Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1035-1041
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

Problems and Solutions in Combustion Performance Test of Building External Thermal Insulation Materials

Chunshan Peng[1*] , Jingjing Li[1], Junwei Li[2]
[1]Henan Quality Polytechnic, Pingdingshan, Henan, China
[2]Ye Younty Market Supervision Management Bureau, Yexian, Henan, China

Abstract:

The quality of building external thermal insulation materials is related to the safety of buildings. With the development of high-rise building thermal insulation materials, people pay more and more attention to the combustion performance. The test results also play a guiding role in whether this type of material can be used in practical engineering. Therefore, it is very important to test its combustion performance. From the current situation of combustion performance testing of external thermal insulation materials, there are still some problems. This requires effective countermeasures. This paper focuses on the problems and Countermeasures of combustion performance detection of building external thermal insulation materials This paper expounds the classification of combustion performance of building materials and their products and the main parameters of material combustion performance affecting fire, and briefly analyzes the main problems and Measures Existing in the detection of combustion performance of building external thermal insulation materials. The application of organic materials in building exterior wall insulation system has obtained very good combustion performance, and this material accelerates the spread of fire on the premise of fire. Therefore, strengthening the combustion performance of organic thermal insulation materials is one of the concerns.

Keywords*: Building External Thermal Insulation Materials, Building Safety, Combustion Performance, Data Fusion.*

I. INTRODUCTION

In the 21st century, due to the rapid depletion of fossil fuels (such as natural gas, oil and coal) and the gradual growth of global population, the energy crisis has become an urgent and fundamental problem restricting human sustainable development. At present, due to many challenges faced by the development and application of new energy, energy conservation and emission reduction have attracted more and more attention [1-2]. In China, building energy consumption has increased by 45 in two decades and reached $43x10^{18}$J in 2010. Therefore, in the context of energy conservation and emission reduction, reducing building energy consumption is of great significance [3]. Another major challenge related to the current energy shortage is the increase in greenhouse gas (GHG) emissions. The energy consumption of buildings

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1035-1041
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

is mainly related to the greenhouse effect and indirectly has an important impact on global climate change. Since 40% of the world's primary energy consumption is used for construction, it accounts for 24% of global greenhouse gas emissions [4-5]. In 2009, the construction industry contributed 18% of China's overall greenhouse gas emissions and one fifth of China's total primary energy consumption. With the development of new technology, the raw materials for manufacturing RPU are no longer limited to petrochemical raw materials, and the application of renewable biomass and appropriate recycled waste is increasing. This makes the RPU board easier to obtain and the average price is lower during the service life. In short, RPU has become one of the most valuable materials to effectively realize building energy conservation and environmental protection.

II. INSTRUMENTS, METHODS AND MODELS

2.1 Test system

The most commonly used thermal analysis technology is thermogravimetric analysis (TGA), which can record the change of sample quality with time / temperature in real time. It can record mass loss, heat flux release rate and heat conversion temperature at the same time, and it is easy for users to analyze the test results [6-7]. The design adopts horizontal double balance measurement system, and the standard configuration is equipped with automatic gas switching, digital gas flow controller and touch screen control. During the test, the shielding gas shall be provided at all times. The reference pot shall be calibrated, and the sample mass shall not exceed 200 mg or the volume shall not exceed 2 / 3 of the volume of the clamp pot.

Developed by the National Institute of standards and Technology (NIST) in 1982, the ISO 5660 cone calorimeter (cone) for measuring small-scale heat release rate is one of the most useful technologies to evaluate the combustion characteristics of materials. The device is based on the principle of J oxygen consumption, and can provide two typical ignition modes, namely, the forced ignition mode of high-voltage spark and the radiation ignition mode of 81 / 2 turn wiring. With the conical design, the heater can provide uniform heat flow to the sample surface located on the sample rack. In addition, the heater can be placed horizontally or vertically to heat the sample. It should be noted that the heating or cooling process should be phased and mild to avoid irreversible damage caused by rapid heating or cooling of the heater. In auxiliary accessories and configuration conecal. With the help of the software, it can record the ignition time, oxygen consumption rate, heat release rate history, CO and CO2 output, flue gas density, etc. The core of the measurement unit is a paramagnetic oxygen analyzer with a measurement range of 1-25% [8].

