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双调风燃烧器锅炉燃烧参数优化的试验研究

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[摘要]　通过对双调风燃烧器锅炉影响燃烧的主要运行参数的试验研究，分析得出了氧量、一次风量、燃烧器各挡板开度、磨煤机给煤量等主要燃烧参数对锅炉经济性的影响规律，并对这些参数进行优化选择，使锅炉的运行经济性得到了明显提高。试验得出的一些结果对同类型锅炉有一定的参考价值。

关键词：双调风燃烧器；燃烧参数；优化；经济性
中图分类号：TK223.23

1　前言

目前，大型电站锅炉采用的燃烧方式主要有四角布置的直流燃烧方式和墙式布置的旋流燃烧方式。采用墙式布置的旋流燃烧锅炉以其热负荷均匀、烟气偏差小、稳燃能力强、NO_x 排放量较易控制等一系列特点而逐渐被人们所认可。墙式布置的 Babcoak &Willcox 公司的 RBC 锅炉更以其结构独特、技术先进、效率较高并注重环保要求等优点而在国内得到了越来越多的应用。

通常，锅炉厂家均向电厂推荐氧量、风煤比、旋流燃烧器的各调节挡板开度等参数，以使锅炉在经济状况下运行，但由于安装、设计煤种的改变或其它方面的原因，按照这些推荐参数运行的锅炉其经济性并不如意，因此有必要对燃烧参数的选择进行现场试验并进行优化选择，以保证锅炉在安全的基础上高效经济运行。在台州发电厂 B&W1004 t/h 双调风燃烧器锅炉大量试验的基础上，经过分析得出了氧量、一次风量、燃烧器调节挡板开度等因素对 RBC 锅炉燃烧经济性的影响规律，据此对燃烧参数进行了优化选择，使锅炉运行经济性有了明显的提高。本文提供的一些结论对同类型锅炉有一定的参考价值。

2　设备概况

台州发电厂 7 号炉是由北京巴布科克·威尔科克斯有限公司（Babcoak &Willcox）设计制造的亚临界压力、自然循环、一次中间再热、前后墙对冲燃烧、平衡通风煤粉炉。该炉采用 B&W 公司的 RBC 燃煤锅炉的标准布置，炉膛深 12 300 mm，宽 14 100 mm，高 49 850 mm（到顶棚），由膜式水冷壁构成。水平烟道布置垂直再热器，尾部竖井由隔墙分成前后烟道，前

