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折流杆换热器在火力发电厂低压加热器上的应用

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摘 要: 简述了折流杆换热器在火力发电厂低压加热器上的应用, 其优点表现在传热效果好, 流体阻力小, 换热器抗腐蚀性、抗冲击性、抗振性增强。可以在发电厂回热系统中推广应用。

关 键 词: 折流杆换热器; 低压加热器; 应用

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1 引 言

现在的火力发电机组中, 从 25 MW 到 300 MW 机组的低压加热器几乎全部采用的是 U 型管折流板式换热器, 它的结构特点是换热管为铜合金光管, 为适应热膨胀的要求, 一般设计成 U 形结构。壳侧采用折流板, 它使壳程流体反复横向流过管束, 增大了流体湍动, 提高了壳程传热系数, 同时对换热管起到支撑作用。但这种结构和流体流动方式有如下严重缺陷: (1)流体反复横向流过管束, 容易激发管束振动, 即产生换热器的流体诱导振动, 这种振动常常使换热管破裂。据统计, 换热器初次使用一个月后就有换热管破裂的情况发生。(2)流体反复横向冲刷管束并不断改变流动方向会产生较大的形体阻力, 往往超过允许的压降值。(3)存在较大的流动死区而引起局部换热系数降低, 结垢严重。

长期以来, 韶关发电厂 8 号机(机组容量为 200 MW)的 4 号低压加热器由于流体横向冲刷管束引起 U 行弯头及换热管与管板连接处破裂, 加之蒸汽腐蚀的影响, 也引起管身的破裂, 经常需要堵管, 造成停机, 损失很大。因此, 在 1998 年初决定对其实施改造。

改造方案是用折流杆换热器代替折流板换热器, 原换热器的壳体不动, 附属设备及管接口均不变, 只更换换热器器芯, 换热管由原来的 ϕ19×1 mm 锡黄铜管换成 ϕ19×2 mm 锅炉用无缝钢管, 换热管与管板的连接采取先用亚弧焊接然后再胀接的方式。加热器为垂直布置。这样改造方便易行而且成本低。改造由原电力工业部茂港电力设备厂完成。换热器的设计参数见表 1。

表 1 加热器设计参数

凝结水压力/MPa	凝结水流量/t·h^{-1}	出水温度/℃	进水温度/℃	进汽压力/MPa	进汽温度/℃	进汽流量/t·h^{-1}
1.32	510.1	143	122	0.42	321.2	17.4

2 折流杆换热器结构特征及其性能特点

2.1 结构特征

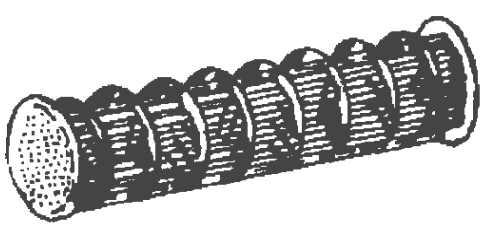

图 1 管束结构

结构设计与折流板换热器比较, 折流杆换热器结构特点主要表现在管束上(如图 1)。它用折流杆圈组件代替传统折流板支承换热管并提高壳程流体的湍动性能。折流杆圈是由一个支承环和一些折流杆组成(见图 2)。折流杆圈的组合方式如图 3 所示。由 4 个折流杆圈按 W、X、Y、Z 组成一组, 在组内 4 个折流杆圈的彼此相位差为 90°, 实现对换热管的4个方向的支承(见图4)。除管束外, 流杆圈的

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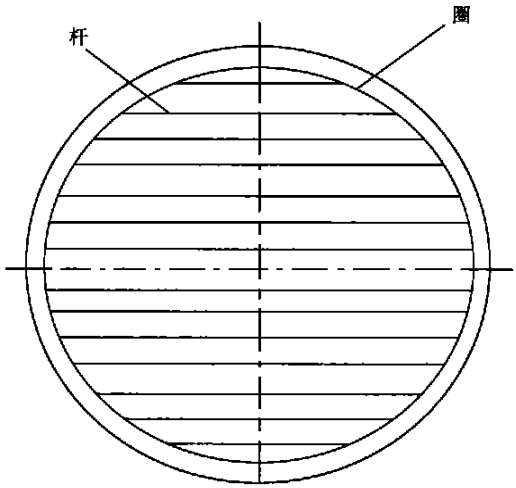