2.2 Traditional dynamic analysis method

Kinetic analysis is to measure and parameterize the reaction rate through the combination of experimental technology and calculation method. The thermal decomposition rate is related to three parameters, namely temperature, conversion and pressure. Therefore, it can be expressed as [9-10]:

$$d\alpha / dt = r(T)\, f(\alpha) h(p) \tag{1}$$

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1035-1041
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

In this work, when the experiment is carried out in each atmosphere, the volatile products will be quickly removed from the test system and the total pressure will remain unchanged. Then the rate equation can be transformed into a simple form:

$$d\alpha / dt = r(T)\, f(\alpha) \tag{2}$$

Please note that t is the sample temperature. For isothermal system, r (T) is a constant, and the reaction rate is only a function of the conversion rate, which can be used to determine the reaction function f(α). For the non-isothermal system, it is assumed that the reaction constant is expressed by arrhenius formula r(T)=Aexp(-Eα/RT). After the latter is substituted into equation (2) and deformed many times, it can obtain the common difference form of constant heating rate, such as:

$$\beta d\alpha / dt = Aexp(-E_\alpha / RT)\, f(\alpha) \tag{3}$$

Where α=(mo-m)/(mo-mf) represents the conversion rate, t is the time, A is the pre-factor, E_α is the activation energy which depends on the change during the whole solid phase reaction, R is the gas constant, T is the temperature, f(α) is the reaction model, m0 is the initial mass of the reactant, M is the mass at a certain time during the reaction, mf is the final mass at the end of the reaction, and P represents the heating rate.

2.3 Classical model for calculating the combustion time of solid combustibles

It is assumed that the solid material is a semi infinite plate whose physical properties do not change with temperature, and remains thermally inert before ignition, the surface layer is transparent and the boundary heat loss can be ignored; Ignition occurs when the surface temperature of the material reaches the ignition temperature. Then, the heat balance equation in the control volume exposed to uniformly distributed heat flow can be described as:

$$pc_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial y}\left(\lambda \frac{\partial T}{\partial y} - q_r\right) \tag{4}$$

The net incident heat flow is expressed as:

$$q = \alpha q_{ext} - h(T_{ig} - T_s) - \sigma\varepsilon(T_{ig}^4 - T_s^4) \tag{5}$$

Considering only convective heat transfer, Drysdale claims that its exact solution is:

$$(T - T0)/(T\infty - T0) = 1 - e^{r^2} erfc(r) \tag{6}$$

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1035-1041
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

When considering the heat radiation loss, quotere assumes a reasonable form of temperature distribution, namely:

$$T - T0 = (qb / 2k)(1 - y / d)^2 \tag{7}$$

Then the ignition time can be expressed as:

$$t_{ig} = \left[Ckpc_p \left(T_{ig} - T_0 \right)^2 \right] / q^2 \tag{8}$$

III. PYROLYSIS KINETICS ANALYSIS OF RPU FOR EXTERIOR WALL INSULATION

3.1 Experimental overview

The isocyanate used is industrial grade poly4,4 '- diphenylmethane diisocyanate vinegar (MDI) with isocyanate content of 30.8%; Polyols are industrial grade polyether polyols with a light value of 463.64 mg KOH / g. All laboratory made polyurethane foam samples used in this study were prepared by one-step technology.

The block polyurethane hard foam of foamed star is kept in an incubator at 70 ℃. When testing, take it out and grind it into powder for use. The thermogravimetric experiment was carried out on SDT q600 (TA, USA) equipment. The sample quality was controlled at 3-5 mg. All samples were referred to the open AI2O3 crucible. The heating range was 30-800 0C. The heating rate was four low heating rates (1 ℃ / min was also used for the reference sample), which were 5, 10, 15 and 20 ℃ / min (< 50 K / min).

