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生物质与城市生活垃圾混烧特性的实验研究

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摘 要: 针对城市生活垃圾与煤混烧发电方法经济效益较差的缺点, 建立了生物质与城市生活垃圾混烧实验系统, 测试了系统设计和运行中主要可控参数对炉膛温度和燃料燃烧效率的影响。结果表明: 炉膛温度随一次风率和掺混质量百分含量的增大而增大, 随过量空气系数的增大而降低; 燃料燃烧效率随一次风率和掺混质量百分含量的增大而增大, 随过量空气系数的增大, 先增大后减小; 当过量空气系数为 1.7、掺混质量百分含量为 15%、一次风率为 75%时, 炉膛温度为 880 ℃, 燃料燃烧效率为 97.4%。

关 键 词: 垃圾焚烧; 生物质; 炉膛温度; 燃烧效率
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引 言

目前, 城市生活垃圾的常用处理方法有卫生填埋、堆肥、焚烧和热解 4种, 其中垃圾焚烧发电可以真正实现固体废物的无害化、减量化和资源化处理, 也是今后处理城市生活垃圾的重要发展方向[1~2]。但是, 由于城市生活垃圾具有成分复杂、波动性大的特点, 为保证燃烧的稳定性, 掺煤燃烧是目前垃圾焚烧行业的一大特色。国内外许多学者对城市生活垃圾与煤混烧进行了比较全面的理论和实验研究[3~5]。认为这样处理垃圾不仅浪费了其它的资源, 而且运行成本较高、经济效益较差[6~7]。

相对于煤、石油等常规能源, 作为可再生能源的生物质能在能源结构中的地位越来越重要[8]。秸秆具有挥发份高、炭活性高, N S含量低, 灰分低, 热值高, 生命周期内燃烧过程 CO_2 零排放等特点, 特别适合燃烧转化利用, 是一种优质燃料。然而, 目前生物质与城市生活垃圾混烧的研究鲜有报道, 为此进行了生物质与生活垃圾混烧实验的研究, 分析结果可以为垃圾发电厂的运营提供参考。

1 实验部分

1.1 实验装置

实验系统如图 1所示。主要包括进料装置、焚烧炉本体、烟气净化装置、控制系统等几部分, 其中焚烧炉采用倾斜往复式炉排炉。

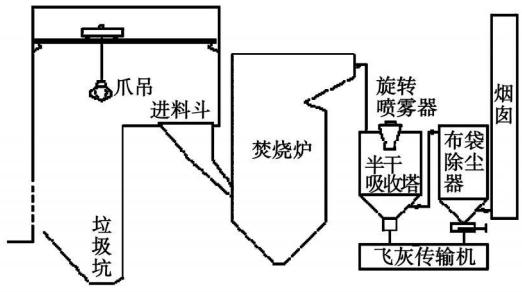

图 1 实验系统流程图

1.2 实验材料

表 1 棉秆和生活垃圾特性

		生活垃圾	棉秆
工业分析/%(wt)	M_{ar}	46.7	9.9
	A_{ar}	11.9	3.6
	V_{ar}	29.6	64.79
	FC_{ar}	11.8	21.71
元素分析/%(wt)	C_{ar}	15.69	42.9
	O_{ar}	14.51	37.8
	H_{ar}	2.73	5
	N_{ar}	0.71	0.67
	S_{ar}	0.03	0.12
	Cl_{ar}	0.47	0.01
$Q_{net,ar}$/kJ·kg^{-1}		5 200	15 300

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实验用垃圾为天津市津南区城市生活垃圾, 掺混的生物质以棉花杆为主, 且棉花杆收集后未做预处理。应用 Varip EI型元素分析仪进行元素分析, 其分析结果如表 1所示。

2　实验结果与分析

炉膛温度和燃料燃烧效率是评价混烧效果的两个主要因素, 因此实验测量了运行中主要可控参数 (一次风率、过量空气系数、棉杆的掺混质量百分含量)的变化对炉膛温度和燃料燃烧效率的影响。

