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# MPS 磨煤机工作特性试验研究

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摘　要: 利用零压摆式取样针煤粉等速取样方法在 MPS 磨煤机出口管道上等速取样煤粉, 通过对煤粉细度、水分和质量的分析, 研究 MPS 磨煤机的工作特性。试验中主要研究了静态分离器挡板开度、动态分离器转速、磨辊液压加载力、磨煤机入口温度及通风量对 MPS 磨工作特性的影响, 从而为国内 MPS 磨煤机制造厂家提供设计参考, 同时也为国内现役和即将投入运行的 MPS 磨煤机提供运行指导。

关　键　词: MPS 磨煤机; 零压摆式取样针; 等速取样
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## 1　前　言

在我国现役及新建的 300 MW 以上机组锅炉中, 正压直吹式制粉系统已得到越来越广泛的应用。MPS 磨煤机作为一种新型的引进型中速磨煤机, 由于具有启动迅速、调节灵活、阻力小、单位磨煤金属磨耗小、结构紧凑、占地面积小及制粉系统简单、单位电耗低、钢材消耗少、占有空间小、爆炸危险性小和噪声低等优点, 其已成为正压直吹式制粉系统主要磨煤机型式之一。然而, 目前在实际中对 MPS 工作特性的试验研究还鲜有介绍。以往对正压直吹式制粉系统的试验, 常用的煤粉取样方法为平头枪煤粉等速取样。但是, 由于这种方法测点扫描的断面有限, 因此在煤粉采样的代表性和准确性方面会产生较大的误差。为了更加客观真实地反映 MPS 中速磨煤机工作特性, 笔者利用从德国引进的根据零压摆式取样针煤粉等速取样原理设计的 AKOMA 装置对扬州第二发电厂 600 MW 机组锅炉的一次风粉管道进行了煤粉等速取样[1], 从而对 MPS 磨工作特性进行了一次较为全面的试验研究。

## 2　设备概述

扬州第二发电厂 600 MW 机组锅炉为美国 BABCOCK &WILCOX 公司生产的亚临界压力, 一次中间再热, 自然循环, 固态排渣煤粉炉。锅炉采用冷一次风正压直吹式制粉系统, 配置 6 台 B &W 公司制造的 MPS-89G 型中速磨煤机, 两台公用的离心式一次风机和 6 台 STOCK 公司制造的电子称重式给煤机。锅炉布置有 A、B、C、D、E 和 F6 排 EI-XCL 型旋流煤粉燃烧器, 每排 6 支, 共分 3 层, 采用前后墙对冲布置。

