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ScienceDirect

Energy Procedia 66 (2015) 197 – 200

Energy Procedia

The 12th International Conference on Combustion & Energy Utilisation – 12ICCEU

ANAEROBIC PYROLYSIS CHARACTERISTICS OF MUNICIPAL SOLID WASTE UNDER HIGH TEMPERATURE HEAT SOURCE

Anqiang Zhang, Lei Xiao, Daohong Wu*

Beijing Shenwu Environmental & Energy Technology Co., Ltd，0086-10-60751999，sw@shenwu.com.cn

Abstract

This study proposed a new pyrolysis technique for municipal solid waste under anaerobic environment with regenerative radiant tube as the high-temperature heat source within a rotating bed reactor. To obtain the optimum condition of this technique, the effect of heating source temperature, arrangement and bed thickness on the distribution, composition and yield of products was experimentally studied. A three-dimensional transient mathematical model was established to describe the pyrolysis process characterized with simultaneous fluid flow, heat and mass transfer in a rotating bed reactor. The simulation model parameters were also modified based on experimental data. Results showed that this new technique has commercial viability due to the possibility to effectively avoid the problem of tar congestion and obtain high caloricity clean gas.

Peer-review under responsibility of the Engineering Department, Lancaster University

Keywords: Municipal solid waste; Pyrolysis; Regenerative radiant tube; Rotating bed reactor; Clean gas

1. Introduction

The problem of solid waste disposal is growing throughout the world, as a result of industrialization and population growth [1]. At present, the total amount of municipal solid waste in China reached 1.5 billion tons, increasing at a rate of 5.0%/yr [2]. Land filling had been by far the dominant approach for municipal solid waste treatment. However, two-thirds of cities in China are surrounded by garbage and many landfills are near the end of their design life [3]. Compared with the conventional land filling of municipal solid waste, incineration is almost always used for power generation or heating systems. However, incineration still can't get rid of the problem of dioxin pollution [4]. Pyrolysis is the thermal degradation of organic material in an oxygen deficient atmosphere producing gas, liquid and solid products. Pyrolysis can avoid the problem of dioxin pollution from the principle and is an effective way to realize harmlessness, reduction and resource utilization with high energy conversion efficiency [5]. It has great significance to accelerate China's energy-saving emission reduction.

2. Heat-Carrier-Free Rotary Hearth Furnace Pyrolysis Technology

Peer-review under responsibility of the Engineering Department, Lancaster University

doi:10.1016/j.egypro.2015.02.019

Shenwu's new heat-carrier-free regenerative rotating bed pyrolysis process is recognized as the first in global. This technology can gasify and liquefy part of municipal solid waste without adding hydrogen and oxygen under normal pressure, yielding with high purity and high calorific value fuel gas and solid carbon. The charger will continuously convey the material from bin to rotating bed. In rotating bed pyrolysis furnace, the roof and wall are fixed, while material will rotate with furnace hearth. The solid carbon generated from material pyrolysis via the heating by regenerative radiant tube combustor will be discharged from discharging port in a sealed way. High temperature solid carbon will be cooled by water spray. The pyrolysis gas generated in furnace will enter into cooling tower via gas pipe. The fixed gas after cooling will be purified and transferred to gas storage tank. The cooled oil water will separate in separation tower, and the oil will be stored in oil tank.

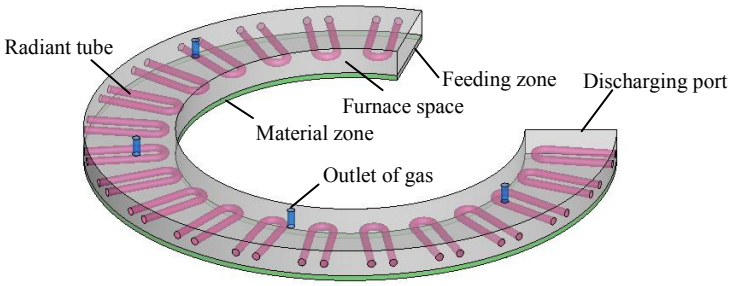


Figure 1. Physical model of heat- carrier- free regenerative rotating bed

3. Experiment

3.1 Materials

Beijing municipal solid waste was taken as raw material. The component analysis of municipal solid waste was shown in Table 1. The industrial and element analysis of municipal solid waste were shown in Table 2.

