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Thermal analysis of plastic contained decorative materials under different oxygen concentration

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Keywords: Thermal analysis; decorative materials; plastic; kinetic model.

Abstract. The combustion characteristics of decorative materials were studied by thermal analysis. The experiments were performed in three kind of oxygen concentration (7%, 14%, 21%), the heating rate were 15˚C /min and 30˚C /min respectively. The ignition point and maximum weight loss rated were analyzed. Based on the Coats-Redfern integral method, the results show that the combustion process were first order reaction.

Introduction

The consumption of plastic-contained decorative materials increases quickly, the average annual growth rate reached 10%. The plastic-contained decorative materials are very flammable, and will release a lot of heat and toxic gases plastic under low oxygen concentrations. A large number of waste plastic generated huge impact on the environment, especially in coastal areas plastic weight ratio has increased to 8% -10%, while the volume ratio is higher than 30% [1-5].

This topic is focused on the combustion of plastic-contained decorative materials under low oxygen concentration. Such effort aimed for recycling plastic-contained decorative materials in an economically and environmentally sustainable manner. Different heating rate, atmosphere were used to identify the optimum experimental parameters.

Materials and methods

Materials. Three kind of plastic-contained decorative materials were selected as raw materials. They were:

(1) Pipe decorative materials: nicely decorated plastic and used to wrap pipes;

(2) PVC board: decorative material for wall and roof, the main component is PVC;

(3) Aluminum composite panel: decorative materials for facade packaging made from aluminum and plastic.

The samples were cut into approximately square pieces of sides 10-15 mm firstly, then were ground to <0.25 mm for TGA analysis and stored in sealed glass vials.

Methods. Thermogravimetry analysis is usually used to analysis the combustion behavior of materials[6-9]. A Shimadzu TGA-60WS analyzer was employed to study the combustion of the plastic-contained decorative materials. The sample (10 mg) was heated at 10℃ min^{-1} to 900℃, with mixed carrier gas passing through the furnace at 100 ml min^{-1}. Shimadzu proprietary software was used to calculate the rate of weight loss against time and temperature. Table 1 showed the experimental conditions method of TG analysis.

Table 1 Experimental conditions method of TG analysis

Sample	Mass(mg)	β(˚C /min)	Flowrate(ml/min)	Oxygen concentration
Pipe decorative materials	10.09	15,30	100	7,14,21
PVC board	9.04	15,30,50	100	14
Aluminum composite panel		15,30		21

Results

Effect of oxygen concentration. Fig. 1 shows the TG curves of pipe decorative materials, PVC and Aluminum composite panel at three kind of oxygen concentration. The weight loss of Pipe decorative materials has two phases and the detail information were listed in Table 2. With the decrease of oxygen concentration, the initial temperature of 1st weight loss phase increased from 237˚C to 273˚C, and the final temperature of 1st weight loss phase increased from 405˚C to 480˚C. The initial temperature of 2st weight loss phase increase from 405˚C to 480˚C, while the final temperature of 2st weight loss phase decreased from 508˚C to 496˚C. The decreases of oxygen concentration make a significance shift of combustion to high temperature zone. Table 3 and Table 4 show the detail information of PVC and aluminum composite panel during the different weight loss process respectively.

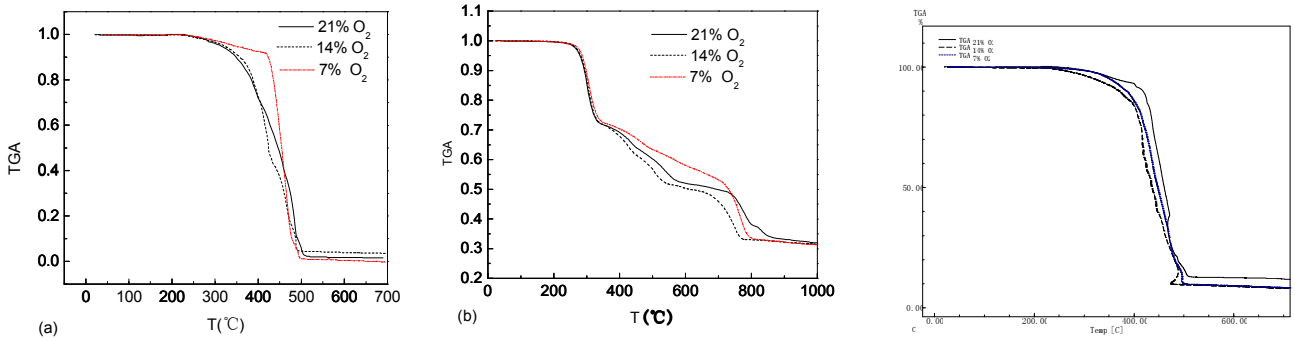

Fig.1 TG curves at three kind of oxygen concentration.(a) of pipe decorative materials; (b) of PVCmaterials; (c) of Aluminum composite panel.