### 2.1　MPS-89G 型中速磨煤机结构

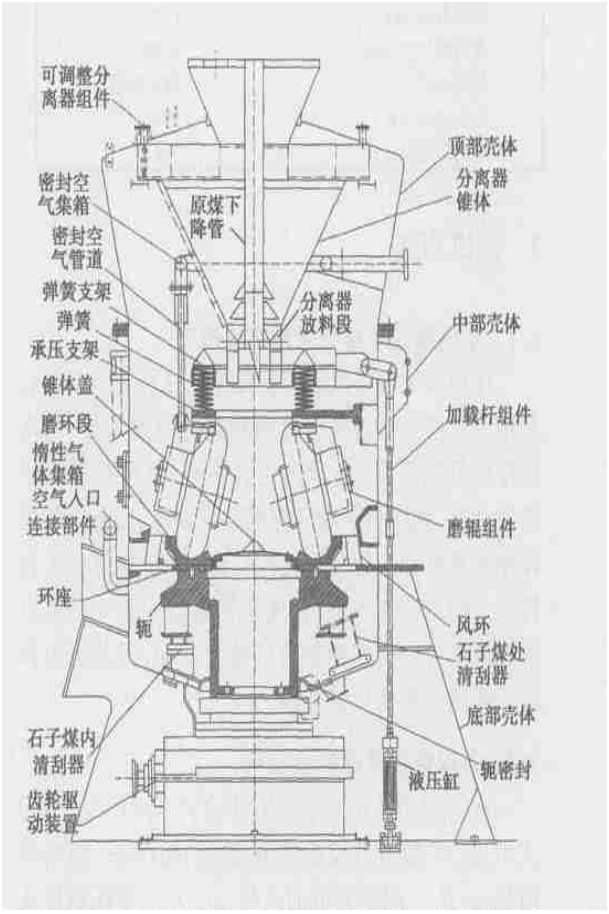


图 1　MPS-89G 磨煤机结构示意图

MPS－89G 型中速磨煤机结构如图 1 所示, 主要由齿轮驱动、底部壳体组件、中部壳体组件及顶部壳

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体组件组成，其中底部壳体组件包括风环、轭、环座、磨环、轭密封空气、石子煤清刮器、一次风室及惰性气体集箱和喷嘴；中部壳体组件包括磨辊组件、承压支架、加载弹簧、弹簧支架和中部壳体；顶部壳体组件则由分离器窗体、分离器锥体、分离器放料部分、内部下煤管、密封空气集箱和摆动阀组件组成。

### 2.2 煤种特性

设计煤种为神府烟煤，煤种特性见表 1。

表 1 设计煤种特性

| $C^y$/% | $H^y$/% | $O^y$/% | $N^y$/% | $S^y$/% | $V^y$/% | $C_{GD}^y$/% | $A^y$/% | $W^y$/% | $Q_{DW}^y$/kJ·kg$^{-1}$ | HGI(可磨系数) |
|---|---|---|---|---|---|---|---|---|---|---|
| 55.85 | 3.44 | 8.93 | 0.7 | 0.31 | 26.53 | 42.7 | 15.45 | 15.32 | 21 407 | 55.00 |

### 2.3 MPS-89G 磨煤机特性参数

MPS-89G 磨煤机特性参数见表 2。

表 2 MPS-89G 磨煤机特性参数

| | |
|---|---|
| 基本出力/t·h$^{-1}$ | 58.5 |
| 煤粉细度 $R_{200}$/% | 75 通过 |
| 磨出口温度/℃ | 79 |
| 煤/风比 | 0.587 5 |
| 转速/r·min$^{-1}$ | 23.92 |
| 磨辊直径/mm | 1 650 |
| 煤粉管尺寸/mm | φ508 |
| 加载方式 | 液压加载 |
| 电机功率/kW | 597 |
| 电机转速 r·min$^{-1}$ | 989 |

## 3 测试方法

### 3.1 零压摆式取样针煤粉等速取样[1]

使用从德国进口的煤粉等速取样装置 AKOMA，利用零压摆式针等速取样原理进行煤粉采样，两次取样质量偏差在 5%以内为合格样，取样结果用于粉量计算，利用自动缩分器缩分煤粉样，缩分后的煤样用于细度和水份分析，进而分析 MPS 磨煤机工作特性。使用该种方法，在煤粉管道上安装一个测点取样枪即可扫描煤粉管道的整个断面，因此可以保证试验的可靠性和精确性。

### 3.2 各根煤粉管道粉量分布

$$m_l = 0.003\,6\, m_s \times (D_l/D_p)^2/(n.t) \qquad (1)$$

式中：$m_l$— 管道内煤粉质量流量，t/h；$m_s$— 煤粉样质量，g；$D_l$— 煤粉管道的内径，m；$D_P$— 零压取样头的内径，m；$n$— 取样点个数；$t$— 取样时间间隔，s。

## 4 试验结果及分析[4]

### 4.1 静态分离器挡板开度对磨煤机工作特性的影响

由 F 磨分离器挡板特性曲线可以看出(见图 2)，煤粉细度与挡板开度在 22°～55°范围内大致呈线性关系，在此范围内关小分离器挡板开度对煤粉细度的影响是明显有益的，而当分离器挡板开度大于 55°时，关小挡板开度会使煤粉变粗。这主要是由于在一定分离器挡板开度范围一定风量下关小挡板开度时，气流旋转加强，出粉变细，而当分离器挡板开度大于某一范围时，减小挡板开度不仅离心分离效果变化不大，而且还会增大通风阻力，使煤粉均匀性变差，粉中大颗粒增多。但文献[2～3]指出，当分离器挡板开度小于某一范围时，继续关小挡板开度，煤粉气流绕流折向门的阻力大增，会有部分气流不经折向门，而从挡板下部缝隙径直流向出粉口，从而使煤粉变粗。因此，分离器挡板开度要在其与煤粉细度呈线性关系的范围内调节。

