6 为简化模型计算的流速和当量比对最高温度的影响。二者对最高温度的影响非常重要，因为过高的温度可能会超过多孔材料的热疲劳极限；另一方面过低的温度可能会导致熄火。与数值模拟的计算工作量相比，如可能会因为给定的流速或者当量比过小，前文所述，计算图 5 曲线中任一点工况的温度最大值，除了初始阶段的预热外，另外至少需要经过 20 个以上的周期，而且存在中途熄火，导致计算失败。应用简化解求解，只需要一个非常简单的迭代公式，计算几乎不需时间。应用简化理论解求解的流速与当量比对最高温度的影响，与实验和数值模拟的结果的趋势完全相同[4, 6~7]，但是与实验结果在定量上还存在一定的差异。这是因为在做理论解的推导时，做了很多假设，气体的物性、对流换热系数等采用了常数，而在实际的燃烧器中变化很大，同时没有考虑热损失；另外实验使用的天然气中甲烷占 88%[7]，与理论解的假设(100%甲烷)不符，这也可能是造成差异的一个原因。

4 结 论

通过类比的方法得到了适用于惰性多孔介质燃烧器的理论解：仅由两个普通的微分方程构成，与热波的移动速度公式相联合，应用分段线性函数，可以求解准稳态平衡下多孔介质燃烧器内的温度分布。同时，上述两个微分方程包括了燃烧器和工况的参数，因此，通过进一步的研究，可能会得到可燃极限、最大半周期等及其重要的燃烧器的控制参数，对于深入理解超绝热燃烧的形成机理和惰性多孔燃烧器的优化设计，有着非同寻常的意义。但是需要指出的是，简化理论解的组分微分方程与固体的温度相耦合，式(18)中固体温度值并非常数，需要作深入的研究，这也是作者将要研究的内容。

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(辉 编辑)

Based on the distribution function of pore lengths and in combination with such parameters as specific surface area and porosity etc. A pore diameter distribution model was established for the first time for CaO product generated in the process of limestone calcination. In conjunction with experimental results, a simulation study was conducted of CaO pore distribution characteristics and their continuously evolving process whenbeing subjected to the influence of sintering. In the course of the study, a section-by-section analysis has been made with emphasis on the pores with a diameter in the range of 0 ~ 50 Å, 50 ~ 200 Å and over 200 Å. The calculation results indicate that the contribution from the pores in three ranges of pore diameters (0 ~ 50 Å, 50 ~ 200 Å and over 200 Å) to specific surface areas in different calcination stages undergoes a continuous change. On this basis, a concept of optimum calcination rate is proposed, which will take place later with an increase in calcination temperature. **Key words**: limestone, CaO, calcination, pore diameter distribution, optimum calcination rate

添加 CaO 对煤粉燃烧后一次颗粒物特性影响的研究= **A Study of the Effect of CaO Addition on Primary Particle Characteristics after Pulverized Coal Combustion**[刊, 汉] /LU Jian-yi, LI Ding-kai (Education Ministry Key Laboratory on Thermal Sciences and Power Engineering under TSinghua University, Beijing, China, Post Code: 100084) // Journal of Engineering for Thermal Energy & Power. — 2006, 21(4). —373 ~ 377

A study is made of the effect of CaO addition (3wt%) to pulverized coal on primary particle characteristics after combustion. With a sedimentation furnace serving as a combustion device under an oxidizing atmosphere and combustion temperature of 1 100 ℃, sample particles after combustion were separated and collected by use of a 8-stage Anderson particle impactor. As seen from the distribution of particle diameters, the addition of CaO to the pulverized coal can reduce the relative amount of fine particles among the primary particles. When Rosin-Rammler distribution function is used to conduct fitting with a particle diameter distribution curve, a very good fitting character has been obtained. As viewed from the emission characteristics, the addition of CaO has reduced the emissions of PM_{10}, $PM_{2.5}$ and PM_1. The SEM image also shows that the particles produced after an addition of CaO contain particle aggregates as a result of merging and clustering. The results of ICP-AES analysis indicate that the content of such heavy metals as Cr, Cu, Ni, Pb and Zn has increased with a decrease in particle diameters. Moreover, when pulverized coal is burned after an addition of CaO, the content of heavy metal elements in the particles has been somewhat reduced. **Key words**: pulverized coal combustion, particle, emission characteristics, heavy metal, additive

大型褐煤锅炉煤粉再燃技术的数值模拟= **Numerical Simulation of Pulverized-coal Reburning Technology for a Large-sized Lignite-fired Boiler**[刊, 汉] /TANG Hao, ZHONG Bei-jing, FU Wei-biao (Aeronautics and Astronautics College under Tsing University, Beijing, China, Post Code: 100084), QIU Peng-hua (Energy Source Science and Engineering College under Harbin Institute of Technology, Harbin, China, Post Code: 150001) // Journal of Engineering for Thermal Energy & Power. — 2006, 21(4). —378 ~ 382

A numerical simulation was conducted of the different combustion air-supply modes for reburning super-fine pulverized coal in an integral furnace of Yuanbaoshan Power Plant No. 3 Boiler on the basis of a dynamic model featuring coal tar NO reduction reaction and by using software Fluent. The numerical simulation results show that a variety of factors, such as the proportion of fuels being reburned, air-coal ratio in the combustion air for reburning and the size of the reburning zone etc. can exercise a major influence on combustion efficiency and NO_x emissions. An optimization calculation has revealed that when the excess air factor in the main combustion zone is controlled at 1.1, a scheme with the following characteristics, namely, the fuel being reburned accounting for 15% of the total fuel amount, coal-air ratio in the combustion air for reburning being set at 2 and the residence time of the flue gas in the reburning zone being about 0.5 s, may be considered as a comparatively well organized mode for reburning. **Key words**: pulverized coal, reburning, numerical simulation

