Thermal degradation and flame retardancy of flexible polyurethane foams modified with borax

Ming GAO [1,a], Shun CHEN [2,b]

[1] School of Environmental Engineering, North China University of Science and Technology, Box 206,Yanjiao Beijing 101601, China

[2] School of Safety Engineering, North China University of Science and Technology, Box 206,Yanjiao Beijing 101601, China

[a] gaoming@ncist.edu.cn, [b] 528784219@qq.com

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Abstract. The main work of this thesis is to study and discuss flame retardant properties of the flexible polyurethane foam (FPUF) added with borax as flame retardant. The flammability parameters, including limiting oxygen index(LOI), rate of heat release (RHR), total heat release (THR), total mass loss (TML) and mass loss rate (MLR), yield of CO, yield of CO_2, smoke production rate (SPR) and total smoke production (TSP) were recorded simultaneously. The thermal degradation of the FPUF samples was studied by TG.

Introduction

Due to its low density, well elasticity, sound-absorbing, air permeability, heat preservation performance, etc. flexible polyurethane foam (FPUF) is widely used as furniture mat, seat cushion, various kinds of soft liner of laminated composite materials, as filtering materials, insulation materials, shock-proof materials, decoration materials, packaging materials and heat insulation materials, etc. The use of flexible polyurethane foam in house interiors, building or public transport constitutes a potential hazard for people in case of fire [1-2]. The need for consumer protection, coupled with the new regulations and environmental concerns, increases the interest in flame-retardant treatments. Because borax has certain flame retardant effect, take away a lot of heat and water loss when heating, water loss after the powder will be covered on the surface of material, which will make it difficult to burn [3]. In this work, flexible polyurethane foam (FPUF) was treated with the borax, the flame retarding behavior of these samples was evaluated by cone calorimeter.

Experimental

Materials

Borax ($Na_2B_4O_4 \cdot 10H_2O$; analytical reagent) was supplied by Tianjin Yongda Chemical Reagent Co. Polyether polyols mixture (Cst-1076A/B) and isocyanurate (MDI; Cst-1076A/B) was supplied by Shenzhen Kesheng Trading Company ltd.

Measurements and characterization

The specimen size for the LOI measurement was 90 × 10 × 10 mm^3 by JF-3 LOI apparatus (Nanjing Jiangning Analytical Instrument Factory). Thermogravimetry (TG) was carried out on a HCT-2 thermal analyzer (Beijing Hengjiu Scientific Instrument Factory) under a dynamic nitrogen (dried) atmosphere at a heating rate of 10℃ min^{-1}. The specimen size for the cone calorimetry experiments was 10 × 10 × 30 mm^3 by PX-07-007 (Phoenix quality inspection instrument co., LTD). At least three samples were tested to obtain average values.

Preparation of modified flexible polyurethane foam samples

Isocyanate, polyether polyols, and dimethyl silicone oil of were well mixed in a 1 L beaker. Next borax was added into the beaker with vigorous stirring for 10 s. FPUF was treated with 2g, 4g, 6g, 8g, 10g of borax, respectively. The mixture was immediately poured into an open mold (300×250×150 mm^3) to produce free-rise foam. Foam blocks so obtained were kept in an oven at 70℃ for 24 h to complete the polymerization reaction. Samples were cut into the desired shape and size by rubbing with fine emery paper, and these test species were used for the evaluation of different properties.

Results and discussion

Thermal stability of flexible polyurethane foams

Limiting oxygen index (LOI) was used to evaluate the fire-resistant behavior of flexible polyurethane foam (FPUF) and flexible polyurethane foam/borax, as shown in Figure 1 [4]. It is clear that LOI value of flexible polyurethane foam (FPUF) is 17.0%. The flexible polyurethane foam (FPUF) was modified by 2g borax content exhibits the high LOI value of 17.9%. When the FPUF was modified by 10g borax content exhibits the high LOI value of 21.9%. FPUF was treated with borax significant improvement its flame retardant behavior.

Degradation stability of flexible polyurethane foams

The simultaneous DTG and TG curves of FPUF and FPUF/borax were carried out in dynamic nitrogen from ambient temperature to 1000℃ and are shown in Figures 2-3. From Figures 2-3 shows we can see that FPUF/borax have slightly higher degradation temperatures and char yield. The increase of char yields agrees with mechanism of flame retardant [5]. These results indicate that the borax can increase the thermal stability of FPUF.

