Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(2):292-297

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

The study on combustion kinetics characteristic of biology-molding fuel

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ABSTRACT

Thermo gravimetric (TG-DTG) analysis was used to study the pyrolysis characteristics of biology-molding fuel (corn straw and bean straw) at different heating rates in a stream of N2. We determine the kinetic parameters including reaction order, frequency factor and activation energies of straw that guided design for combustion boiler using biology-molding fuel.

Keywords: Biology molding Fuel; Thermo gravimetric analysis; Combustion kinetics.

INTRODUCTION

Combustion theory of biomass focus on the burning characteristics of original and loose biological materials or the burning characteristics of combination of biological materials and coal [1-10]. Due to the scarcity of the research on microcosmic burning mechanism of biology-molding fuel, the efficiency of burning devices of biology-molding fuel isn't high, impeding the application and popularization of biology-molding fuel. By means of burning a fraction of comminuted biology-molding fuel and analyzing related parameter and burning characteristics via thermobalanc, the microcosmic burning mechanism of biology-molding fuel verifies Eigen values of curve, parameters of combustion dynamic, providing theoretical reference for high-efficient burning and reasonable application of biology-molding fuel, which consists of the Study on Combustion Kinetics Characteristic of biology-molding fuel.

EXPERIMENTAL INSTRUMENT AND EXPERIMENTAL CONDITION

The experimental instrument is thermo balance. Comminute straw biology-molding fuel with machinery and classify the straw power with sample sieve into 4 classes as small as diameter (D) 18mu, 60mu, 80mu, 120mu. Respectively do the research in various heating rate as 10, 20 and 40℃/min. The experimental temperature is 650℃, TG-DTG range 0.02kg and 5mv/min.

DTA OF MOLDING FUEL UNDER VARIOUS EXPERIMENTAL CONDITIONS

Judging from figure 1 and figure 2, the general changing characteristics of the four analysis curve don't vary much. The burning process of molding fuel is classified into three stages in TG, DTG and DTA. The first stage: the first protruding peak on DTG curve; the first concave valley on DTG curve; the initial mild setting stage of TG curve. The above listed 3 changes show that weightlessness rate of the fuel in this stage increases and then drops in peak value (known from the protruding peak on DTG curve); the reaction of fuel is endothermic reaction (known from the concave valley on DTG curve), quality of fuel decreases (known from the dropping of TG curve). The comprehensive analysis shows that this stage mainly consists of water loss.