图 2　折流杆圈图

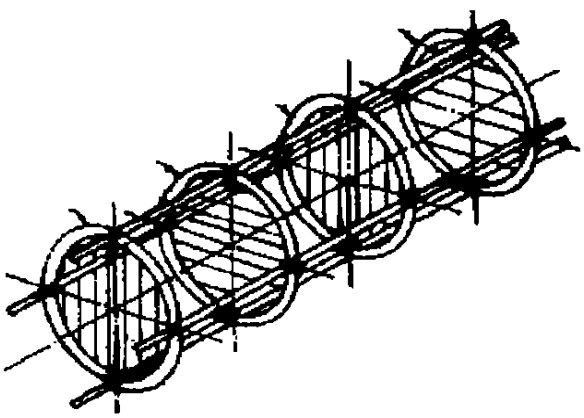

图 3　折流杆圈组

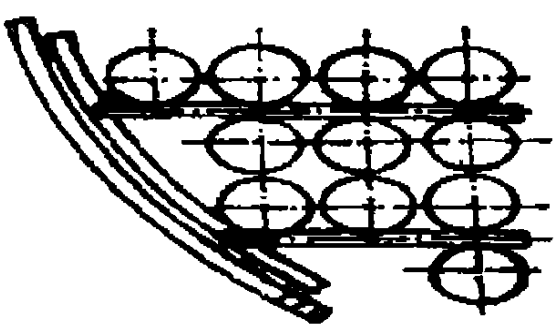

图 4　折流杆换热管支撑结构

组合方式如图 3 所示。由 4 个折流杆圈按 W、X、Y、Z 组成一组, 在组内 4 个折流杆圈的彼此相应差为 90°, 实现对换热管的 4 个方向的支承(见图 4)。除管束外, 折流杆换热器的其它结构与传统折流杆换热器的其它结构与传统折流板换热器基本相同, 允许按传统设计方法进行设计。

2.2　性能特点

(1) 在这种换热器中, 传热管由折流栅支撑, 折流栅又由折流杆和折流环组成, 具有良好的弹性性能。同时传热管与折流杆为圆弧接触, 四周均被固定, 能有效地防止换热管的破坏振动。

(2) 折流杆对传热管起支撑作用的同时, 又增大了流体的湍动, 提高了壳程传热系数。这里流体湍动的提高是借助流体流过折流环和折流杆时的文丘里效应和涡流脱体来实现的, 没有改变流体流动方向。壳程流体主要是呈轴向流动, 与管内流体流动过程基本相同, 可以使换热器产生最佳的热力和水力效果。

(3) 在折流杆换热器中, 壳程流体不存在横向流过管束, 基本消除了流体诱导振动的因素, 同时壳程压降比折流板换热器明显减小。

(4) 壳程流体大体一致的轴向流动基本消除了流动死区, 减少了污垢的沉积。

3　折流杆换热器的使用效果

20 世纪 70 年代, 美国 Phillips 公司首先开发了折流杆换热器, 80 年代进入我国。目前这种新型的换热器在国外已得到广泛的应用, 在我国也已从研究、试验阶段走向了实际应用, 但仅仅局限于石化行业, 在电力行业还从未使用过。韶关发电厂 8 号机的 4 号低加的改造是第一次使用折流杆换热器。

改造后的加热器于 1998 年年底投入使用。在 1999 年 10 月, 广东省电力试验研究所对其进行了性能验收试验。试验在满负荷下进行了两次, 均达到了设计要求。试验的测量值及计算值列于表 2。