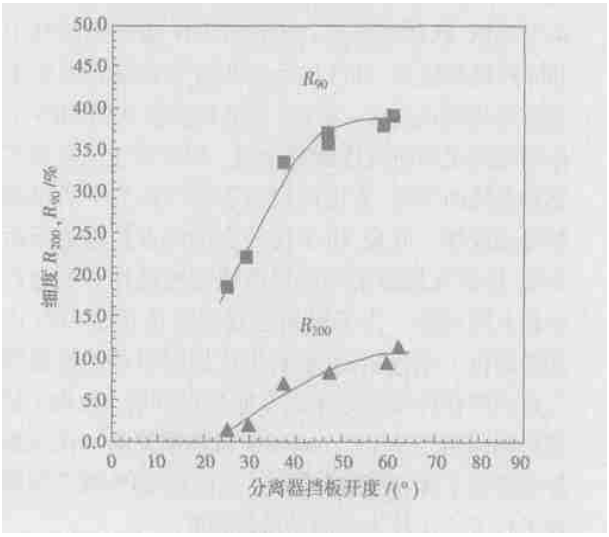


图 2 F 磨静态分离器挡板特性

### 4.2 动态分离器转速变化对磨煤机工作特性的影响

从图 3 中 A 磨动态分离器的分离特性试验结果可以看出，在挡板开度不变的情况下，当动态分离器转速在 85～100 r/min 范围内变动时，煤粉细度 $R_{90}$

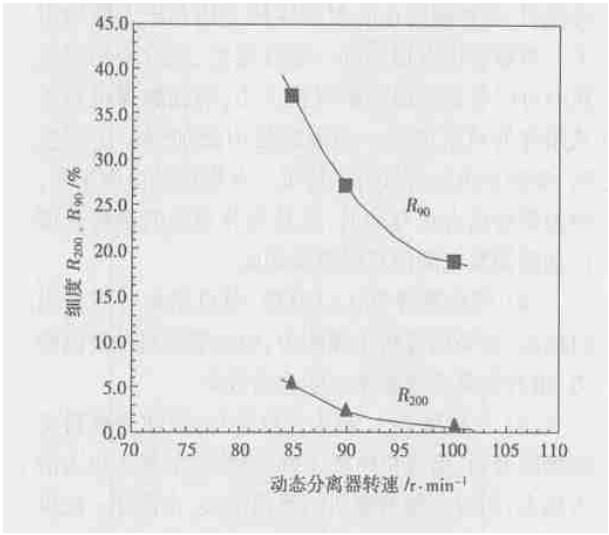


图 3　A 磨动态分离器挡板特性

呈单调递减变化且变化很灵敏。这是因为动态分离器属于回转型离心式分离器, 其分离效率主要取决于转子的回转速度和气粉混合物的容积流量。当磨煤机通风量一定时, 回转速度越大则分离效率越高。

## 4.3　磨辊液压加载力对磨煤机工作特性的影响

表 3　F 磨磨辊加载力调整前后对比

| F 磨 | 工况 1 | 工况 2 | 工况 3 |
|---|---|---|---|
| 一次风量(标准状态)/t·h$^{-1}$ | 86 | 88 | 87 |
| 分离器出口温度/℃ | 74 | 74 | 73 |
| 液压加载力/MPa | 12.3 | 14.9 | 17.1 |
| 磨煤机差压/kPa | 3.37 | 3.97 | 1.83 |
| 磨煤机电流/A | 93 | 95 | 97 |
| 细度 $R_{90}$/% | 36.9 | 35.4 | 33.5 |
| 细度 $R_{200}$/% | 8.0 | 7.8 | 7.1 |

通过表 3 可以发现增加磨煤机加载装置的液压定值, 可提高煤层上的磨制能力并改善分离器的分离能力, 从而使煤粉细度降低, 但磨煤电耗因磨辊负载增大而增大, 并且磨煤机的磨损加重。当碾磨初压较低时, 提高碾磨压力对磨煤机差压的影响不大(从工况 1～工况 2, 磨煤机差压略有升高, 这可能和煤质及通风量增大有关), 当碾磨压力提高到一定程度后, 增加碾磨压力可以迅速地降低磨煤机差压, 从而降低风机电耗。这也从另一个侧面说明, 当碾磨压力不高时增加碾磨压力对磨煤机出力影响不大, 但当碾磨压力提高到一定程度后可显著地提高磨煤机出力。但是, 碾磨压力超过某一值后制粉系统经济性会开始降低。而从燃烧经济性来看, 增加碾磨压力是有利的, 尤其当分离器的挡板开度已达到调整极限位置时更是如此。

