鳍片分离式浓淡燃烧器的开发与应用

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〔摘要〕适当提高煤粉浓度,可改善燃烧稳定性。在试验研究的基础上,开发了一种通用、低阻、高效的鳍片分离式浓淡燃烧器,将煤粉浓度浓缩到着火距离的最佳值,提高了低负荷稳燃性能。本文结合该型燃烧器在山东电网的应用实绩,介绍了试验结果及设计要点。

关键词　锅炉　煤粉浓度　浓淡分离　燃烧器　开发应用
分类号　TK223.23　TK229.63

0　前言

煤粉浓淡燃烧是近几年发展起来的一种新的煤粉燃烧技术。这种燃烧技术研究与开发的关键是煤粉气流中煤粉颗粒的分离与浓缩。由于采取了不同的技术,国内出现了多种不同的高浓度煤粉燃烧器。通过大量的试验研究后,我们院研制开发了一种鳍片分离式煤粉浓淡燃烧器(发明专利号92106425.X),已应用于十几台锅炉的改造中。改造后提高了锅炉的低负荷稳燃能力,取得了较好的效果。

1　浓淡燃烧稳燃机理

1.1　煤粉浓度对着火的影响

国内外研究表明:提高煤粉浓度,可缩短着火距离。但是,如果煤粉浓度过高,则因一次风量太少,不足以使挥发分完全燃烧。导致颗粒温度降低,反而延迟着火。如果煤粉浓度过低,则因着火热增加,对着火不利。因此存在着一个最佳煤粉浓度值使着火距离最短。根据 Saka及徐明厚等人的试验研究认为[1]:对于挥发分较低的贫煤,最佳煤粉浓度在 0.7 – 1.0kg/kg左右。对于挥发分较高的烟煤,最佳煤粉浓度值约为 0.6– 0.8kg/kg。因此适当提高煤粉浓度可缩短着火距离(如图 1)。

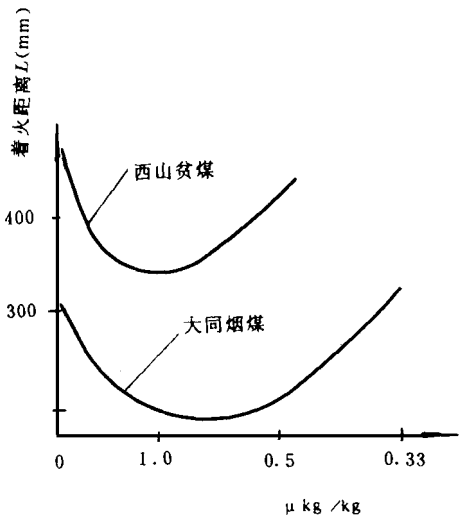

图 1　着火距离与煤粉浓度的关系

1.2　浓淡燃烧稳燃原理

一次风煤粉气流经过浓缩,在燃烧器喷口前形成高浓度煤粉气流,使浓煤粉气流处于向火侧,淡煤粉气流朝向背火侧。被浓缩后的煤粉气流可降低着

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火热和着火温度,加之卷吸邻角的高温烟气,从而使着火加速,缩短着火距离,形成稳定的着火源,提高了燃烧的稳定性 (见示意图 2)。

