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An Experimental Study on the Burning Behavior of Fabric used Indoor

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Abstract

Fabrics used indoor has a major impact on the development and spread of indoor fires and fire hazards because of its easy ignition, fast burning speed and the rapid spread rate. In this paper, the burning behavior of five kinds of fabrics used indoor such as cotton woven, jeans, woollen sweater, linen rope and sponge, were studied by means of the cone calorimeter. The ignition time, the heat release rate, the mass loss rate, the yield of CO and the smoke production rate of the five kinds of fabrics used indoor were analyzed and compared at different external heat flux conditions with the specific experimental data and image. Our results indicated that: with the increase of the heat flux, five kinds of fabrics were more and more to be ignited; in higher heat flux condition, average heat release rate and the peak mass loss rate were higher; In lower heat flux condition, due to the incomplete combustion, smoke production rate and the yield of CO were higher; and the effect of the density of the structure and moisture content to burning behavior of fabrics can't be ignored. Fire risk order of five kinds of fabrics is: woollen fabrics> sponge fabrics> cotton fabrics> linen fabrics.

Keywords: Building fire, Fabric, Cone calorimeter, Burning behavior

1. Introduction

Fire is one of the serious disasters to human social, especially indoor fires, which affect people's life and property security immediately. According to statistics, The quantity and mortality of fabric fire used indoor is higher than other causes of fire [1, 2]. Because fabric has thin thickness, large specific surface area, porous, easy accumulation characteristics, low intensity radiation or flame will be ignited, and flame propagation speed is very fast, once catch on fire in the limited space ,they will release a large number of toxic smoke and heat in few minutes, so people will get poisoned and suffocated, losing the ability to escape, eventually leads to death [3].Therefore, the correct evaluation of fabric burning behavior is very important to the occurrence, development and prevention of indoor fire.

In this paper, the burning behavior of cotton cloth, jeans and a sweater (wool), linen rope, sponge, which are common indoor fabrics, were researched by cone calorimeter in order to evaluate the fire risk.

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2. Experimental materials and methods

2.1. Test samples and test conditions

According to the requirements of the international standard ISO5660-1, which using cone calorimeter to test heat release of building materials, the sample size were cut into the size of 100 mm x 100 mm × 18 mm. In the experiment, the sample with the aluminum foil wrapped its back and sides to reduce the quality losses [4].In order to guarantee smooth surface of combustion, sample is clamped with stainless steel mesh. Because at low intensity radiation or flame most fabrics used indoor will be ignited, this paper tested the thermal radiation at 20 kW/m^2 and 30 kW/m^2, to research burning behavior of five samples. Specific design parameters were shown in table 1.

Table 1. Design parameters of operating condition

weight(g) / heat flux(kW/m^2)	cotton cloth	blue jeans	sweater (wool)	linen rope	sponge
20	5.5	9.3	18.6	6.8	3.0
30	6.7	25.1	15	6.9	3.2

2.2. Instrument equipment

Cone calorimeter is based on the oxygen consumption principle material combustion performance test instrument [5]. Because of its extremely similar combustion environment with the real combustion environment, the test results and the large burning test results exist good correlation, which can be used to characterize the burning behavior, in evaluating material, material design and fire prevention etc, it has important reference value, at present cone calorimeter has become one of the most important instruments to research burning behavior of materials [6-8].

The basic combustion characteristic parameters tested by cone calorimeter are: Time to Ignition(TTI) ,Heat Release Rate(HRR), Mass Loss Rate(MLR), Smoke production rate(SPR), CO Yield(COY),and so on .

3. Results and analysis

3.1. Time to ignition(TTI)

TTI is a very important parameter to evaluate the burning behavior of materials [9]. At the same condition, the shorter the TTI of material is, the easier material will be ignited, and the flame will spread to the surrounding material easily, so the fire risk of material is bigger also. From data shown by table 2, we can see: firstly, with heat flux increases, the TTI of the various samples are shortening, which indicated heat flux is the main reason; secondly, at the same radiate heat conditions, the intensity of organizational structure has an important effect on burning behavior of materials. For example, due to intensity of organizational structure of sponge is very loose, the TTI of sponge is shortest; jeans and cotton are woven by the cotton fibre, but because the jeans woven structures are reinforced, and thus at the same heat flux condition, the longer jeans ignited.

3.2. Heat Release Rate(HRR)

HRR is one of the most important parameters to describe the process of fire, which decided the energy release in fire, and is a basic parameter of the fire danger degree [9]. Peak heat release rate represents the maximum heat release rate of material [9]. The average heat release rate represents the average level of heat material releases in fire. The bigger the average heat release rate is ,the more violent material burns.

From fig.1 we can see, firstly, under different heat flux conditions, test of several common fabrics with HRR -t curve shows the initial flat stages - heat release - late flat feature.

