

Study on Flame Retardants and Flame Retardant Technology of Wood-Based Panels

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Abstract: At present, a large number of wood-based panels are used for flooring and building decoration. When a building fires, wood-based panels burn and emit a large amount of heat, making the flame spread rapidly, causing a large number of casualties and major economic losses. Therefore, a large number of combustible and flammable wood-based panels used in the interior decoration of buildings are potential fire hazards. China stipulates that the use of wood-based panels in high-rise buildings must undergo flame retardant treatment. Flame retardant board is a special kind of man-made board. At present, the mainstream flame retardant board products on the market include flame retardant density board and flame retardant plywood. Flame retardant board has stable chemical properties, high ignition point and corrosion resistance. In the production process of flame retardant board, some manufacturing processes can be used to integrate flame retardant into the board, so it has good flame retardancy. At present, flame-retardant panels are rarely used in ordinary household decoration, and most of them are used in public building projects. The flame retardant panel has a high ignition point, which can effectively control the fire process and reduce smoke and toxic gas in case of fire. With the continuous improvement of consumers' awareness of fire safety, the demand for flame retardant board market is increasing year by year, with broad market development prospects. As the main material of wood floor, furniture, and interior decoration in China, the output and demand of ordinary plywood are increasing rapidly. This paper introduces the classification and flame retardant principle of wood-based panels, analyzes the commonly used wood flame retardants and flame retardant treatment methods, and forecasts the future development trend of flame retardants and flame retardant technology, in order to better promote the rapid development of the domestic wood-based panel industry.

Keywords: Flame Retardant, Wood-Based Panels, Mechanism, Treatment, Wood Floor

1. Introduction

Generally, wood-based panels are combustible materials and have the characteristics of combustibility at a certain temperature. At present, a large number of plywood, particleboard and fiberboard are used in buildings. When a building fires, wood-based panels burn and emit a large amount of heat, making the flame spread rapidly, causing a large number of personal injuries and major economic losses

[1]. Therefore, a large number of combustible and flammable wood-based panels used in the interior decoration of buildings are potential fire hazards. In China, all kinds of wood-based panels are classified as Class B combustible materials. According to the provisions of the fire protection law, the use of wood-based panels in high-rise buildings must undergo flame retardant treatment [2-4].

Flame retardant board, also known as flame retardant board, including flame retardant density board and flame

retardant plywood, is a kind of wood-based panel made by adding flame retardant to the panel production line through a special process in the wood-based panel production process. Fire-retardant panels are produced with wood as the main raw material. Due to the rationality of its structure and the fine processing in the production process, the defects of wood can be largely overcome, and the physical and mechanical properties of wood can be improved [5-6]. At the same time, fire-retardant wood-based panels also overcome the shortcomings of common wood-based panels that are easy to burn, and effectively improve the fire-retardant properties of wood-based panels. The production of fire-retardant panels is an important method to fully and reasonably use wood and improve wood properties. With the continuous improvement of consumers' awareness of fire safety, the demand for flame retardant board market is increasing year by year, with broad market development prospects [7]. This paper introduces the classification and flame retardant principle of wood-based panels, analyzes the commonly used wood flame retardants and flame retardant treatment methods, and forecasts the future development trend of flame retardants and flame retardant technology.

2. Classification of Flame-Retardant Wood-Based Panels

Classification of flame-retardant board: the first class of flame-retardant board is weather-resistant, boiling water fire-resistant wood-based board, which has the advantages of durability, high temperature resistance and steam treatment. Class II flame retardant board is water resistant flame retardant board, which can be soaked in cold water and hot water for a short time. The third class of flame retardant board is moisture resistant flame retardant board, which can be soaked in cold water for a short time and is suitable for furniture and general building use at room temperature [8]. The fourth type of fire retardant board is non-moisture resistant fire retardant board, which is used under normal indoor conditions. The fire retardant board is commonly used in basswood, ash, birch, elm, poplar, etc. Decorative wood veneer fire retardant board is made of natural wood decorative wood veneer on fire retardant board. Decorative wood chips are thin wood chips made of high-quality wood by planing or rotary cutting. Decorative wood chip veneered flame retardant board is one of the most commonly used materials for interior decoration. Because the decorative wood chip on the surface of the product is made of high-quality wood by planing or rotary cutting, it has better decorative performance than flame retardant board [9]. According to the decorative surface, it can be divided into single-sided decorative wood veneer flame retardant board and double-sided decorative wood veneer flame retardant board; According to the water resistance, it can be divided into Class I decorative wood veneer flame retardant board, Class II decorative wood veneer flame retardant board and Class III decorative wood veneer flame retardant board;

According to the texture of decorative wood chips, it can be divided into radial decorative wood chip veneered flame retardant board and chord decorative wood chip veneered flame retardant board. The commonly used wood species for decorative wood chips include birch, ash, oak, Shuiqinggang, elm, maple, walnut, etc.