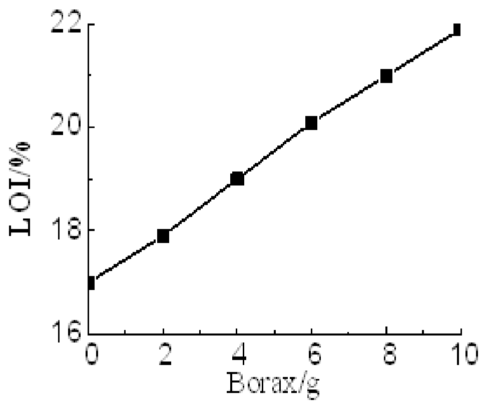


Fig 1.LOI of FPUF containing different borax

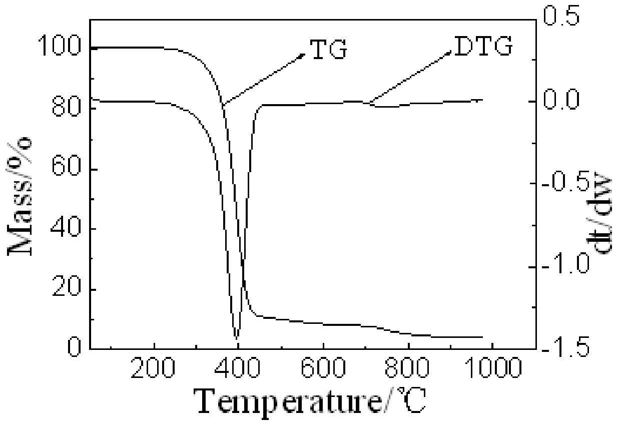
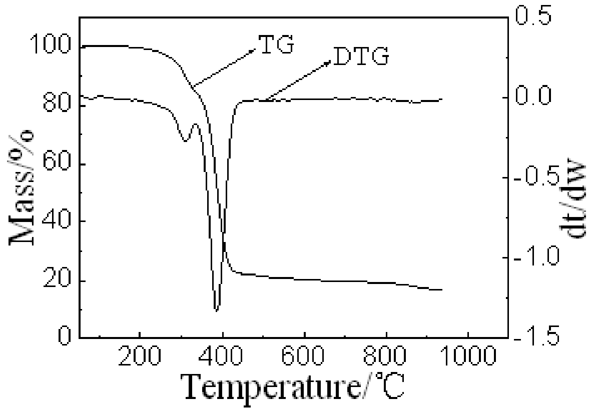


Fig 2.Thermogravimetric curve of FPUF



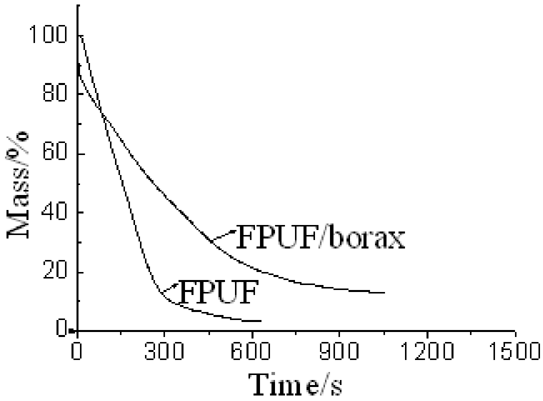


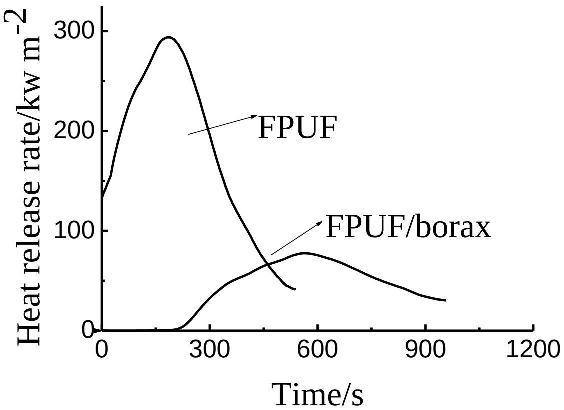
Fig 3.Thermogravimetric curve of FPUF/borax Fig 4.The mass percentage of samples

From the Fig. 4, it can be seen that there is a main and quick decomposition stage of the mass loss behavior of FPUF and FPUF/borax. Compared char yield of FPUF with FPUF/borax have slightly higher char yield. These results indicate that the borax can increase the flame retardancy of FPUF.

Heat Release

The rate of heat release (RHR) was recognized to quantify the size of fire [6]. From Figure 5, we can see that the heat release rate is different between FPUF and FPUF/borax. Heat release rate of FPUF is higher more than FPUF/borax. In a short time the borax absorbs a lot of heat, increasing the flame retardancy of FPUF. The heat release rate of FPUF/borax decreases.

From Figure 6, we can see that the total heat release of FPUF and FPUF/borax are very different, the total heat release of FPUF greater than the total heat release of FPUF/borax. Heat release of FPUF in the combustion process is more, and heat release rate is big. It can be seen that after adding borax in the FPUF can influence the total heat release of materials in the process of combustion. Borax in the material of the flame retardant behavior shows good flame retardancy.



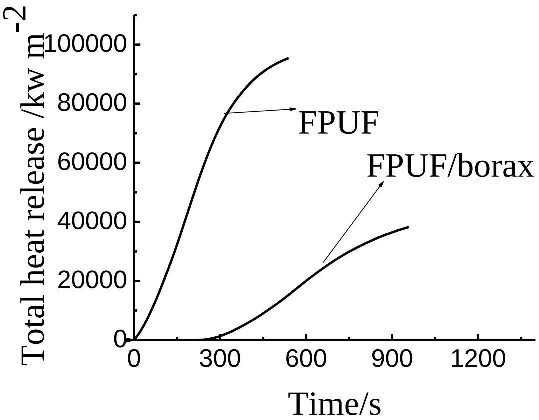


Fig 5.Heat release rate profile of samples Fig 6.Total heat release profile of samples

Gas and Smoke Release

Carbon dioxide yield, carbon monoxide yield, carbon dioxide yield, smoke production rate (SPR) and total smoke production for samples are shown in Figures 7-10.