由表 2 可以看出, 在满负荷(200 MW)下, 温升为 21 ℃, 出水端差小于 5 ℃, 完全达到了设计要求。

这次改造是在原壳体不改变的情况下进行的, 在固定的壳体内径下进行折流杆换热器的布管。由于换热管外径都是 ϕ19, 因此, 换热面积在改造前后基本相同。在达到相同的运行参数条件下, 虽然改造后的换热器换热面积没有减少, 但与改造前的折流板换热器比较仍具有以下优点:

(1) 换热管由铜管改为钢管, 钢管的导热系数比铜管的小, 而且换热管管壁增厚, 在相同的传热面积下达到同样的传热效果, 说明折流杆换热器比折流板换热器的传热性能好。

表 2 加热器性能试验数据

	工况 1	工况 2
机组负荷/MW	202.15	203.85
凝结水流量/t·h⁻¹	528.23	527.85
出水温度/℃	141.5	141.6
进水温度/℃	120.5	120.6
进汽压力/MPa	0.429 2	0.432 5
进汽温度/℃	355.5	357.2
饱和汽温/℃	146.2	146.5
疏水温度/℃	146.5	146.8
进水压力/MPa	0.939 6	0.943 2
出水压力/MPa	0.721 6	0.727 2
进汽口与疏水口压差/MPa	0.06	0.061
温升/℃	21.0	21.0
端差/℃	4.7	4.9
水阻/MPa	0.218	0.216
汽阻/MPa	0.06	0.061

(2) 换热管由 φ19×1 mm 铜管改为 φ19×2 mm 锅炉用无缝钢管,换热管与管板的连接采用先焊后胀的方式,换热器芯抗腐蚀性、抗冲击性、抗振性增强。因此换热器的使用寿命延长。实际上,改造后的折流杆换热器从投入使用到目前为此三年多的时间还没有换热管破裂的现象发生。

(3) 改造后的换热器壳侧的压降比改造前的降低。

(4)锡黄铜管比锅炉用无缝钢管贵得多,换热管由铜管改为钢管,在相同的换热面积达到同样的使用效果情况下,换热器的成本大大降低。

4 折流杆换热器在火力发电厂回热系统推广应用问题探讨

折流杆换热器在韶关电厂的应用表明,折流杆换热器可以完全取代折流板换热器。折流杆换热器的制造与折流板换热器比较起来要注意两点:首先,对于折流板换热器只需进行管板与折流板孔的配钻,就可满足管束组装要求。而对于折流杆换热器管板孔的加工,则须保证管板孔间的管间距具有允许的位置度,才能保证换热管顺利穿过两个管板。其次,折流圈上折流杆的间距也必须控制在装配上允许的公差范围内,才能顺利进行管束的组装。一般地说,凡具有制造传统折流板管壳式换热器的厂家,在设计制造一些简单而必要的工艺装备之后,都有能力生产折流杆管壳式换热器,不需添置专用设备。

电厂回热系统中的低压加热器或高压加热器,都是壳侧走蒸汽,管侧走水。壳侧为蒸汽冷凝放热,其传热系数远大于管侧。本文作者在对韶关电厂低压加热器进行热力设计时也发现传热热阻主要集中在管侧。这样势必在管内形成热量传递的喉口效应。如换热管采用缩放形不锈钢管,那么管内换热将被强化,整个换热器的传热性能将大大提高。与铜管加热器相比,不锈钢管芯抗腐蚀性、抗冲击性、抗振性强,从而减少了振动腐蚀造成的泄漏和损坏的机率。此外,对于直流锅炉来说,回热加热器采用了不锈钢管芯后可实现给水水质的无铜化运行,减少了铜离子在锅炉管道及汽轮机通道等处的堆积,减少了锅炉爆管等事故的发生。因此,对于电厂回热系统中的低压加热器或高压加热器,采用折流杆缩放形不锈钢管换热器将会取得比较理想的效果。