2 浓淡燃烧器的试验研究

2.1 实现浓淡燃烧的几种浓缩装置

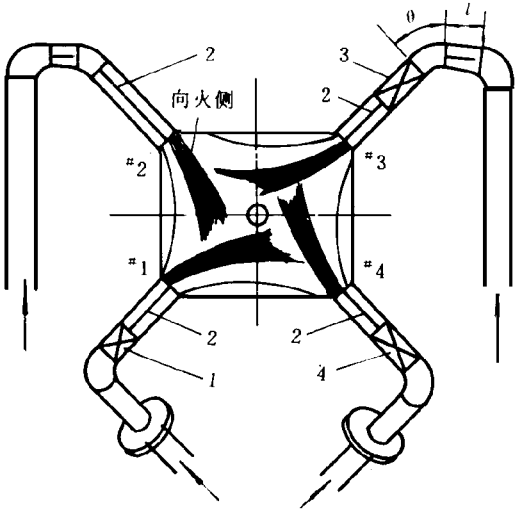

图 2 左浓右淡燃烧器结构原理

1, 24度浓缩分配装置; 2, 浓淡分流隔板;
3, 180度浓缩分配装置; 4, 204度浓缩分配装置

煤粉浓缩装置是浓淡燃烧器的关键部分,国内外多是利用原有的一次风管,按照常规的煤粉浓度输送风粉,到了燃烧器前的某个位置时,与一新设置的浓缩装置结合,在该装置内实现煤粉浓缩 (如图 3 中的 *b*. *c*),然后将浓淡不同的两部分气流分别用管路送往燃烧器不同部位的浓淡火嘴。有的则是利用靠近燃烧器前的送粉管道弯头,借助煤粉气流流经弯头时的离心分离作用形成浓煤粉气流,在弯头出口处加装转换装置,换向后将浓煤粉气流调整到相反的方向,送入炉膛的向火侧 (如图 3. *e*. *f*) 或者直接利用弯头分离加装分流隔板组成。

2.2 鳍片式浓淡燃烧器的研究开发

煤粉浓缩装置是浓淡燃烧器的重要组成部分。已有的某些煤粉浓缩装置的结构复杂,体积较大,旧锅炉改造时往往无合适的空间,实施困难。一些煤粉

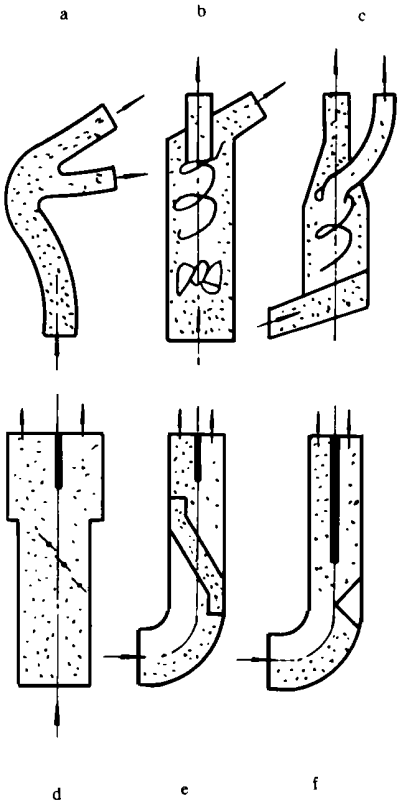

图 3 实现浓淡燃烧的几种煤粉浓缩装置

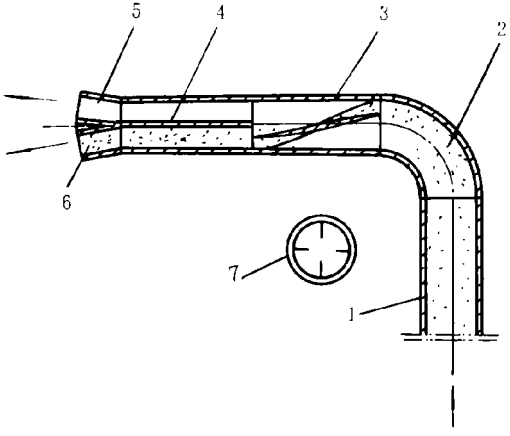

图 4 鳍片分离式浓淡燃烧器

1. 一次风管　2. 煤粉管道弯头　3. 浓缩分配装置
4. 浓淡分流隔板　5 6. 分别为淡 浓火嘴　7. 螺旋鳍片

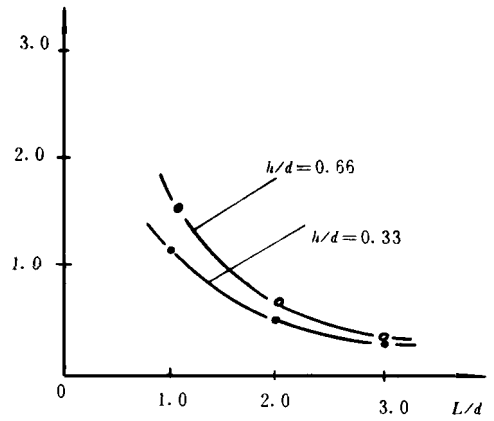

图 5 阻力系数与结构系数的试验曲线

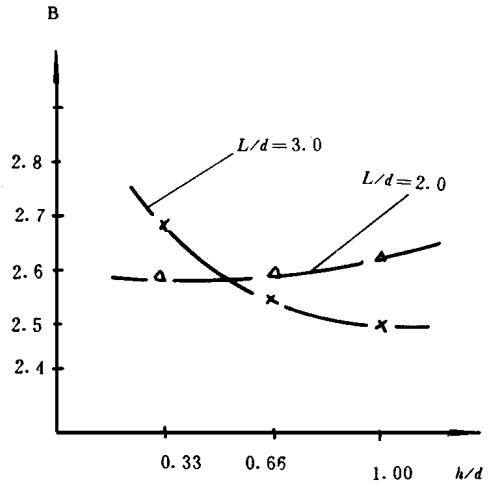

图 6 浓淡比与结构系数的试验曲线

浓缩装置还不同程度地存在着阻力大、磨损快、易堵管、浓淡比低、通用性差的问题。虽然有的装置能将浓煤粉转向 180°,但其浓淡比低,远离煤粉浓度最佳值,且受限于一次风管道的布置方式。

