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燃煤飞灰粒度对比电阻影响机制的试验研究

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摘 要: 通过采集国内3家电厂的灰样, 在高温炉中全灰化后, 采用机械筛分法将其筛分为> 154 μm、90～154 μm、45～90 μm 和< 45 μm 4种粒度的灰样, 利用自主研发的DR型高压粉尘比电阻试验台测定各粒径飞灰的比电阻。结果发现, 由于表面导电和容积导电共同影响飞灰的比电阻, 并且细颗粒具有更高的孔隙率, 所以粒径较细的飞灰比电阻峰值较高, 且比电阻达到峰值以前, 灰样越粗则比电阻越高, 在比电阻达到峰值后, 则规律恰好相反。

关 键 词: 飞灰; 全灰化; 粒度; 比电阻

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1 引 言

飞灰的比电阻是电除尘器赖以设计、改进及运行的重要参数之一, 是提高除尘效率的重要依据。近年来, 随着国内外大型电除尘器的不断涌现, 人们对飞灰比电阻特性的认识在不断深入。但由于飞灰比电阻的变化受其颗粒的物化特性、烟气工况、煤种以及锅炉燃烧条件等一系列因素的影响, 加之受实验条件所限, 有许多问题需要进一步研究分析。

烟道飞灰的一个显著特点就是粒径分散度高, 亦即粒径分布域宽, 通常分布在几百微米至1 μm 以下(这里指动力径, 对于几何径分散域往往更宽)。因此有必要对飞灰粒度与比电阻的关系做深入研究。

2 灰样采集及处理

试验采集了东北A电厂、华北B电厂和西北C电厂3个样本灰样。

在实际的烟道飞灰中存在着含量不等的碳粒及 Fe_2O_3 和 Fe_3O_4, 文献[1]研究表明, 它们对飞灰比电阻的影响不尽相同, 较高的含碳量可使飞灰的比电阻下降, 而 Fe_3O_4 的比电阻比 Fe_2O_3 低约2～3个数量级, Fe_3O_4 含量在通常范围内变化, 可使飞灰的比电阻在一个数量级内产生波动。为了排除由于合碳量及铁含量的不同而造成的实验偏差, 单纯研究飞灰的粒度与比电阻两者之间的关系, 将飞灰进行了无碳化处理, 使灰中残余碳充分燃尽, 且使 Fe_3O_4 充分氧化为 Fe_2O_3, 从而降低它们对飞灰比电阻的影响。即将灰样置于马弗炉中, 在900～1 200 ℃的温度下恒烧1 h, 使灰样的含碳量降到1%以下。然后将其筛分为> 154 μm、90～154 μm、45～90 μm 和< 45 μm 4种粒度的灰样进行比电阻的测试, 为了减小实验偏差, 将这4种灰样同时装入比电阻测试箱内的4组互为高压并联电极盘中, 在相同工况下测试。

3 测试方法及设备仪器

比电阻的测定使用华北电力大学研发的DR型高压粉尘比电阻试验台[2], 该试验台采用升降式托盘电极, 其上、下电极的同心度、平行度具有可调节功能, 而且借助于灰盘升降装置, 可将灰样表面的压强精确地恒定于10 g/cm^2 的标准值, 从而有效地提高了测量精度。该电极的结构型式符合已被国际上广泛承认的“美国机械工程师协会(ASME)动力规范28标准”。

DR型高压粉尘比电阻试验台的硬件由主测控盘、辅测控盘、立式高温电极箱及直流高压电源设备4部件组成; 测量线路包括高电压调控、微电流检测和温度测控3个系统, 如图1和图2所示[3]。

如图1所示, 主测控台为一桌面屏式盘台。仪表屏上集中安装了除高电压(1 kV 以上)测量仪表外的全部测量、控制仪器仪表。本盘台可完成直流高压的调控、1 kV 以下电压信号的测量、10^{-10}～10^{-3} A 微电流信号的检测及0～300 ℃加热温度的测控。从安全考虑, 辅测控盘台专门用于1 kV 以上电压信号的测量。

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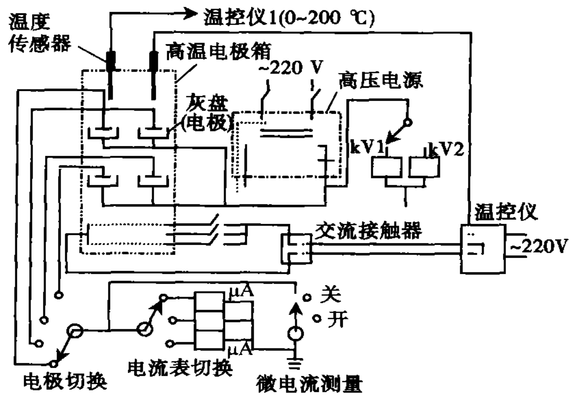