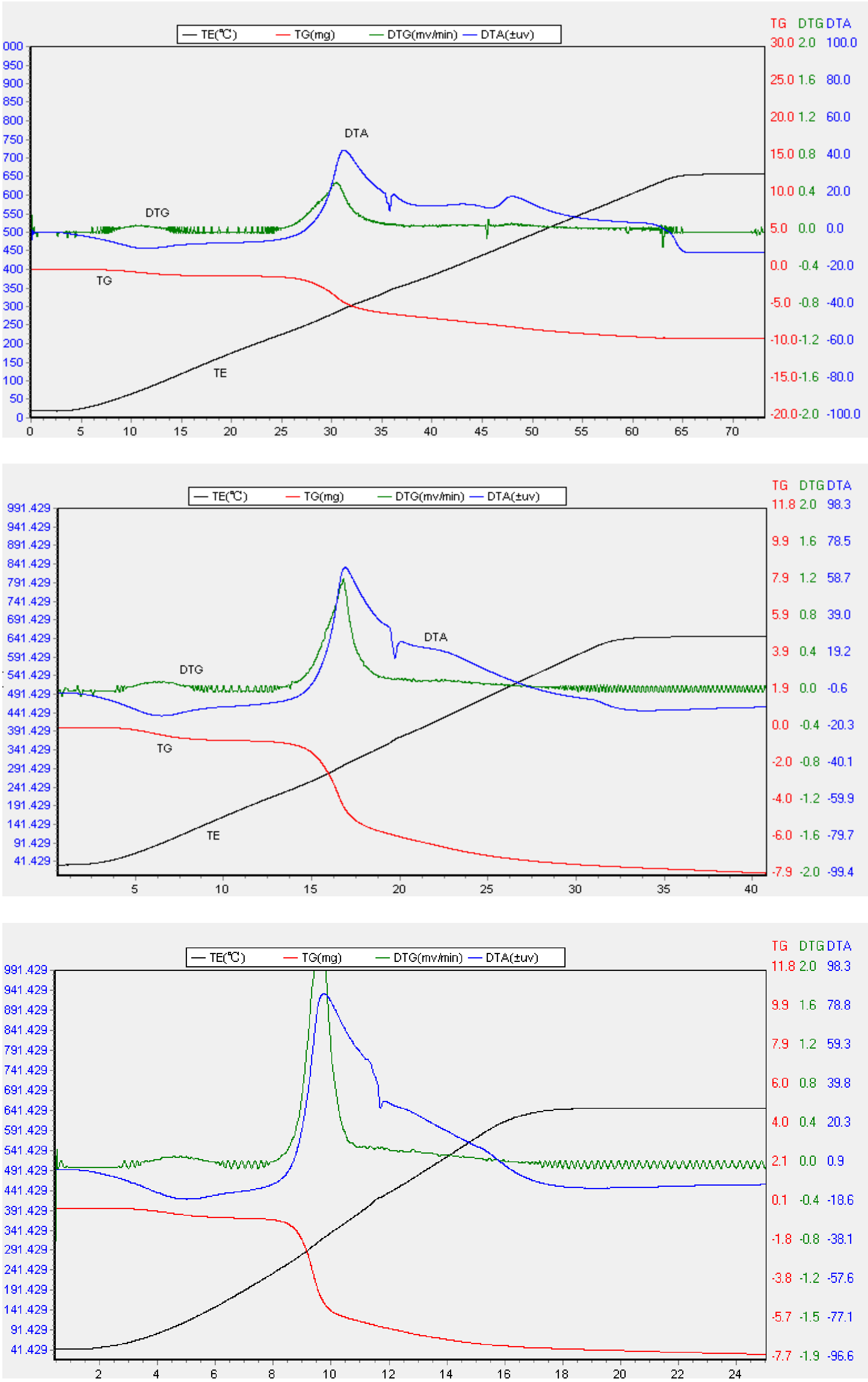

Figure 1. DTA curve of molding fuel of corn straw

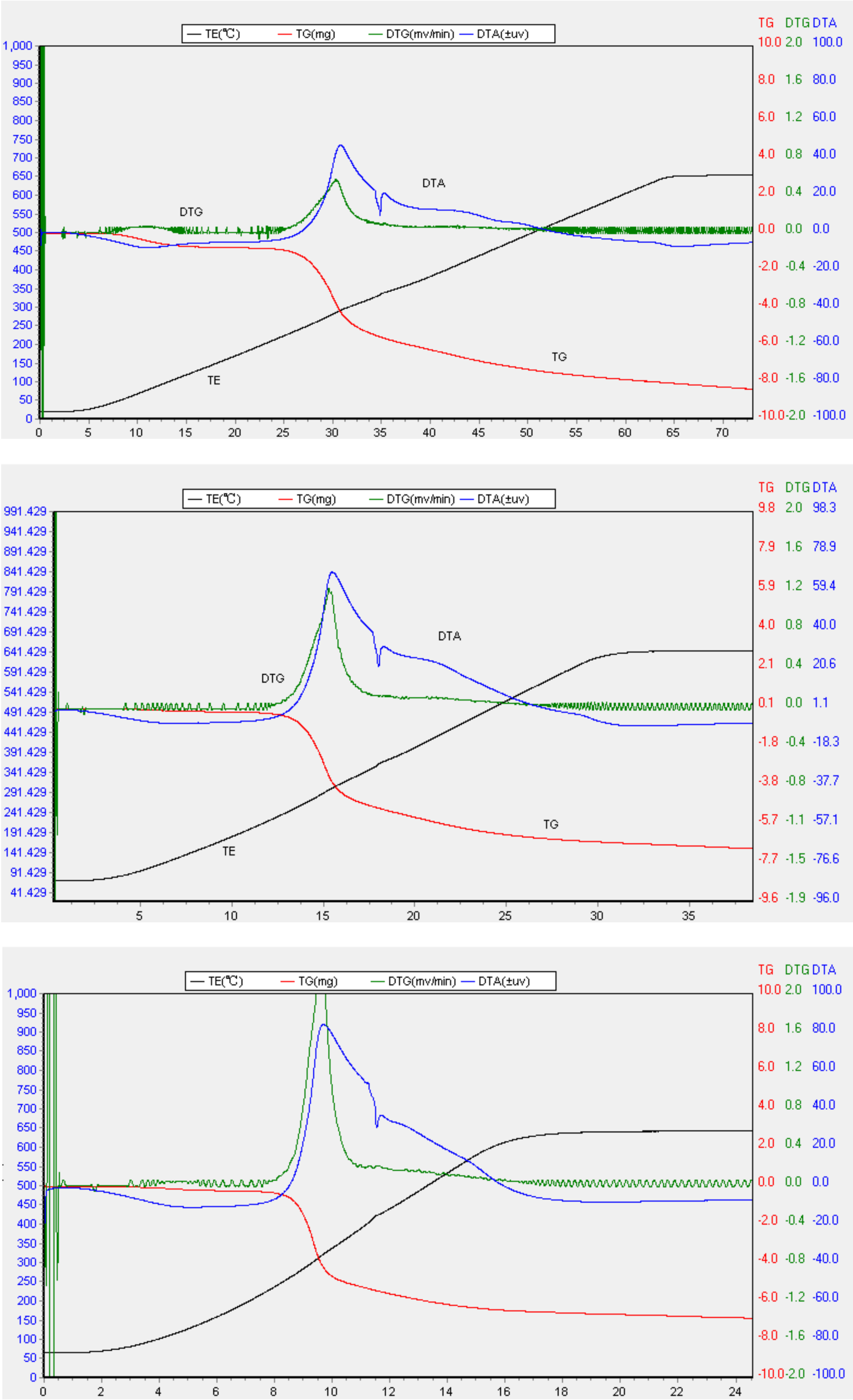

Figure 2. DTA curve of molding fuel of bean straw

The second stage: the second protruding peak on DTG curve; the second first-half protruding peak on DTA curve; the sharp setting stage of TG curve. In this stage, the weight loss rate of the fuel is the highest; the lost of quality is the greatest, existing in a sharp heat-emitting process. The comprehensive analysis shows that this stage is mainly a volatilization and burning one, shown as BC stage in DTG. The third stage: the stage after the second protruding peak on DTA curve; the stage after the sharp setting stage of TG curve. In this stage, the quality of fuel keeps decreasing; weight loss rate of fuel mildly rises and falls around a certain stable standard and the reaction is heat-emitting one.

ANALYSIS ON EIGEN VALUE DTA OF THE MOLDING FUEL

According to the thermal analysis system and the relevant analysis on table 1, we got the Eigen value of molding fuel under different experimental standards and conditions shown in table 1 as follows.

Table 1 Eigen Value DTA of Biology-molding Fuel

Material	HR (℃/min)	D (mm)	Mass (mg)	TG					DT		DTA		
