Goumans/Senden/van der Sloot, Editors
Waste Materials in Construction: Putting Theory into Practice

DIRECT MELTING PROCESS FOR MSW RECYCLING

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Abstract

"Direct Melting Process for MSW Recycling" is a system where various kinds of wastes are directly melted in a single step, and their ashes are converted into slag and metal for recycling. In this process coke and limestone are charged into the melting furnace with the waste for high temperature melting and the adjustment of basicity. And high-temperature reducing atmosphere acts to facillitate the volatization of alkali salts and heavy metals contained in the waste, suppress the entry of heavy metals into the slag. Therefore the slag is non-noxious and can be utilized effectively as civil engineering and construction materials.

1. INTRODUCTION

In Japan approximately 50 million tons of municipal wastes are produced a year and it is becoming increasingly difficult to secure sites available for the final disposal of the incineration residue of these wastes. To overcome this difficulty, various methods for reducing the quantity of wastes have been sought to lengthen the useful life of each of the final disposal sites presently available.

More than a decade ago the first commercial plant of MSW direct melting process was constructed and has been in operation still now. The direct melting process permits recycling of wastes because the slag, one of the final products of the process, is non-noxious and can be utilized as a civil engineering and construction material. This paper describes the characteristic features and adveantages of the direct melting process as well as the progress thus far attained in recycling.

2. PROCESS DESCRIPTION

2.1 Two routes of waste melting

The waste melting technology can be classified largely into two types: the one is a two-step system in which wastes are incinerated first and the ashes produced from this incineration step are then melted, and the other is a system where wastes are directly melted in a single step.

Compared with the former system, the latter single-step route provides a simpler equipment configuration and requires less manpower for its operation.

2.2 Features of direct melting process

"Direct Melting Process for MSW Resycling" is shown in Fig. 1 and has the following special features:

(1) The system provides a high degree of flexibility in adjusting to different types of wastes, combustible or incombustible, including even wastes that cannot be recycled at the collection level and those unsuitable for incineration, e.g., sludge and landfill wastes.

(2) All slag and metal produced as the final output of the waste melting process can be reused effectively as a resource. Therefore, the dust collector ash is the only waste this system discharges, helping lengthen the useful lives of final disposal sites.

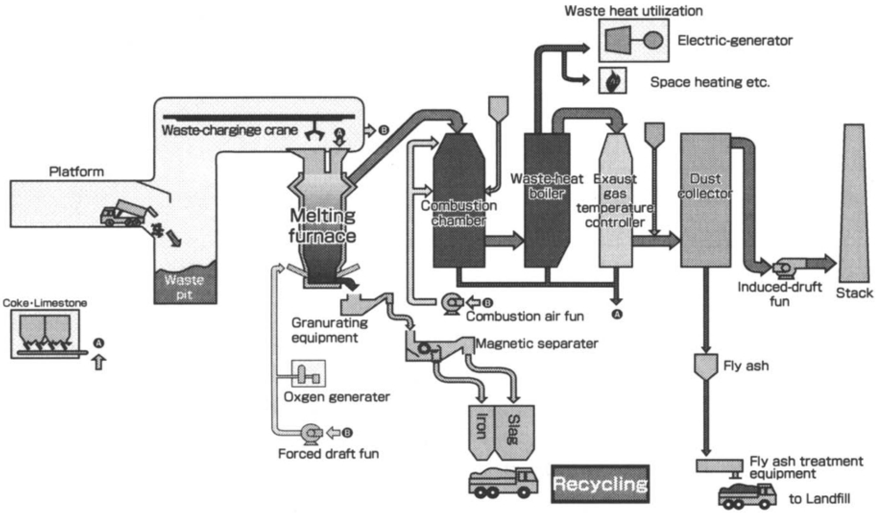


Fig. 1 Fundamental Flow of Direct MeltingProcess for MSW Recycling

(3) The energy recovered as heat from the process can be effectively utilized for electricity generation.

(4) The process provides superior control of toxic gas emissions, and is, itself, environmentally sound.

