Combustion Waste Gas Cleaning by Carbonized Refuse-Derived Fuel (RDF)

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1. Introduction

An incinerator, a boiler, a cupola, a kiln, a furnace, a metallurgical smelter and a diesel engine emit undesirable, un-burnt, sub-micron particle and/or hydrocarbon with/without chlorine; namely, dioxin. To steer clear of the generation of such harmful materials or remove them in the exhaust gas, various methods are proposed from a viewpoint of environmental protection. However, for example, the combustion at the higher temperature with the higher air ratio for suppressing the fine particle generation causes secondary pollution due to NO\textsubscript{x} generation. For this reason, additional equipment for removing it must be also set up. The modern cupola needs also complicated equipments for a quench treatment of waste gas to prevent dioxin generation and a bag filter to recover the fines. Under such circumstances, the development of more simple and cost-effective equipment for cleaning waste gas is strongly required. For this reason, the packed bed filter of coke has been recently proposed and researched1) as Japanese national project, in which several carbonaceous materials were regarded as a candidate of a packed particle, without any experimental validation. In contrast, Refuse-Derived Fuel (RDF) has been focused worldwide from the environmental aspect. The carbonized RDF is a fuel produced from a municipal solid waste (MSW) that has undergone processing, including separation of recyclables and noncombustible materials, shredding, size reduction, pelletizing, and then heated up for carbonization. It is known that the particle generated by a joss stick is 0.3 μm in average size. The sub-micron particle generator was carefully selected because an industrial waste gas includes very fine powder. The sample weight was monitored by a high-accurate balance with re-produc-

2. Material

Tables 1 and 2 list six samples of carbonaceous materials used for this study. They were selected as typical one from over twenty candidates as a packed particle. The RDF was industrially carbonized at 973 K, referred as the sample A. Samples B to D were available in the steelworks for the general use. They are thought of most common packed particles for the filter. Commercially available charcoal is the sample E, and graphite, the sample F. All materials prepared were crushed into 5 g in weight for the experiments mentioned later. The surface area of samples was measured by BET method using nitrogen, after the drying treatment at 473 K for 30 min. The porosity was also measured by a mercury porosity-meter.

3. Method

Under the flowing condition of combustion waste gas, the capture property of un-burnt, fine powder by the samples was examined. Figure 1 shows a schematic diagram of the experimental apparatus; in which a joss stick is combusted as a simulated fuel and then sub-micron particles generated was captured by the sample suspended at the flow of waste gas. It is known that the particle generated by a joss stick is 0.3 μm\textsuperscript{2}) in average size. The sub-micron particle generator was carefully selected because an industrial waste gas includes very fine powder. The sample weight was monitored by a high-accurate balance with re-produc-

Table 1. Samples used for this study.

| A | B | C | D | E | F |
|---|---|---|---|---|---|
| Carbonized RDF | Pitch Coke | BF\textsuperscript{1)} | EAF\textsuperscript{2)} | Charcoal | Graphite |

\textsuperscript{1)} Blast furnace, \textsuperscript{2)} Electric arc furnace

Table 2. Chemical compositions of samples used. (mass%)

| Sample | F.C. | Ash | VM | S | H | N | O |
|---|---|---|---|---|---|---|---|
| A | 17.00 | 0.16 | 1.0 | 0.96 | 45.2 | 1.1 | 1.0 |
| B | 98.3 | 0.9 | 1.0 | 0.03 | 96.66 | 0.3 | 1.4 |
| C | 91.3 | 7.5 | 1.2 | 0.32 | 91.22 | 0.3 | 0.4 |
| D | 85.9 | 12.9 | 1.2 | 0.44 | 84.70 | 0.2 | 0.9 |
| E | 70.3 | 0.4 | 3.0 | 0.07 | 90.8 | 0.8 | 0.6 |
| F | 39.8 | 0.1 | 50.9 | 0.1 | 34.9 |

\textsuperscript{a)} Blown carbon, \textsuperscript{b)} Electric arc furnace

Fig. 1. Schematic diagram of the experimental apparatus for measuring the cleaning property of waste gas.

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tivity of 0.1 mg through the line connected to the sample. The combustion rate of the joss was also measured by another balance. Air flow-rate was kept to be constant; 120 Nl per h, by using a roller pump. Under these conditions, the combustion rate was constant: \(0.755 \times 10^{-6} \text{kg/s}\). As soon as the joss stick was ignited, the experiment started. After seven hours, the experiment finished and the sample was taken out for checking a final weight and for the observation of the cross section.

4. Results and Discussion

Figure 2 shows weight changes of the samples with time. Weight changes of all samples was enough large for measuring. It was most noteworthy that the weight change depends on a kind of sample, strongly. The order of the sample rate was:

\[ \text{A(RDF)} \gg \text{E} \gg \text{D}=\text{B}=\text{C}>\text{F} \]  

(1)

In particular, the sample A showed quickly increased before 15 ks and reached the saturated state. As a result, the final weight increase of the sample A was as much as three to ten times larger than the others. The very slight decrease of the sample in the final stage may suggest that the phenomena of adsorption and desorption could be reversible and that strictly speaking, the capture rate of fine power should be expressed by a difference between powder departing rate and powder adhering rate.\(^{3,4}\) The SEM observation of cross section of the sample also revealed that the fine powder generated by the combustion was mainly caught within the sample, not only on the surface of the sample. These results were beyond our expectation both that the fine powder generated accumulates only on the surface of the sample and that there is no significant difference in weight increase if the sample size and shape is the same as others.

These results were most likely caused by a fact that the sample is a porous material. Figure 3 shows the relationship between the final amount captured by the sample and BET specific surface area. Obviously, the relationship has strongly positive. With increasing the surface are from D to E and A, the amount correspondingly increased from 0.012 to 0.13 g. In contrast, C, B and F having very small surface areas showed very slight increase. The value of 0.01 g in weight increase could be almost caused by the powder deposition on the surface of the sample.

In contrast, Fig. 4 shows a plot of a final captured amount against porosity. The value of porosity was evaluated by a conventional method\(^{5}\) from true density and apparent density based on data of mercury porosity-meter. Very interestingly, there was no clear relationship. For example, the sample F shows small increase in spite of its large value in porosity. These results conclude that the more porous material with wide BET surface area is more suitable for catching the sub-micron powder in the combustion waste.
gas. More in-depth discussion of relationship between pore size of the particle and particle size in gas will be needed for designing porous structure of the packed material in the close future. Moreover, thermal conditions of carbonization of the RDF for enlarging its BET surface area will be discussed more fundamentally in the close future.

5. Conclusion

Capture property of particle material in the combustion gas were strongly influenced by a kind of carbonaceous material. The carbonized RDF showed significant advantage for the gas cleaning, in comparison to ordinary coke. The weight increase of the samples was well explained by BET specific surface area, not porosity. These results appeal a possibility that the carbonized RDF offers many benefits for cleaning waste gases from the viewpoints of not only cost performance, but also material recycling. The carbonized RDF used as packed particles of the gas filter become a fuel elsewhere.

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