Table 2 Weight loss temperature range and weight loss rate of pipe decorative materials (β=15˚C /min^{-1})

Reaction conditions	Phase 1			Phase 2		
Oxygen Concentration/%	T_i/˚C	T_f/˚C	Weight loss/%	T_i/˚C	T_f/˚C	Weight loss/%
21	237	405	30	405	508	67
14	241	433	55	433	504	39
7	273	480	89	480	496	7

Table 3 Weight loss temperature range and weight loss rate of PVC materials (β=15℃/min^{-1})

Reaction conditions	Phase 1			Phase 2			Phase 3		
Oxygen Concentration/%	T_i/˚C	T_f/˚C	Weight loss/ %	T_i/˚C	T_f/˚C	Weight loss/ %	T_i/˚C	T_f/˚C	Weight loss/ %
21	225	334	27	334	653	22	653	849	18
14	231	331	26	331	550	21	550	769	18
7	240	337	25	337	717	22	717	801	18

Table 4 Weight loss temperature range and weight loss rate of aluminum composite panel (β=15˚C /min^{-1})

Reaction conditions	Phase 1			Phase 2		
Oxygen Concentration/%	T_i/˚C	T_f/˚C	Weight loss/%	T_i/˚C	T_f/˚C	Weight loss/%
21	262	439	59	469	515	28
14	270	443	53	443	494	34
7	321	446	46	446	498	40

Ignition point. The ignition point of materials can be found by the thermal decomposition of the weight loss curves. It is generally recognized that the mutation point on the TGA curve as the temperature rises is the ignition point. Table 5 listed the ignition point of the aluminum composite panel under three oxygen concentration. The ignition point is decreased from 353.43˚C at 21% oxygen concentration to 427.67 ˚C at 7% oxygen concentration.

Table 5 Ignition point of aluminum composite panel under different oxygen concentration (β=15˚C /min)

Oxygen concentration(%)	Ignition point(˚C)
7	427.67
14	370.1
21	353.43

Fig.2 shows the DTA (a) and DTG (b) curves of PVC materials at three kind of oxygen concentration. The exothermic peak on the DTA curve is basically showing the trend of moving to a low temperature region with the decrease of oxygen concentration, and the peak shape gradually become wide. When the oxygen concentration dropped to 7%, two peaks on the DTA curve is not easy to distinguish. From the DTG curvemaximum weight loss rate in the whole reaction process can be recognized. With the reduction of oxygen concentration, the great weight loss rate gradually increased.

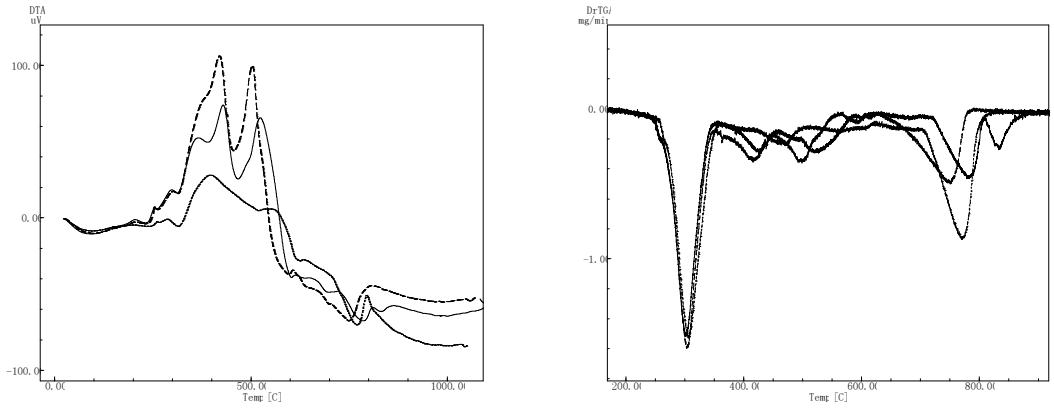

Fig.2 DTA (a) and DTG (b) curves of pipe decorative materials at three kind of oxygen concentration.