## 4.4　磨煤机入口温度对磨煤机工作特性的影响

表 4　C 磨分离器入口温度调整前后对比

| C 磨 | 工况 1 | 工况 2 |
|---|---|---|
| 一次风量(标准状态)/t·h$^{-1}$ | 94 | 95 |
| 煤粉质量(取样计算得出, 空气干燥基)/t·h$^{-1}$ | 39.0 | 40.1 |
| 磨煤机入口风温/℃ | 276 | 288 |
| 分离器出口温度/℃ | 74 | 79 |
| 一次风速/m·s$^{-1}$ | 25.7 | 24.8 |
| 热风门开度/% | 60 | 76 |
| 冷风门开度/% | 42 | 23 |
| 磨煤机电流/A | 108 | 105 |
| 煤粉残留水分/% | 4.38 | 3.94 |
| 原煤全水分/% | 15.45 | |

从表 4 可以看出, 提高磨的入口温度, 可以增加分离器出口温度, 提高磨煤机干燥能力, 增加磨煤机的磨制能力。在给煤量不变时, 可减少磨内的再循环煤量和煤层厚度, 使制粉电耗降低。同时由于开大热风门, 关小冷风门降低排烟温度和散热损失, 也对提高燃烧效率有明显的效果。

## 4.5　通风量对磨煤机工作特性的影响

表 5　E 磨通风量调整结果对比

| E 磨 | 工况 1 | 工况 2 | 工况 3 |
|---|---|---|---|
| 一次风量(标准状态)/t·h$^{-1}$ | 95 | 92 | 82 |
| 收到基原煤质量/t·h$^{-1}$ | 45.9 | 45.3 | 45.2 |
| 煤粉质量(取样计算得出, 空气干燥基)/t·h$^{-1}$ | 41.4 | 38.8 | 38.8 |
| 风煤比 | 2.07 | 2.03 | 1.81 |
| 磨煤机电流/A | 96 | 98 | 96 |
| 磨煤机入口风温/℃ | 252 | 256 | 276 |
| 分离器出口温度/℃ | 74 | 75 | 75 |
| 细度 $R_{90}$/% | 29.4 | 28.5 | 28.5 |
| 细度 $R_{200}$/% | 4.6 | 3.5 | 3.5 |
| 一次风速/m·s$^{-1}$ | 30.2 | 28.4 | 25.1 |

磨煤机的通风量对煤粉细度、磨煤机电耗、石子煤量和最大磨煤出力有影响。如表 5 所示, 当一次风速大于某一数值时, 在一定的给煤量下增大通风量(工况 2 到工况 1), 煤粉变粗, 磨内循环量减小煤层变薄, 磨煤机电耗下降; 但由于风环风速增大, 石子煤量减小, 风机电耗增加, 减薄煤层和降低磨煤机电流使磨煤机的最大出力潜力加大, 同时也会使磨煤机的磨损增大。但是, 在保证一次风速不致过低的情况下, 在一定的给煤量下降低通风量(工况 2 到工况 3), 并没有完全出现与增大通风量截然相反的结果($R_{90}$保持不变, 磨煤机电流下降)。其主要原因

是,此时降低通风量提高了磨煤机入口温度,因此在一定程度上减少了磨内的再循环煤量和煤层厚度,从而抵消了通风量降低导致磨内的再循环煤量和煤层厚度增加的影响,甚至出现磨煤机电流下降的现象,同时也对提高锅炉效率产生了更加积极的影响。

4.6 煤质变化对磨煤机工作特性的影响

由于条件所限,这里部分引用了该机组调试期间煤质变化对磨煤机工作特性的定性影响[5]。当煤质改变可磨性变差时石子煤量明显增大,磨煤机出力降低;当煤中有石块和铁块时,磨煤机振动就会突然增大。可见,MPS 磨煤机对煤质有较高的要求。

## 5 结束语

利用零压摆式取样针煤粉等速取样方法对 MPS 磨煤机的工作特性进行了试验研究,得出结论如下:

(1) 煤粉细度与静态分离器挡板开度在 22° ~ 55°范围内大致呈线性关系,在此范围内关小分离器挡板开度可明显地改善煤粉细度,偏离此范围关小分离器挡板开度会使煤粉细度升高。