2. 1　炉膛温度的研究

2. 1. 1　一次风率对炉堂温度的影响

图 2为过量空气系数 α= 1. 7, 纯垃圾和棉杆的掺混质量百分含量 R= 15% (R=棉杆的质量 /(棉杆质量 +垃圾质量))时, 一次风率对炉膛温度的影响曲线。一次风量的主要作用是使燃料中的挥发份燃烧及固体焦炭粒子氧化。垃圾和棉杆的主要可燃物质是其中的挥发份, 所以在本实验运行范围内, 随着一次风率增大, 炉膛内的燃料挥发份燃烧更加充分, 固体焦炭粒子的氧化更完全, 利于进一步的燃烧, 因此随着一次风率增大, 炉膛温度逐渐增大。但是, 在实际运行中, 一次风率存在一定的上限, 这是因为在过量空气系数一定的情况下, 增大一次风量, 要减少二次风量, 使得炉膛内气流的扰动减弱, 减少了可燃物在炉膛内的停留时间, 增大了排烟损失; 另一方面, 一次风量的增大, 使得一次风管内的风速、阻力过大, 对安全运行不利。

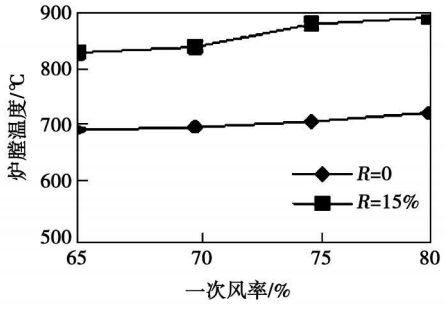

图 2　一次风率对炉膛温度的影响

2. 1. 2　过量空气系数对炉堂温度的影响

图 3为一次风率 75%、纯垃圾和棉杆的掺混质量百分含量 R= 15%时, 过量空气系数对炉膛温度的影响曲线。在本实验运行范围内, 随过量空气系数增大, 炉膛的温度降低。这是由于随着过量空气系数增大, 烟气流量增大, 导致炉膛出口烟气热损失增大, 因而炉膛内温度降低。

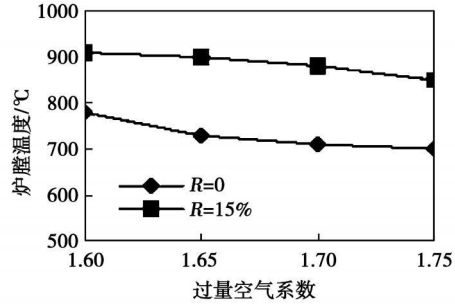

图 3　过量空气系数对炉膛温度的影响

2. 1. 3　棉杆百分含量对炉堂温度的影响

图 4为一次风率 75%、过量空气系数 α= 1. 7时, 棉杆掺混百分含量对炉膛温度的影响曲线。从图中可以看出, 当其它工况条件相同时, 炉膛温度随秸杆量的增加而增大。这是由于实验用生活垃圾的热值较低 (只有 5 200 kJ/ kg), 所以燃烧时炉膛温度较低, 在没有燃油助燃的情况下, 一般维持在 700 ℃左右。随着棉杆掺入量增多, 混合物热值相应增大, 因此炉膛温度逐渐变大。当棉杆的质量百分含量为 15%左右时, 混合物的热值达到 6 700 kJ/ kg, 接近锅炉的燃烧设计工况, 锅炉的燃烧状况最佳。

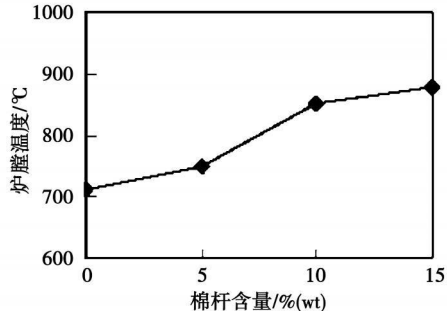

图 4　棉杆掺混百分含量对炉膛温度的影响

2. 2　燃料燃烧效率的研究

燃料的燃烧效率主要受燃料的气体不完全燃烧热损失 q_3和固体不完全燃烧热损失 q_4两方面的影响。在燃料燃烧过程中, 形成完全燃烧产物二氧化碳 CO_2和水蒸气 H_2O的同时, 也产生一氧化碳 CO, 氢气 H_2、甲烷 CH_4及碳氢化合物等可燃气体, q_3就是指烟气中含有的上述可燃气体没完全燃烧放出其燃烧热, 而造成的热量损失; q_4是指灰渣 (包括飞灰、炉渣等)中未燃尽可燃物造成的热损失。

