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Study on the Application of New Mold Inhibitor in Wood Composite Panel

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Abstract: Medium density fiberboard is a kind of man-made board made of wood fiber or other plant fiber, which is crushed, separated and dried, then applied with urea formaldehyde resin or other applicable adhesives, and then hot pressed. As MDF is a kind of composite material made of natural biomass materials, its internal nutrients are rich, and it is vulnerable to microbial erosion and mildew. The strains causing MDF mildew mainly include Aspergillus niger, Trichoderma viride, Penicillium tangerine, etc. The surface of MDF shows black or dark green mildew spots after mildew, which reduces its decorative performance and use performance, pollutes the living environment, and causes serious economic losses and waste of resources. Studies have shown that when the fungal spores in the air reach a certain concentration, indoor residents or workers will have allergies, asthma and other respiratory diseases. Therefore, the research and development of wood-based composites with antimildew function is of great value to improve the quality of living environment, prolong the service life of wood products and improve the comprehensive utilization rate of wood. In this study, a new mold inhibitor was added to the glue solution to prepare fiberboard. The effects of the addition of mold inhibitor on the physical and mechanical properties and mold resistance of fiberboard were investigated. The results showed that the viscosity of the resin system decreased with the increase of the amount of the two mold inhibitors. With the increase of the amount of mold inhibitor, the internal bonding strength, elastic modulus and static bending strength of the plate decreased in varying degrees. However, the addition of mold inhibitor significantly improves the mold resistance of the plate. The addition of mold inhibitor A is more conducive to the control of Trichoderma viride, while the addition of mold inhibitor B is more conducive to the control of Aspergillus niger. The amount of mold inhibitor B is appropriate at about 2%-3%. This study provides a new possible way for the application of new mold inhibitor in MDF, and has good practical significance.

Keywords: Fungicide, Mold, Medium Density Fiberboard, Urea Formaldehyde Resin, Sterilization

1. Introduction

Medium density fiberboard (MDF) is a kind of man-made board made of wood fiber or other plant fiber, which is crushed, separated and dried, then applied with urea formaldehyde resin or other applicable adhesives, and then hot pressed. Its density is generally in the range of 500-880 kg/m^3, and its thickness is generally 5-30 mm. MDF is widely used in furniture manufacturing and interior decoration because of its good secondary processing performance. It is one of the wood-based panels in great demand in China. However, as MDF is a kind of composite material made of natural biomass materials, its internal nutrients are rich, and it is vulnerable to microbial erosion and mildew [1-3]. The strains causing MDF mildew mainly include Aspergillus niger, Trichoderma viride, Penicillium tangerine, etc. The surface of MDF shows black or dark green mildew spots after mildew, which reduces its decorative performance and use performance, pollutes the living environment, and causes serious economic losses and waste of resources. Studies have shown that when the fungal spores in the air reach a certain concentration, indoor residents or workers will have allergies, asthma and other respiratory diseases. Therefore, the research and development of wood-based composites with antimildew function is of great value to improve the quality of living environment, prolong the service life of wood products and improve the comprehensive utilization rate of wood [4].

With the expansion of the application range of MDF, higher requirements are put forward for its mildew resistance and combustion performance. The mildewability of ordinary medium density fiberboard not only affects the appearance quality of products, reduces the physical and mechanical properties of the board, but also pollutes the living environment and affects human health. Therefore, the antimildew performance of MDF has become the focus of the industry. With the continuous improvement of the world economic level and people's quality of life, the requirements for the flame retardant performance of indoor materials are higher. Medium density fiberboard (MDF) used for interior decoration and furniture manufacturing is a combustible material, so the flame retardant treatment of MDF has attracted increasing attention. At present, the medium density fiberboard is treated with conventional fungicides in China. The organic-inorganic flame retardants such as phosphorus, nitrogen and boron are mainly used for flame retardant treatment. However, there are few reports on MDF treated with antimildew and flame retardant at the same time [5].

