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Fabrication of Laminated Flooring Decorated by Resin Impregnated Paper with Improved Flame Retardant, High Wear-Resistant, Low Formaldehyde Emission

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Abstract: A new type of laminated flooring decorated by resin impregnated paper was designed, with the advantages of high stability, low deformation, natural and beautiful surface texture, comfortable foot feeling, low formaldehyde emission, improved flame retardant, high surface hardness and high wear resistance. The structure of this engineered wood flooring is based on the ordinary laminated flooring, followed by a decorative layer of thin wood pieces, and then the transparent improved flame retardant, wear-resistant paper is added to the top. After main influencing factors analysis, the surface unevenness was seriously affect the flame-retardant performance. The wear-resistant paper pressing technology commonly affects the decorative effect of laminated flooring. The hot-pressing temperature is the most important factor affecting the adhesion of resin impregnated. The optimal hot-pressing parameters are selected as the hot-pressing pressure of 3.5 MPa, hot-pressing temperature of 180 °C, and hot-pressing time of 40 s. The new laminated flooring was improved with high flame retardant, high wear-resistant, combined with the conventional advantages of both solid wood composite flooring and reinforced wood flooring. The new laminated flooring decorated by resin impregnated paper has broad application prospects.

Keywords: wood; laminated flooring; structural design; hot-pressing technology; wear-resistant layer

1. Introduction

According to the wood laminated flooring whether or not coated with resin impregnated paper, laminated wood flooring are currently divided into two main types of laminate flooring. Both of the two flooring have the advantages of little deformation and high dimensional stability. However, the wood laminated flooring has poorer wear resistance than the latter. The latter has excellent wear resistance due to the surface being covered with a wear-resistant layer, but its foot comfort is poor. The decorative paper texture on the surface is artificially printed, lacking the naturalness of natural wood. The fiberboard in the core layer requires a large amount of adhesive in the production process, which can easily cause excessive formaldehyde release and harm to the human body[1–3]. At present, the main method for flame retardant flooring is to add flame retardants into the base material of the floor by impregnation. However, this method increases the production cycle and costs a lot. In addition, it can also negatively affect the physical and mechanical properties of the floor after introducing large amounts of flame retardants.

The laminated flooring coated with improved flame retardant and wear-resistant paper developed in this study aims to provide a floorboard product with good stability, small deformation, natural and beautiful surface texture, comfortable foot feel, high surface hardness, improved flame retardant and wear resistance[4,5]. The use of coloring paint or fireproof paint on the veneer decorative layer of the floorboard can make the natural veneer color on the whole floorboard more

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uniform, and the fireproof paint enables the floorboard to be fireproof. As this wear-resistant laminate floorboard has various advantages such as wear resistance, flame resistance, no fading, elimination of coating process and affordable price while inheriting the beautiful natural texture of precious tree species, it meets the market demand and is suitable for office and civil use, construction, shipbuilding, interior decoration and other fields.

2. Materials and Methods

2.1. Materials and Instruments

The substrate of the solid wood laminate floorboard was from Zhejiang Yuhua Wood Industry Co., Ltd.The intrinsic quality, symmetrical structure, uniform thickness, and moisture content of the substrate directly affect the effect of hot pressed veneers and the physical and mechanical properties of the product. The wear-resistant and flame-retardant resin was made with flame retardant ingredients including ammonium polyphosphate $(NH_4PO_3)_n$ (n>1500) (APP) and Pentaerythritol($C_5H_{12}O_4$) (PER), mixed into urea methylene formaldehyde resin (MUF). APP and PER was purchased from Shanghai McLean Biochemical Technology Co., Ltd. Urea-melamine formaldehyde resin (MUF) was purchased from Zhejiang Yuhua Wood Industry Co., Ltd. Veneer decorative layer was a 0.2 mm maple birch veneer, with no cracks, holes and other defects on the surface. Impregnated base paper was from Zhejiang Dilong New Materials Co., Ltd. (80 g/m^2). The main experiment equipment included a universal mechanical testing machine (Jinan Xinguang), a hot-pressing laminator (Qingdao Guosen), a rotational viscometer (Brookfield Corp), etc.

2.2 Laminating of Decorative Veneer and Balance Layer on the Substrate

The moisture content of the decorative layer and balance layer veneers should be uniform, and the moisture content of the surface layer should be lower than that of the substrate. The structure of the slab without resin impregnated paper is shown in Figure 1.

Figure 1. Slab structure.