				Te (℃)	TL (℃)	TC (℃)	DW (mg)	%	DTG (mg/min)	Te (℃)	Te (℃)	Tm (℃)	TC (℃)
corn straw	10	18	12.2	219.4	298.2	370.6	9.23	75.67	0.5	288.1	294.7	262.1	334
	10	60	12.5	247.8	290.4	325.3	8.32	69.33	0.6	284	264.5	290.4	330.3
	10	120	12	213.6	290.4	360.9	8.23	54.87	0.6	295.3	266.6	287.8	360
	20	18	12	257.7	295	331.9	7.76	62.08	1.2	299.6	272.6	300.9	373.4
	20	60	12	251.1	300.7	346	6.96	58	1.2	298.7	271.3	302.7	352.6
	20	120	12.5	234.2	301.7	375.4	7.88	51.84	1.2	302.7	273.1	299.6	380.6
	40	18	15	270	306.3	342.1	7.3	60.83	1.9	302.4	280.3	322	429.6
	40	60	15.2	270.9	308.4	345.4	6.81	54.48	2.7	317.1	279.9	321.2	428.4
	40	120	15.2	262.8	308.4	353.1	7.21	47.43	2.8	324	281.5	328	450.8
bean straw	10	18	16.7	205.1	301.3	391.1	10.5	62.93	0.53	302.5	249.9	317.1	380.6
	10	60	18.1	203.3	302.1	392.7	11.2	61.66	0.5	294.9	237.8	315.4	395
	10	120	15.6	240.4	304.7	364	9.77	62.64	0.4	289.8	260.3	317.1	330.4
	20	18	17.1	258.6	314.2	367.7	8.87	51.87	1.1	306.3	276.9	323.3	438.2
	20	60	17.3	256.4	314.8	369.3	9.3	53.76	1	316.4	267.1	327.8	440.9
	20	120	15.1	251.7	303.4	351.9	10.5	69.67	1.2	309.6	271.7	316.6	432.7
	40	18	17.6	281.1	326.6	369.7	9.2	52.27	2.8	334.4	274.8	342.6	531.1
	40	60	17.6	283.8	329.8	373.8	9.09	54.44	2.9	342.1	282.1	347.7	544.4
	40	120	18.2	277.8	319.2	360.4	8.95	49.18	3.1	333.6	273.6	334.4	539.1

