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Research on the Combustion Characteristics of Combustibles in Libraries

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Abstract

The library is a public place with a large number of combustibles, complex flow of people, and large fire risks and hidden dangers. Through a field survey of the library, this article selects representative paper, tables and chairs, bookcases, curtains, plastic polymer (PVC), foam (ESP) and other combustible materials, through smoke density, cal value , horizontal and vertical combustion rate and oxygen index determination experiments, the maximum smoke density, smoke density level, oxygen average, calorific value average, horizontal combustion rate, vertical total combustion time and other parameters of each combustible are obtained, and the reuse factor analysis method makes a comprehensive evaluation of the combustibility of combustibles. The research results show that there is a correlation between the factor analysis variables, which can well evaluate the combustibility of combustibles; the size of the combustion performance of combustibles is sorted as foam>paper>curtain>pine>fir>plastic. The better the combustion performance of combustibles, the greater the fire hazards, and the more unfavorable it is to rescue and evacuation. The above research results can provide a reference for the daily fire prevention and emergency management of the library.

Keywords

Smoke Density; Calorific Value; Horizontal and Vertical Combustion; Oxygen Index; Combustion Characteristics.

1. Introduction

Library fires will not only cause a large loss of valuable library resources, but also pose a huge hidden danger to the safety of people's lives and property. In order to reduce and prevent the fire hazards of libraries, it is necessary to pay attention to the study of the combustibility of combustibles in libraries. Combined with actual fire prevention work, we can provide data support and fire analysis for the prevention of fire accidents, and improve the specific measures of library fire management.

Extensive research on the combustion characteristics of combustibles has been carried out at home and abroad. Hongchao Sun et al. [1] studied the ignition and combustion characteristics of solvents involved in nuclear fuel recycling facilities and the fire behavior of solvent fires. Haidong Xu [2] designed a direct combustion experimental system and conducted experimental research on the combustion characteristics of low-concentration coal mine gas using metal fiber burners. Jiaqing Zhang [3] analyzes the ignition time, mass loss rate, heat release rate, total heat release and other relevant parameters to evaluate the combustion behavior under different external radiation levels and initial fuel thickness. Xu Diqi and others [4] oxidized the coal sample at different pre-oxidation temperatures and used a conical calorimeter to test the main combustion characteristic parameters such as ignition time, heat release rate and total heat release of the coal sample. Zhang Jiyuan [5] uses

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a combination of fire experiment and numerical simulation to reveal the mechanism and influence mechanism of fire combustion characteristics under the coupling of pressure and temperature factors. Yang Jiyuan [6-8] and others used the velocity curve of the mass change of combustibles in the thermo-weight test to calculate the relevant physical and chemical indicators to study the combustibility of combustibles. Li Yuyao [9] measured the combustion characteristics such as cable mass loss rate, flame morphology, flame forward position, and temperature and radiation heat between double cables. In order to explore the flammability of a variety of forest combustibles, Sun Weitao et al. [10-13] determined their ignition point, calorific value, ash content, crude fat content and water content, etc., and comprehensively evaluated their combustion through the main component analysis method.

In summary , he research on the combustion characteristics of combustibles at home and abroad mostly focuses on the in-depth analysis of a certain combustion experiment. There is no comprehensive analysis of multiple test results, and only a few articles apply mathematical analysis methods to make comprehensive judgments. However, it focuses on forest herb combustibles, and the research on the combustion properties of library combustibles is very lacking. Lack. Therefore, this article focuses on the comprehensive analysis of the combustion characteristics such as calorific value, smoke density, combustion rate and oxygen index of common combustible materials in libraries, in order to provide a reference basis for library fire prevention management..

2. Materials and Experimental Methods

2.1 Sample Collection

Most of the combustible materials in the library are book paper. Pine and fir are basically the raw materials for tables, chairs and other wooden utensils. Plastic polymers (PVC) and curtains are in smaller quantity and smaller in size than paper and wooden materials in the library, but they cannot be ignored in the process of fire and spread. Risk factors. Combustibles in libraries are generally relatively stable. Most of them are fixed combustibles, and a few are caused by human factors. They are temporary combustibles. According to the fixed combustibles in the library, this paper selects the main combustibles that meet the test in terms of flammability and operability, and finally selects pine, fir, plastic polymer (PVC), foam (ESP), paper and curtains for the experiment.

2.2 Experimental Method

(1) Smoke density experiment. Using a cutting instrument

to make a sample of (20mm)×(20mm)×(15mm), the JCY-2 smoke density tester was used to conduct three experiments on each combustible to determine the maximum smoke density (MSD) and smoke density level (SDR) of each combustible.