2. 2. 1　一次风率对燃烧效率的影响

过量空气系数 α= 1. 7, 棉杆的掺混质量百分含

量 R=15%时, 一次风率对燃料燃烧损失的影响如图 5所示, 对燃料燃烧效率的影响如图 6所示。从这两图中看出, 随一次风率增大, 燃料的气体不完全燃烧热损失 q_3和固体不完全燃烧热损失 q_4均减小, 燃烧效率升高。这是因为一次风的增加, 对炉膛内的燃料燃烧是有利的。另外, 从图中可以看出, 固体不完全燃烧热损失减小的幅度要大于气体不完全燃烧热损失减小的幅度。这是因为当一次风率为65%时, 燃料中挥发份已接近完全燃烧, 再增加一次风量, 对挥发份的燃烧影响不是很大, 而对焦炭粒子的氧化燃烧有促进作用。同时也说明气体不完全燃烧损失与固体不完全燃烧相比, 固体不完全燃烧损失起主要作用。

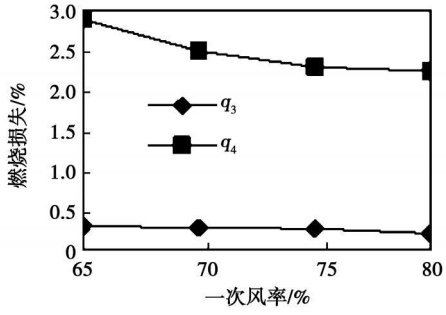

图 5 一次风率对燃烧损失的影响

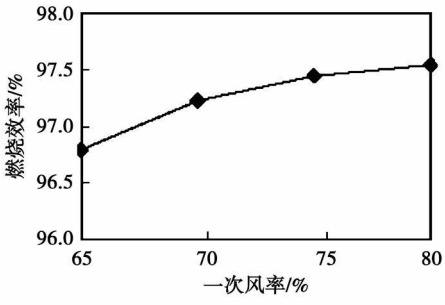

图 6 一次风率对燃烧效率的影响

2.2.2 过量空气系数对燃烧效率的影响

一次风率 75%、棉秆的掺混质量百分含量 R=15%时, 过量空气系数对燃料燃烧损失的影响如图 7所示, 对燃料燃烧效率的影响如图 8所示。从这两图中可看出, 随过量空气系数增大, 燃料的气体不完全燃烧热损失 q_3和固体不完全燃烧热损失 q_4先减小后增大, 相应的燃烧效率先增大后减小。

这是因为当过量空气系数小于最佳值时, 增加送风量可以增加燃料与空气的接触, 有利于完全燃烧, 因而降低气体不完全燃烧热损失 q_3和固体不完全燃烧热损失 q_4。当过量空气系数超过最佳值时, 则由于降低了炉内温度水平, 缩短燃料在炉内停留时间, 气体不完全燃烧热损失 q_3和固体不完全燃烧热损失 q_4反而增大。