Analysis on TG Eigen value: under the same fineness (for example: 1mm), the Initiative-point temperature (Te) and inflexion point temperature (TL) on TG of the fuel rise with increasing of heating rate while the TC changes irregularly. Under the same heating rate, each Eigen value of TG decreases with increasing of heating rate for the difference resulting from changes of fineness of fuel materials. To take Eigen value Teas example, the difference is 34.2℃ under10℃/min, 23.5℃ under 20 ℃/min, 8.1℃under 40k/min. The other two Eigen value have the same characteristic, showing that the higher the heating rate is, the less the fineness of fuel materials affect the temperature of Te, TL and TC, the closer their values are. Due to different quantity of the added materials, Material weight loss (DW) changes without fixed rules. But the weight loss rate of fuel change with a fixed rule, which reflects the burning degree of fuel. Under the same heating rate, weight loss rate of fuel decreases with increasing of fuel fineness, or in other word, the smaller the fuel grain is, the less fully the fuel burns. The reason is that the smaller the fuel grain is, the greater the bulk density is, and the less fully the fuel burns. When the fineness of fuel are the same, weight loss rate decreases with increasing of heating rate.

Analysis on DTG: for the fuel of the same fineness, the Max weight loss rate DTG rises with increasing of heating rate and Te corresponding to the greatest weight loss rate rises as a result. Under the same heating rate, the fineness of material has little effect on Max weight loss rate DTG. Generally speaking, the greater the fineness is, the greater the Max weight loss rate DTG and the corresponding temperature Te.

Analysis on DTA: under the same fineness, Te，the temperature of Initiative-point on DTA varies little, which ranges between 260℃～300℃, since the temperature of the initial point represents the temperature of fuel volatile constituent release, which is decided by the characteristics of fuel, and varies little accordingly. However, Tm, the peak temperature of DTA and TC, the temperature of stop point, rise with increasing of heating rate. Under the same heating rate, DTA Eigen value temperature decreases with increasing of heating rate due to the extreme difference resulting from fineness changes of fuel.

ANALYSIS ON PARAMETER OF COMBUSTION KINETICS WITH MOLDING FUEL

In light of DTA of biology molding fuel and relevant analyzing software, we can get the dynamics parameter of burning reaction, which enable us to do qualitative and quantitative research on the rate of speed and the influencing factors of the burning reaction of biology molding fuel. The experimental result of molding fuel in different conditions is shown in table 2 as follows. Fitting curve based on DTA analyzed with one element indefinite regressive analysis by thermal analysis system, in figure3 as follows.

