双燃料煤粉流化床复合燃烧锅炉的物质平衡与热量平衡

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〔摘要〕 本文分析了双燃料煤粉流化床复合燃烧锅炉的物质平衡及热量平衡,得到了炉膛及空气预热器的物质平衡方程、沸腾层及煤粉炉膛的热平衡方程以及炉膛出口过量空气系数、锅炉气体未完全热损失、固体未完全热损失的计算公式。

关键词 混合燃料 复合燃烧 物质平衡 热量平衡
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0 引言

在同一炉膛中同时采用煤粉燃烧和流化床燃烧的煤粉流化床复合燃烧锅炉可克服煤粉燃烧和流化床燃烧的缺点,因为同台锅炉中采用了两种燃烧方式,使锅炉的物质平衡及热量平衡比其它锅炉复杂。而两种燃烧方式又燃烧两种燃料的双燃料煤粉流化床复合燃烧锅炉的物质平衡及热量平衡更为复杂,本文以一台进口的双燃料煤粉流化床复合燃烧锅炉为例,来分析这些问题。

1 双燃料煤粉流化床锅炉简介

图 1为某双燃料煤粉流化床复合燃烧锅炉简图,树皮在炉膛底部的流化床中燃烧,以砂子作为流化媒体。采用微斜布置的水冷布风板,管式风帽。煤粉燃烧器布置在炉膛侧墙中部。炉膛四周布置了全焊膜式水冷壁,沿烟气流向,在炉膛后部布置了蒸发屏、转向室、顺流布置的第二级过热器、逆流布置的第一级过热器。 空气预热器共分三级: 第一级空气预热器采用卧式布置,加热流化床燃烧所需空气;立式布置的第二、三级空气预热器加热煤粉燃烧所需空气,同时将一部分空气作为二次风喷入炉膛。 省煤器布置在第

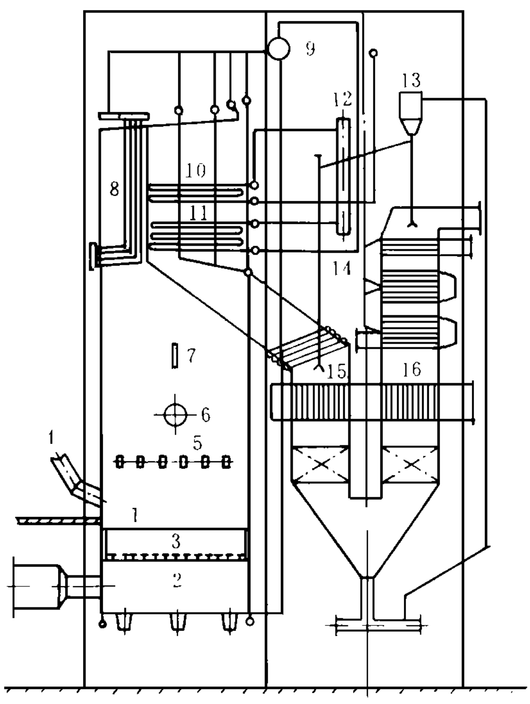

图 1 双燃料煤粉流化床复合燃烧锅炉简图
1. 点火室 2.水冷风室 3.风帽 4.树皮入口溜管
5.二次风喷口 6.燃烧器 7.三次风喷口 8.蒸发屏
9.锅筒 10.过热器二 11.过热器一 12.减温器
13.吹灰装置 14.空气预热器一 15.空气预热器三
16.空气预热器二 17.省煤器

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二、三级空气预热器之间。两级过热器之间设自制冷凝水喷水减温器。第二级空气预热器和第一级空气预热器空气入口设有暖风器。尾部受热面采用钢球吹灰。

2 物质平衡

2.1 灰平衡

图 2为双燃料煤粉流化床复合燃烧锅炉炉膛的灰平衡框图，由图可见，飞灰份额为:

$$\alpha_{fh} = \frac{A_{arm}B_m\alpha_{fhm} + A_{ars}B_s\alpha_{fhs}}{A_{arm}B_m + A_{ars}B_s} \quad (1)$$