(2) Oxygen index experiment. The combustibles are made into samples in (120mm)×(6mm)×(3mm) format by cutting instruments. Using the HC-2 oxygen index meter, three experiments are carried out on each combustible, and the average oxygen index of each combustible is determined, and the combustion properties are obtained by reference to the indicators.

(3) Horizontal and vertical combustion experiment. Use cutting instruments to make combustibles into samples in (120mm) × (13mm) × (3mm) format, three groups each, and use the CFZ horizontal and vertical combustion tester to determine the average linear combustion speed and vertical combustion time of each combustible according to the following calculation, and divide the combustion grade. .

In the formula: V--linear combustion speed, mm/min

L---Burning length, mm

T—time, s

(4) The calorific value experiment. The sample format is divided into 1g using a grinding instrument, and the ZDHW-9000F high-precision calorific value detector is used to conduct three experiments

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on each combustible, determine the average calorific value of each sample, and calculate the average value.

3. Experimental Data Analysis

3.1 Experimental Data Analysis of Smoke Density

It can be seen from the comprehensive table of smoke density values (Table 1) that the maximum smoke density order of combustibles is ESP>paper>PVC>pine>curtain>fir; the smoke density grade is: ESP>paper>PVC >pine>curtain>fir. The higher the density of combustible smoke, the stronger the light-blocking, which is more detrimental to the safe evacuation of personnel after a fire, and it is easy to cause panic among the masses, causing poisoning, suffocation and other adverse consequences. At the same time, PVC and ESP will produce droplets during combustion, which can quickly spread fire and form a secondary fire. Especially in a high-temperature environment, their physical characteristics accelerate the combustion rate, and the amount of heat and smoke generated also increases significantly. This not only reduces the chances of escape for the people present, but also increases the difficulty of firefighters..

3.2 Oxygen Index Experimental Data Analysis

By testing the oxygen index data, the average oxygen index of the sample is calculated. The specific oxygen index average table (Table 2). It is generally believed that the oxygen index refers to the minimum oxygen content required for flame combustion of the substance under certain conditions in a certain oxygen and nitrogen mixed gas. An oxygen index of less than 22 is a flammable substance, an oxygen index between 22 and 27 is a flammable substance, and an oxygen index greater than 32 is a flammable substance. Paper has a low oxygen index and is a flammable material. When a fire occurs, it will quickly promote combustion, making the flames spread more quickly and widely. Especially in environments such as libraries, archives and offices, the storage capacity of paper documents and books is often large. Once a fire occurs, it will not only cause a large amount of property loss, but also may Endanger the safety of personnel. PVC has a high oxygen index and is a flammable substance, which means that it requires a higher oxygen concentration during combustion, which can slow down the spread of fire to a certain extent, thus gaining valuable time for fire extinguishing. In addition, high oxygen index PVC usually has good self-extinguishing, reducing the risk of continuous combustion after a fire. However, it should be noted that this does not mean that high-oxygen plastics are safe under any circumstances. If it is in a high temperature environment or in the presence of other flammable substances, it may still cause a fire. The order of oxygen index from large to small is: PVC>pine>curtain>cedar>ESP>paper.

3.3 Horizontal and Vertical Combustion Experimental Data Analysis

According to the horizontal combustion record data, the combustible combustion rate table is obtained (Table 3). From the above data, it can be seen that the combustion rate of combustibles is sorted from large to small as paper>ESP>pine>pine>curtain>PVC. The higher the linear combustion rate, the faster the horizontal propagation speed, among which the paper propagates the fastest, which also indicates that the library storing a large number of paper materials will spread very fast once it catches fire, which is not conducive to firefighting and personnel evacuation.According to the time of flame combustion of combustible materials, the vertical combustion schedule is derived (Table 4). From the table data, it can be seen that the burning time of combustible materials is sorted from large to small as follows: cedar> pine> PVC> paper> ESP> curtain. The longer the burning time of the flame, the better the combustion performance and the slower the vertical propagation. The longest burning time of pine wood means that it has the best combustion performance. This is because long-term combustion can not only release more heat, but also reduce fuel waste to a certain extent. Therefore, the vertical combustion and propagation speed of cedar is slower, so it can effectively slow down the spread of fire in the event of a fire. The flame burning time of curtains is the shortest, indicating that their combustion performance is the worst, which means that in the case of contact

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with the fire source, the curtain material is more likely to ignite and continue to burn, resulting in the spread of fire. In addition, the combustion of curtains in the vertical direction is relatively fast, which is particularly noteworthy, because the flames propagate along the vertical direction of the curtains and may quickly extend to the entire room, increasing the risk of fire.According to the determination of horizontal and vertical combustion experiments, there is a great risk of fire in which direction ESP and paper are burned. There are a large number of book combustibles in the library, which provides very convenient conditions for the vertical and horizontal spread and outbreak of fire. Therefore, it is necessary to strengthen the standardized management of book fire prevention, such as increasing separation measures to prevent books from being arranged horizontally and vertically.