研究结果表明:采用螺旋鳍片结构的煤粉浓缩分配装置可以解决上述问题。煤粉颗粒进入浓缩分配装置后,沿鳍片所形成的螺旋槽道,在离心力及重力的作用下紧贴槽壁沿换向角 U进入由分流隔板组成的导流管及火嘴。

煤粉浓缩分配装置是由设在圆筒体内壁上的 1 ~ 4个螺旋鳍片组成 (见图 4)。优化选型试验在双相流模化试验装置上进行,其模化试验条件、试验系统及试验方法详见“煤粉浓缩分配器的模拟试验”[2]。

经过阻力系数测定,风量偏差试验,浓淡分配特性及圆管中浓度比恢复性能,变粉尘浓度和变风速的模拟试验等,优选出了最佳结构参数 (h/d、L/d、n、T) 的螺旋鳍片式煤粉浓缩分配装置。试验结果 (见图 5, 6) 表明:该分配装置在合理的结构参数内有较高的浓淡比,其阻力小,性能稳定,可进行变形设计。使用该装置构成的浓淡燃烧器,可以将向火侧煤粉浓度提高到 0.75 kg/kg,为背火侧淡煤粉浓度的 3倍。

3 改造设计与现场应用

3.1 改造设计要点

3.1.1 浓缩分配装置的选型

锅炉的一次风管道现场布置方式差异较大,因此在采用螺旋鳍片式煤粉浓缩分配装置时,需结合具体的空间布置结构确定换向角 U,选择浓缩分配装置的结构参数及旋向,它将直接影响着改造效果。在确定了换向角 U,螺旋升角 T及管道尺寸等之后,可由 $T = \mathrm{arctg}(360L/\pi U)$ 求相应参数。

3.1.2 送粉管道弯头的利用

已有的试验结果表明利用弯头的离心分离作用实现浓淡分离的最佳弯头角 θ为 45°~ 115°[3]。在离心分离的作用下,绝大部分的煤粉颗粒贴近弯头的外侧流动,对于 $115° < \theta < 45°$的弯头外侧的煤粉浓度反而有所降低。应采取相应的防止措施 (如图 2中的 l段),如在两弯头之间的直管内加隔板等,以便合理的利用弯头。对于 $\theta > 115°$的弯头由于煤粉气流流过时受湍动的影响,分离效果变差,可在弯头的多余处增设弧形隔板加以解决。

3.1.3 分流隔板的设置

经分离后的浓淡煤粉气流沿风管流动过程中,煤粉的浓淡比会随着管道的长度逐渐恢复,试验测定风管的恢复特性与 L/d有关,对于圆管测得浓淡比 $B = 2.57 - 0.367L/d$,即当 $L/d = 7$时,两侧的浓淡比会完全恢复。对于方风管恢复长度 $L/D_d = 3.3$因此在浓缩装置与火嘴之间的管段上必须设置分流隔板,以防被分离的煤粉恢复。

3.2 几个典型实施例

3.2.1 枣庄热电厂两台 65 t/h 煤粉锅炉,直吹式

制粉系统。设计燃用当地烟煤。近年来煤质不断下降,导致低负荷时燃烧不稳,时常要投油助燃。尤其是单台磨煤机 (一层火嘴) 运行时,必须投油助燃。

为了提高锅炉的稳燃能力,将三层一次风喷燃器改为右浓左淡式燃烧器。改后的低负荷稳燃试验证明效果良好。由改前的最低稳燃负荷 38 t/h (额定负荷的 58%) 降到了单磨稳燃负荷 23.2 t/h (为额定负荷的 35%)。试验期间的入炉煤 $Q_{net.ar}$= 18 764 kJ/kg, V_{ad}= 22.08%, A_{ad}= 36.9%,达到了改造目的。