At present, there are three main methods for antimildew treatment of MDF: pretreatment of raw materials with antimildew agents, application of antimildew agents in the production process or post-treatment of finished products with antimildew agents. The results show that the antimildew MDF prepared by adding the antimildew agent to the adhesive and mixing it evenly, and then preparing the antimildew MDF by spraying glue, pre pressing, hot pressing and other processes, or soaking the wood fiber with the bamboo vinegar compound, and then drying, mixing glue, pressing plate and other processes has good antimildew effect [6-8]. The application of borate, zinc oxide, etc. in the process of plate preparation can endow the plate with mold proof function [9-11]. By using several water-soluble fungicides to impregnate, brush and spray MDF products, the antimildew effect of MDF is significantly improved, but the physical and mechanical properties are greatly reduced. Based on previous studies, it is known that post-treatment reduces the physical and mechanical properties of the plate, and the operation is relatively troublesome in the actual production; Pretreatment increases the process steps of plate preparation, prolongs the preparation time and increases the cost; Compared with pretreatment and post-treatment, mold proof treatment in MDF production stage is simple, low cost, and has little impact on the physical and mechanical properties of the plate [12-13]. In this study, a new mold inhibitor was added to the glue solution to prepare fiberboard. The effects of the addition of mold inhibitor on the physical and mechanical properties and mold resistance of fiberboard were investigated, which provided a theoretical basis for the development of a new mold resistant MDF.

2. Materials and Methods

2.1. Materials

Two new fungicides (A and b) are self-made in the laboratory. The main raw materials of fungicide a are phenols, and the main raw materials of fungicide B are amines; Urea formaldehyde resin adhesive, solid content 51%, self-made in the laboratory; Poplar fiber, moisture content 5%; Paraffin lotion, solid content 50%.

2.2. Instrument

Digital display rotary viscometer, bolefield company, USA; Hot press, Suzhou XinXieLi company; Universal mechanical testing machine, Instron, USA; Constant temperature and humidity box, Tianjin taist company; Constant temperature magnetic stirrer, German IKA company.

2.3. Preparation of Medium Density Fiberboard

Preparation of ordinary medium density fiberboard: weigh dry poplar fiber and urea formaldehyde resin adhesive respectively, mix and apply glue in the mixing and sizing machine, connect the blast dryer with the mixing and sizing machine, dry the wet fiber after sizing for 10 min, and then evenly pave it in the forming frame. After pre pressing, put the slab into the universal test press to press the ordinary MDF. MDF hot pressing process parameters: pressure 2.6 MPa, temperature 180°C, time 280s, pressing density 750 kg/m^3, specification 400 mm × 400 mm × 10 mm ordinary medium density fiberboard.

Preparation of mold proof medium density fiberboard: mix urea formaldehyde resin adhesive and mold proof agent, and stir with constant temperature magnetic stirrer at room temperature for 15 min to make the mold proof agent and adhesive mix evenly. Weigh the dry poplar fiber and urea formaldehyde resin adhesive respectively, mix and apply the glue in the mixing and sizing machine, connect the blast dryer with the mixing and sizing machine, dry the wet fiber after sizing for 10 min, and then evenly pave it in the forming frame. After pre pressing, put the slab into the universal test press to press the mold proof MDF. MDF hot pressing process parameters: pressure 2.6 MPa, temperature 180°C, time 280s, pressing density 750 kg/m^3, specification 400 mm × 400 mm × 10 mm moldproof medium density fiberboard.

2.4. Performance Test and Characterization

The resin viscosity shall be determined according to GB/T 14076-2004. After the hot pressed medium density fiberboard is aged for 24 hours, the test specimen is prepared according to the standard, and the internal bonding strength, static bending strength and elastic modulus are measured according to the requirements of GB/T 17957-2013 standard. In the above tests, each group presses four medium density fiberboards, and 8 test pieces are taken from each board, and the results are taken as the average value.

The antimildew performance of MDF was tested according to GB/T 18261-2000 test method for Fungicides against wood mold and cyanobacteria, and the size of the test piece was 50 mm × 20 mm. Eight samples were prepared with two kinds of fungicides in different proportions, and the common MDF sample was used as the blank control. Aspergillus niger var. Niger tiegh and Trichoderma viride pers. After the test piece is inoculated, put the Petri dish into the biochemical incubator immediately (temperature 25°C, relative humidity 90%) and culture for one month. Observe regularly every seven days, measure the moldy area of the sample, and record the classification. Calculate the effectiveness of each fungicide against mold, and take the average value of 8 samples.