The pre-laminating pressure was about 0.5-1 MPa, and the time was 30-60 min (or aging for 3 min).During hot-pressing, attention should be paid to inspecting and cleaning the steel plate of the hot press to ensure that there are no garbage or foreign objects on the surface of the steel plate. Then, the hot press should be heated and preheated to ensure that the hot-pressing temperature meets the process requirements. It also can make the veneer fully contact with the substrate. However, a too high pressure will affect the thickness and precision of the board and eventually the thickness tolerance of the flooring product. If a high pressure is maintained for a long time, the substrate will be compressed and even the adhesive layer is damaged, while a too low pressure will cause poor contact between the veneer material and the substrate, and even difficulties in gluing, and it is also not conducive to the flow of the adhesive.Referring to the lamination process of the ordinary solid wood composite flooring combined with multiple experimental analyses, when the lamination temperature is set at 110 °C, the hot-pressing pressure is set at 0.7 Mpa, and the hot-pressing time is set at 90 s, the lamination quality and efficiency can be guaranteed.

2.3. Preparation of Improved Flame Retardant and Wear-Resistant Paper

Prepare flame retardant resin, weigh an appropriate amount of MUF, APP and PER , stir with a blender for 5 minutes to mix evenly, and set aside for later use. Measure resin viscosity and curing

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time according to the method specified in GB/T 14732-2017. Prepare flame-retardant wear resistant paper by immersing the impregnated base paper in the prepared flame-retardant resin for 3 minutes. Use a dry spray machine to evenly spray Al_2O_3 (Shanghai McLean Biochemical Technology Co., Ltd.) on the surface of the impregnated paper at a rate of 38 g/m2 to increase surface wear resistance. Place it in a 103 ℃ blast drying oven for 2 minutes, then apply the flame-retardant resin on both sides of the impregnated paper to achieve a total weight gain of about 5 times that of the base paper. Place it in a 103 ℃ blast drying oven for another 2 minutes. Flame retardant wear resistant paper should be sealed and stored for future use.

2.4. Hot-Pressing of Laminated Flooring Coated with Improved Flame Retardant and Wear-Resistant Paper

The process parameters for hot pressing—pressure, temperature, and time—are detailed in Table 1. The flame-retardant and wear-resistant paper is laminated onto the flooring surface to produce solid wood composite flooring faced with this paper. Pressure, temperature, and time are the three essential elements of hot pressing. In accordance with the requirements of the orthogonal experimental design, three values are selected for pressure, temperature, and time: 3.0 MPa, 3.5 MPa, and 4.0 MPa; 160°C, 180°C, and 200°C; 30 s, 40 s, and 50 s. Experiments are conducted based on various set combinations. Each experimental condition is replicated three times.

Table 1. Orthogonal Experiment Schedule.

Test No.	A	B	C
	Hot-pressing pressure （MPa）	Hot-pressing temperature （°C）	Hot-pressing time （s）
1	3.0	160	30
2	3.0	180	40
3	3.0	200	50
4	3.5	160	40
5	3.5	180	50
6	3.5	200	30
7	4.0	160	50
8	4.0	180	30
9	4.0	200	40

2.5. Performance Test of Laminated Flooring Coated with Improved Flame Retardant and Wear-Resistant Paper

The experimental testing items include critical heat flux (CHF), flame tip height within 60 s, wear-resistant speed, surface bonding strength, static bending strength, and formaldehyde emission. Critical heat flux is tested according to the national standard GB/T 11785-2005. The height of the flame tip is measured within 60 s according to the national standard GB/T 8626-2007. The wear-resistant speed and static bending strength are tested according to the experimental method specified in the national standard GB/T 24507-2020. The surface bonding strength is tested according to the test method specified in the national standard GB/T 17657-2022 4.15. Formaldehyde emission is tested according to the national standard GB/T 17657-2022 4.60.

3. Results and Discussion

3.1. Influence of Flame Retardant Content in Impregnated Flame Retardant Resin on Viscosity and Curing Time

It is important to study the effects of flame retardant components APP and PER on resin viscosity, as their addition can affect resin viscosity. Add different proportions of APP and PER flame retardant components to MUF, with the total amount of flame retardant components accounting for 15% of the

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resin content. The viscosity changes over time are shown in Figure 2. It can be seen that the addition of flame retardant components accelerates the growth rate of resin viscosity, and the higher the PER ratio, the faster the growth rate. Therefore, increasing the APP/PER ratio can reduce the growth rate of resin viscosity. In this study, the flooring was prepared at the ratio 2:1 of APP to PER, and finally, the viscosity of the resin was adjusted and reduced by adding urea to weaken the hydrogen bonding in the system, resulting in an overall viscosity of the resin below 50 MPa•S (20 °C) after 6 hours.