(2) 配动态分离器的 MPS 磨煤机煤粉细度随着分离器转速的提高呈单调递减变化且变化很灵敏,因此与静态分离器相比,动态分离器对煤粉细度的调节更加灵活方便。

(3) 提高磨辊液压加载力可使煤粉细度降低,但磨煤电耗增加和磨煤机的磨损加重。当碾磨初压较低时,提高碾磨压力对磨煤机差压和出力影响不大。当碾磨压力提高到一定程度后,继续增加碾磨压力可以显著地提高磨煤机出力,降低磨煤机差压从而降低风机电耗。当碾磨压力增加到一定程度后,制粉系统经济性开始降低。从燃烧经济性来看,增加碾磨压力是有利的,尤其当分离器的挡板开度已达到调整极限位置时更是如此。

(4) 提高磨煤机入口温度,可以增加分离器出口温度,提高磨煤机干燥能力,增加磨煤机的磨制能力,也对提高燃烧效率有明显的效果。

(5) 一次风速大于某一数值时,增加通风量会使煤粉变粗,磨煤机电耗下降,磨煤机的最大出力潜力加大,同时也使磨煤机的磨损增大;在保证一次风速不致过低的情况下,降低通风量可提高磨煤机入口温度,进而降低磨煤机电耗,提高燃烧效率。

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law governing the influence of various parameters on the system performance. The above results can provide a theoretical basis for the optimized design and the selection of optimized operating conditions for a combined heat and electric power (cooling) system. **Key words**: finite-time thermodynamics, combined heat and electric power (cooling) system, parameter optimization, configuration optimization

300 MW 机组锅炉汽包寿命在线监测系统的研究＝**The Study of an On-line Monitoring System for the Service Life of the Steam-drum of a** 300 **MW Power Plant** [刊, 汉] / GUAN De-qing, MO Jiang-chun, LI Li, et al (College of Energy and Power Engineering under the Changsha University of Science &Technology, Changsha, China, Post Code: 410076) // Journal of Engineering for Thermal Energy &Power. — 2005, 20(1). —57 ~ 60

By using a three-dimensional finite element theory a finite element analysis was conducted of the stress field of a 300 MW power plant boiler-drum under the action of an internal pressure. The theoretical stress concentration factor thus obtained is greater than the recommended value of TRD 301 by 17.3%. The thermal stress of the boiler drum under a quasi-steady state was calculated by using the theory of thermal elasticity. On this basis a proposal was put forward to improve the TRD301-based method for calculating fatigue life and an on-line monitoring system for the service life of a 300 MW plant boiler-drum developed. By utilizing a computerized and intelligent data acquisition system and communications data conversion the management of temperature, pressure and service life was implemented for the whole process of the boiler drum operation. The use of the monitoring system on a 1021 t/h boiler at a power station has attested to the effectiveness of the system, which has attained the aim of on-line monitoring of boiler drum life and of properly guiding the boiler operation. **Key words**: boiler drum, fatigue life, on-line monitoring system

电站锅炉炉内三维温度场在线检测与分析＝**On-line Detection and Analysis of the Three-dimensional Temperature Field in a Utility Boiler** [刊, 汉] / LOU Chun, ZHOU Huai-chun (National Key Laboratory on Coal Combustion under Huazhong University of Science and Technology, Wuhan, China, Post Code: 430074), LU Chuan-xin, PEI Zhen-lin (Wuhan Steel and Electric Power Co. Ltd., Wuhan, China, Post Code: 430082) // Journal of Engineering for Thermal Energy &Power. — 2005, 20(1). —61 ~ 64

A set of visual monitoring system for three-dimensional temperature fields was installed on a 670 t/h utility boiler. The system comprises several image detectors of furnace flame, a video-frequency slicer and an industrial control device, etc. Through the radiation image treatment of furnace flame and by adopting a regularization method an on-line monitoring was implemented for the in-furnace three-dimensional temperature field (12 layers of cross-section divided along the boiler height direction). The results of the detection indicate that due to the supplementary burning of blast-furnace gas two high-temperature combustion zones have been formed along the furnace height direction. In-furnace average temperature correlates relatively well with boiler load and main steam pressure. Through the analysis of a boiler flame-extinction incident it can be shown that the monitoring system plays an important role in combustion diagnosis. **Key words**: utility boiler, flame radiation image, three-dimensional temperature field, on-line monitoring, combustion diagnosis