3. Flame Retardant Mechanism of Flame Retardant

The mechanism of flame retardant inhibiting and preventing combustion can be summarized as the following theories [10-12]:

According to the isolation theory, the flame retardant can form a physical barrier on the surface of the wooden board to prevent the escape of volatile gases; At the same time, it prevents oxygen from contacting with wood and isolates combustible wood from high temperature.

According to the heat conduction theory, the flame retardant can increase the heat conductivity of wood and make the heat emitted from the surface greater than the heat absorbed from the fire source, thus reducing the wood surface temperature and preventing the wood surface from catching fire.

According to the gas dilution theory, the flame retardant will produce chemical decomposition at high temperature, release non-combustible gas, dilute the combustible gas formed by wood pyrolysis, and produce an environment with non-combustible mixed gas.

According to the carbonization theory, the flame retardant reduces the initial temperature of pyrolysis, making the degradation develop in the direction of increasing carbon production and reducing volatile substances. Because flame retardants can rapidly dehydrate and carbonize wood at high temperatures, the thermal conductivity of the carbon produced is much lower than that of wood, thus inhibiting heat transfer and flame propagation.

For flame retardancy, the above flame retardancy mechanisms complement each other. One flame retardant often has more than one flame retardant effect, and several flame retardants can work at the same time. Therefore, more than two composite components can be selected in the formula of flame retardant to achieve better flame retardant effect.

4. Common Flame Retardants for Wood-Based Panels

4.1. Inorganic Flame Retardant

Inorganic wood flame retardants are a kind of traditional flame retardants, mainly including phosphorus, halogen, boron and nitrogen flame retardants. There are many kinds of inorganic halogenated flame retardants. Because of the high price of bromine and the high toxicity of bromine, chlorine is used more than bromine in flame retardants. Commonly used phosphorus-nitrogen flame retardants include diammonium

hydrogen phosphate, ammonium polyphosphate, ammonium sulfate, ammonium sulfite, etc. Phosphorus-nitrogen series is considered to be the most suitable wood flame retardant because of the synergistic effect of phosphorus and nitrogen in wood flame retardants to improve the flame retarding effect, among which diammonium hydrogen phosphate is the best. In addition to the fact that halogen flame retardants are prone to produce strong corrosive and toxic hydrogen halide gas during combustion, and the smoke density is relatively high, which has gradually decreased in recent years, flame retardants containing nitrogen, phosphorus and boron elements have become the main body of wood flame retardants. Inorganic flame retardants have a wide range of sources, low prices, good flame retardancy, and less smoke and toxic gases released during combustion. They are widely used in the flame retardant treatment of wood materials, accounting for more than half of the total demand for flame retardants. However, due to its strong hygroscopicity and poor water loss resistance, it cannot be used in the environment with high humidity or water contact. The surface of the product is prone to frost and discoloration, and it is difficult to paint; It is corrosive to metal and has adverse effects on wood material and strength [11-13].

Aluminum oxide, magnesium oxide, antimony oxide and other metal oxides are mainly used in fireproof coatings, and can also be directly mixed with fiber and particle to produce flame-retardant wood-based panels. Alumina is a widely used inorganic flame retardant, which can slow down the burning speed of polymers, reduce the amount of smoke generated by combustion, and also capture harmful gases. Aluminum oxide will not produce corrosive combustion products, nor will it evaporate and seep from the polymer, and will not be affected by water and some aqueous solutions. Moreover, it has good coloration, non-toxic, pollution-free and low price, and currently ranks first in the amount of flame retardant. Magnesium oxide is also an important flame retardant, and its flame retardant mechanism is based on decomposition and heat absorption, as is aluminum oxide. It has good flame retardancy and smoke suppression effect, and the gas released from decomposition does not have environmental problems.

