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Development of Waste Plastics Recycling Process Using Coke Ovens

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Abstract

The Japan Iron & Steel Federation, as its voluntary energy-saving action plan, proposed a 10% energy reduction by 2010 with 1990 as the basis. Further, it has put forward an additional 1.5% energy saving by the use of waste plastics as a metallurgical raw material. Coke-making process is considered to be a promising area to which the thermal decomposition of waste plastics is applicable because the process involves coal carbonization in a high-temperature, reducing atmosphere. To evaluate the conversion rate of various waste plastics using coke ovens after carbonization, laboratory tests and actual coke oven tests were conducted. As a result, the yield of coke, gas, tar and light oil was 20%, 40% and 40%. And it was found that the 1% addition of waste plastics in raw coal did not deteriorate the coke strength. Waste plastics recycling process using coke ovens started at Nippon Steel Nagoya and Kimitsu Works in 2000.

1. Introduction

At the advent of the 21st century, mankind is facing global environmental problems, causing the industrial sector to take initiatives in establishing recycling for the efficient utilization of our natural resources. As a measure of the Japanese steel industry in view of global environmental issues, the Japan Iron & Steel Federation proposed, in its voluntary energy-saving action plan, a 10% energy reduction by 2010 with 1990 as the basis. Further, the federation has put forward an additional 1.5% energy saving by utilizing waste plastics as a metallurgical raw material. The amount of waste plastics to be recycled for achieving the target is about 1 Mt/y.

The coke-making process is considered suitable as a waste plastic recycling means, because the process involves coal carbonization in a high-temperature and reducing atmosphere. Through tests, the viability of a chemical recycling process to recover coke, tar, light oil and gas from general waste plastics mixed in coal by carbonization in coke ovens without deteriorating the quality of coke was verified[1,2).

This paper describes the technology for waste plastics recycling process into chemical raw materials using coke ovens.

2. Study of Conversion of Waste Plastics into Chemical Raw Materials Using Coke Ovens

Fig. 1 outlines a coke-making process. In coke ovens, coal charged into coke oven chambers is carbonized at a temperature of

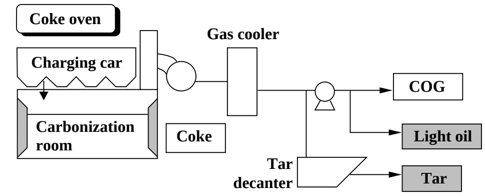

Fig. 1 Coke-making process flow

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about 1,100°C in a reducing atmosphere, and is converted into products, namely coke, tar, light oil and coke oven gas (COG), etc. At the exit from ascension pipes at the top of the ovens, ammonia liquor is used for flushing high temperature gas generated in the chambers through the carbonization, and the gas is cooled quickly to about 80°C or less. Then, the gas is cooled in a primary gas cooler to about 35°C, where condensation liquid is separated into tar and ammonia liquor at a tar decanter.

The carbonization conditions in the coke ovens are considered suitable for the recycling of waste plastics because charged plastics decompose easily at high temperatures in a reducing atmosphere.

3. Test, Test Results and Discussions

3.1 Evaluation of Carbonization Product Yields

We conducted a test of processing general waste of plastic containers and packages (the analysis results of which are shown in **Tables 1 and 2**) using commercial coke ovens. The yields from the carbonization of the general waste plastics at the test were 20% of coke, 40% of tar and light oil, and 40% of gases, approximately (see **Fig. 2**).

3.2 Influence of Waste Plastic Addition on Coke Quality

We evaluated, through a test in commercial coke ovens, the coke strength in the case that general waste plastics after a volume reduction treatment is added to coal by 1 mass %. The coke strength was evaluated in terms of drum index (DI^{150}_{15}), which indicates the coke strength at the room temperature, and CSR, which indicates the coke strength after high temperature reactions. The result was that when general waste plastics were added to coal by 1 mass %, the coke strength figures were the same as in the case where no waste plastics were added (see **Figs. 3 and 4**).

The annual consumption of coking coal of the Japanese steel industry is about 50 Mt. If waste plastics are to be added to the coal charge by 1 mass %, the waste plastics consumed will add up to about 500,000 t/y. This corresponds to half the target processing amount for the additional 50% energy saving by the utilization of waste plastics in the JISF's voluntary energy saving action plan.

