The 6th International Symposium on East Asian Resources Recycling Technology
October 23 - 25, 2001, Gyeongju (慶州), Korea
ISBN: 89-952527-0-7 93530

Development of Waste Plastics-Based RDF and Its Combustion Properties

Woo Zin Choi[1], Young Hee Chung[2]

[1] Dept. of Environmental Eng., The Univ. of Suwon

[2] Korea Recycle System, Inc.

Abstract

The refuse-derived fuel(RDF) is manufactured using waste plastics-based materials and its physical and chemical properties are analyzed. The manufacturing process consists of hand picking, primary magnetic separation, crushing, secondary magnetic separation, feeding and extrusion. The RDF products have a higher calorie content of over 6,000 kcal/kg and high stability because the waste plastics and paper are mainly selected. The combustion flue gas of RDF products is satisfied with the emission criteria of incinerator. The heavy metal concentration of combustion byproduct from the RDF boiler is also satisfied with the criteria and appears to be lower concentration than that of a common municipal waste incinerator.

Introduction

Realization of a society based on recycling is essential to the preservation of the global environment and the natural resources. Korea has been actively promoting recycling in a wide range of fields and the total amount of wastes generated from household and industry is expected to increase year by year. However, the recycling rate of waste plastics is less than 20% in 1999, due to the limited recycling technologies and lack of economics on recycling.

Therefore, recycling mainly consisted of using waste plastics as raw materials and incineration for heat recovery.

Various technical development activities are under way for achieving more effective waste plastic utilization. In order to avert global warming, better control of carbon dioxide emissions is becoming necessary. Among potential countermeasures, the increased utilization of previously unused energy in refuse is especially promising.

Refuse-derived fuel(RDF) is a solidified fuel produced from combustile wastes, and has been commercialized and used in various areas, such as boilers, cement kiln, blast furnaces, etc. RDF consists of mainly waste paper and plastic, and is relatively friendly to the environment.

In Korea, active enforcement of the recycling law for containers and packaging will presumably increase the quantity of waste plastics to be collected separately from other wastes and recycled. Though this separate collection of wastes is done by local governments, the degree of separation is limited and, moreover, there is a possibility that the wastes may contain chlorine which interferes with incineration. In the present work, RDF is manufactured using waste plastics-based materials and its physical and chemical properties are discussed. The combustion properties in boiler designed for RDF combustion are also analyzed.

Experimental

The physical composition of the three raw materials used for RDF manufacture is given in Table 1.

Table 1. Physical composition of raw materials used for RDF manufacture.

Item / section	Physical Composition (%)					
	Paper	Vinyls/Plastics	Wood	Rubber	Textiles	Glass/Metals
Sample 1	2.8	92.3	-	3.4	1.5	-
Sample 2	4.4	90.4	2.2	-	3.0	-
Sample 3	1.7	91.7	1.4	-	5.2	-
Average	3.0	91.5	1.2	1.1	3.2	-

Table 2. Proximate and ultimate analyses of raw materials

section		Sample 1	Sample 2	Sample 3	Average
Proximate Analysis (wt.%)	Combustibles	84.1	80.7	85.8	83.5
	Moisture	5.7 (13.7)	4.5 (5.2)	2.4 (2.7)	4.2 (7.2)
	Ash	10.2	14.8	11.8	12.3
Ultimate Analysis (wt.%)	Carbon	53.56	56.11	59.12	56.26
	Hydrogen	7.26	8.25	7.50	7.67
	Oxygen	22.49	16.19	16.13	18.27
	Nitrogen	0.15	0.78	0.92	0.61
	Surfur	0.0	0.0	0.0	0.0

* ( ) values in moisture is measured at just before the RDF manufacture.

The samples 1 and 2 are collected from the local governments, which are generated from the household, and sample 3 is obtained from the industrial plant. These samples are prepared from the plastic-based wastes by separation and removal of PP- and PE-based containers and other plastics for recycling. The samples mainly consist of vinyls/plastics, paper and textiles. The proximate and ultimate analyses of the raw materials are shown in Table 2. The raw materials have combustibles 83.5, moisture 4.2, and ash 12.3%, respectively. Fig.1 shows the RDF manufacturing process consisting of hand picking, primary magnetic separation, crushing, secondary magnetic separation, feeding and extrusion. The dimension of the final products is 30×30×50 mm. Fig. 2 shows front view of RDF demonst ration plant. Fig. 3 shows side view of the extruder used in the present work.