3. Results and Discussion

3.1. Effect of the Amount of Mold Inhibitor on the Viscosity of Urea Formaldehyde Resin

After adding mold inhibitor into adhesive system, the viscosity of the system will change due to the characteristics of some aqueous solutions. In general, the viscosity of the system decreased with the increase of the amount of the two fungicides. At the same dosage, the viscosity of the system formed by fungicide B was higher than that of the system formed by fungicide a. The main reason is that the solid content of mold inhibitor B is higher than that of mold inhibitor A. after mold inhibitor A is added to the urea formaldehyde resin system, more water is brought in, which leads to the increase of resin viscosity.

When the amount of mold inhibitor is increased, the viscosity of the system decreases rapidly, which makes it easier to atomize the adhesive, improves the sizing uniformity of the adhesive to a certain extent, and facilitates the sizing operation. If the addition amount is too large, it is easy to bring in too much moisture, which dilutes the concentration of adhesive, and may affect the bonding strength. At the same time, the moisture brought in may cause the moisture content of slab to be too high, and it is easy to produce too much water vapor during hot pressing. If it cannot be discharged in time during hot pressing, it will cause bubbling, delamination and other defects, resulting in defects of slab. Therefore, the amount of mold inhibitor should be controlled in an appropriate range, and the amount should not be too high.

Table 1. *Effect of addition amount of mold inhibitor on viscosity of resin system.*

Type	Addition ratio		Viscosity
	UF resin	Mold inhibitor	(mPa·s)
A	100	0	2857
	99	1	2649
	98	2	2454
	97	3	2279
B	100	0	2857
	99	1	2741
	98	2	2654
	97	3	2351

3.2. Effect of Addition Amount of Mold Inhibitor on Internal Bonding Strength

The reaction between urea formaldehyde resin and wood is very complex. It is generally believed that the hydroxymethyl urea in urea formaldehyde resin reacts with the hydroxyl group in wood to form ether bond in the process of bonding wood; meanwhile, the resin can also partially penetrate into the gap structure of the wood, and form adhesive nails after curing, providing mechanical adhesive relay. The resin is self crosslinked and cured to form a stable network crosslinking structure, providing its own cohesion.

Through the determination of the internal bonding strength of fiberboard, it can be seen from table 2 that the internal bonding strength decreases with the increase of the amount of mold inhibitor A, reaching the minimum value of 0.57MPa when the amount ratio is 97:3. The internal bonding strength of the fiber board bonded with urea formaldehyde resin is 0.68MPa, so the addition of mold inhibitor affects the bonding performance to a certain extent, thus affecting the internal bonding strength.

Table 2. *Effect of mold inhibitor addition on internal bonding strength.*

Type	Addition ratio		Internal
	UF resin	Mold inhibitor	bond (MPa)
A	100	0	0.68
	99	1	0.67
	98	2	0.65
	97	3	0.57
B	100	0	0.68
	99	1	0.64
	98	2	0.61
	97	3	0.55

It can also be seen from table 2 that with the increase of the addition amount of mold inhibitor B, the internal bonding strength of the plate also decreases, and the decrease range is greater than that of the addition of mold inhibitor A, reaching the minimum value of 0.55MPa when the addition amount ratio is 97:3. It can be seen from this that the addition of the two kinds of antimold agents has affected the bonding performance to a certain extent, which may be due to the excessive moisture brought in by the addition of antimold agents, thus affecting the bonding performance.

3.3. Effect of the Amount of Mold Inhibitor on Elastic Modulus and Static Bending Strength

It can be seen from table 3 that with the addition of mold inhibitor A and B, the elastic modulus and static bending strength of the board decrease, and the elastic modulus and static bending strength of ordinary fiberboard reach 3110MPa and 35.1MPa respectively. When the addition ratio of mold inhibitor A is 97:3, the elastic modulus and static bending strength of mold proof fiberboard decrease to 3000MPa and 29.5MPa respectively, and when the addition ratio of mold inhibitor B is 97:3, The elastic modulus and static bending strength of mold proof fiberboard decreased to 2980MPa and 28.4MPa respectively. It can be seen that the addition of the two kinds of antimold agents affects the elastic modulus and static bending strength to a certain extent, and the effect of antimold agent B on the elastic modulus and static bending strength is greater than that of antimold agent A. Therefore, in order to ensure certain physical and mechanical properties of fiberboard, the addition amount of the two antimildew agents should not be too high and should be controlled in the range of 1%-2%.