Table 1. Comprehensive Table of Smoke Density Values

	Are there any drops	Is there any irritating smell	Maximum smoke density	Tobacco density level
Pinewood	Not have	Not have	16	10
Firwood	Not have	Not have	3	2
PVC	Have	Have	20	13
ESP	Have	Have	35	26
Curtain	Not have	Not have	10	9
Paper	Not have	Not have	27	21

Table 2. Oxygen Index Average Table

Combustible materials	Pinewood	Firwood	PVC	Curtain	Paper	ESP
Oxygen concentration value	28.5	25.25	40.95	27.75	14.25	15.25

Table 3. Combustion rate of combustible materials

Name	Burning time (t/s)	Burning length (L/mm)	Burning speed (v/mm/min)
Curtain	58.03	31	32.05
Paper	16.04	78.5	294.95
PVC	601.23	115.9	11.56
Pinewood	22.45	21	56.12
Firwood	23.15	25	63.49
ESP	38.46	118	187.08

Table 4. Vertical Combustion Schedule

Combustible materials	Combustible materials always have flame burning time (s)
Firwood	958.17
Pinewood	535.74
PVC	340.82
ESP	138.82
Curtain	64.68
Paper	257.21

ISSN: 2414-1895 DOI: 10.6919/ICJE.202504_11(4).0014

Table 5. Thermal Average Table

Combustible materials	Pinewood	Firwood	Paper	PVC	Curtain	ESP
Calorific value (J)	19802.7	21053.40	15295.25	25416.33	16431.33	46.87

Table 6. Data table related to combustion characteristics

Combustible materials	Maximum smoke density	Vertical total combustion time	Average oxyge nconcentration	Maximum horizontal combustion rate	Average heat
Pinewood	16	958.17	28.5	58.16	19802.7
Firwood	3	535.74	22.25	65.56	21053.4
PVC	20	340.82	40.95	11.56	15295.25
ESP	35	138.82	15.25	198.03	46.87
Paper	27	64.68	14.25	44.95	25416.33
Curtain	10	257.21	27.75	32.05	16431.33

Table 7. Bartlett Test Table

KMO test and Bartlett's test		
KMO value		0.419
Bartlett sphericality test	Approximate card square	26.047
	df	10.000
	p	0.007***

Table 8. Interpretation Table of variance

Explanation of total variance						
Component part	Characteristic root			Interpretation rate of variance after rotation		
	Characteristic root	variance percentage	accumulation	Characteristic root	variance percentage	accumulation
Maximum smoke density	3.332	66.631%	66.631%	2.573	51.466%	51.466%
Vertical total burning time	1.435	28.696%	95.327%	1.302	36.046%	77.512%
The average oxygen concentration	0.215	4.302%	99.629%	1.106	22.116%	99.629%
Maximum horizontal combustion rate	0.017	0.337%	99.966%			
Thermal average	0.002	0.034%	100.0%			

ISSN: 2414-1895 DOI: 10.6919/ICJE.202504_11(4).0014

Table 9. Factor load coefficient table after rotation

Factor load coefficient table after rotation				
Component part	Factor load coefficient after rotation			Commonality (common factor variance)
	Factor 1	Factor 2	Factor 3	
Maximum smoke density	0.961	0.072	0.261	0.997
Vertical total burning time	0.975	-0.002	0.222	0.999
The average oxygen concentration	0.103	0.984	-0.143	0.999
Maximum horizontal combustion rate	-0.741	0.082	-0.660	0.992
Thermal average	0.373	-0.568	0.730	0.994

Table 10. Factor Weighting Result Table

Name	Interpretation rate of variance after rotation	Cumulative variance interpretation rate after rotation	Weight
Factor 1	0.515	0.515	51.658%
Factor 2	0.26	0.775	26.143%
Factor 3	0.221	0.996	22.199%

Table 11. Comprehensive Score Table

Index	Comprehensive Score	MDS% MAX		IO X	QX(J/g)	V MAX(mm/min)	Rank
ESP	3.9118618	35	138.82	15.25	46.87	198.03	1
Paper	0.319050686	27	257.21	14.25	25416.33	44.95	2
Curtain	0.278333121	10	64.68	27.75	16431.33	32.05	3
Pinewood	-0.535139429	16	958.17	28.5	19802.7	58.16	4
Firwood	-1.343999992	3	535.74	22.25	21053.4	65.56	5
PVC	-1.992004814	20	340.82	40.95	15295.25	11.56	6