Table 1. Composition of Beijing municipal solid waste

Composition	kitchen	Fabric	plastic	paper	metal	glass	stone
Volume ratio /%	27.69	1.01	12.15	39.01	0.51	19.0	0.63

Table 2. Industrial and element analysis of municipal solid waste (air dried)

Industrial analysis (wt%)				Element analysis (wt%)			
Moisture	Ash	Volatile	Fixed carbon	C	H	N	S
3.80	25.14	63.75	7.31	25.10	2.78	1.89	0.26

3.2 Operating conditions

To explore optimum pyrolysis condition of regenerative rotating bed and obtain high calorific value gas, the heating temperature and material thickness was investigated experimentally. The experimental condition was shown in Table 3.

Table 3. Experimental condition

Number	Thickness (mm)	Rotating speed (r/min)	Heating temperature (℃)
1	150	90	750
2	150	150	650
3	150	80	850
4	100	80	750
5	200	150	750

Table 4. Distribution of pyrolysis products

Number	Carbon (wt%)	Liquid (wt%)	Gas (wt%)
1	50.37	2.67	46.96
2	48.93	3.80	47.27
3	48.40	1.90	49.70
4	5 .00	3.10	45.90
5	47.73	5.70	46.57

3.3 Results and discussion

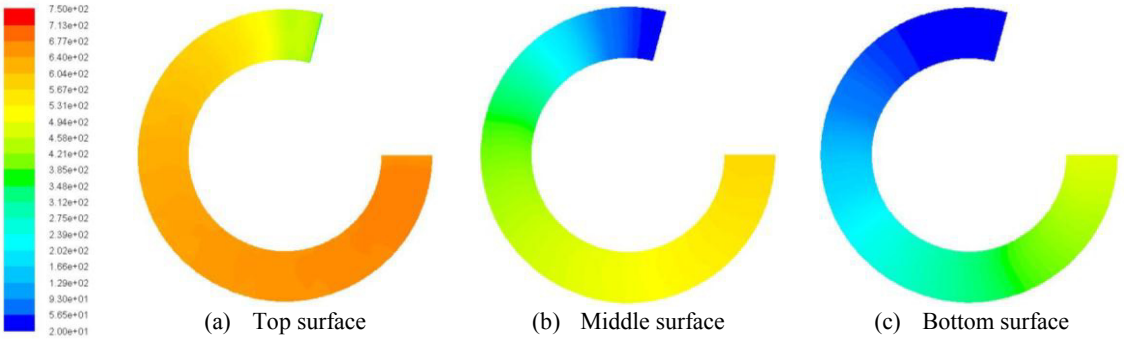
Based on lots of experiments, the distribution of pyrolysis products and composition of gas are shown in Table 4 and Table 5, respectively. The results show that heat-carrier-free rotary hearth furnace pyrolysis technology can avoid the pyrolytic tar and obtain clean gas with high calorific value. The comparison of 1 #, 2 # and 3 # show that the more heating temperature, the lower the liquid yield and the less the pyrolysis time, but the higher the energy consumption. In consideration of liquid yield and energy consumption, the best pyrolysis temperature is 750℃. The comparison of 1 #, 4 # and 5 # show that the change of liquid yield was not obvious with increasing material thickness, but the pyrolysis time became longer. In consideration of liquid yield and pyrolysis time, the best material thickness is 150mm.

Table 5. Composition and calorific value of pyrolysis gas

Number	Composition (V%)						Low heat values (kcal/m^3)
	H_2	CO_2	CH_4	CO	C_nH_m	Other	
1	26.9	17.5	30.7	9.6	8.1	7.2	5356.9
2	29.8	18.0	29.9	9.7	6.8	5.8	4860.1
3	29.6	13.3	32.7	10.2	7.3	6.9	5438.4
4	26.4	16.5	31.7	9.8	9.4	6.2	5398.6
5	30.2	17.5	30.0	9.7	6.6	6.0	4895.0

4. Simulation

For the further study of the pyrolysis reaction mechanism of municipal solid waste, a three-dimensional mathematical model was established to describe the pyrolysis process characterized with simultaneous fluid flow, heat and mass transfer in the rotating bed reactor. The gas-side surface of radiant tubes was of constant temperature B.C.. The pyrolysis gas at four outlets was of constant pressure. The top, side and bottom surfaces of reactor were assumed to be adiabatic. The model predicted the temperature, velocity and composition distributions in the rotating bed reactor.



(a) Top surface (b) Middle surface (c) Bottom surface

Figure 2. Temperature field of municipal solid waste at different heights

Figure 2 shows the temperature evolutions of packed bed. The temperature of packed bed gradually increases along the circumference. At the same time, different material thickness are at different stages of pyrolysis due to the difference of temperature distribution. The pyrolysis process occurs at the top of the material first, and then gradually advances to the bottom of material.