5 结束语

对于目前火力发电厂回热系统中旧加热器的改造,在不改变壳体及附属设备的情况下,采用折流杆换热器器芯,换热管为锅炉用无缝钢管,完全可以满足性能要求,而且成本降低、使用寿命延长;对于整台加热器的制造,可以采用缩放形不锈钢管折流杆换热器,预期可有效提高换热性能,减少换热面积,实现给水水质的无铜化运行。

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(渠 源 编辑)

自动同步离合器棘轮棘爪碰撞问题的讨论 = **Some Observations Concerning the Collision of Ratchet and Pawl in an Automatic Synchronizing Clutch** [刊, 汉] / SONG Cheng-jun, WEI Jun-bo, HUO Zhao-bo (Harbin No. 703 Reearch Institute, Harbin, China, Post Code: 150036), GONG Li-xin (Luoyang North Yichu Motor Car Co. Ltd., Luoyang, China, Post Code: 471031) // Journal of Engineering for Thermal Energy &Power. — 2003, 18 (3). —301 ~ 303

A dynamics simulation model for the ratchet/pawl mechanism of an automatic synchronizing clutch was set up with the help of ADAMS dynamics analysis software. A dynamics analysis was conducted of the collision of ratchet and pawl along with a discussion from a theoretical perspective. **Key words**: ratchet/pawl mechanism, collision force, automatic synchronizing clutch, differential angular speed

Delphi 和 AHP 集成的火电建设工程模糊综合评价方法 = **Fuzzy and Comprehensive Evaluation Method for a Thermal Power Plant Construction Project by the Integration of Delphi Method and AHP (Analytical Hierarchy Process)** [刊, 汉] / CHEN Jian-hong, SHENG De-ren, LI Wei (Institute of Power Plant Thermal Energy Engineering and Automation under the Zhejiang University, Hangzhou, China, Post Code: 310027), MENG Wei (Zhejiang Provincial Electric Power Development Co., Hangzhou, China, Post Code: 310027) // Journal of Engineering for Thermal Energy &Power. — 2003, 18 (3). —304 ~ 307

Based on the principles of system engineering, through an argumentation performed by experts and with the use of Delphi method the authors have set up a multi-hierarchy comprehensive-evaluation index system for thermal power plant construction projects. With the help of an analytical hierarchy process established was a relatively consummate evaluation model and method for the above-cited projects, and the procedures and method for project comprehensive evaluation were also determined. The calculation results of some actual cases indicate that the evaluation method based on a multi-hierarchy index system and multi-objective synthesis makes it possible to quantitatively address many influencing factors involved in a thermal power plant construction project, thereby ensuring the objectivity and precision of project evaluation. The authors have also explored the following items: the establishment of an index system for the multi-hierarchy comprehensive evaluation of thermal power plant construction projects, the determination of index weights and the creation of a fuzzy comprehensive evaluation model, etc. **Key words**: thermal power plant construction project, Delphi method, analytical hierarchy process, index system

单元初始㶲效率和㶲流价值分布 = **Efficiency of Unitary Primary Exergy and Distribution of Exergy Flow Values** [刊, 汉] / YANG Zhao, LIU Bin, LI Xun (Heat Engineering Institute under the Tianjin University, Tianjin, China, Post Code: 300072) // Journal of Engineering for Thermal Energy &Power. — 2003, 18 (3). —307 ~ 309

After an analysis of the non-equivalence of exergy the authors put forward a series of concepts, such as exergy elastic factor, primary exergy loss rate, etc. On the basis of the exergy elastic factor analyzed is the influence of exergy efficiency of various constituent elements in an unitary system on the exergy efficiency of the system as a whole. A method for calculating the primary-exergy loss rate is derived and the analytical calculation of a specific case given. The results of the analysis indicate that the primary exergy consumed by the unitary exergy of various constituent elements in the system can truthfully reflect the exergy consumption characteristics of these constituent elements, thus facilitating a scientific analysis of the energy-saving potential of the various constituent elements of the system. **Key words**: exergy, elastic factor exergy flow distribution