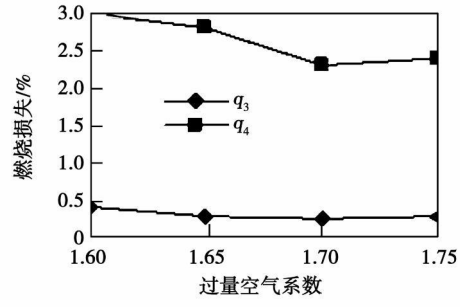

图 7 过量空气系数对燃烧损失的影响

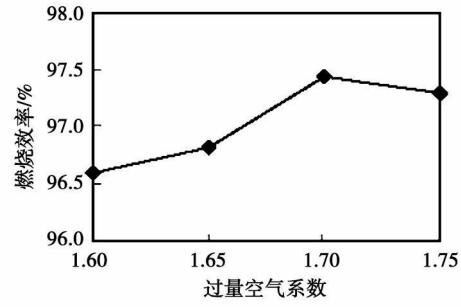

图 8 过量空气系数对燃烧效率的影响

2.2.3 棉秆含量对燃烧效率的影响

过量空气系数 α=1.7、一次风率 75%时, 棉秆百分含量对燃料燃烧损失的影响如图 9所示, 对燃料燃烧效率的影响如图 10所示。从这两图中可看出, 随棉秆百分含量 R增大, 燃料的气体不完全燃烧热损失 q_3和固体不完全燃烧热损失 q_4均减小, 燃烧效率升高。

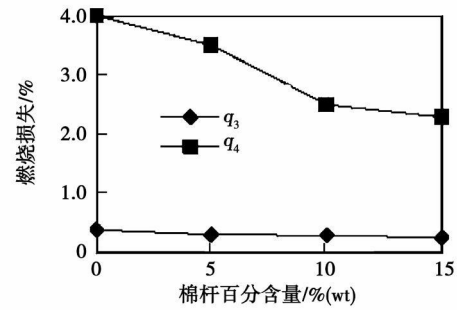

图 9 棉秆含量对燃烧损失的影响

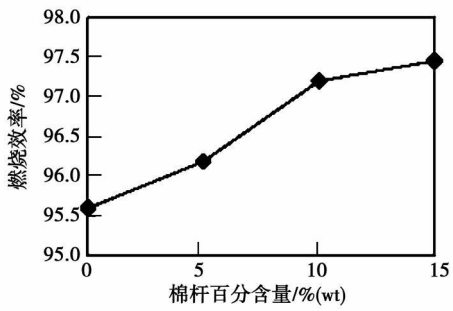

图 10　棉杆含量对燃烧效率的影响

其原因为棉杆比例增加后,燃料的挥发份份额增大,一方面使烟气中可燃气体燃烧充分,气体不完全燃烧损失 q3减少;另一方面使得燃烧初期挥发份逸出速度加快,固体颗粒孔隙急剧增加,加快了气体扩散速度,使颗粒中碳的反应速度加快,导致灰渣含碳量降低,因此固体不完全燃烧损失 q4减少。这两方面的综合效果最终导致燃料的燃烧效率升高。

3　结　论

分析了生物质和城市生活垃圾混合物在倾斜往复式炉排焚烧炉内的燃烧过程。研究了主要运行参数过量空气系数、一次风率、掺混质量百分含量对炉膛温度和燃烧效率的影响规律,在本实验运行范围内,得出以下结论:

(1)炉膛温度随一次风率和掺混质量百分含量的增大而增大,随过量空气系数的增大而降低。

(2)燃料的燃烧效率随一次风率和掺混质量百分含量的增大而增大,随过量空气系数的增大而先增大后减小;气体不完全燃烧损失与固体不完全燃烧相比,固体不完全燃烧损失起主要作用。

(3)当过量空气系数为 1.7、掺混质量百分含量为 15%、一次风率为 75%时,炉膛温度为 880 ℃,燃料燃烧效率为 97.4%。

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(编辑　孙显辉)

新设计、新系统

能量储存和灵活的电网负荷管理新的解决办法

据《Gas Turbine World》2009 年 3~4 月号报道,第二代 CAES(压缩空气能量储存)技术的灵活性提供了可重新供给能量独特的负荷管理、灵活的电网调整、同步备用、需要的电力和调峰管理。

功率:以各种标准的燃气轮机和底部循环膨胀器为基础并具有抽气用于增大燃气轮机功率,装置的功率从 15 MW 到超过 400 MW。

热耗率:装置的热耗率约为 3 903~4 009 kJ/(kW·h),千瓦时能量比(储存的非峰值千瓦时能量与峰值输出能量之比)为 0.70~0.75;DLE(干式低排放)燃烧的排放减少二分之一到三分之二。