Comparisons between simulated temperature and measured data in the rotating bed reactor were shown in Figure 3. We can see that the calculated results are consistent with the measured data. At this end, the top temperature of material is almost 690℃ and the bottom temperature rises up to 510℃. The results show that the municipal solid waste can be an adequate pyrolysis in the rotating bed reactor.

The temperature and velocity distributions at cross section of outlets were shown in Figure 4 and Figure 5. The pyrolysis gas is heated by high-temperature radiant tubes, and is discharged through the outlets at the top of reactor. The residence time of pyrolysis gas in the reactor is 5~20s. In the flowing process, the pyrolysis oil is cracked into smaller molecules in high-temperature zone, leading to the reduction of oil yield and the increase of gas yield. During the course of the experiments, much pyrolysis oil was not found in oil-gas-water separation system. This is consistent with the simulation results.

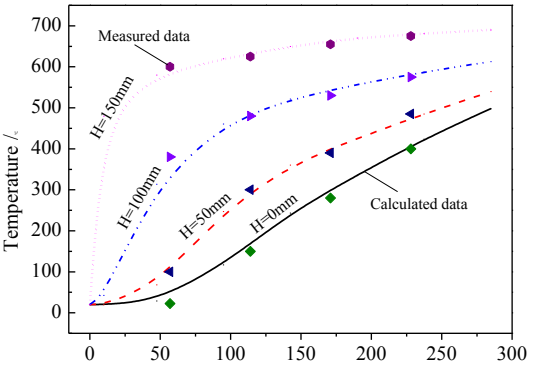


Figure 3. Evolution of municipal solid waste bed temperature

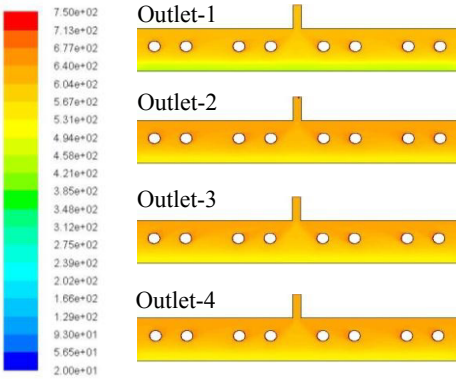


Figure 4. Temperature field of outlet surface

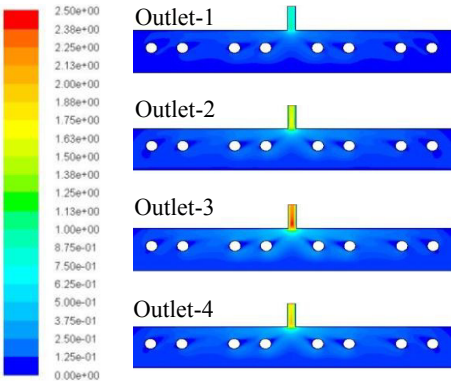


Figure 5. Velocity field of outlet surface

5. Conclusions

This paper proposed a new pyrolysis technique for municipal solid waste with regenerative radiant tube as the high-temperature heat source within a rotating bed reactor. The optimum condition of this technique was experimentally studied. A three-dimensional transient mathematical model was established and modified based on experimental data. Results showed that this new technique has commercial viability due to the possibility to effectively avoid the problem of tar congestion and obtain high caloricity clean gas.

References

[1] Jiao Zheng, Yu-qi Jin, et al.. Pyrolysis characteristics of organic components of municipal solid waste at high heating rates. Waste Management 29 (2009) 1089–1094.

[2] Xue Bing, Geng Yong, Ren Wan-xia, et al. An overview of municipal solid waste management in inner Mongolia autonomous region, China. J Mater Cycles Waste Manage 13(2011)13 283–92.

[3] Hui Zhou, AiHong Meng, et al.. An overview of characteristics of municipal solid waste fuel in China: Physical, chemical composition and heating value. Renewable and Sustainable Energy Reviews 36(2014) 107-122.

[4] José Ezequiel Santibañez-Aguilar a, José María Ponce-Ortega, et al.. Optimal planning for the sustainable utilization of municipal solid waste. Waste Management 33 (2013) 2607–2622.

[5] Chunguang Zhou, Qinglin Zhang, et al.. A study of the pyrolysis behaviors of pelletized recovered municipal solid waste fuels. Applied Energy 107(2013) 173-182.

[6] I. Velghe, R. Carleer, J. Yperman, S. Schreurs. Study of the pyrolysis of municipal solid waste for the production of valuable products. Journal of Analytical and Applied Pyrolysis 92 (2011) 366–375.