(5) All these features mean substantial cutbacks in the expenses incurred at all stages of waste treatment from collection to final disposal.

2.3 Outline of direct melting process

The melting furnace proper used for this process is a shaft furnace and receives the waste, coke and limestone from the top. The shaft furnace consists of three zones - the drying/preheating zone (maintained around 300℃), the thermal decomposition zone (at 300℃ to 1000℃), and the combustion/melting zone (at 1700℃ to 1800℃).

In the drying/preheating zone the waste charged is dried on heating. The waste thus dried gradually descends through the furnace and is fed through the thermal decomposition zone, where organic substances thereof are gasified.
The gases produced in this way are discharged from the furnace top and completely burnt in the subsequent combustion chamber. The hot exhaust gas from the combustion chamber is sent then to the

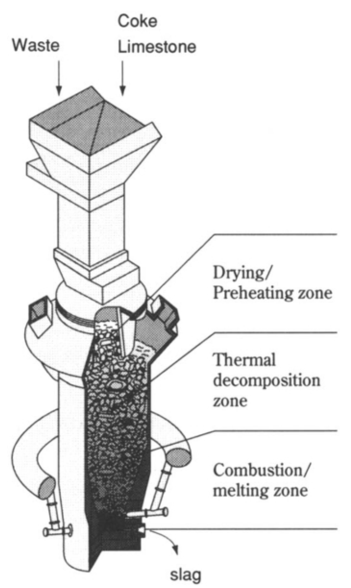


Fig.2 Direct melting furnace

waste-heat boiler to recover steam for electricity generation and other energy-efficient applications.

Ashes and inorganic matter that survive the above thermal decomposition descend with coke to the combustion/melting zone.

The coke burns in the presence of the air blown into the furnace through tuyeres, evolving a high temperature and intense heat, with which the ashes and inorganic substances are melted completely.

The hot melt produced in this way is, following the adjustment of its basicity by CaO contained in the limestone charged, discharged from the system through the taphole and sent through the granulating cage, where it is rapidly cooled and solidified as granular mixture of slag and metal.

The granular mixture is separated with the magnetic separator into slag and metal for recycling purposes.

3. WASTE RECYCLING THROUGH MELTING PROCESS

3.1 Recycling of melt

If the waste melting technology is to be viable, environmentally and economically, the melt as the by-product of the process must be not only harmless and compact but also recyclable as a useful resource. To meet this requirement, the following are imperative.

(1) The melt is completely molten and non-noxious.

(2) The melt can be separated into slag and metal.

(3) The slag thus separated is highly consistent in quality.

To meet all these requirements, both software and hardware need to be established to ensure a highly stable flow of melting unaffected by any change in the properties of the charge into the system. The coke-bed type melting system, as noted earlier in the process description, fully satisfies these requirements. More specifically, the system is so configured that the melt can be discharged from the furnace bottom only after it has moved clear of the hot coke bed, an important feature effectively

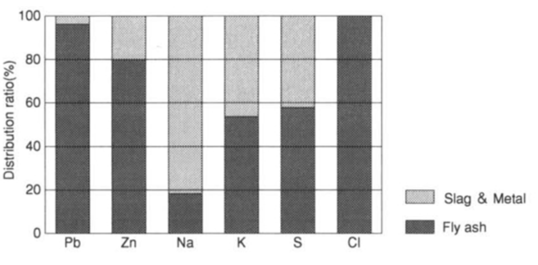


Fig.3 Distribution ratio of each element

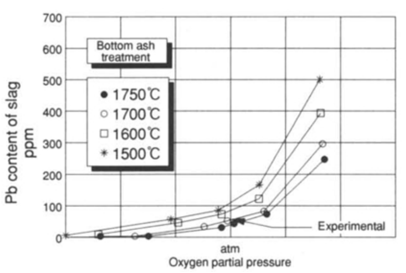


Fig. 4 Relationship between Pb content of slag and oxygen partial pressure

preventing the melt from being discharged while still containing solids.

And the high-temperature reducing atmosphere acts to facilitate the volatization of alkali salts and heavy metals contained in wastes, suppress the entry of heavy metals into the slag and increase the content of heavy metals in the fly ash.