3.2 Results and discussion

In the same reaction, the pre exponential factor and activation energy show the so-called compensation effect of synergistic change and development. On the one hand, it introduces large errors in the calculation of activation energy and the determination of model. On the other hand, it becomes an opportunity for the constant activation energy EA to further solve the pre exponential factor and identify the reaction mechanism function

When a > 0.6, EA is basically constant. We can solve the corresponding pre exponential factor a through the compensation effect equation. The equation is expressed as ina = a EA + B, where. And B can be obtained from different models in CR analysis. This so-called forced isokinetic relation can give the corresponding isokinetic temperature tiso = 1 / (AR) (where R is the gas constant). The forced isokinetic relationship at each concentration and the kinetic parameters calculated by the combined CR method are shown in Table 1. In general, the calculated isokinetic temperature falls within the range of experimental pyrolysis temperature and increases with the increase of heating rate).

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1035-1041
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

TABLE I. Equivalent dynamic parameters of RPU in air atmosphere obtained by CR method (α= 0.6-0.98)

HEATING RATE	a	b	K_{iso}	T_{iso}	R2
5	0.0174	-4.10399	0.016507	692	0.99161
10	0.0169	-4.15159	0.015739	711	0.99116
15	0.0166	-4.12725	0.016127	724	0.98941
20	0.0164	-4.20092	0.014982	734	0.99063

It should be emphasized again that at high conversion, pyrolysis in oxidizing atmosphere shows stable activation energy, which can be considered as a separate step in multi non reaction. Therefore, the model reconstruction generally applied to the primary one-step reaction can also be applied here. Once the compensation coefficient of a = 0.6-0.98 is determined, the pre exponential factor can be determined by bringing the equal conversion activation energy into the compensation effect equation.

With the improvement of computer computing power, compared with time-consuming and labor-consuming experimental methods, efficient and environmental friendly numerical prediction is more and more popular. As mentioned above, the prediction of pre exponential factor depends on the accurate solution of activation energy and the application of compensation effect (note that the pre evaluation reaction is a one-step reaction). Further, the thermodynamic function can be solved by the equation brought into the literature by A. The calculation results are listed in Table 2. In four oxygen-containing atmospheres, the baking value and Gibbs free energy are positive at high conversion, but the direct function is negative. This shows that the pyrolysis of RPU is a non spontaneous endothermic process at high temperature. In the complex Di increasing principle, the negative Di value represents a relatively slow process relative to the transient system of the activated complex. However, with the increase of oxygen concentration, this negative value first decreases and then increases in the air atmosphere. This shows that the reaction process is the slowest in 15% oxygen / 85% nitrogen. It is assumed that the activation energy is directly proportional to the energy barrier that needs to be crossed by the reaction. The non monotonic increase of the direct value under different oxygen-containing atmospheres and the change of the activation energy provide strong evidence for the existence of the critical oxygen concentration, and further explain that the concentration is between 10% and 15%.

TABLE II. Ina thermodynamic function of RPU pyrolysis in oxidizing atmosphere

ATMOSPHERE	EA(KJ/MOL)	INA	H #(KJ/MOL)	S #(KJ/MOL)	G #(KJ/MOL)
5% O2/95%N2	120	15.5	121.19	-111.14	212.19
10% O2/90%N2	80	10.53	112.82	-133.19	227.79
15O/ O2/85}N2	106	13.2	729.4	-174.38	221.01
20% O2/80%N2	128	18.1	990.56	-152.04	226.03

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1035-1041
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

IV. MODELING AND DECOUPLING OF RPU COMPLEX PYROLYSIS REACTION

In nitrogen atmosphere, the pyrolysis test of polyurethane was carried out at 5, 10, 15 and 20 ℃ min^{-1}. The temperature boundary of a reaction is defined by the weight loss per minute reaching 0.002. The starting temperature of thermogravimetry, the temperature at the maximum weight loss rate and the residue rate can be used as the characteristic parameters to evaluate the thermal stability of RPU. The TG-DTG curve and corresponding characteristic parameters of pure RPU made in the laboratory are shown in Figure 5.1 and table 5.1 respectively. It can be seen that pyrolysis occurs in the range of 200.8-640.1 ℃, and the TG curve moves to the high temperature region with the increase of heating rate. An interesting phenomenon can be observed. Before 462 ℃, at the same temperature, the mass of RPU increases with the increase of heating rate, but after this temperature, the trend begins to reverse gradually. This interesting phenomenon also appeared in the data reported by Li et al. On RPU pyrolysis. This shows that low heating rate and long heating time are conducive to the formation and escape of low-temperature products, but are unfavorable to the formation and escape of high-temperature products (such as aniline); At the same time, it is proved that the reaction after this temperature is different from that before. Finally, the residue rate is the highest at 5 ℃ min-1, indicating that reducing the heating rate can promote the occurrence of the reaction in the initial stage (more conducive to the diffusion of gaseous products), but inhibit the occurrence of the reaction as a whole. At the end of the experiment, there were black residues in the increasing pot at four heating rates, and the final mass was between 15% - 20%, which was consistent with the experimental report.