MPS 磨煤机工作特性试验研究＝**Experimental Investigation of the Operating Characteristics of a MPS Coal Pulverizer** [刊, 汉] / YUE Jun-feng, HUANG Lei, CHEN Hua-gui (Technical Center of Jiangsu Provincial Electric Power Co., Nanjing, China, Post Code: 210036) // Journal of Engineering for Thermal Energy &Power. — 2005, 20(1). —65 ~ 68

By using a zero-pressure pendulum sampler and an isokinetic sampling method the samples of pulverized coal were taken at the outlet piping of a MPS coal pulverizer. Through an analysis of the fineness, moisture content and mass of the pul-

verized coal a study was conducted of the operating characteristics of the MPS coal pulverizer. During a series of tests a study was conducted to mainly identify the impact of some major factors on the operating characteristics of the MPS coal pulverizer. Such factors include: the damper opening degree of a static classifier, the rotating speed of a dynamic classifier, the hydraulic loading force of a grinding roll, pulverizer inlet temperature and primary airflow rate. The above study can be helpful in providing design reference data for domestic manufacturers of the MPS coal pulverizer and offering operational guide for MPS coal pulverizers now in commission and also those soon to be put into operation. **Key words**: zero-pressure pendulum sampler, isokinetic sampling of pulverized coal, MPS coal pulverizer

加湿热空气对流冷凝换热冷凝液量的实验研究=**Experimental Research of Condensate Flow Rate of Convection-condensation Heat Exchange of Humidified Hot Air Flow** [刊, 汉] / ZHUANG Zheng-ning, LI Jiang-rong, CHE De-fu, et al (College of Energy &Power Engineering under the Xi'an Jiaotong University, Xi'an, China, Post Code: 710049) //Journal of Engineering for Thermal Energy &Power. — 2005, 20(1). —69 ~ 72

The condensing heating surfaces of a condensing-type gas-fired boiler were used to serve as a prototype. On this basis a simulation of the flue gases in the above-mentioned boiler tail section was conducted by using humidified hot air. Through a single-row bare-tube recuperater a condensation heat exchange was carried out. Within a relatively wide range of humidified hot air temperature (100-200 ℃) and vapor volumetric factor (4%-16%) a study was conducted of the generation law of condensate flow rate. The result of tests indicate that vapor partial pressure, cooling water flow rate and humidified hot airflow rate are major influencing factors of vapor condensate flow rate. Vapor condensation rate is 40% - 75%. After a multivariate linear regression analysis of experimental data a new empirical relation was proposed to calculate the condensate flow rate. **Key words**: condensation type boiler, humidified hot air, condensate, convection condensation heat exchange

非均等配风下的风水冷选择性冷渣器冷态排渣特性=**Cold-state Slag Discharge Characteristics of an Air-water Cooled Selective Slag Cooler under a Non-uniform Air Distribution** [刊, 汉] / YE Xue-min, LI Chun-xi, FAN Xu, et al (Department of Power Engineering, North China University of Electric Power, Baoding, China, Post Code: 071003) //Journal of Engineering for Thermal Energy &Power. — 2005, 20(1). —73 ~ 75

With the air-water cooled selective slag cooler of a 450 t/h circulating fluidized bed boiler serving as a prototype and through a cold-state simulation test a study was conducted of the slag discharge characteristics in various chambers under a uniform and non-uniform air distribution. The impact of airflow ratios in various chambers on the slag discharge rate was analyzed. The results of the tests indicate that the lower limit of actual fluidized airflow of the slag cooler is higher than the design value. Under the condition of a basically unchanged total airflow rate of an air blower and even under a decreased airflow rate and through adjustment of airflow ratio in various chambers it is possible to significantly enhance the slag discharge speed of the slag cooler. The experimental data thus obtained can serve as a guide and reference for ensuring the safe operation of slag coolers. **Key words**: circulating fluidized bed, air-water cooled selective slag cooler, slag discharge characteristics, non-uniform air distribution

注汽涡轮增压柴油机的试验研究=**Experimental Study of a Steam-injected Turbo-charged Diesel** [刊, 汉] / LU Ben (Key Laboratory of Thermal Power Engineering &Thermal Sciences under the Tsinghua University, Beijing, China, Post Code: 100084), WEN Xue-you (Harbin No. 703 Research Institute, Harbin, China, Post Code: 150036) //Journal of Engineering for Thermal Energy &Power. — 2005, 20(1). —76 ~ 79

Tests were conducted on a steam-injected turbo-charged diesel, a new type of power system. Under various diesel operat-