Fig.3 shows the example of the ash melting test result under the reducing atmosphere condition. [1]

Fig.4 shows the result of simulation analysis of ash melting process. According to this result Pb content of slag decreases in the high temperature and reducing atmosphere. [2]

Meanwhile, ferrous materials, if any, in the slag may impair the recyclability of the slag because they can cause red rusting and volume expansion. To avoid this, a wet type magnetic separator has been developed as a means for separating the melt into slag and metal with high efficiency.

Table 1 Leaching Test Results of Slag(mg/l)

	Direct Melting Slag	Eiviromental standard for soil	Lower limit of analysis
Mercury alkyl	N.D.	N.D.	0.0005
Total mercury	N.D.	0.0005	0.0005
Cadmium	N.D.	0.01	0.001
Lead	N.D.	0.01	0.005
Organic phosphorus	N.D.	N.D.	0.01
Hexachrome	N.D.	0.05	0.005
Arsenic	N.D.	0.01	0.005
Cyanogen	N.D.	N.D.	0.001
PCB	N.D.	N.D.	0.0005
Trichloroethlene	N.D.	0.03	0.002
Tetrachloroethelene	N.D.	0.01	0.0005

Table 2 Chemical composition of Slag

		Direct Melting Slag	Blast-furnace Slag (reference)
main compo-nents	SiO_2	37~42	30~41
	CaO	33~45	35~45
	Al_2O_3	12~18	12~20
others	MgO	1.2~1.8	3~7
	Na_2O	3.5~6.3	0.23
	K_2O	0.4~0.6	0.24
	S	0.2~0.3	0.6~1.6
	FeO	0.1~0.8	0.3~1.7
	M-Fe	0.1~0.4	

Table 3 Physical properties of Slag

Grading (%)	16.0	100.0
	9.5	99.0
	4.75	94.5
	2.36	59.2
	1.18	23.8
	0.60	8.4
	0.30	2.6
	0.15	0.9
Unit Volume weight (kg/ ℓ)	standard	1.590
	light-duty	1,431
Absolute specififc gravity		2.74
Absorption (%)		0.806

With the proprietary, wet type magnetic separator, it is today possible to keep the metal content of the slag at 0.5% or lower.

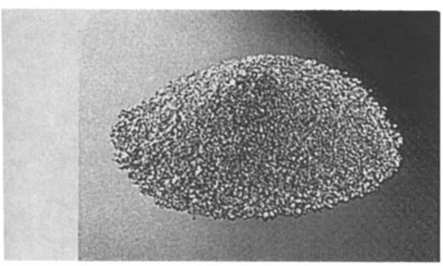
Such a high efficiency of magnetic separation comes from the unique process feature that the slag and metal solidify separately as the melt is granulated, which owes much to the excellent fluidity of the slag - a benefit of the combination of high-temperature heating by coke and the basicity adjustment by limestone.

3.2 Physical properties and uses of slag and metal

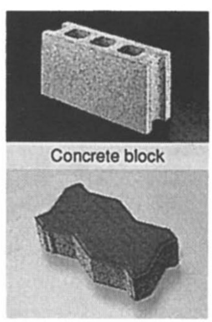
As evident from Table 1 which indicates the results of the leaching tests conducted on the slag, all measurements stand below the enviromental standard for soil.

Table 2 shows the typical chemical compositions of the direct melting slag and blast-furnace slag as a reference. For the contents of the three main constituents - SiO_2, CaO and Al_2O_3, the slag is roughly comparable to the blast-furnace slag. In terms of the alkali content, however, the former is a little higher than the latter. The physical properties of the slag are indicated in Table 3.