投资费用:对于压缩空气被储存在地下的大型装置为 800~850 美元/kW;对于分布电力生产并且压缩空气被储存在地面以上的小型装置为 1 200 美元/kW。

电网保障:在装置运行过程中,尤其在从 30%~100%额定功率的瞬时负荷以及从冷态停机起的瞬时负荷时,在少于 3~5 min 内就能达到 70%的额定功率。　　(吉桂明　摘译)

jun (College of Energy Source and Environment, Southeast University, Nanjing, China, Post Code: 210096), XIN Cheng-yun (College of Chemical Industry and Environment, Zhongbei University, Taiyuan, China, Post Code: 030051) // Journal of Engineering for Thermal Energy & Power. — 2010, 25(3). — 330 ~ 334

In a mist spray dry flue-gas desulfuration system, experimentally studied was the application of steam phase change to help remove fine particles. With a due amount of steam being added to the wet flue gases after the desulfuration reaction, a supersaturated water-steam environment necessary for the condensation and growth of fine particles was formed and the condensed and grown-up dust-burden droplets were subsequently removed by a highly efficient demister. The fine particle number concentration and particle diameter distribution were real-time measured by using an electrical low-pressure impactor. Furthermore, the influence of operating conditions for mist spray dry flue-gas desulfuration (such as Ca/S and slurry quantity) and the amount of steam added on the fine particle removal efficiency was also investigated. It has been found that a part of slurry droplets and products from the desulfuraation reaction can be evacuated from the desulfuration tower together with the flue gases, leading to an increase of the fine particle number concentration. In the semi-dry-method desulfuration process, the steam phase change can be used to help remove the fine particles and the removal efficiency will enhance with an increase of the amount of steam added. When the amount of steam added is 0.08 kg/m³, the removal efficiency of the fine particle number concentration can increase by over 55%. The desulfuration operation conditions exercise a relatively big influence on the effectiveness of the steam phase change. **Key words:** semi-dry-method desulfuration; fine particle number concentration; removal of fine particles; supersaturation; steam phase change

地表水水源热泵输配系统优化模型的研究 = Study of a Model for Optimizing a Surface-water Source Heat Pump Transmission and Distribution System [刊, 汉] / BAI Xue-lian, ZHANG Yan-jun, WANG Hou-hua (College of Urban Construction and Environment Engineering, Chongqing University, Chongqing, China, Post Code: 400045) // Journal of Engineering for Thermal Energy & Power. — 2010, 25(3). — 335 ~ 339

With minimum energy consumption for transmission and distribution serving as an ultimate objective, relevant requirements for indoor comfort and building energy conservation as the restriction conditions and by utilizing the optimization tools box of Matlab, studied was a model for optimizing a surface water source heat pump transmission and distribution system with the main factors influencing the energy consumption of the surface water source heat pump transmission and distribution system being identified. By using the above-mentioned method, an applied analysis of the water source heat pump test system was conducted and an optimized cooling and frozen water flow operation scheme for the system changing with load rates was obtained. For a system operating at a part load for the majority of time, the optimized operation can save energy consumption by over 10% as compared with the constant flow rate operation. The optimization model can be easily used for practical engineering projects, providing optimum parameters for the design and operation of a transmission and distribution system and realizing a flow rate regulation and control with the change of the load rates. The foregoing can effectively reduce the energy consumption in water source water transmission and distribution, and enhance the system energy utilization efficiency. **Key words:** water source heat pump; water transmission and distribution system; water pump; energy consumption; optimization model

生物质与城市生活垃圾混烧特性的实验研究 = Experimental Study on the Mixed Combustion Characteristics of Biomass and Municipal Solid Waste [刊, 汉] / XIE Hai-wei, ZHANG Yan (Tianjin City Key Laboratory on Refrigeration Technology, College of Mechanical Engineering, Tianjin Commerce University, Tianjin, China, Post Code: 300134), ZHANG Yu-feng (Environment College, Tianjin University, Tianjin, China, Post Code: 300072) // Journal of Engineering for Thermal Energy & Power. — 2010, 25(3). — 340 ~ 343