折流杆换热器在火力发电厂低压加热器上的应用 = **The Use of a Baffle-rod Heat Exchanger on the Low-pressure Heater of a Thermal Power Plant** [刊, 汉] / HUANG De-bin, DENG Xian-he (Education Ministry Key Lab-

oratory on Intensive Heat Transfer and Process Energy Saving under the South China University of Science and Technology, Guangzhou, China, Post Code: 510640) // Journal of Engineering for Thermal Energy & Power. — 2003, 18 (3). —310 ~ 312

A brief account is given of the use for the first time of a baffle-rod heat exchanger on the low-pressure heater of a thermal power plant. The heat exchanger offers a variety of merits, such as high heat transfer efficiency, low fluid resistance, and the ability to resist corrosion, shocks and vibrations. It is suited for use in heat regeneration systems of power plants.

Key words: baffle-rod heat exchanger, low-pressure heater, applications

670 t/h 锅炉稳燃的改进措施及其效果 = **Measures for Promoting the Stable Combustion in a 670t/h Boiler and Their Effectiveness** [刊, 汉] / XIAO Han-cai, (Power Engineering Department, Changsha Electric Power Institute, Changsha, China, Post Code: 410077), HE Xiao-nai (Jiangxi Xinyu Power Plant, Xinyu, Jiangxi Province, China, Post Code: 336500) // Journal of Engineering for Thermal Energy & Power. — 2003, 18 (3). —313 ~ 314

The 670t/h boiler of a 200MW power plant often has to cope with a variety of unfavorable conditions, which can seriously impair the stable combustion of the boiler, and even cause a flame failure or entail the necessity to go for a copious oil-assisted combustion. Such conditions include high ash content of coal and low peak-shaving load, etc. A series of measures were taken to improve the situation, which resulted in a stable combustion, higher efficiency and reduced oil consumption for the boiler, contributing to an increase in economic benefits.

Key words: coal high ash content, peak-shaving low load, fork-shaped pulverized coal spray nozzle, two-location biased separation, stable combustion

供暖系统运行中的常见问题及处理 = **Common Problems Occurring in a Heat Supply System and Measures Taken for Their Resolution** [刊, 汉] / BAI Zhen-yu (Department of Capital Construction, Harbin Medical University, Harbin, China, Post Code: 150086) // Journal of Engineering for Thermal Energy & Power. — 2003, 18 (3). —315 ~ 316

Based on the experience accumulated over the recent two decades in technical modification and operation management of heat supply systems the author has analyzed a whole range of problems often encountered by nearly all the heat supply systems in China. The problems include hydraulic maladjustment, system air accumulation, system loss of water and pressure instability, etc. A scheme for resolving the above-mentioned problems is proposed with some examples of heat-supply system technical modification being presented.

Key words: heat supply system, hydraulic maladjustment, pressure fluctuation, technical modification

火电厂备用电源自投与 FSSS 系统的配合 = **Coordination of the Self-starting of a Backup Power Supply with a Furnace Safeguard Supervisory System at a Thermal Power Plant** [刊, 汉] / LU Zhi-qiang (Changguang Coal Mine Power Plant, Changxin County, Zhejiang Province, China, Post Code: 313116) // Journal of Engineering for Thermal Energy & Power. — 2003, 18 (3). —317 ~ 318

Key words: thermal power plant, backup power supply, self-starting, furnace safeguard supervisory system, actuation signal for furnace flame-extinction protection

螺杆压缩机变速箱齿轮齿断裂原因分析 = **Analysis of the Cause of Speed-change Gearbox Gear-tooth Rupture in a Screw Compressor** [刊, 汉] / LI Jun, LI Qing-rui (Daqing Petrochemical General Works, Daqing, Heilongjiang Province, China, Post Code: 163000) // Journal of Engineering for Thermal Energy & Power. — 2003, 18 (3). —319 ~ 320

Key words: gear, rupture, hardness, lubrication