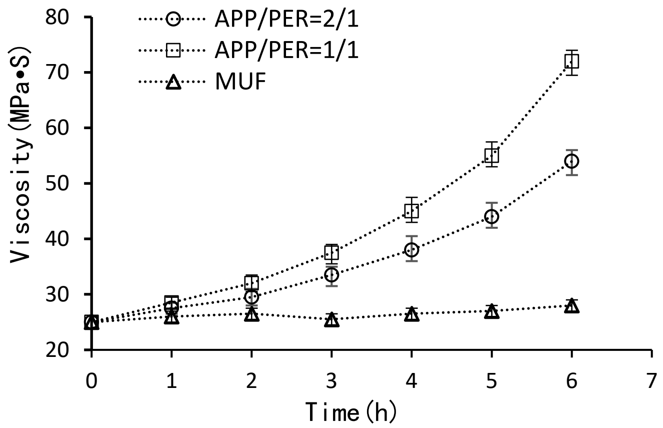

Figure 2. Effect of flame retardant ingredient addition on viscosity.

The addition of APP will promote the curing of resin. Under the current process, the curing time of impregnated flame-retardant resin is suitable between 350 s-500 s. We can further adjust the ratio of formaldehyde, urea, and melamine F/(M+U) to achieve the desired curing time. The effect of adjusting the F/(M+U) ratio on curing time is shown in Figure 3. According to the process conditions, the curing time of the floor trial production in this experiment is controlled at around 420 s.

Table 2. Effect of F/(M+U) ratio on curing time.

F/（M+U）	Curing time (s)								Mean±SD
	I	II	III	IV	V	VI	VII	VIII	(s)
1.20	550	566	582	573	559	575	560	564	566±10
1.21	513	525	537	530	534	514	520	529	525±9
1.22	450	468	484	462	472	470	453	475	467±11
1.23	412	423	436	430	430	418	420	424	424±8
1.24	385	395	411	402	390	386	397	411	397±10
1.25	345	358	373	352	367	363	348	362	359±10
1.26	306	319	331	312	327	317	327	311	319±9
1.27	248	254	263	245	263	265	248	260	256±8
1.28	207	215	225	205	223	209	224	218	216±8

3.2. Influence of Flame Retardant Components on the Flame Retardant Performance

Comparing the total flame retardant content with the resin content ranging from 0% to 20%, the flame retardant performance is shown in Figure 3. It can be seen that the addition of flame retardant components enhances the flame retardant performance of the floor, and the cost-effectiveness is higher when the total amount of flame retardant components added is 15%.

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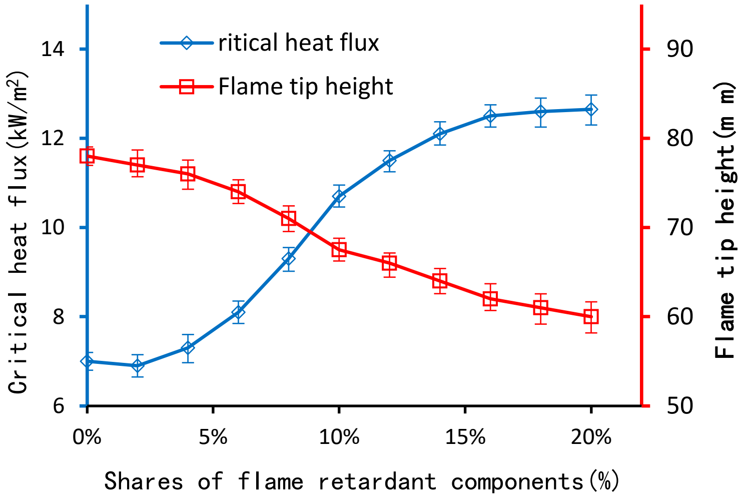

Figure 3. Influence of the proportion of flame retardant components on flame retardant performance.