灰渣份额为:

$$\alpha_{hz} = 1 - \alpha_{fh} \quad (2)$$

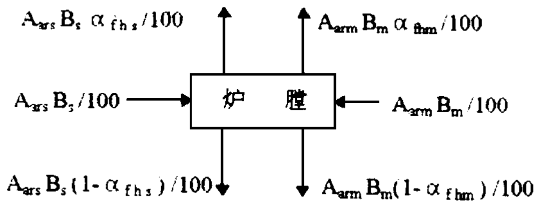

图 2 炉膛灰平衡框图

2.2 风平衡

图 3为双燃料煤粉流化床复合燃烧锅炉的风量平衡框图，由图可得炉膛出口过量空气系数和各级空气预热器空气入口的过量空气系数分别为:

$$\alpha''_l = \frac{\alpha_m B_{jm}V_m^0 + \alpha_S B_{jS}V_S^0 + \Delta\alpha_{l1}B_{jm}V_m^0 + \Delta\alpha_{l2}B_{jm}V_m^0}{B_{jm}V_m^0 + B_{jS}V_S^0} \quad (3)$$

$$\alpha'_{ky1} = \alpha_S - \Delta\alpha_{bs} + \Delta\alpha_{ky1} \quad (4)$$

$$\alpha'_{ky2} = \alpha_m + \Delta\alpha_{zf} + \Delta\alpha_{ky2} + \Delta\alpha_{ky3} + \Delta\alpha_{ky1} \quad (5)$$

$$\alpha'_{ky3} = \alpha_m + \Delta\alpha_{zf} + \Delta\alpha_{ky3} \quad (6)$$

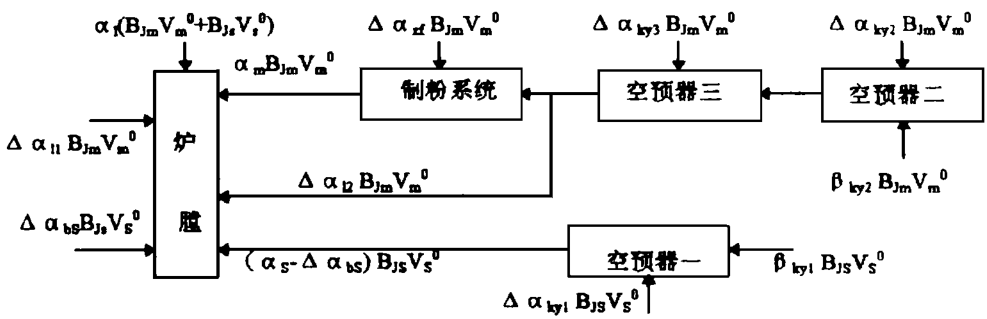

图 3 风平衡框图

3 热量平衡

3.1 沸腾层烟气侧热平衡

图 4为双燃料煤粉流化床复合燃烧锅炉炉膛的热平衡框图，由图可得沸腾层的热平衡方程为:

$$B_sQ_{rs} + \Delta\alpha_{bs}B_{js}I^0_{lks} + (\alpha_s - \Delta\alpha_{bs})B_{js}I^0_{rks} + Q^{hz}_{4m} + Q^{hz}_{6m} = Q_S + B^*_{js}I^*_s + Q_{3sft} + Q^{fh}_{4fht} + Q^{hz}_{4s} + Q_{5s} + Q_{6s} \quad (7)$$