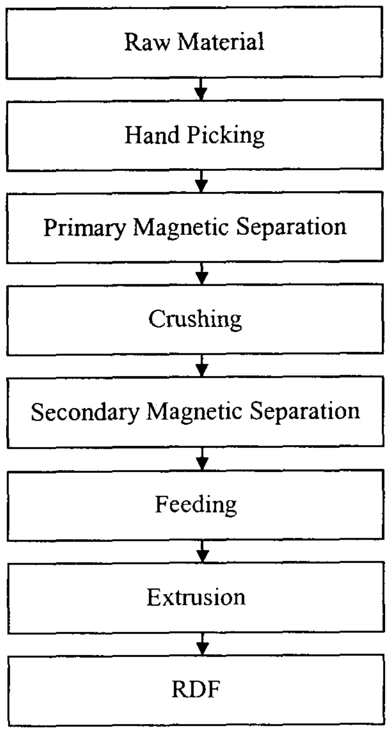

Fig. 1 RDF Manufacturing process

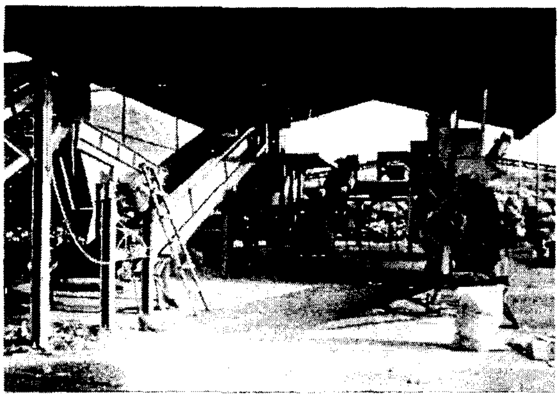

Fig. 2. Front view of the RDF demonstration plant.

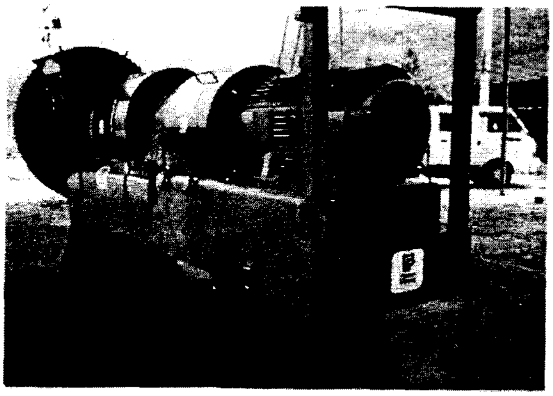

Fig. 3. Side view of the extruder used in the present work.

The specific information on the crusher and extruder for RDF manufacture is given in Table 3.

Table 3. Major facilities for RDF manufacture

Item / Contents	Crusher	Extruder
Manufacture	Holzmag (W .Germany)	Warren & Baerg (USA)
Model No.	M/Cutting Rotor (7/24)	250 Cuber
Capacity	1.2～5.0 ton/h	4.0～6.0 ton/h
Treatment Materials	Paper, wood, plastic	Paper, wood, plastic
Horse power	100 HP	200 HP
Weight	12,000 kg	7,290 kg

In the present work, physical properties on the RDF products are measured such as calorific value, specific gravity, absorbancy, ignition loss, heavy metal contents, etc. Combustion tests are conducted for 7.5 hours on RDF products using a boiler designed for RDF combustion.

The major composition of the combustion flue gas, and heavy metal content and ignition loss on combustion byproducts are also measured.

Results and Discussion

The Calorific value and apparent density for the RDF products are given in Table 4. The products have a higher calorie content in the range of 5,980 to 6,270 kcal/kg. The average calorific content for the conventional RDF prepared from the municipal wastes is normally less than 5,000 kcal/kg. The apparent density for the products appears to be favourable with average value of 0.299 t/m^3.

As shown, the RDF manufactured with the raw material sample 2 shows higher absorbancy than RDF manufactured with the raw material sample 1 and 3. As can be noted in Table 5, the RDF with the raw material sample 2 also shows higher saturated water content and is not dense enough compared to the RDF prepared with raw material sample 1 and 3.

Table 4. Calorific value and apparent density for RDF products.