多孔介质内往复流动超绝热燃烧的简化解= **A Simplified Solution for the Super-adiabatic Combustion of Reciprocal Flows in Porous Media**[刊, 汉] /SHI Jun-rui, XIE Mao-zhao (Energy Source and Power Engineering College under Dalian University of Science and Technology, Dalian, China, Post Code: 116024) // Journal of Engineering for Thermal Energy & Power. — 2006, 21(4). —383 ~ 386

A simplified theoretical solution has been obtained through an analogy with stable-state reversed-flow burners followedby a comparison with experimental results. Such a solution is applicable to super-adiabatic combustion in adiabatic inertial po-

rous media under the condition of reciprocal flows. The solution under discussion comprises two constant differential equations, in which all control parameters have been included, thus contributing to an in-depth understanding of the effect of these control parameters on the characteristics of burners. Compared with the results of a numerical simulation, the temperature curves of porous-medium solids can be predicted exceedingly well by use of sectioned linear functions of the simplified solution. The maximal temperatures inside the burners obtained by making use of the simplified theoretical solution exhibit an identical tendency as that of the experimental values. However, the above maximal temperatures are usually greater than the experimental ones with the error between them being assessed at about 20%. **Key words**: theoretical solution, super-adiabatic combustion, porous medium, reciprocating

一种天然焦燃烧特性的试验研究＝**An Experimental Study on the Combustion Characteristics of a Kind of Natural Coke**[刊, 汉] /DONG Yong, WANG Chun-bing, WANG Wen-long, et al (Energy Source and Environment Research Institute Affiliated to Energy Source and Power Engineering College under the Shandong University, Jinan, China, Post Code: 250061) //Journal of Engineering for Thermal Energy &Power. —2006, 21(4). —387～390

Natural coke is a kind of solid residue produced after coal has been heated and decomposed following its contact with magmatic rocks. It has been formed by destructive distillation after coal layers are subjected to heating and baked when magmatic rocks have intruded into coal layers or thereabouts. Natural coke is usually regarded as a kind of energy source difficult to be utilized. With a view to exploring new ways of comprehensive utilization of natural coke, an experimental study has been performed of such combustion characteristics as ignition and burn-up etc. of the natural coke and Jining-originated coal as well as a mixture of the two with the help of a thermogravimetry analytic method. The thermogravimetric test results show that the ignition temperature of natural coke is 876.3 K, regarded as the highest ignition temperature followed by a second highest specific to blended coals. Jining-originated coal is characterized by the lowest ignition temperature. The natural coke, however, has the shortest burn-up time, Jining-originated coal an intermediate one and the blended coals require the longest burn-up time. Summing up the experimental study and theoretical analysis, the authors conclude that natural coke-blended coal fuel can be used in power-plant boilers. The present research findings can provide a basis for employing natural coke as power plant fuels. **Key words**: natural coke, thermogravimetry, combustion characteristics, ignition, burn-up

燃煤飞灰粒度对比电阻影响机制的试验研究＝**An Experimental Study of the Mechanism Governing the Impact of the Size of Coal-fired Fly Ash Particle on Specific Resistance**[刊, 汉] /QI Li-qiang, YAN Wei-ping, YUAN Yong-tao (Environment Science and Engineering College under the North China University of Electric Power, Baoding, China, Post Code: 071003) //Journal of Engineering for Thermal Energy &Power. —2006, 21(4). —391～394

After the ash samples have been collected from three domestic power plants and fully incinerated in a high temperature furnace, they were sifted by employing a mechanical sifting method into four categories of particle diameters, i.e. ＞145 μm, 90～154 μm, 45～90 μm and ＜45 μm. On a self-developed DR type high-pressure dust specific-resistance test rig, the specific resistance of fly ash of various particle diameters were determined. The test results show that superficial and volumetric electric conduction will jointly affect the specific resistance of fly ash and, furthermore, fine particles have a higher porosity. As a result, the fly ash with relatively small particle diameters has a higher peak value of specific resistance Moreover, before the latter reaches its peak value, the more coarse the ash samples, the higher their specific resistance. After the specific resistance has reached its peak value, however, the governing rule will evolve in an exactly opposite way. **Key words**: fly ash, ash incineration, particle diameter, specific resistance

水煤浆热解过程中 HCN 和 NH_3 释放特性的分析＝**An Analysis of HCN and NH_3 Release Characteristics of Coal-water Slurry in its Pyrolysis Process**[刊, 汉] /MENG De-run, ZHAO Xiang, ZHOU Jun-hu, et al (Education Ministry Key Laboratory on the Clean Utilization of Energy Resources and Environmental Engineering under the Zhejiang University, Hangzhou, Zhejiang, China, Post Code: 310027) //Journal of Engineering for Thermal Energy &Power. —2006, 21(4). —394～396, 400

A pyrolysis test was performed of coal-water slurry and its raw coal in an inertial atmosphere and of its raw coal in a vapor atmosphere on a fixed bed reactor to study HCN and NH_3 release characteristics. The results show that with an increase in temperature the amount of HCN released from the raw coal and coal-water slurry changes slowly and finally tends to be constant. In the vapor atmosphere, however, the amount of HCN released from the raw coal will with a change in temper-