4.2. Organic Flame Retardant

Organic flame retardants have developed rapidly in recent years, mainly using composite systems containing phosphorus, nitrogen and boron. For example, boric acid, borax and zinc borate can be used, which not only has good flame retardance, but also will not significantly reduce the strength of the plate when the amount is large, and will reduce the moisture absorption of the plate. Borax has a good effect, but its solubility is low. Although it can inhibit the spread of surface flame, it also promotes smoke combustion and white heat combustion, so it is generally only used as an additive of flame retardant. Although boric acid slows down smoking and white-hot combustion, it is beneficial to flame propagation. Therefore, it can be considered to use these chemicals in combination to obtain better comprehensive performance.

At present, the organic flame retardant with anti-loss is an important research direction of flame retardant. Its mechanism is that phosphorus or halogen participates in polymerization or polycondensation reaction, and combines into the main chain or side chain of the polymer, so that the flame retardant components are fixed in the wood, and are not easy to lose in the environment with high humidity or outdoor application, thus improving the durability of the wood flame retardant effect. Its disadvantages are unstable flame retardance, high cost, and a large amount of smoke and toxic gas generated during combustion. The antiloss organic flame retardants can be prepared in the following ways: select appropriate cosolvent and emulsifier to mix insoluble flame retardants with saline water solution or lotion to treat wood. For example, zinc borate has a good flame retardant effect and can be prepared into an aqueous solution in the presence of ammonia. After treatment of wood, ammonia volatilizes during the drying process, and zinc borate will deposit in the wood; Select appropriate emulsifier to prepare flame retardant such as ammonium polyphosphate into emulsion to treat wood. The method of secondary treatment is adopted, such as treating the wood with borax aqueous solution first and then with zinc chloride solution for secondary treatment. The chemical reaction takes place in the wood to generate insoluble zinc borate and deposit it in the wood. The reaction of soluble salt and metal salt can form insoluble metal salt complex, thus obtaining anti-loss flame retardant.

4.3. Resin Flame Retardant

Resin flame retardant is a new flame retardant developed in recent years. Adopt resin wood fire retardant. Amino resin is the most widely studied anti-loss system. Amino resin can be obtained by reacting nitrogen source with formaldehyde. Amino resin-type wood flame retardant can be prepared by using urea, melamine and formaldehyde. Its principle is to add phosphoric acid or phosphorus-nitrogen compounds in the manufacturing process of formaldehyde, urea, dicyandiamide and melamine resin, and form anti-loss flame retardant through resin curing. Phosphide makes nitrogen-phosphorus play a synergistic role, and reducing the amount of use can achieve the flame-retardant effect of each compound used alone. The resin-based flame retardant has good anti-loss, anti-migration and anti-moisture properties, and its cost is between inorganic flame retardant and organic flame retardant. It has little impact on wood strength and is corrosion resistant, but its flame retardant effect is not as good as common inorganic flame retardant.

4.4. Reactive Flame Retardant

Reactive wood flame retardant uses chemical reaction to load flame retardant elements or groups containing flame retardant elements onto wood molecules by forming stable chemical bonds. The obtained flame retardant wood not only has the advantages of anti-loss and durability, but also has high flame retardant efficiency per unit mass of flame

retardant because the flame retardant elements are distributed on the wood in monomolecular state. Hydroxyl and benzene rings on wood macromolecules are common functional groups suitable for flame retardant treatment. They can react with flame retardant through esterification, transesterification, etherification, acylation and halogenation [8-9].

Elements or compounds containing flame retardant elements and reactive groups react to achieve flame retardancy. It can be seen that wood treated with reactive flame retardants can achieve durable flame retardancy.

4.5. Other New Flame Retardant

In recent years, high and new technologies in materials, chemical industry and other fields have also been applied in wood flame retardant technology. Traditional flame retardants have high moisture absorption and poor weather resistance, and are easy to lose when exposed to water or high environmental humidity. The period of validity after wood treatment is short. In the past ten years, the formulation of new flame retardant with anti-loss, strong weather resistance and lasting effect has been widely valued and has made great progress; However, due to its high price, complex treatment process or toxicity, the application of this formula is limited to some extent, and it cannot completely replace the traditional flame retardant at present [14].