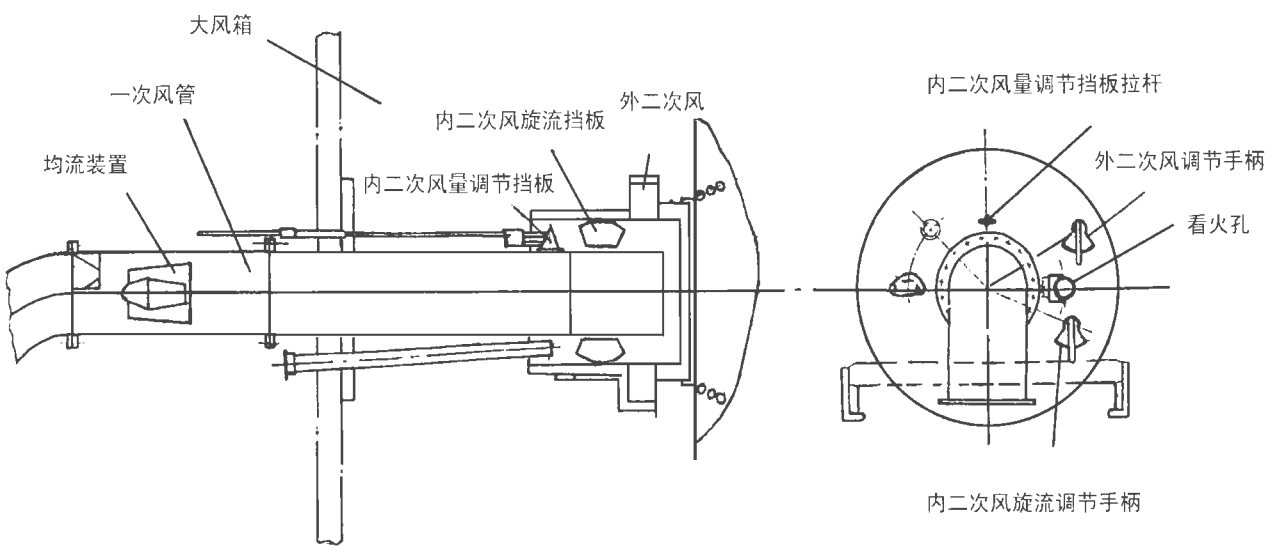

图 1　双调风燃烧器结构简图

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部布置水平再热器，后部布置一级过热器和省煤器，在分烟道的底部设置了烟气调节挡板以调节再热汽温，在尾部烟道布置了三分仓回转式空预器。

锅炉的燃烧系统由 EI－DRB 型燃烧器、风箱、高能点火器、油枪组成。EI－DRB 型燃烧器设置有双层调风机构，内外层二次风的风量和旋流强度均可调节，见图 1。32 只燃烧器分四层前后墙对称布置，其中 16 只燃烧器的二次风按顺时针方向旋转，另外 16 个按逆时针方向旋转，如图 2。制粉系统采用正压直吹 MPS 中速磨制粉系统。锅炉设计热效率为 92%。

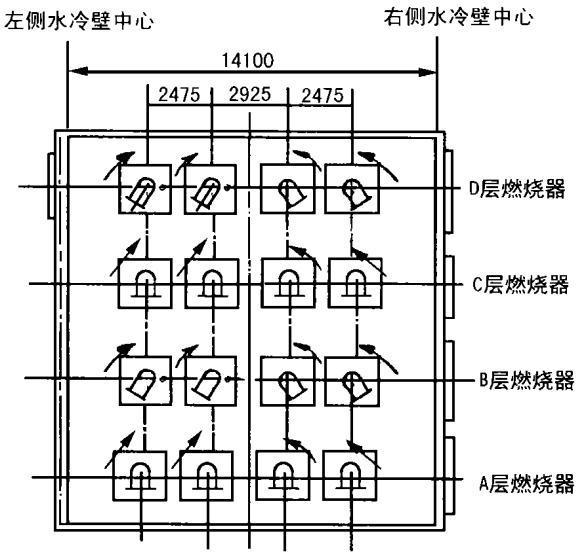
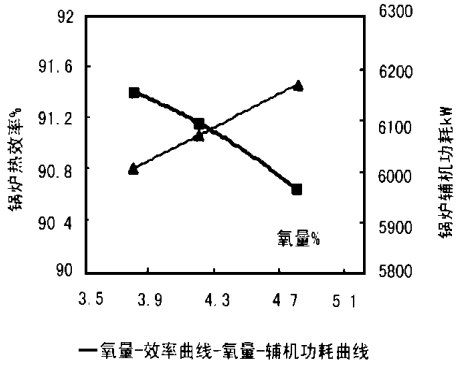


图 2 前墙燃烧器布置

3 进行的主要试验研究工作

3.1 炉膛出口氧量的变化对锅炉经济性的影响

根据该炉低氧量(如氧量小于 3.5%时)运行中再热汽温明显偏低的实际情况，安排了炉膛出口氧量分别为 3.8%、4.2%、4.8%时进行试验。试验结果见图 3。由图 3 可知，在试验范围内，保持其它条件不变的情况下，随着炉膛出口氧量的增加，锅炉热效率呈明显下降趋势。需要指出的是，以上结果仅对试验氧量范围而言。一般来说，炉膛出口的过剩空气系数大于 1.2 后，尽管随着过剩空气系数的继续增加，锅炉的飞灰可燃物会得到一定程度的下降，但氧量增加而导致的排烟热损失的增加在炉膛出口氧量大于 3.8%后远甚于机械未完全燃烧热损失上所得的收益，这一点对于燃用较低灰份煤种的锅炉更是如此。同时，随着氧量的增加，锅炉的送引风机风量也随之增加，导致送、引风机的电耗明显升高，增加了锅炉的辅机功耗，从而降低了锅炉的经济性。