In the light of the shortcomings of the power generation method by burning a mixture of municipal solid waste and biomass resulting in inferior economic benefits, set up was a biomass and municipal solid waste mixed combustion

test system with the influence of the main controllable parameters during the design and operation of the system on the furnace temperature and fuel combustion efficiency being mesured. It has been found that the furnace temperature will rise with an increase of the primary air rate and dilution/mixing mass percentage content and decrease with an increase of the excess air ratio. The fuel combustion efficiency will increase with the primary air rate and dilution/mixing mass percentage content. It will increase first and then decrease with an increase of excess air ratio. When the excess air ratio is set at 1.7, dilution/mixing mass percentage content is 15% and the primary air rate is 75%, the furnace temperature will reach 880 ℃ with the fuel combustion efficiency being assessed at 97.4%.
Key words: waste incineration, biomass, furnace temperature, combustion efficiency

SOFC/MGT顶层循环混合发电系统改进 = Improvement of a SOFC/MGT (Solid Oxide Fuel Cell/Micro Gas Turbine) Top-level Cycle Hybrid Power Generation System [刊, 汉] / DUAN Li-qiang, HE Bin-bin, YANG Yong-ping (Education Ministry Key Laboratory on Power Plant Equipment Condition Monitoring and Control, North China University of Electric Power, Beijing, China, Post Code: 102206) // Journal of Engineering for Thermal Energy & Power. — 2010, 25(3). — 344 ~ 349

The measures for improving the hybrid power generation system of a typical top-level cycle SOFC/MGT (solid oxide fuel cell/micro gas turbine) were proposed and ceramic mesotron membrane was used to separate the reaction product at the positive pole of the cell pile in the first stage. The hydrogen thus separated was introduced onto the positive pole of the cell pile in the second stage to continue the electrochemical reaction after having been cooled, pressurized and preheated. The reaction product from the cell pile in the second stage and the gas remaining after the hydrogen separation were fed into the rear combustor to conduct a combustion reaction. In combination with a specific calculation case, a simulation analysis was performed of the above two-stage tandem power generation system. The research results show that because of an increase of the hydrogen quantity for electrochemical reactions, the hydrogen quantity for the combustion reaction will decrease, making it possible to remarkably lower the exergy loss of the whole system and thereby raising the power generation efficiency of the improved system by 2.92 percentage points, which is higher than the reference system at an identical utilization rate of the fuel cell piles and at a same turbine inlet temperature. The foregoing measure is regarded as an effective method for improving the SOFC/MGT hybrid power generation system.
Key words: solid oxide fuel cell, micro gas turbine, hybrid power generation system, top-level cycle, ceramic mesotron membrane

乳化燃烧技术中涡流共振乳化器的开发与应用 = Development and Application of an Eddy-current Resonance Emulsifier in Emulsification Combustion Techniques [刊, 汉] / DENG Sheng-xiang, LI Xin-hui, ZHOU Jie-min (College of Energy Science and Engineering, Central South University, Changsha, China, Post Code: 410083) // Journal of Engineering for Thermal Energy & Power. — 2010, 25(3). — 350 ~ 352

The emulsification combustion process is required to uniformly blend the mutually indissolvable oil and water to prepare a emulsification solution. To solve such problems in the oil/water mixer as discrete and nonuniform mixing, short service life, frequent jamming, high operation cost and heavy maintenance work load etc., the angle and number of the inlet eddy-current guiding plates and outlet resonant reeds to be installed were taken into consideration by designing an eddy-current resonance-agitation mixing device suitable for mutually indissolvable liquids. The device can force the liquids to produce a compulsory compression through an eddy mixing and high frequency resonance and to form fine liquid droplets, thus realizing a uniform mixing of multiple liquids mutually indissolvable. The emulsified oil can be stabilized and kept for more than 3 months. As a mixing device for fuel oil emulsification combustion, the agitator was used for denatured coal tar emulsification combustion. The oil saving rate can be increased from the original 5.25% to 6.75%, effecting an enhancement of more than 22%. The mixing device has a continuous service life of more than 8 years.
Key words: eddy resonance, emulsifier, homogeneous mixing, coal tar, emulsification combustion