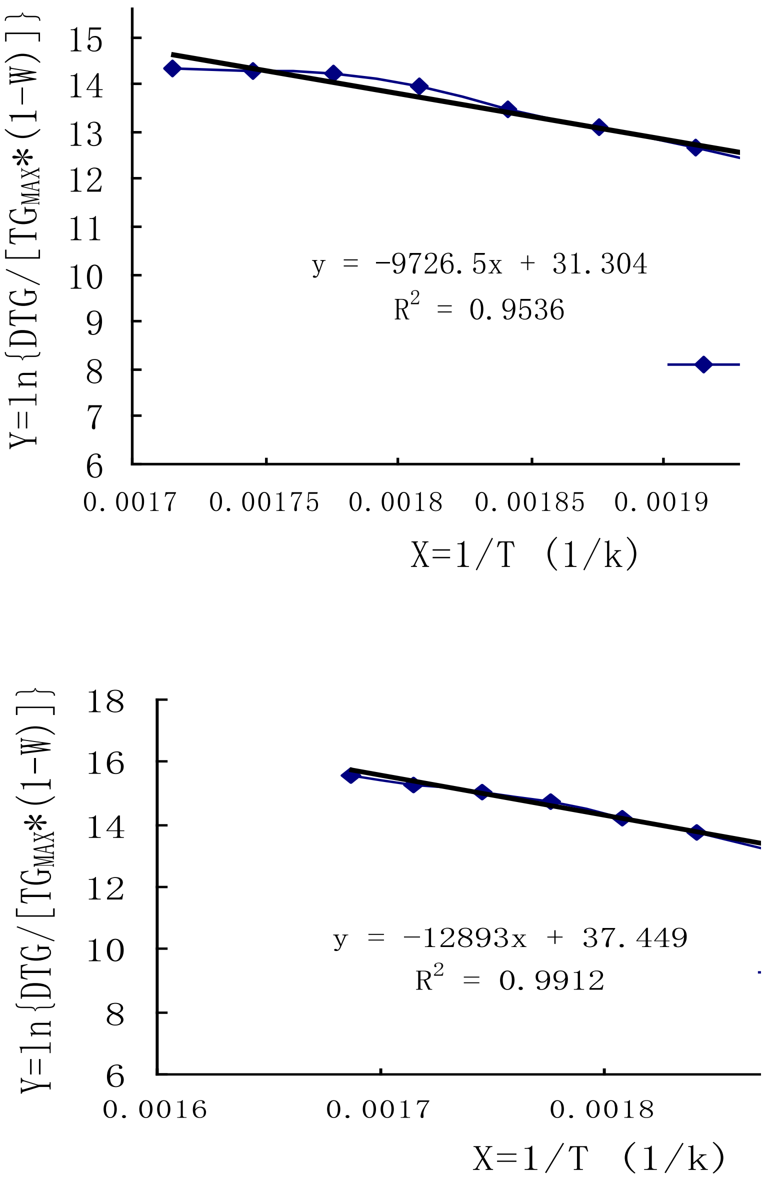

Figure 3. Fitting Curve of Burning Dynamics Parameter of Corn and Bean Molding Fuel

Table 2 Regressive Analysis Results DTA of Biology Molding Fuel

Material	HR (℃/min)	D (mm)	Mass (mg)	volatile release reaction dates		
				E (KJ/mol)	frequency factor	Correlation coefficient
corn straw	10	18	12.2	80.87	3.9×10^{11}	0.9536
	10	60	12.5	105.46	5.1×10^{12}	0.9624
	10	120	12	80.44	9.8×10^{13}	0.9845
	20	18	12	116.3	1.02×10^{11}	0.9831
	20	60	12	126	1.77×10^{18}	0.9772
	20	120	12.5	106	2.75×10^{13}	0.9954
	40	18	15	112.21	6.45×10^{15}	0.9763
	40	60	15.2	109.86	3.45×10^{16}	0.981
	40	120	15.2	103.87	7.21×10^{16}	0.9751
Bean straw	10	18	16.7	110.7	2.04×1017	0.9812
	10	60	18.1	107.19	1.84×1016	0.9912
	10	120	15.6	99.83	6.18×1015	0.9741
	20	18	17.1	115.31	6.126×1018	0.9857
	20	60	17.3	119.05	2.25×1017	0.9638
	20	120	15.1	104.67	7.816×1015	0.9902
	40	18	17.6	117.32	4.137×1018	0.9875
	40	60	17.6	120.39	2.305×1017	0.9922
	40	120	18.2	107.98	6.324×1015	0.9653

CONCLUSION

1) DTA of biology molding fuel can be classified into their stages: endothermic and water lose reaction in the first stage takes place between 25~200℃; the main reactions taking place in the second stage are volatile release and combustion reaction, which take place between 200~380℃ with max weight loss rate temperature of 300℃; the main reaction in the third stage is burning reaction of fixed carbon, which ends around 550℃. Borderlines of the there stages intersect. DTA of all the samples are alike.

2) Changes of heating rate and fineness have effect on active energy of molding fuel. Regularity of the effect of fuel material fineness on active energy is not clear, which rises and falls irregularly.

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