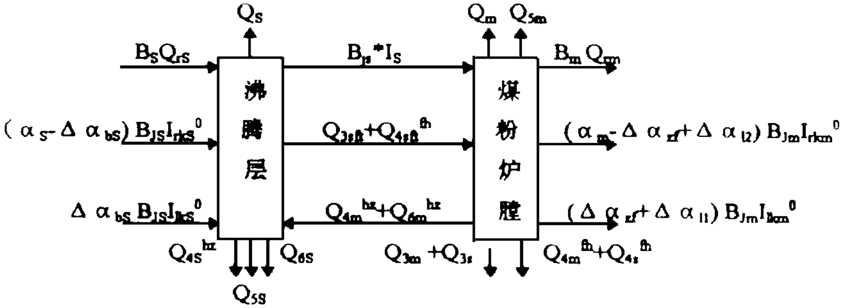

图 4 炉膛热平衡框图

由
$$B_{js} = \frac{100 - q_{4s}}{100} B_s \quad (8)$$

$$B^*_{js} = \frac{100 - q_{4fts}}{100} B_s \quad (9)$$

$$W = \frac{100 - q_{3fts} - q_{4fts}}{100 - q_{3s} - q_{4s}} \quad (10)$$

$$h = \frac{Q_s}{Q_s + B_s Q_{5s}} \quad (11)$$

得沸腾层埋管吸热量:

$$Q_s = hB_{js}\Big[Q_{rs}\frac{W(100 - q_{3s} - q_{4s}) - q_{6s} + q^{hz}_{4m} + q^{hz}_{4m}}{100} + \Delta T_{bs} I^0_{lks} + (T_s - \Delta T_{bs}) I^0_{rks} - \frac{100 - q_{4fts}}{100 - q_{4s}} I''_s\Big] \quad (12)$$

3. 2　煤粉炉膛烟气侧热平衡

煤粉炉膛是布置在沸腾层上部的空间,煤粉和在沸腾层中未燃尽的树皮在该空间燃烧,其热平衡如图 4所示,由图得到煤粉炉膛的热平衡方程为:

$$B_m Q_{rm} + (\Delta T_{zf} + \Delta T_{l1}) B_{jm} I^0_{lkm} + (T_m - \Delta T_{zf} + \Delta T_{l2}) B_{jm} I^0_{rkm} + B^*_{js} I''_S + Q_{3sft} + Q^{fh}_{4sft} = Q_m + Q_{3m} + Q_{3s} + Q^{fh}_{4m} + Q^{fh}_{4s} + Q^{hz}_{4m} + Q^{hz}_{6m} + Q_{5m} \quad (13)$$

根据

$$Q_{4m} = Q^{fh}_{4m} + Q^{hz}_{4m} \quad (14)$$

$$B_{jm} = \frac{100 - q_{4m}}{100} B_m \quad (15)$$

$$h = \frac{Q_m}{Q_m + B_m Q_{5m}} \quad (16)$$

得煤粉炉膛的吸热量:

$$Q_m = h\Big[B_m Q_{rm}\frac{100 - q_{3m} - q_{4m} - q^{hz}_{6m}}{100} + \frac{100 - q_{4fts}}{100 - q_{4s}} I''_s + Q_{rs}\frac{(1 - W)(100 - q_{3s} - q_{4s})}{100 - q_{4s}} + (\Delta T_{zf} + \Delta T_{l1}) \cdot B_{jm} I^0_{lkm} + (T_m - \Delta T_{zf} + \Delta T_{l2}) B_{jm} I^0_{rkm}\Big] \quad (17)$$

3. 3　锅炉的气体和固体未完全燃烧热损失

$$q_3 = \frac{Q_{3m} + Q_{3s}}{B_m Q_{rm} + B_s Q_{rs}} \times 100 = q_{3m}\frac{B_m Q_{rm}}{B_m Q_{rm} + B_s Q_{rs}} + q_{3s}\frac{B_s Q_{rs}}{B_m Q_{rm} + B_s Q_{rs}} \quad (18)$$

$$q_4 = \frac{Q_{4m} + Q_{4s}}{B_m Q_{rm} + B_s Q_{rs}} \times 100 = q_{4m}\frac{B_m Q_{rm}}{B_m Q_{rm} + B_s Q_{rs}} + q_{4s}\frac{B_s Q_{rs}}{B_m Q_{rm} + B_s Q_{rs}} \quad (19)$$