图 1　测量系统图

如图 2 所示,电极箱为立式布置,上下双体结构。箱内安装有升降式高压托盘电极及加热组件。直流高压输电线从电极箱顶端引入,经高压绝缘瓷瓶、中心吊管、底部高压绝缘子与可旋式高压母盘连接。母盘上对称安放有 4 个兼作高压端电极的升降式灰盘,电极组件的悬吊高度与悬吊角度均可调节。将装入灰样的灰盘安放在母盘的插孔上后,旋转母盘使灰盘平稳、准确地平移至相应的电极组件垂直下方,使两者保持同轴。然后调节母盘底部的旋丝,使相对应的灰盘缓慢上升,直至盘内灰样平面与上电极平行接触,进而将上电极轻轻托起。此时电极组件的额定重量恰好全部施加在灰样表面之上,使灰样表面的压强保持额定压强。采用这种机械式电极定位方法可以消除因安放过力,或因高低压电极平行度、同轴度偏差而引起的人为测量误差,使测量重现性明显提高。

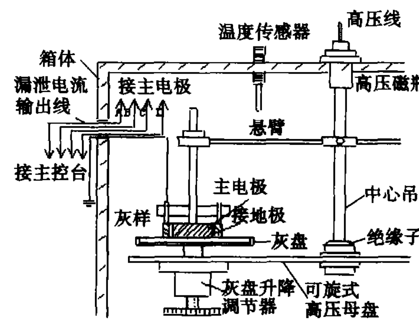

图 2　高温电极箱

4　试验结果及分析

试验数据如表 1 所示。

表 1　不同粒度飞灰温度 ~ 比电阻数据($\times 10^{10}$ Ω·cm)

	粒径 μm											
	＞154			90~154			45~90			＜45		
	A	B	C	A	B	C	A	B	C	A	B	C
20 ℃	0.27	0.16	0.3	0.25	0.14	0.28	0.27	0.22	0.23	0.21	0.20	0.12
50 ℃	0.07	0.05	0.12	0.07	0.04	0.31	0.05	0.03	0.11	0.04	0.03	0.08
100 ℃	8.8	0.38	8.6	3.5	0.49	36.0	2.8	2.1	7.6	6.0	5.9	18.0
120 ℃	5.1	1.4	49.0	15.0	3.0	100	27.0	5.2	97.0	29.0	16.0	96.0
130 ℃	7.0	2.6	67.0	21.0	4.2	160	38.0	7.2	210	49.0	23.0	330
140 ℃	5.2	1.7	525	14.0	3.6	140	36.0	5.8	180	44.0	18.0	310
160 ℃	1.6	0.63	28.0	4.7	1.5	69	16.0	2.8	130	34.0	9.2	280
180 ℃	0.46	0.29	9.6	1.6	0.58	35.0	8.4	1.5	85.0	26.0	4.8	210
200 ℃	0.12	0.12	5.8	0.45	0.26	16.0	3.3	0.61	62.0	21.0	2.7	180

由表 1 及图 3 ~ 图 5 可以看出,温度对飞灰比电阻来说是非常敏感的因素之一。在室温到 200 ℃之间出现两个极值点:40 ~ 50 ℃时为最低点;130 ~ 160 ℃时出现最高点。这是因为,当粉尘处于低温时,水份未完全失去,水分子均匀地分布于颗粒体内部,当温度上升时颗粒体内部的水份开始向外蒸发,在粒子表面形成一层液膜,这时粉尘表面比电阻大大下降,使其合成比电阻降至最低点。当温度继续上升时,水份随蒸发而减少,粉尘比电阻急剧上升,在 130 ~ 160 ℃之间,水份蒸发殆尽,比电阻达到最大值,当温度继续上升时,粉尘的容积导电增强,比电阻下降。

从表 1 中可明确地看出,对于任何一种飞灰,粒径不同则孔隙率、充填度和比表面积也不同。粒度小则堆积密度减小,从而孔隙率增大,表明空气/粒子容积比增大。单就这一点看,粒度减小使粒子的导电性能减弱,提高飞灰比电阻。所以,当温度从室温开始升高时,灰粒表面和内部的水份开始向外蒸发,但表面导电性仍然保持优势,因此在此温度段细灰的合成比电阻低于粗灰。当温度超过 100 ℃时,水份逐渐蒸发殆尽,表面导电特征逐渐消失,此时仅存在容积导电一种形式。而与此同时,颗粒表面被