Kinetic model. Kinetic model of APCP pyrolysis can be described in

$$\frac{\mathrm{da}}{\mathrm{dt}} = A\exp\left(-\frac{E}{RT}\right)f(a) \tag{1}$$

f(α) is corresponding function with materials and reaction rate, decided by reaction mechanism. In this paper, Coats-Redfern integral method was used to describe the kinetic model. The equation of Coats-Redfern is listed in (2). Detailed description of Coats-Redfern method is elsewhere[7].

$$\ln\left[\frac{g(a)}{T^2}\right]=\ln\left[\frac{AR}{\beta E}\left(1-\frac{2RT}{E}\right)\right]-\frac{E}{RT} \tag{2}$$

A linear regression was performed on equation (2), when the ln[AR/(ΦE)(1-2RT/E)] and -E/R were obtained, The value of the activation energy E and frequency factor A could be obtained. The kinetic parameters of PVC materials combustion in different oxygen concentration atmosphere were carefully analyzed, the reaction function in phase 1 and phase 2 are all first order reaction, the fit curves in phase 1 and phase 2 were shown in Fig.3, and detailed kinetic parameters were shown in Table 6.

Each sample correlation coefficient of fitting equation is close to 1, so the experimental data is fit to linear regression. When the oxygen concentration is 21%, 14% and 7%, the corresponding activation energies of PVC board during the thermal decomposition reaction were 242.9 kJ/mol, 369.2 kJ/mol and 485.9 kJ/mol respectively.

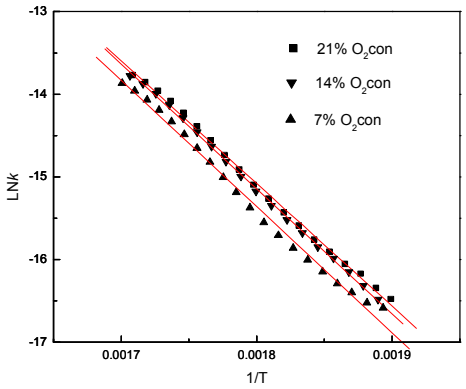

Fig.3 Kinetic fitting results of PVC combustion at stage 1

Table 6 Kinetic perameters of PVC combustion under different oxygen concentrations at stage 1 (β=15˚C /min)

O_2 concentration(%)	Order	r^2	A/ s^{-1}	E/kJ·mol^{-1}
21	1	0.999	2.15e+004	118.4563
14	1	0.999	6.84e+012	144.2711
7	1	0.988	3.42e+013	152.3431

Conclusions

Three typical kinds of plastic decorative materials, decorative pipe, PVC board and aluminum panels were chosen to investigated the combustion behavior under different oxygen concentrations. Ignition point of aluminum composite panel increase with the decrease of oxygen concentration.

The kinetic parameters of PVC combustion in different oxygen concentration were all first order reaction.

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References

[1] J.X. Zhao: China Building Materials Science & Technology, Vol. 6 (2009), p.61

[2] X. Lu, J.H. Li, Y.X. Weng and Y.F. Nie: Technigues and Equipment For Enviro.poll.cont. Vol.3 (2002), p.46

[3] Z.G. Zhu: Aluminium Fabrication. Vol. 6 (2011), p. 52

[4] B.X. Liu and J. Liu: New Building Materials. Vol. 8 (2005), p. 29

[5] Z.X. Chen: Metal World. Vol. 3 (2003), p. 11

[6] Y.F. Liao and X.Q. Ma: J. Fuel Chem and Techno. Vol. 3 (2009), p. 296

[7] R.Z. Hu:Thermal analysis kinetics[M]. Beijing: Science Press, 2001.

[8] R. Font, A. Fullana and J. Conesa: J Anal Appl Pyrolysis, Vol. 74 (2005), p. 429

[9] Y.H. Yu, S.D. Kim, J.M. Lee, K.H. Lee: Energy, Vol. 27 (2002), p. 457