Secondly, sample moisture regain of fabric has a significant effect on the initial release time. Between fibre fabrics, the moisture regain of cotton is 11%, the moisture regain of lien fibre is 12%, but the moisture regain of net gross is 14-15%, therefore, sweaters need to absorb more heat to evaporate fabric moisture, while the heat release time of cotton is earlier than lien rope.

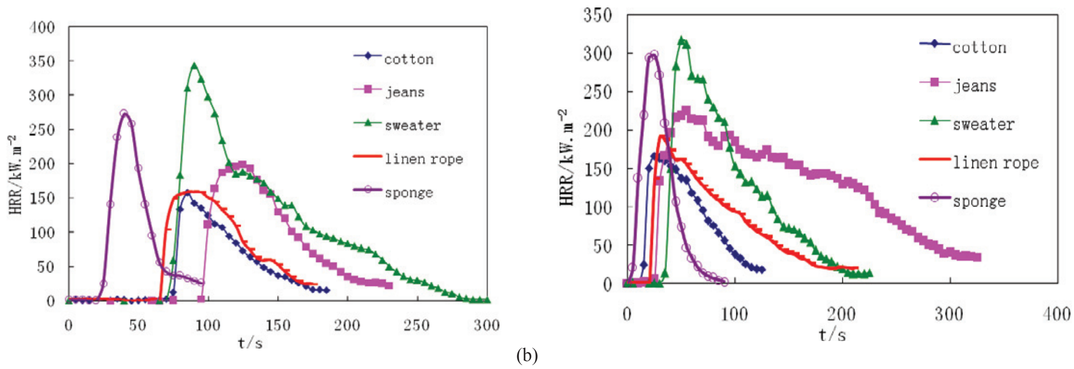
Table 2.Time to Ignition of different samples under different conditions

material	TTI(s)	
	20(kW/m^2)	30(kW/m^2)
cotton cloth	68	10
jeans	87	20
sweater (wool)	61	26
linen rope	64	17
sponge	23	2

Sponge not fibre fabric, but because the ignition point is low, about 150-180 ℃, so the greater the heat flux is, the earlier the initial heat release time of material is.

Thirdly, the density of the structure of fabric also has effect of heat release rate. For example, jeans and cotton cloth are both made of cotton fibre, but because the structure of jeans texture weaves closely, the initial heat release time of jeans are earlier than cotton cloth.

In conclusion, from the heat release rate, 5 interior fabric fire risk order is: sweater (woollen) > sponge>jeans> linen> cotton cloth.



(a) (b)

Fig.1. HRR curve of sample with the heat flux (a) 20kW/m^2 and (b) 30kW/m^2

Table3. HRR of different samples under different heat flux conditions

heat flux(kW/m^2)	the first peak of heat release rate / the average heat release rate(kW/m^2)				
	cotton cloth	jeans	sweater (wool)	linen rope	sponge
20	157.52/8.67	199.45/11.85	343.95/16.9	158.91/12.06	272.81/17.15
30	166.54/16.4	225.75/24.17	317.03/20.95	191.56/14.94	297.67/21.47

3.3. Mass Loss Rate(MLR)

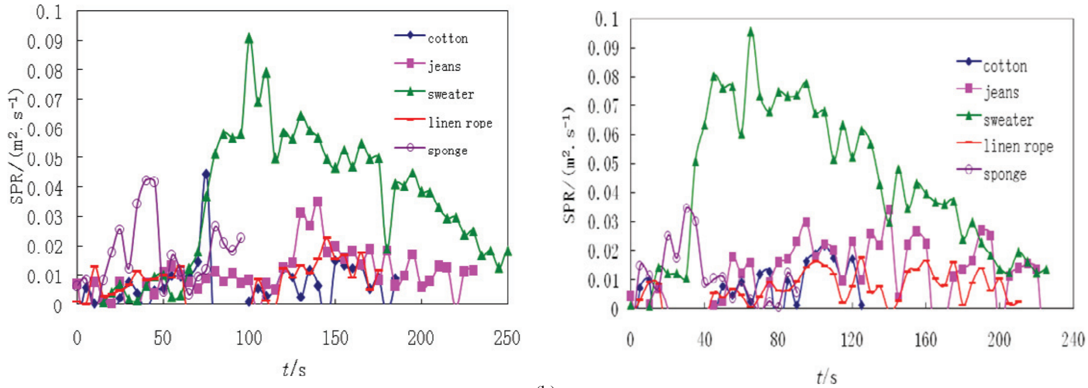
Mass loss rate is the decomposition rate of combustion [10]. Generally, mass loss rate is bigger, indicating the material easier combustion, the flame propagation speed is faster, the greater the risk of fire. Combined with the data in table 3, 4, we can be see: for the same sample, mass loss rate increases, heat release rate is greater; and for different samples, because the heat of combustion is different, the bigger the mass loss rate, not necessarily heat release rate is bigger also.