3 炉膛出口氧量对锅炉经济性的影响

炉膛出口氧量的降低不但使锅炉的经济性有明显的提高，而且对减少炉内 NO_x 的产生也有一定的作用。测试表明，随着氧量的降低，锅炉尾部烟道的 NO_x 排放量也呈下降的趋势，其幅度可达 8%左右。

由于实际运行煤种偏离设计煤种，锅炉的再热汽温在氧量小于 3.5%后很难达到设计值。采用较低氧量运行，对锅炉的再热汽温会产生不利的影响，但通过调节尾部烟气调节挡板，再辅以磨煤机给煤量分配的适当调整，在炉膛出口氧量 3.8%左右时，能够将再热气温控制在设计范围内。

3.2 一次风量变化对锅炉经济性影响的试验研究

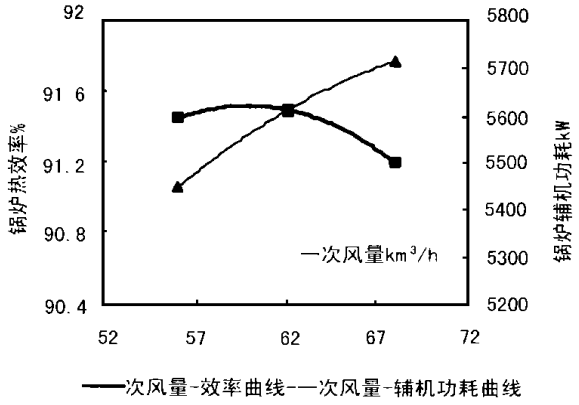


图 4 一次风量变化对锅炉经济性的影响

为了研究一次风量的变化对锅炉燃烧经济性的影响，在 56×10^3 ~ $68\times10^3 Nm^3/h$ 范围内对一次风量进行了试验。从图 4 可看出，在 56×10^3 ~ $64\times10^3 Nm^3/h$ 范围内，一次风量对锅炉效率的影响较小，但随着一次风量的增加，锅炉的经济性出现明显下降的趋势。从试验结果分析，一次风量维持在适中量如 56×10^3 ~ $64\times10^3 Nm^3/h$ 既对锅炉燃烧有利，

又不会导致一次风管的堵塞。过高的一次风量将使煤粉着火推迟，火焰中心升高，导致飞灰可燃物和排烟温度上升，对锅炉的经济性产生不利的影响；在保持送风量不变的情况下，一次风量的增加必然使炉膛出口氧量增加，从而降低锅炉的经济性；而且，随着一次风量的增大，磨煤机出口煤粉也将逐渐变粗，这对锅炉的燃烧是十分不利的；同时，从图 4 可知，随着一次风量的增加，锅炉辅机电耗也将有较大的增加。因为一次风量和风压的增加势必导致空预器漏风的增加，从而使一次风机耗电有较大的增加；不但如此，伴随一次风量的增加，一次风管内流速也随之升高，从而加剧一次风管的磨损，增加电厂的检修工作量。所以，运行控制一次风量不宜过高。

3.3　燃烧器外二次风调节挡板对锅炉经济性的影响

双调风燃烧器的外二次风挡板对锅炉的煤粉燃尽有明显的影响。从单个燃烧器调整情况看，过大的外二次风挡板开度使着火点明显变远，着火不良。随着外二次风挡板的逐渐关小，煤粉的着火点变近，旋流强度明显增加。但此时应注意煤粉气流的飞边、结焦，当燃用易结焦性煤种时，尤应注意这一点。试验结果表明，外二次风挡板较恰当的位置为 35%～45%。