3.2.2　黄台电厂两台 100 MW 机组所配 410 t/h 锅炉,燃用贫煤。# 1,# 2角处一次风管道呈倾斜状态布置,# 3,# 4角处的管道弯头为水平布置 (如图 2所示)。为了实现左浓右淡的燃烧方式,对应 # 1,# 3,# 4角分别选用了 Ψ= 24°、180°、240°,三种浓缩分配装置。在火嘴与浓缩分配装置之间设置了立式浓淡分流隔板,# 2角则直接利用立式分流隔板将弯头分离出的浓煤粉气流引入火嘴,使四角的煤粉气流全部调整到向火侧。

经改造后,低负荷稳燃能力有很大提高。在燃用发热量 $Q_{net.ar}$= 18 000~ 21 000 kJ/kg, V_{ad}= 9%~ 12%的煤质时,机组电负荷 50 MW (蒸发量 195 t/h,为额定负荷的 46%) 的条件下,炉膛燃烧稳定,无需投油助燃。比改前的 70 MW 调度负荷降低了 20 MW。实测 Ψ= 180°的浓缩装置阻力,在 W_1= 24 m/s时, △P= 120 Pa,证明其阻力很小。

3.2.3　黄岛电厂 125 MW 机组所配 400 t/h-M412型锅炉,主要燃用贫煤,煤质极不稳定。在浓淡燃烧器改造之前,于 1994年 7月 17日进行了改前低负荷稳燃试验,当时在入炉煤 $Q_{net.ar}$= 18.88 MJ/kg, V_{ad}= 11.1%,稳燃负荷只能降至 98 MW。浓淡燃烧器改造后,于 1995年 1月 21日进行了低负荷稳燃试验。入炉煤 $Q_{net.ar}$= 16.64 MJ/kg, V_{ad}= 11.99%。机组负荷在 70~ 75 MW 间波动,燃烧很稳定。

4　结论

(1)适当提高煤粉浓度,可以减少着火热并降低着火温度,因而使着火强化。在切向燃烧的煤粉锅炉上采用鳍片式浓淡燃烧器,具有较好的低负荷稳燃性能。对于节约助燃用油,提高机组的调峰能力,是一项有效的技术措施。

(2)改造实绩证明:采用鳍片式浓淡型燃烧器具有阻力低、耐磨损,结构简单,运行可靠,浓淡分离效果好等特点,能将煤粉浓度浓缩到着火距离的最佳值,且通用性很强,特别适用于新机组的设计选型和在役锅炉的改造。

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(渠　源　编辑)

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power, steam turbine, real-time simulation

采用热天平研究煤粉燃烧特性时氧通量的计算= **The Calculation of Oxygen Flux During the Study of Pulverized Coal Combustion Characteristics with the Help of a Thermobalance** [刊 ,中] /Zhu Qunyi, Zhao Guangbo, et al (Harbin Institute of Technology), Lu Wei(Harbin University of Science & Technology) //Journal of Engineering for Thermal Energy & Power, 1997, 12(6): 438~ 441

Described in this paper is the method of calculating the oxygen flux through a crucible outlet section during the study of pulverized coal combustion characteristics with the use of a thermobalance. Through the analysis and calculation of combustion characteristic curves of Zhi Jin coke it is found that the oxygen needed for the combustion of a sample was transferred to the sample layer surface in a diffusion mass transfer manner through the crucible outlet section. The oxygen partial pressure and oxygen flux on the sample layer surface can be determined by the use of Fick's diffusion law. **Key words**: thermobalance, pulverized coal combustion, oxygen flux

电厂锅炉锅筒寿命计算= **The Calculation of the Boiler Drum Life of a Utility Boiler** [刊 ,中] /Wang Yunmin (Changsha Electric Power Institute) //Journal of Engineering for Thermal Energy & Power, 1997, 12(6): 442 ~ 444

On the basis of an analysis of fatigue-caused life loss during the operation a boiler drum this paper presents a method for calculating the fatigue life of a boiler drum taking into account its wall temperature distribution, thermal stress cycle, mechanical stress and cycle stress amplitude, etc. With the boiler of Huaibei Power Station being taken as an example calculated is the fatigue life of the boiler drum. **Key words**: boiler drum, temperature field, stress, fatigue life

锅筒式蒸汽锅炉水处理工艺设计计算= **Calculation of the Water Treatment Technological Design of a Drum Type Steam Boiler** [刊 ,中] /Kuang Pingjian(Boiler & Pressure Vessel Inspection Institute Under the Harbin Municipal Labor Bureau) //Journal of Engineering for Thermal Energy & Power, 1997, 12(6): 445~ 447

