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Heat generation of refuse derived fuel with water

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Abstract

In order to clarify the scenario of fires and accidents resulting from spontaneous combustion of Refuse Derived Fuel (RDF), exothermic phenomenon of RDF with water at ambient temperature was characterized by Calvet calorimeter (C 80 and MS 80), Thermal Activity Monitor and Dewar. The spontaneous combustion characteristic of RDF without additional water was examined by Thermogravimetry and Differential Thermal Analysis and Spontaneous Ignition Tester. The experimental results show the heat generation of RDF with different water content occurred instantly after additional water was added into RDF, while no exothermic phenomenon can be observed if no additional water was added into RDF at room temperature. It means that the self-heating of RDF does not only result from fermentation of RDF because of the prompt heat generation and temperature rise of RDF with water. It is possible that the self-heating of RDF results from heat of wetting first when additional water/vapor is absorbed by RDF. The further quantitative analysis for the self-heating of RDF with water/vapor should be made to explain the process of spontaneous combustion of RDF in detail.

Keywords: Spontaneous ignition; Refuse derived fuel; Calvet calorimeter; Thermal activity monitor; Dewar; Heat of wetting

1. Introduction

Recently, fires and accidents resulting from spontaneous combustion of Refuse Derived Fuel (RDF) frequently occurred in Japan (Gao et al., 2004; Tsuruda, 2004). According to the Fire and Disaster Management Agency in Japan (2003), the accident frequency of RDF is 5×10^{-2}/year, which is much larger than the fire frequency of 3×10^{-4}/year related with dangerous goods. RDF is mostly made from domestic garbage, and shaped into cylinder with 1.5–3 cm in diameter and 5–10 cm in length. Table 1 gives the main compositions of RDF. Usually, the volatile content (product of pyrolysis) of 72.6–76.3% (wt) exists in RDF, and the water content in RDF is less than 10%. The additive of calcium hydroxide with 2–4% (wt) is needed in the process of shaping RDF.

In order to know the cause of the spontaneous combustion of RDF, investigation with several different experimental methods, including Thermogravimetry and Differential Thermal Analysis (TG-DTA), Spontaneous Ignition Tester (SIT), Calvet calorimeter (C 80 and MS 80), Thermal Activity Monitor (TAM) and Dewar, were used in this paper.

2. Experiments

The samples of RDF were small chips from cylinders with $\phi20\times50$ mm, which were taken from the RDF storage in Mie Prefecture, Japan. The additional water content for various tests in this paper means mass percent of the additional water to the total mass of the sample, and RDF without water means no additional water was added into the RDF sample.

The exothermic characteristic of the RDF sample without water was firstly screened by thermal stability tests using TG-DTA (Thermo plus TG 8120, Rigaku Co. Ltd, Japan) and SIT (SIT-2, Shimadzu Co. Ltd, Japan). In order to detect

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Table 1
Main compositions of refuse derived fuel

Water content (%)	Volatile content[a] (%)	Carbon content (%)	Hydrogen content (%)	Nitrogen content (%)	Sulphur content (%)	Chloride content (%)	Calcium content (%)
<10	72.6–76.3	46.2–51.8	6.60–7.11	1.11–1.30	0.48–0.59	0.53–0.90	2.1–2.7

[a] The volatile may include water and part of carbon, hydrogen, nitrogen and so on.

the heat generation from the RDF samples at room temperature, it was necessary to use several thermal calorimeters having much higher sensitivity. So the experiments by C 80 and MS 80 (Setaram, France), and TAM (2277 TAM, Thermometric Inc., Sweden) were carried out, which have resolution of 0.10, 0.08, and 0.05 μW, respectively. The isothermal mode was chosen for these experimental methods.

The spherical Dewar vessel of 1000 ml with the overall heat transfer coefficient of 0.1968 J/m^2 s K was used to conduct the heat accumulation tests at room temperature and 50 °C, respectively. Compared with the normal heat accumulation tests described in the Recommendation on the Transport of Dangerous Goods—Manual of Tests and Criteria by United Nations (2003), the overall heat transfer coefficient of the 1000 ml spherical Dewar is one-eighth of a 500 ml cylindrical Dewar, which is assumed to be equal to 50 kg package when heat accumulation test is considered. Therefore, this set-up ensures a better adiabatic condition to measure the faint heat generation from the RDF samples.

3. Results and discussion

3.1. Information from the experiments by TG-DTA and SIT

3.1.1. TG-DTA experiments

The scanning rate of the TG-DTA tests was set to 2.0 K/min. The atmosphere was air supplied with 60 ml/min flow rate, and an open aluminum sample cell was used. Sample mass was from 10.86 to 27.42 mg. The results from the TG-DTA tests show the onset exothermic temperature for RDF without additional water was higher than 140 °C (Table 2 and Fig. 1).

Table 2
Onset exothermic temperature for the RDF samples by TG-DTA

Test no.	Sample mass (mg)	Onset exothermic temperature (°C)
1	18.970	159.1
2	24.550	168.0
3	24.150	156.8
4	17.130	160.2
5	10.860	166.0
6	16.120	179.2
7	19.610	170.1
8	27.420	177.2
9	19.470	165.0
10	11.640	145.0
Average	$18.99^{+8.43}_{-8.13}$	$164.66^{+14.54}_{-19.66}$

3.1.2. SIT experiments

The SIT test is used as a screening method to judge the property of spontaneous ignition, which temperature range is 10–300 °C. The SIT tests for RDF were conducted from 110 to 190 °C in this paper. A schematic diagram of SIT is shown in Fig. 2. The sample cell is made of quartz. The thermocouples and the heaters are set around the sample cell and the adiabatic condition can be kept by comparing the sample cell temperature between inside and outside. When the SIT tests were carried out, air atmosphere with 5 ml/min was used after the isothermal condition of the test system was established with nitrogen atmosphere. The curves in Fig. 3 suggest that the onset exothermic temperature for RDF was higher than 130 °C when no additional water was added in the RDF samples.

3.2. Calvet calorimeter experiments

For Calvet calorimeter, two experimental vessels are placed in a calorimeter block which imposes the temperature of the experiment as fixed or variable. Two symmetrical thermal flux meters composed of thermocouples connected in series surround the experimental vessels and thermally connect them to the calorimeter block. Therefore, high quantification of measurements and excellent sensitivity (low detection threshold) are provided by Calvet calorimeters. C 80 and MS 80 are two typical Calvet heat flux calorimeters. The difference between C 80 and MS 80 is that the later has better detection sensitivity and much better capability for keeping isothermal condition. In order to

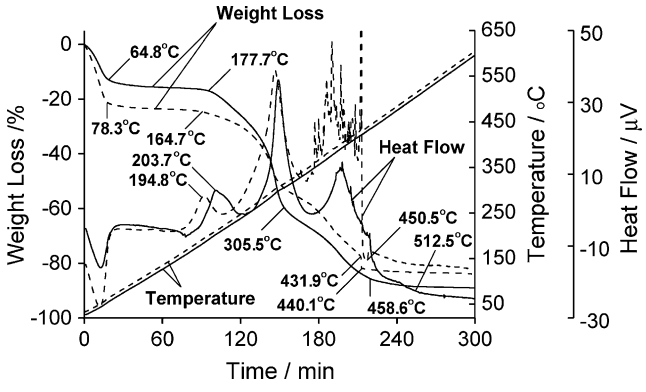

Fig. 1. Examples of the TG-DTA results for the samples of RDF.