3.4　燃烧器内二次风旋流挡板开度对锅炉经济性的影响

内二次风旋流挡板开度在某一范围内对锅炉燃烧最有利。过大或过小的内二次风旋流强度均对燃烧产生不利的影响。内二次风旋流挡板开度过大，将使旋流强度减小，从而减少烟气的回流和烟气的紊流强度。但太小的内二次风旋流挡板开度，将使内二次风阻力增加，从而使二次风量减少，使煤粉燃烧所需的初始氧量明显不足，对燃尽产生不利的影响。将燃烧器的内二次风旋流挡板的开度分别置于 20%、30%、45%进行了试验，试验结果表明，内二次风旋流挡板开度在 30%～45%间较为合适，见图 5。

3.5　燃烧器内二次风量调节挡板开度对锅炉经济性的影响

双调风燃烧器的内二次风风量调节挡板的开度是内外二次风配比的重要决定因素，它的开度大小将对外二次风和内二次风旋流强度产生重要影响。在其它条件不变的情况下，分别将内二次风量调节挡板开度置于 35%、50%、65%进行了试验。从试验结果分析，内二次风风量挡板开度在 40%～55%间较为合适，可使锅炉效率达到较好水平，见图 5。

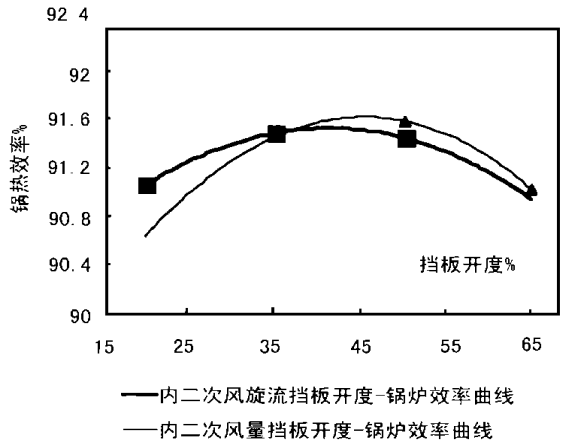


图 5　内二次风调节挡板开度对锅炉经济性的影响

3.6　磨煤机煤量分配对锅炉经济性的影响

各磨煤机煤量分配对锅炉效率有一定的影响。从试验情况看，各磨煤机煤量均匀分配比倒宝塔分配的锅炉效率要略高一些，但只要将各层二次风量进行适当调整，煤量分配的影响可减至最小。所以各磨煤机间煤量分配可根据汽温情况来进行调整。

3.7　优化燃烧参数后的验证试验

通过对大量现场试验数据的分析研究，得出了各主要燃烧参数对锅炉经济性的影响规律。为验证这些分析结果，选择这些优化的燃烧参数进行了验证试验，试验结果表明，与日常运行工况相比，燃烧参数优化后锅炉的飞灰可燃物从 4.5%下降至 1.95%，锅炉热效率从 90.9%上升至 92.3%，而锅炉的辅机功耗则明显下降，锅炉的经济性有了显著的提高。

4　结论

燃烧参数的选择对双调风燃烧器锅炉的经济性有十分重要的影响，特别是双调风燃烧器各调节挡板的开度对锅炉的飞灰可燃物有直接的影响，应根据各燃烧器的着火情况加以仔细的调整。实际测试表明，经过燃烧参数的优化选择可使锅炉的热效率提高 1%以上，同时锅炉辅机功耗明显下降，二者可使机组的供电煤耗下降 5g/(kW·h)以上，由此而产生的经济效益是十分巨大的。