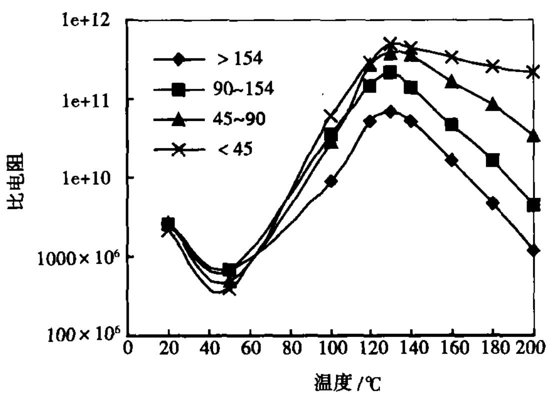

图 3　A 电厂不同粒径飞灰温度—比电阻曲线

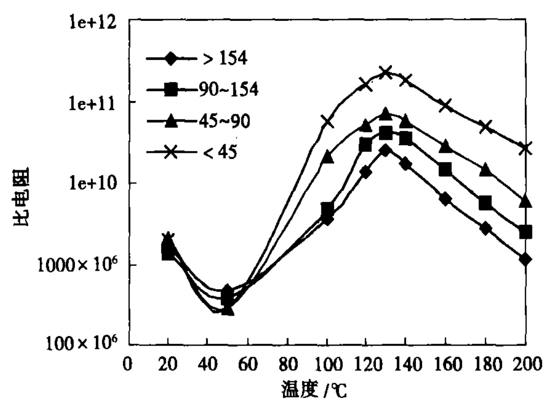

图 4　B 电厂不同粒径飞灰温度—比电阻曲线

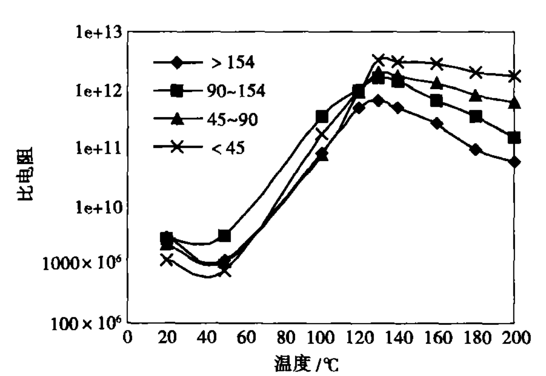

图 5　C 电厂不同粒径飞灰温度—比电阻曲线

一层气膜包围, 气膜不易电离, 而颗粒体内部更易电离为离子和电子导电, 并且, 粗颗粒由于体积较大, 相同距离内颗粒数较少。其间气膜的总厚度较薄, 即粗颗粒具有更低的孔隙率, 相对空气/粒子容积比小, 亦即充填率高, 故容积导电性能较之细灰更占优势, 更易导电。而细颗粒体积小, 相同距离内颗粒数多, 气膜总厚度较厚, 比电阻较大。所以, 在比电阻峰值后, 细颗粒比电阻比粗颗粒比电阻的下降趋势要缓, 即"温度~比电阻"曲线后半段的斜率细颗粒的要比粗颗粒小。

此外, 由表中数据可知, 粒径越细飞灰的峰值比电阻越高, >154 μm 粒径段与<45 μm 粒径段飞灰的峰值比电阻相差六倍以上。这主要因为, 当颗粒粒度小时, 其堆积密度减小, 从而孔隙率增大, 空气/粒子容积比增大, 使颗粒的导电性能减弱, 提高飞灰的比电阻。另外, 文献[4] 研究表明, 细灰中 Al_2O_3、CaO 和 MgO 等有助于提高飞灰的比电阻的化学成份含量较高, 这也导致了细颗粒飞灰比电阻的升高。

5　结　论

通过以上的试验结果及分析, 可以得出如下结论: 燃煤飞灰的粒度对比电阻有一定影响。在排除含碳量及含铁量等因素的影响后的灰样, 即全灰化灰在室温至比电阻达到峰值以前, 灰样越粗则比电阻越高, 在比电阻达到峰值后, 则规律恰好相反。粒径越细飞灰的峰值比电阻越高, >154 μm 粒径段与<45 μm 粒径段飞灰的峰值比电阻相差六倍以上。这主要是因为飞灰的比电阻受表面导电和容积导电共同影响, 并且粗颗粒由于体积较大, 具有更低的孔隙率。当温度从室温开始升高时, 灰粒表面和内部的水份开始向外蒸发, 但表面导电性仍然保持优势, 因此在此温度段细灰的合成比电阻低于粗灰。当温度超过 100 ℃时, 水份逐渐蒸发殆尽, 表面导电特征逐渐消失, 此时容积导电逐渐成为仅存的一种形式。而与此同时, 颗粒表面被一层气膜包围, 气膜不易电离, 而颗粒体内部更易电离为离子和电子导电, 故孔隙率较低的粗颗粒的容积导电性能较之细灰更占优势, 更易导电。所以, 在比电阻峰值后, 细颗粒比电阻比粗颗粒比电阻的下降趋势要缓, 即"温度~比电阻"曲线后半段的斜率细颗粒的要比粗颗粒小, 并且粒径较细的飞灰比电阻峰值较高。

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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-