5. Flame-Retardant Treatment Method of Wood-Based Panel

The flame retardancy of wood depends not only on the performance and dosage of flame retardant, but also on the processing technology of flame retardant. The effect of flame retardant treatment on wood strength, moisture absorption and other properties depends on the type of flame retardant used, acid-base property and processing conditions. Therefore, it is one of the keys of wood flame retardant technology to select appropriate flame retardant treatment process, which can improve the flame retardant performance without significantly affecting the physical and mechanical properties of wood. Only if the flame retardant formula is suitable and the process is reasonable, can better flame retardant effect be achieved [8-12].

5.1. Immersion Method

The impregnation treatment can be divided into atmospheric pressure and pressurized pressure. Normal pressure treatment includes normal temperature soaking and hot and cold lees soaking. There is another difference between one soaking and two soaking in the normal pressure soaking: the two soaking is to soak the wood in two kinds of flame retardants in turn. The two chemicals can react with each other and generate a third component insoluble in water in the wood and deposit it in the wood cell wall or cell cavity. Pressure impregnation is to put wood materials and flame retardants into closed high-pressure containers, and inject flame retardants into wood cell walls and cell cavities under certain pressure.

5.2. Finishing Method

Surface finishing is to paint the adhesive containing flame retardant or the incombustible materials such as gypsum board, calcium silicate board, iron sheet and metal foil on the surface of wood or wooden materials to form a layer of flame retardant protective layer for flame retardance. The process is simple, does not change the wood production process, and is also convenient for on-site construction application. However, this method is only limited to surface treatment, and it covers the original texture of the wood, and loses the wood texture. In addition, due to the limitation of the thickness and type of wood, attention must also be paid to the selection and proportion of flame retardant, otherwise it will affect the bonding strength.

5.3. Wood-Based Panel Method

It is suitable for wood-based panel production and has little impact on the physical and mechanical properties of the panel. The methods are as follows: First, spread the powder flame retardant evenly on the board surface and melt it into the board under the condition of hot pressing, which avoids the expansion of the board surface during pressure impregnation and the drying after treatment. The disadvantage is that it is difficult to apply sufficient dose, and it is also difficult to keep the flame retardant on the board surface during hot pressing; The second is to brush or spray liquid flame retardant on the board surface, which can penetrate into the board during hot pressing, but is easy to cause bubbles on the board surface.

In the production of wood-based panels such as wood shavings and fibers, flame retardants are mixed in adhesives or wood shavings and wood fibers. The addition of flame retardant may affect the curing of adhesive, so it is necessary to adjust the formula or curing agent dosage. The main ways to add flame retardant are: impregnation treatment (particle, fiber, etc.): this method has good flame retardant effect, but it needs to add impregnation equipment. The flame retardant is limited to solution type and requires secondary drying. The waste liquid after impregnation will cause environmental pollution. The flame retardant is added to the adhesive to make a flame retardant adhesive. The flame retardant used shall be compatible with the resin adhesive and shall not affect the curing conditions and bonding strength of the adhesive. After the shavings or fibers enter the mixing barrel, add a proper amount of flame retardant while stirring. This method is simple in process, has unlimited flame retardant forms, and can be controlled in both chemicals and aqueous solutions, which will not cause waste, and does not need to increase the drying capacity of the shavings or fibers. The flame retardant can be sprayed at the same time with or after the glue spraying [15].

6. Conclusion

To sum up, although a lot of research has been done on wood flame retardants, there are still many aspects to be

improved and deepened. First of all, further research must be carried out on the basic mechanism of various flame retardants. The research results will help us better understand the mechanism of flame retardants, and will provide an effective theoretical basis for the development of new flame retardant systems. Secondly, we should further research and develop efficient multicomponent composite flame retardant system to further improve the anti-loss, migration resistance and reduce costs, and realize industrial production. Chemical modification methods can be considered, especially reactive flame retardants, which react with hydroxyl groups after entering the wood. Esterification of wood is one of the effective ways to solve the problem of moisture absorption. In addition, the formula of wood material flame retardant studied should not only have flame retardant function, but also have many functions such as corrosion prevention, insect prevention, dimensional stability, etc. At the same time, the cost should be reduced to make the price reasonable. Finally, the impact of flame retardants and flame retardant wood-based panels on the environment is also an important aspect. The research on new flame retardant systems, smoke suppression properties and the impact of flame retardant wood on human health and the environment in the production and use process will be important topics in the future research of wood flame retardant.

Author Contributions

The Manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

Conflicts of Interest

The authors declare that they have no competing interests.

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