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（静　编）

observed when the blade spacing ratio has a variation interval of 2. 5 ~3. 0. **Key words**: pulverized coal concentrator, mound body, louver, resistance characteristics

火电厂水力输灰系统阻垢防垢研究＝**A Study of Scale Inhibition and Prevention for a Thermal Power Plant Wet-ash Transportation System** [刊, 中] /Chen Yafei, Gao Xiang, Fang Mengxiang, et al (Zhejiang University) //Journal of Engineering for Thermal Energy &Power. -1999, 14 (4). -

Discussed in this paper are the scale prevention measures for an ash water transportation system and the scale inhibition mechanism of scale inhibiting agents. An experimental study of scale inhibition and prevention was conducted of a kind of utility boiler-fired coal with ash rich in CaO, addressing such a variety of topics as the scale characteristics and scale inhibition rate when scale inhibitors of various formulas are adopted, and the scale inhibition and prevention effectiveness when steel/rubber combination pipes and ash water precipitation tank are employed. A comparison analysis has also been performed with respect to different kinds of methods used. **Key words**: wet ash transportation, scale, scale inhibition and prevention

各向异性散射介质的辐射传热分析＝**An Analysis of Radiation Heat Transfer in Isotropically and Anisotropically Scattering Media** [刊, 中] /Xing Huawei, Ruan Jian, Zheng Chuguan (Central China University of Science & Technology) //Journal of Engineering for Thermal Energy &Power. -1999, 14 (4). -

With the use of a combined Monte-Carlo and Zone method of numerical calculation (called MCZ method for short) an analysis was conducted of the radiation heat transfer in isotropically and anisotropically scattering media. For convenience of comparison an one-dimensional slab system is employed. With the help of specially prepared programs calculated respectively are the hemispherical reflectivity and transmissivity of isotropically scattering absorbing media and linear phase-function anisotropically pure scattering media as well as the radiation heat transfer in flat slabs of linear phase-function anisotropically scattering absorbing media. Fairly satisfactory conclusions were obtained. **Key words**: hemispherical reflectivity, hemispherical transmissivity, MCZ method, isotropical scattering, anisotropical scattering, phase function

用 PIV 测量法研究燃气轮机叶轮与导叶叶轮间的速度场＝**A Study of the Velocity Field Between a Gas Turbine Runner and Guide Vane Wheel with the Use of PIV Measurement Method** [刊, 中] /Zhao Yabin (Jiangsu Petrochemical Institute) //Journal of Engineering for Thermal Energy &Power. -1999, 14 (4). -

A test rig for the experimental research of fluid flow condition inside the cavity ahead of a gas turbine first stage blade wheel is described along with the test method and results. Particle imaging technology was employed to measure the velocity field inside the disk cavity. Analyzed is the effect of the magnitude of seal gas flow rate on the flow field at various locations. Also studied is the relationship between the critical parameters of main flow into the cavity and the flow field. **Key words**: gas turbine, experiment, PIV system

分配联箱气液两相流流型对垂直并联管分配特性的影响＝**The Effect of Gas/Liquid Two-phase Flow Pattern in a Distribution Header on the Distribution Characteristics of Vertical U-Junction Pipe System** [刊, 中] /Cheng Zhuoming, Zhou Yunlong (Northeast Power Engineering Institute) //Journal of Engineering for Thermal Energy & Power. -1999, 14 (4). -

A theoretical and experimental study was conducted of the flow distribution characteristics of low-mass flow in a vertical U-junction parallel-connected pipe system. Obtained were the distribution characteristics of gas phase and gas/liquid two-phase mass flow rate as well as the flow pattern record of various branch pipes. Also analyzed is the effect of flow pattern in distribution headers on the flow distribution and the flow pattern in various branch pipes. **Key words**: gas/liquid two-phase flow, parallel pipes, flow distribution