On the other hand, it is considered that, when waste plastics are added to coal in a larger amount (e.g. more than 2 mass %), coke strength may be deteriorated, depending on the composition of the plastics[3]. Further studies on the upper limit of the waste plastic addition without decreasing coke strength are required.

Table 1 Ultimate analysis and ash content of waste plastics

Ultimate analysis (mass%, dry)				Ash
C	H	N	S	(mass%)
72.6	9.2	0.3	0.04	5.0

Table 2 Component of waste plastics

Component (mass%)						
PE	PS	PP	PVC	PVDC	PET	Others
21.4	24.8	13.7	52	0.4	15.5	19.0

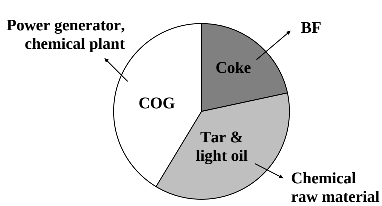

Fig. 2 Conversion rate of waste plastics

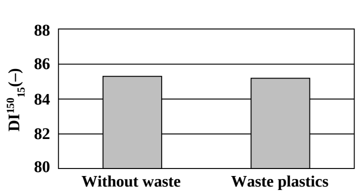

Fig. 3 Influence of waste plastics addition on DI^{150}_{15}

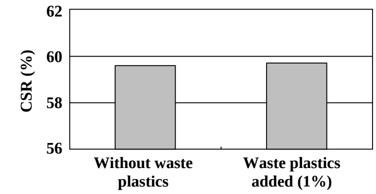

Fig. 4 Influence of waste plastics addition on CSR

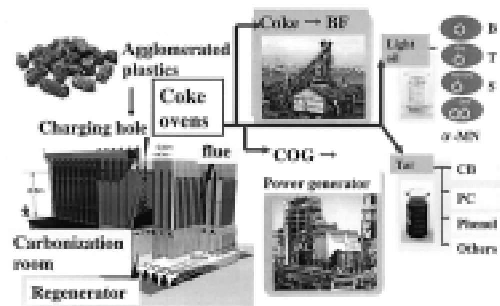

Fig. 5 Outline of waste plastics recycling process using coke ovens

3.3 Waste Plastics Recycling Process Using Coke Ovens

Fig. 5 shows the process flow of the waste plastic recycling by the Coke Oven from Waste Plastics to Chemical Raw Materials Method. After waste plastic containers and packaging are pre-treated for crushing, removal of foreign matters and briquetting, they are mixed with blended coal, charged into coke ovens, and decomposed at 1,200°C at the maximum without oxygen supply to yield 20% of coke, 40% of tar and light oil, and 40% of COG (a hydrogen-rich gas), approximately. The collected material is used as a chemical raw material. The recovered coke is used to reduce the iron ore in a blast furnace, the tar and light oil are used as raw materials for plastics etc., and the COG is used at a power plant, etc. as a clean energy source.

The waste plastics recycling by the coke ovens from waste plastics to chemical raw materials method has been approved by the authority as a chemical recycling technology in accordance with domestic Containers and Packaging Recycling Laws. Nippon Steel started the waste plastic recycling activities by said method in 2000. The first two plants by the method began operation at Nagoya and Kimitsu Works in 2000. The treatment capacity is 40,000 t/y each[4,5]. Two more plants that employ the same method started up at Muroran and Yawata Works in 2002, with a treatment capacity of 20,000 t/y each. All these plants including the pre-treatment facilities and the coke ovens are running well.

4. Summary

(1) It is possible to convert general waste plastics into coke, tar, light oil and gas by the waste plastics recycling process using coke ovens and reuse them as chemical raw materials.

(2) The method is approved as a chemical recycling technology in accordance with the Containers and Packaging Recycling Law,

and the plants in which the method is applied have been in commercial operation at Nagoya and Kimitsu Works since 2000. The plants including the waste plastics pretreatment facilities and the coke ovens are running well.

(3) Further studies shall be focused on identification of problems in the long-term stable operation of the facilities as an established social infrastructure and the solution thereof.

References

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