Photo 1 shows the appearance and use of the slag. The slag can be utilized effectively as civil engineering and construction materials, especially as base concrete aggregates for interlocking blocks. [3] In addition,

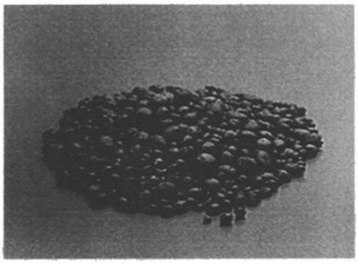


Appearance of slag

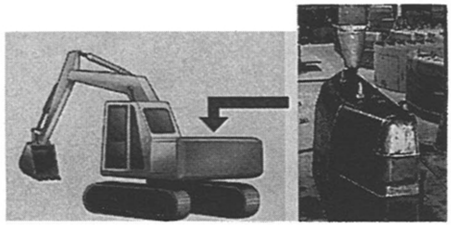


Interlocking block

Phoot 1 Uses of slag



Appearance of metal



Counterweight for construction machine

Photo 2 Uses of metal

the results of the past paving tests have indicated that it can be put into commercial use also as aggregates for asphalt paving.

Photo 2 indicates the appearance and typical use of the metal. The metal is easy to handle and is already in commercial use as counterweights for construction machinery.

3.3 Recycling of fly ash

The fly ash is naturally expected to be cleaned of harmful substances and sent to final disposal sites. Noting that heavy metals can be separated from the melt and enriched during the melting process, however, it would be a matter of great significance if the enriched heavy metals could be recovered from the system and returned to mines.

Fly ash treatment process using an existing pellet production facility is expected to overcome this difficulty. The chlorination and volatilization process involves addition of calcium chloride to the baked pellet feed to a rotary kiln and recovery of usable metals and good quality pellets from the kiln. Since there are upper limits set for the Zn, Na, K and Cu contents of the pellet for blast furnace use, Na and K which are contained in large amounts in the fly ash need to be eliminated in advance.

To determine the feasibility of the above treatment process, preliminary tests using fly ash were carried out.

It has been found possible, at least technically, to recover heavy metals from the fly ash as one of the final products of the waste melting process. But there are several restrictions that need to be overcome including the limited availability of suitable locations and still high treatment costs. This technology, however, has received widening interest as a great breakthrough into a 100% resource recycling system based on the waste melting process.

4. Coustruction Record

The history of R&D for the direct melting process dates back more than 20 years, and two commercial plants of its kind were delivered 17~18 years ago to Kamaishi City and Ibaraki City each. These direct melting process have satisfactorily been in operation.

They have fully proved compatible with the changing natures of wastes and anti-pollution regulations that are becoming increasingly exacting. Noting this, Ibaraki City constructed a new plant for the capacity addition and renewal; this plant went on stream early in 1996. Besides, construction of similar plants are now under way at four sites in Japan. (See Table 4)

Table 4 Construction Record

	Start-up	Capacity	Power Plant
Kamaishi City, Iwate Pref.	1979	50t/d × 2 furnaces =100t/d	Not Provided
Ibaraki City, Osaka Pref.	1980	150t/d × 3 furnaces =450t/d	1600kw×2units
Ibaraki City, Osaka Pref.	1996	150t/d × 2 furnaces =300t/d	5000 kw×1 unit
Iryu-kumiai, Hyogo Pref.	1997	60t/d × 2 furnaces =120t/d	1100 kw×1 unit
Kagawatobu-Kumiai Kagawa Pref.	1997	65t/d × 2 furnaces =130t/d	1600 kw×1 unit
Iizuka City Fukuoka Pref.	1998	90t/d × 2 furnaces =180t/d	1200 kw×1 unit
Ibaraki City Osaka Pref.	1999	150t/d × 1 furnace =150t/d	3500 kw×1 unit

5. CONCLUSIONS

A revolution is in process in the area of waste treatment in Japan. What is demanded most is a system that can deal with types of wastes with greater flexibility and enable total recycling of resources.

From this point of view, the direct melting process may provide a suitable answer to the above requirement. The high-temperature reducing atmosphere inherent in the coke-bed melting furnace helps efficiently separate the charge into the system altogether and recycle the by-products of the process.

Gradually, Progress has been achieved in the commercial utilization of the waste melting process. [4] But, to reshape our society into a recycling-oriented one, We feel that much more effort should be channeled into this area and hope that the direct melting process will contribute to total recycling of MSW

6. REFERENCES

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