双调风燃烧器锅炉燃烧参数优化的试验研究＝**An Experimental Study on the Optimization of Combustion Parameters of a Dual Air-Register Burner Boiler** [刊, 中] /Hu Jiangen, Huang Yuming, et al (Zhejiang Provincial

Electric Power Testing Research Institute) //Journal of Engineering for Thermal Energy &Power. -1999, 14 (4). -

Through the experimental research of main operating parameters of a dual air-register burner boiler, which have an effect on combustion, the authors have identified the variation relationship between boiler economic performance and such factors as oxygen content, primary air flow rate, various damper openness of the burners, and coal pulverizer feed rate, etc. The optimized selection of the above-cited parameters results in a significant enhancement of the boiler operating efficiency. The test results can serve as practical reference data for analogous boilers. **Key words**: dual air-register burner, combustion parameters, optimization, economic performance

四角燃烧煤粉锅炉稳燃技术的分析与应用=**Analysis and Application of Stable Combustion Technology of a Tangentially Fired Pulverized-Coal Boiler** [刊, 中] /Qiu Jihua, Chen Gang, et al (National Key Laboratory of Coal Combustion under the Huazhong University of Science &Technology) //Journal of Engineering for Thermal Energy & Power. -1999, 14 (4). -

With respect to the combustion stability features of pulverized coal-fired boilers a variety of measures are proposed to achieve the stable combustion of pulverized coal. Categorized into four aspects, such measures are based on a pulverized coal burner of stable combustion type, dense-sparse pulverized coal combustion, proper consideration of the effect of secondary air on the primary air ignition, and a tangential circle formed in the boiler. The results of application of these measures on 670 t/h, 420 t/h and 220 t/h boilers are also presented in the paper. **Key words**: boiler, combustion, stability, pulverized coal

旋转机械故障诊断专家系统的设计和实现=**The Design and Implementation of a Rotating Machine Failure Diagnosis Expert System** [刊, 中] /Yuan Yue (Yinhuada Co. under the North China Electric Power Scientific Research Institute) //Journal of Engineering for Thermal Energy &Power. -1999, 14 (4). -

On the basis of the research results of a failure diagnosis inverse problem a rotating machine failure diagnosis expert system has been designed by utilizing Visual C ++ 5. 0 programming environment. Expounded are the system design philosophy as well as the theory and technology for its implementation. Also presented are the system functions, specific features and some results of application. **Key words**: failure diagnosis, expert system, rotating machine

锅炉过热汽温的预测智能控制=**The Prediction and Intelligent Control of a Boiler Superheated Steam Temperature** [刊, 中] /Liu He, Xu Yuxin, et al (North China Electric Power University) //Journal of Engineering for Thermal Energy &Power. -1999, 14 (4). -

In the light of a great hysteresis and inertia specific to boilers presented in this paper is a new type of control method. Under this method a future process output is first predicted. Then, on the basis of existing deviations and predicted output change trends a corresponding control intensity can be selected by simulating the human control thought. When used on a superheated steam temperature control system the simulation results show that the control quality achieved is superior to that of a conventional control method. Furthermore, it also features a relatively high robustness. **Key words**: superheated steam temperature, forecast, intelligent control

循环流化床烟气脱硫的实验研究及其数学模型=**Experimental Study of Circulating Fluidized Bed Flue Gas Desulfurization and its Mathematical Model** [刊, 中] /Wu Yinghai, Huang Zhen, Li Daji (Southeastern University) //Journal of Engineering for Thermal Energy &Power. -1999, 14 (4). -

The authors have set up a flue gas desulfurization test rig for a circulating fluidized bed. On the basis of increased moisture reaction mechanism established is a mathematical model for the circulating fluidized bed flue gas desulfurization. The calculated results of the model were compared with test ones. It is shown that the model can relatively well reflects the variation relationship between the desulfurization efficiency, water spray quantity and Ca/S ratio. **Key words**: circulating fluidized bed, flue gas desulfurization, mathematical model