Item / Sample	Calorific Value (kcal/kg)		Apparent Density (t/m^3)	
	Dry Base	Wet Base	Raw Material	RDF
Sample 1	6,030	5,400	0.060	0.256
Sample 2	6,270	5,700	0.091	0.275
Sample 3	5,980	5,560	0.106	0.366
Average	6,090	5,550	0.085	0.299

Table 5. Absorbancy and saturated water content for RDF products

Item / sample	Absorbancy (%)	Saturated water content(%)	Remark
Sample 1	71.7	41.7	Dense
Sample 2	91.2	47.7	Flaky
Sample 3	73.3	42.3	Very dense
Average	78.7	43.9	

In this investigation, combustion characteristics for RDF products has been colleced from the continuous combustion tests. A boiler designed for RDF is used at feed rate of 40 kg/hr. The total operating time is 7.5 hours with consumption of 202 kg RDF and 34 kg of bunker-C oil, respectively. The exit temperature of the boiler and average residence time are measured at 516℃ and 0.9 s, respectively. The ignition loss and heavy metal concentration obtained from the combustion byproduct are presented in Table 6. As can be noted, most of heavy metals are not detected except lead (Pb) and copper (Cu) with average concentration of 0.03 and 0.115 ppm, respectively. The test results indicate that heavy metal concentration of the combustion byproduct from the RDF boiler appears to be much lower concentration than that of a common solid waste incinerator.

Table 6. Ignition loss and heavy metal concentration in combustion byproduct.

Item / Sample	Ignition Loss(%)	Concentration (mg/l)					
		Pb	Cu	As	Hg	Cr^{+6}	CN
Sample 1	5.83	ND	0.07	ND	ND	ND	ND
Sample 2	5.61	ND	0.07	ND	ND	ND	ND
Sample 3	4.11	0.06	0.16	ND	ND	ND	ND
Average	5.18	0.03	0.115	ND	ND	ND	ND

The bottom ash obtained from the municipal waste incinerator contained heavy metal concentrations of As 114, Cr 428, Cd 23, Pb 569 and Hg 63 ppm (Choi, 1999).

In the present work, the concentration of acid gases and heavy metals in flue gas are also measured from the boiler duct. The analysis is carried out by using a portable flue gas analyzer. The test results presented in Table 7 indicate that higher concentration of carbon monoxide (CO) and hydrogen chloride (HCl) in the flue gas than that of the emission criteria of incinerator.

Table 7. Results of flue gas analysis from the combustion of RDF products

Item / Sample	Concentration (ppm)				Emission Standard (ppm)
	CO	NOx	SOx	HCl	
Sample 1	895	183	97.6	394.1	CO 600
Sample 2	1,048	140	110.0	121.5	SOx 300
Sample 3	488	160	157.0	456.2	NOx 200 HCl 50
Average	878	153	121.5	308.9	

Further study is under way to reduce the acid gas from the RDF products. This can be done by removing impurities from the raw materials and by adding calcium hydroxide ($Ca(OH)_2$) to raw materials before extrusion.

Table 8 shows the heavy metal concentrations in particulates obtained from the flue gas. The heavy metal concentration in flue gas from the RDF incinerator is satisfied with the criteria and appeared to be almost same level with the commercialized RDF of Japan (NEDO, 1999).

Table 8. Heavy metal concentration in particulates from the flue gas

Item / Sample	Analysis (mg/Sm^3)					
	Zn	Ni	Cd	Pb	Cr	Cu
Sample 1	0.088	0.003	ND	0.066	0.012	0.022
Sample 2	0.048	0.003	ND	0.042	0.030	0.027
Sample 3	0.059	0.003	ND	0.055	0.026	0.036
Average	0.065	0.003	ND	0.054	0.022	0.028

Conclusions

In the present paper, RDF is manufactured using waste plastics-based materials and its physical and chemical properties are discussed. The combustion characteristics in boiler designed for RDF combustion are also analyzed.

The RDF products have a higher calorie content in the range of 5,980 to 6,270 kcal/kg and high stability because raw materials used in the present work consist of over 90% waste plastics. The combustion results indicate that heavy metal concentration of the combustion byproduct from the RDF boiler appears to be much lower concentration than that of a common municipal waste incinerators. The HCl concentration in flue gas during combustion reached to 300 ppm, which was not satisfied with the emission criteria of incinerator. This may be due to the high chlorine content in waste paper and plastics. Further study is need to improve the combustion characteristics of RDF by removing impurities from the raw materials and adding calcium hydroxide to raw materials before extrusion.

Acknowledgment

The authors wish to acknowledge the financial support provided by the Regional Research Center (RRC), Center for Environmental and Clean Technologies (CECT), the University of Suwon.

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