Figure 7 shows the more carbon dioxide is release in the process burning of FPUF, much more than FPUF/borax release in the burning. FPUF in a short time can quickly burn, release large amounts of carbon dioxide. The carbon dioxide content significantly decreased for FPUF/borax in the burning produce, which indicates the borax can absorb a lot of heat in a relatively short time.

Generally, the smoke production and toxic gas formation along with the heat release rate play a critical role in fire conditions [7]. One of most toxic gases released from burning FPUF is carbon monoxide. Usually, the flame retardant materials produce more carbon monoxide per mass unit burned than untreated materials. The carbon monoxide formation at the expense of carbon dioxide is however an important fire retardant principle [7]. From Figure 8, we can see that the FPUF/borax produce more CO than FPUF before 375 s, but after 375 s the CO release of FPUF/borax great decrease.

The effect of flame retardant on smoke formation was measured. The smoke production rate and total smoke production as the function of time is shown in Figures 9-10. For samples, smoke is formed first at the beginning of burning and shortly prior to the end of burning. From figures we can see that the effect of borax on smoke release of FPUF is quite obvious. This may be also attributed to the borax on suppressing combustion.

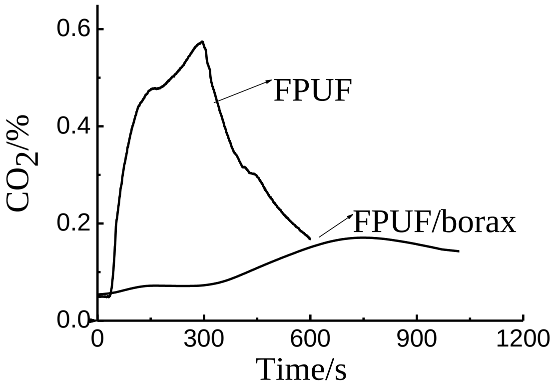


Fig 7.CO_2 yield profile of samples

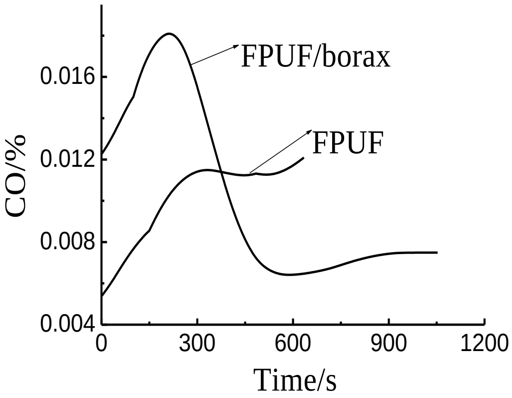


Fig 8.CO yield profile of samples

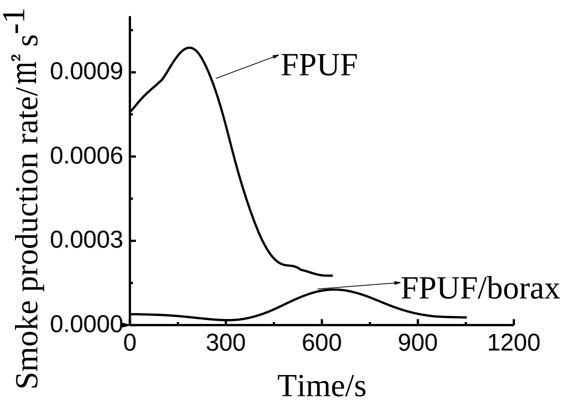


Fig 9.Smoke production rate of samples

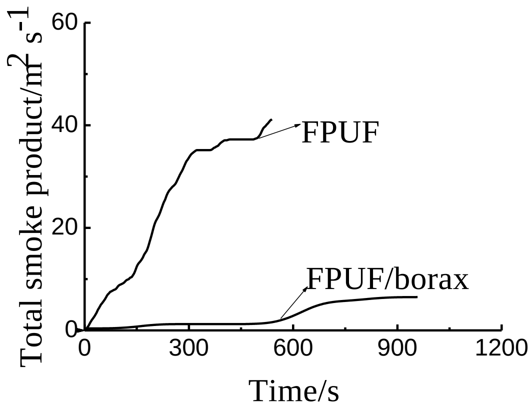


Fig 10.Total smoke production of samples

Conclusions

Borax as a flame retardant was mixed into FPUF, which make LOI, thermo-stability, char yield, CO yield increase, and make CO_2 yield, smoke production rate, total smoke production, heat release rate profile, total heat release decrease. The incorporation of borax into FPUF improved the flame retardancy.

Acknowledgement

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