Table 3. *Effect of the amount of mold inhibitor on elastic modulus and static bending strength.*

Type	Addition ratio		MOE (MPa)	MOR (MPa)
	UF resin	Mold inhibitor		
A	100	0	3110	35.1
	99	1	3100	34.1
	98	2	3050	31.2
	97	3	3000	29.5
B	100	0	3110	35.1
	99	1	3080	30.8
	98	2	3010	30.1
	97	3	2980	28.4

3.4. Effect of the Amount of Mold Inhibitor on the Performance of Fiber Board Against Aspergillus Niger

It can be seen from table 4 that the anti Aspergillus niger performance of the plate can be significantly improved after adding preservatives. With the increase of the proportion of fungicide, the control efficacy of fiberboard added with fungicide A increased to 98.9%, and that of fiberboard added with fungicide B increased to 100%. Therefore, the addition of mold inhibitor can effectively prepare medium density fiberboard with good resistance to Aspergillus niger. When the proportion of fungicide A is 97:3, the control effect can reach 98.9%, and when the proportion of fungicide B is 97:3, the control effect can reach 100%. The effect of fungicide B against Aspergillus niger was better than that of fungicide A.

Table 4. *Effect of the amount of mold inhibitor added on the performance of sheet against Aspergillus niger.*

Type	Addition ratio		Value	Control effectiveness (%)
	UF resin	Mold inhibitor		
A	100	0	5	—
	99	1	2.54	44.8
	98	2	1.11	68.9
	97	3	0.02	98.9
B	100	0	5	—
	99	1	2.41	46.3
	98	2	1.01	70.9
	97	3	0	100

Table 5. *Effect of the amount of mold inhibitor added on the green Trichoderma resistance of sheet metal.*

Type	Addition ratio		Value	Control effectiveness (%)
	UF resin	Mold inhibitor		
A	100	0	5	—
	99	1	2.41	45.7
	98	2	1.01	70.2
	97	3	0	100
B	100	0	5	—
	99	1	2.76	43.3
	98	2	1.51	67.4
	97	3	0.03	97.5

It can be seen from table 5 that the anti Trichoderma viride performance of the plate can be significantly improved after adding preservatives. With the increase of the proportion of fungicide, the control efficacy of fiberboard added with fungicide a increased to 100%, and that of fiberboard added with fungicide B increased to 97.5%. Therefore, the addition of mold inhibitor can effectively prepare MDF with good resistance to Trichoderma viride. When the proportion of fungicide A is 97:3, the control effect can reach 100%, and when the proportion of fungicide B is 97:3, the control effect can reach 97.5%. The effect of fungicide A on controlling Trichoderma viride was better than that of fungicide B.

4. Conclusions

The viscosity of the resin system decreased with the increase of the amount of the two fungicides. When the addition ratio is 97:3, the resin viscosity is the lowest, and the lower viscosity is more suitable for spraying and increasing the uniformity of sizing, but it has a negative impact on the internal bonding strength, elastic modulus and static bending strength of the plate. From the test results, it can be seen that the internal bonding strength, elastic modulus and static bending strength of the plate decrease to varying degrees with the increase of the amount of mold inhibitor. However, the addition of mold inhibitor significantly improves the mold resistance of the plate. The addition of mold inhibitor A is more conducive to the control of Trichoderma viride, while the addition of mold inhibitor B is more conducive to the control of Aspergillus niger. The amount of mold inhibitor B is appropriate at about 2%-3%. To sum up, when the addition amount of antimildew agent is about 2%, the prepared MDF can give consideration to better antimildew effect and physical and mechanical properties. This study provides a new possible way for the application of new mold inhibitor in MDF, and provides a certain practical basis for the development of technology and application technology of mold proof wood composite board.

Author Contributions

The Manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. Zhiyong Zheng and Ruiqi Li contributed equally and should be considered as co-first authors.

Conflicts of Interest

The authors declare that they have no competing interests.

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