With some specific examples a fairly detailed description is given of the method for calculating the water treatment technological design of a steam boiler. Through the organic integration of the boiler and the relevant calculations of the water treatment the demineralized water quantity required by the boiler is determined on the basis of the boiler parameters, operating conditions and water quality data. Finally, the various performance parameters of the water treatment equipment are identified. Such an approach makes it possible to eliminate the inconveniences of the feedwater treatment design method when only calculation formulas are given and the demineralized water quantity required by the boliler is assumed to be a known quantity. In conclusion, the method of designing regeneration equipment is also presented, thus further improving the water treatment technological design. Key words: boiler water treatment, ion exchanger, drum type steam boiler

鳍片分离式浓淡燃烧器的开发与应用= **The Development and Application of Fin-separation Type Dense-dilute Burners** [刊 ,中] /Miao Changxin, Li Kai, Li Jiansheng(Shandong Electric Power Scientific Research & Test Institute) //Journal of Engineering for Thermal Energy & Power, 1997, 12(6): 448~ 451

It is possible to improve combustion stability by properly increasing the concentration of pulverized coal. On the basis of an experimental study a versatile, low-resistance and high-efficiency fin-separation type dense-dilute burner has been developed. By bringing the pulverized coal concentration to an optimum value to facilitate

ignition the above-cited burner can enhance the stability of combustion at boiler low loads. In connection with the use experience of such burners at Shandong Electric Grid this paper presents the test results and key points in the burner design. **Key words**: boiler, pulverized coal concentration, dense-dilute separation, burners, development and application

辐射屏法用于高温输热管网隔热保温的实验与工程应用= **Experimental and Engineering Application of Radiation Screen Method for the Thermal Insulation of High-temperature Heating Pipe Network**[刊,中]/Li Yefa, Zhang Xuesheng, et al(China National University of Science& Technology)//Journal of Engineering for Thermal Energy & Power, 1997, 12(6): 452~454

Based on the principle of the absence of natural convection in a rectangular air-tight space under certain conditions the engineering application of radiation screen method for thermal insulation has finally been made possible through theoretical calculations, simulation tests and intermediary experiments. As a result, excellent energy-saving results and economic benefits were attained. **Key words**: radiation screen, air-tight space, effective thermal conductivity, thermal emissivity

自适应学习率的BP网络算法及其在汽轮发电机组故障模糊诊断中的应用= **BP Network Algorithm with Self-adaptive Learning Rate and Its Use in the Fuzzy Diagnosis of Turbogenerator Failures**[刊,中]/Li Yong, Li Hongyuan, et al (Northeast Electric Power Institute), //Journal of Engineering for Thermal Energy & Power, 1997, 12(6): 455~458

To overcome the shortcomings of a BP network, this paper proposes a BP algorithm with self-adaptive learning rate, thus once for all overcoming the demerits of BP networkds, i.e., slow convergency and inability to determine the value of learning rate. In addition, the disadvantage of BP network liable to fall into a local minimum point can also be effectively eliminated. Through the use of such an improved algorithm successfully realized is the fuzzy diagnosis of turbogenerator failures. **Key words**: neural network, BP algorithm, turbogenerator, fuzzy diagnosis

国内外循环流化床锅炉的设计改进= **Design Improvenents of Circulating Fluidized Bed Boilers at Home and Abroad**[刊,中]/Yao Huizhen(Northwest Electric Power Construction General Co.)//Journal of Engineering for Thermal Energy& Power, 1997, 12(6): 459~461

Based on the analysis of the operation conditions of many circulating fluidized bed boilers of various types and in the light of experiences gained in the improvement of the start-up and commissioning tests of such boilers the present paper discusses the design development tendency of their air distribution device and ignition mode, and proposes a new design philosophy concerning the ash and slag discharge control and the monitoring of fluidized bed temperature. **Key words**: circulating fluidized bed boiler, air distribution, ignition, operation, analysis

无上排气芯管旋风分离器的性能预测= **Performance Prediction of a Cyclone Separator without an Upper Exhaust Core Pipe**[刊,中]/Lin Wei, Wang Naining(East China Polytechnical University)//Journal of Engineering for Thermal Energy & Power. 1997, 12(6): 462~465

A performance prediction is conducted of a cyclone separator without an upper exhaust core pipe. Under a non-orthogonal adhesion body coordinate system a numerical simulation of an internal gas phase field has been performed with the help of a non-intersecting SIMPLE algorithm. Under a Lagrange coordinate system