3.4 Analysis of Calorific Value Experimental Data

The combustion calorific value of combustibles is an important parameter that represents the potential fire hazard of combustibles. There are a large number of combustibles in the library, and there is a great risk of fire. According to the experimental data, the average value is calculated and the combustibility is evaluated. For details, see the thermal average table (Table 5). It can be seen that the order of the size of the calific value is: paper> cedar> pine> curtain> PVC> ESP. Among them, the combustion calorific value of paper is the highest, more than 25MJ/kg, which is a flammable substance with high heat output, accounting for the largest proportion in the library, and its distribution and control should be highly valued by managers; the calorific value of pine and fir wood products and plastic products is more than 10MJ/kg, which also has High fire hazard. There are a large number of tables, chairs, benches, bookcases and other wooden materials in the study room on each floor of the library. There are also wood products in offices and others, which are the most important flammable substances that cause fire and spread.

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4. Comprehensive Analysis

4.1 Factor Analysis

Using the factor analysis method, the correlation of the combustion characteristics of combustibles is explored by integrating the experimental data of the maximum smoke density, oxygen index average, vertical total combustion time, maximum combustion rate and heat average of six combustibles. Factor analysis is based on the idea of dimension reduction. Under the condition of losing as little or as little loss of original data information as possible, a large number of complex variables are gathered together to form some separate common factors that can reflect the basic information of the original variables. While reducing the number of variables, it can reflect the intrinsic connection between the variables. The data table related to combustion characteristics (Table 6) is as follows.

4.2 Test and Analysis

It can be seen from the Bartlett test table (Table 7) that $P<0.05$, that is, there is correlation between variables, factor analysis can be carried out, and the analysis results are valid. It can be seen from the variance interpretation table (Table 8) that the cumulative interpretation contribution rate of the first three factors is more than 99%, indicating that the combustion characteristics of combustibles can be well evaluated by using the first three factors.

It can be seen from the factor load coefficient table (Table 9) that the first factor is more related to the two variables of maximum smoke density and maximum smoke density level, the second factor is more related to the average oxygen index variable, and the third factor is more related to the two variables of combustion rate and maximum smoke density. It can be seen from the factor weight result table (Table 10) that the weight of factor 1 is 51.658%, the weight of factor 2 is 26.143%, and the weight of factor 3 is 22.199%, of which the maximum weight of the indicator is factor 1 (51.658%), and the minimum value is factor 3 (22.199%) . Factor 1 has a large correlation with the combustion characteristics of combustible materials, and vice versa, factor 2 is less. According to the comprehensive score table (Table 11), the correlation order of the six combustibles with their combustion characteristics is divided into: ESP> paper> curtain> pine> pine> PVC. It shows that in complex and real situations, the higher the correlation, the higher the danger of combustible materials, and the greater the fire safety hazards.

5. Conclusion and Discussion

This paper conducts a systematic study on the combustion characteristics of the main combustibles in the library. By investigating the layout, types, quantities and other physical properties of combustibles inside the library, the experimental combustibles are selected to conduct four experiments on smoke density, oxygen index, calorific value and combustion speed to evaluate the combustion characteristics of combustibles. The result is:

(1) MSD order: foam>paper>plastic>pine>curtain>cedar; SDR order: foam>paper>plastic>pine>curtain>pine

(2) The order of the average oxygen index is: plastic>pine wood>curtain>fir wood>foam>paper

(3) The order of the size of horizontal combustion rate: paper > foam > pine > pine > curtain > plastic

(4) The order of vertical flame burning time is: cedar> pine>plastic>paper>foam>curtain

(5) The order of the size of the calotic value is: paper > pine wood > pine wood > curtain > plastic > foam

(6) Size of combustion performance: foam>curtain>paper>pine wood>fir wood>plastic

In view of the characteristics of the fire in the library, the fire factors in the library are experimentally identified, and the specific combustion characteristics of combustibles in the library are further understood. It provides a basis for the analysis of fire hazards in the library in the future, and the fire hazards in the library are controlled within an acceptable range to effectively reduce the library. The rate of fire in the museum. Through factor analysis to evaluate the combustion characteristics of

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library combustibles, in order to provide objective and true feedback on the fire safety of libraries, describe the real combustion of combustibles more accurately and rigorously, and realize the standardization of fire prevention measures for library combustibles..

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