符　号　表

a— 灰份额;
A— 灰分,%;
B— 燃料消耗量,kg/s;
B_j— 计算燃料耗量,kg/s;
B^*_j — 沸腾层计算燃料耗量,kg/s;
I^0_{lk}— 理论冷空气焓,kJ/kg;
I^0_{rk}— 理论热空气焓,kJ/kg;
I''_S— 沸腾层出口烟气焓,kJ/kg;
q_3— 气体未完全燃烧热损失,%;
q_4— 固体未完全燃烧热损失,%;
q_5— 散热损失,%;
q_6— 灰渣物理热损失,%;
Q_3— 气体未完全燃烧损失热量,kW;
Q_4— 固体未完全燃烧热损失热量,kW;
Q_5— 散热损失热量,kW;
Q_6— 灰渣物理热损失热量,kW;
Q_r— 锅炉输入热量,kJ/kg;
V^0— 理论空气量,Nm³/kh;
T— 过量空气系数;
ΔT_{l1}— 炉膛漏风系数;
ΔT_{l2}— 二次风份额;
ΔT_{bs}— 播撒风份额;
ΔT_{zf}— 制粉系统漏风系数;
W— 沸腾层燃烧份额;
j— 保热系数;
U— 空气预热器过量空气系数;

下　标

l— 炉膛	**ar**— 空气干燥基
s— 树皮	**fh**— 飞灰
ft— 沸腾层	**m**— 煤
hz— 灰渣	**ky**— 空气预热器

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On the basis of a paper entitled "Unit consumption analysis model of a heat supply system" and by utilizing modern energy saving theory the authors have set up a generalized discrete model for the unit consumption of a cogeneration turbine set heat supply. This not only provides a basis for developing further a continuous model but also by way of calculating specific examples makes it possible to investigate the multifarious factors affecting the unit consumption of CHP heating on the basis of a totally new quantitative index analysis. Practice has shown that this is a useful study, enlightening authors in the creation of a new mode of combined heat and power generation. **Key words** heat supply, unit consumption, cogeneration, energy-saving, exergy

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An analysis is conducted of the thermal performance of a novel solar cavity receiver with a bundle of tubes serving as an absorber. On the basis of a heat resistance network and the general control equations of solar energy a numerical analysis is performed of the influence on the heat resistance of such environmental conditions as solar direct irradiation, ambient temperture and wind velocity. **Key words** solar cavity receiver with a tube bundle as its abosorbe, solar energy, heat resistance, boundary condition

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An analysis is made of the material and heat balance for a dual-fuel pulverized coal-fired fluidized bed multiple combustion boiler. Obtained are a material balance equation for the boiler furnace and air heater, a heat balance equation for the fluidized bed and the pulverized coal-fired furnace and a calculation formula for furnace outlet excess air faclor, unburned flue gas heat loss and unburned carbon heat loss. **Key words** mixed fuel, multiple combustion, material balance, heat balance

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The exergy analysis of an intercooled reheat steam injected gas turbine cycle has shown that such a cycle has a significantly higher exergy efficiency as compared with a simple STIG cycle. Also analysed in this paper are the effect on exergy efficiency of the equipment performance and various cycle parameters, and the locations where various kinds of irreversible losses took place. As a result, intrinsiclly different conclusions in respect of heat balance are obtained. **Key words** intercooled reheat STIG Cycle, irreversible loss, exergy efficiency

220 t/h百叶窗分级循环流化床投资成本分析 = **Investment Cost Analysis of a 220 t/h Louver Stepped Cycle fluidized Bed**〔刊,中〕/Chen Yulin, Li Yuying (Jiamusi Thermal Power Station)// Journal of Engineering for Thermal Energy & Power. -1997, 12(1). -15~18

This paper deals with the investment cost of a 220 t/h louver stepped cycle fluidized bed installed at Jiamusi