At the same time, it can be seen from the DTG curve under each temperature rise rate that the mass loss rate increases with the increase of temperature rise rate, which is due to the increase of activated molecular concentration. Generally speaking, RPU can be pyrolysis in three or four atmospheres. In addition to the volatilization of surplus small molecules and adsorbed water in the synthesis process, then at about 230 ℃, the weakest carbamate acetate bond in the soft segment and hard segment will break to form isocyanate and polyol (which may be the same as that used in the raw material). These products further undergo random chain cutting at 250-450 ℃. The shear chain reaction of random chain plays an important role in material thermal weightlessness. This intense reaction stage causes the foam to lose more than half of its mass at 250-400℃. Finally, depending on different heating rates, the second-order reaction may occur in varying degrees. Finally, at all reaction rates, due to the formation of aniline, the reaction ends between 550-625 ℃, and the reaction ends earlier at low heating rate.

It can be seen that the heating rate will change the pyrolysis mechanism in nitrogen atmosphere to varying degrees. Therefore, in the next modeling process, in order to ensure the consistency of the model mechanism gate, we choose the heating rate at 5, 10, 15 and 20 ℃ min^{-1} as the modeling data basis.

V. CONCLUSION

Through the methods of experimental test and theoretical analysis, the pyrolysis mechanism and combustion characteristics of typical exterior wall insulation material RPU are systematically studied in

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1035-1041
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

this paper. At the same time, the effects of gas atmosphere on pyrolysis mechanism, ambient oxygen concentration and additives on pyrolysis kinetics, heating rate on thermal stability, ignition mode and external radiation intensity on combustion characteristics were deeply studied. In addition, the pyrolysis kinetics of RPU was comprehensively studied by using different equal conversion and simulation fitting methods.

REFERENCES

[1] Teng Jiaying, Wu Xianguo, Zhai Haizhou. IPD Collaborative Management Framework Based on BIM and Multi-party Contract. Journal of Civil Engineering and Management, 2013, 030 (002): 80-84
[2] Zhang Jianping, Fan Zhe, Wang Yangli. Dynamic Management of Construction Resources and Real-time Cost Monitoring Based on 4D-BIM. Construction Technology, 2011, 40 (002): 225-225
[3] Wang Guangbin, Zhang Yang, Tan Dan. Research on Cost Accounting Theory and Implementation Method of Engineering Project Based on BIM. Progress and Countermeasures of Science and Technology, 2009, 026 (021): 47-49
[4] Yang Zhenqing, Zhang Hong, Zhang Lili. Application of BIM Technology in Mechanical and Electrical Construction. Architectural Technology, 2015, 46 (002): 132-134
[5] Ying En Tian, Li Yong, Xiong Kai. Analysis on Influencing Factors of Bim Application in Construction Enterprises Based on AHP. Journal of Guilin University of Technology, 2016, 36 (03): 119-125
[6] Zeng Xudong, Zhao Ang. Application Research of Building Energy Saving Design Based on Bim Technology. Civil Architecture and Environmental Engineering, 2006, 028 (002): 33-35
[7] Chen Yan, Dai Hongjun, Liu Jing. Framework of Building Information Model in Project Management Information System. Construction Technology, 2008 (02): 9-12
[8] Liu Zhan Sheng, Li Bin, Wang Yang. Application of BIM Technology in Construction Management of Doha Bridge. Construction Technology, 2015 (12): 76-80
[9] Xu Jun, Li Anhong, Liu Houqiang. Application and Risk Analysis of BIM in Railway Industry. Journal of Railway Engineering, 2014, 31 (3): 129-133
[10] Ma Shaoxiong, Li Changning, Chen Cunli. Application of BIM Technology in Construction Management of a Project. Construction Technology, 2016 (11): 126-129