3.4. Smoke release performance and toxicity

In the building fire, the limited oxygen, and more for not complete combustion, often contains a lot of fire smoke toxic or harmful gases, the visibility of the site of a fire is very low, influencing people to get out. According to statistic, in recent years, in building fires, more than 80% of the deaths were due to inhalation of toxic smoke and death. Therefore, the smoke production rate is one of the most important indexes in evaluating material's contribution in fire [11].

Table 4.MLR of different samples under different heat flux conditions

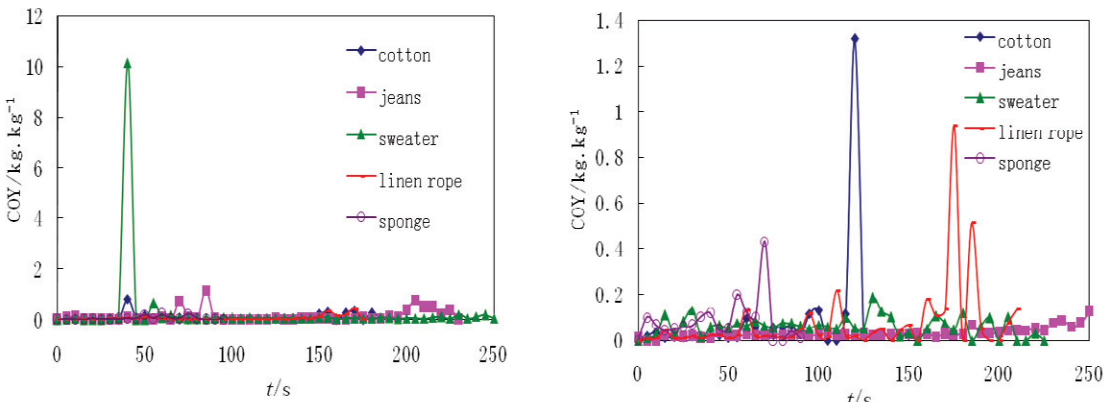
heat flux(kW/m^2)	the peak of mass lose rate / the average mass lose rate (g/s)				
	cotton cloth	jeans	sweater (wool)	linen rope	sponge
20	0.120493/0.0052	0.168699/0.0073	0.22095/0.0089	0.14333/0.0076	0.14049/0.0067
30	0.135674/0.0119	0.188235/0.0139	0.239618/0.0196	0.202721/0.0104	0.201067/0.01



(a) (b)

Fig.2. SPR curve of sample with the heat flux (a) 20kW/m^2 and (b) 30kW/m^2

According to fig.1 and fig.2 we can see: as the heat flux increases, the initial smoke release time arrivals early, and when the first peak of heat release rate occurs, the smoke production rate also have a maximum, then, with the heat release rate decreases. The comparison can be found: the smoke production rate of sponge is fastest, after 40-50s reaches a peak, this is because the sponge loose structure favorable combustion; in fibre fabrics, the descending order of smoke production ability is sweater>jeans>hemp>cotton.



(a) (b)

Fig.3. CO yield curve of sample with the heat flux (a) 20kW/m^2 and (b) 30kW/m^2

In building fire, CO is the most common toxic constituent in smoke. So CO generation is to measure the rate of fire of fire risk of important parameters of material [12].From Fig.3 we can see, the samples of CO yield with heat flux decrease. This is because under higher heat flux condition, completeness of combustion is higher, CO is mainly the production of incomplete combustion conditions. In the five test samples, the descending order of CO yield capacity is: sweater > sponge> jeans> cotton>hemp rope.

4. Conclusion

In this paper, the burning behavior of five kinds of samples was researched by cone calorimeter to evaluate their fire hazard under heat flux of 20 kW/m^2 and 30 kW/m^2, get the following conclusions:

(1) Along with the heat flux increases, the ignition time of samples is significantly reduced; but under the same heat flux condition, the bigger the intensity of organizational structure is, the material is not readily ignited.

(2) Along with the heat flux increases, the bigger the heat release rate of sample is, the bigger the mass loss rate is; in fibre fabric, along with the radiation intensity increases, the less the sample moisture regain of fabric is, the initial het release time goes earlier; the bigger the density of the structure of fabric is, the bigger the peak heat flux and average heat flux are.

(3) Along with the radiation intensity increases, the smoke release time ahead of time, the yield of CO decreases with the heat flux increases. Because the sponge loose structure favourable combustion, it release smoke in advance; in fibre fabrics, the descending order of smoke production ability is sweater>jeans>hemp>cotton.

(4) All in all, Fire risk order of five kinds of fabrics is: woollen fabrics> sponge fabrics> cotton fabrics> linen fabrics.

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