3.3. Analysis of Heat Release Rates

The magnitude of heat release rate can effectively measure the fire hazard of different materials, and the higher the heat release rate, the higher the surface hazard. Flame retardant materials play an important role in the initial 600 s of a fire, but as the fire rapidly develops, fire-resistant materials no longer play a significant role. From Figure 4, it can be seen that the heat release rate of the board changes rapidly. The first peak that appears rapidly is in the early stage of ignition, followed by the formation of a carbonized protective layer on the flame-retardant impregnated film paper, effectively reducing the thermal decomposition of the wood material and thus reducing the heat release rate in the early stage of the fire, which can effectively suppress the expansion speed of the fire. It can be seen that the surface coated with flame-retardant impregnated paper has a significant improvement in the flame resistance of solid wood composite flooring. Within the first 600 s, the flame retardant performance is comparable to that of flame-retardant solid wood composite flooring produced by immersion method, but the amount of flame retardant used is only 1/4, which can save a lot of costs.

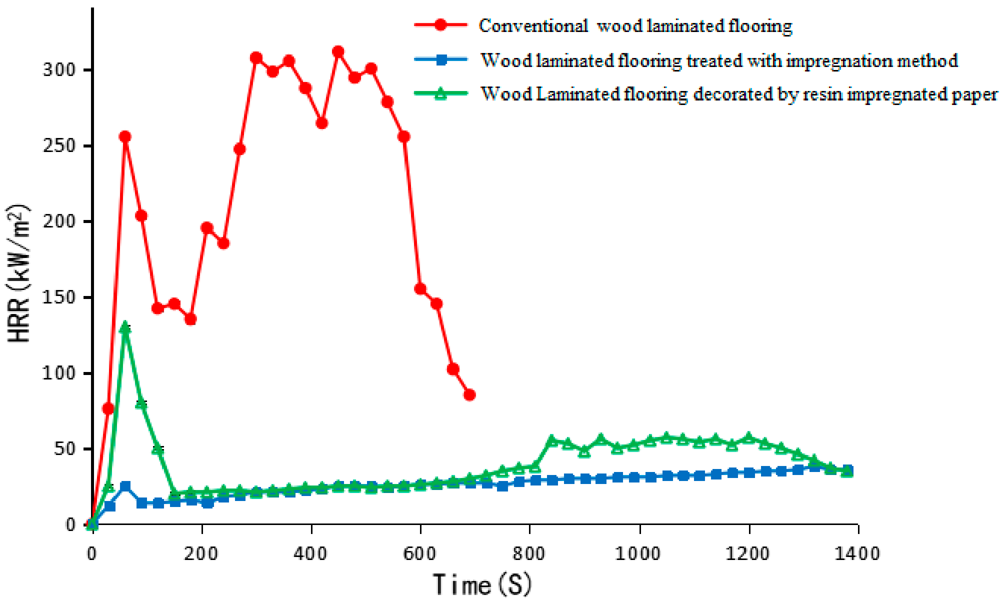

Figure 4. Heat release rate curves of flooring samples.

3.4. Influencing Factors of Composite Structure

The structure of laminated flooring coated with improved flame retardant, wear-resistant paper is shown in Figure 5, which is composed of improved flame retardant, wear-resistant paper, decorative layer, substrate, and balance layer. The maple birch veneer was used as the decorative layer, and melamine modified urea formaldehyde resin adhesive was used to bond the decorative layer with the substrate[6,7].The laminating technology is similar to that in the production of the veneer solid wood laminate floorboard[8]. The slab was pre-laminated before laminated by hot-pressing. When laminating, it is necessary to comprehensively consider the material, thickness and moisture content of the decorative veneer and the balance layer, and the moisture content should be controlled so that the tension of the surface layer is less than that of the balance layer[9]. The surface of the decorative layer can be colored to ensure its smoothness, which is conducive to adding improved flame retardant, wear-resistant paper to the surface and making the wood grain clear, resulting in a beautiful surface. When entering and exiting the board, and pay attention to the garbage on the board surface. The distance between each board and the two ends of the press should be as consistent as possible, and hot-pressing should be strictly carried out according to the experimental design parameters[10,11]. The hot-pressing temperature mainly depends on the temperature required for resin melting and curing, but the heat resistance of the substrate artificial board should also be considered, and the temperature should not be too high during laminating[12]. The hot-pressing pressure can quickly transfer the temperature of the board to the adhesive layer, and the resin will spread evenly under the pressure to form a bright and smooth film[13].A step-by-step pressure relief process is adopted to avoid defects such as layering, bubbling, and uneven surface of the veneer thin wood[14–17]. Using step-by-step hot-pressing, first apply decorative layer wood veneer and balance layer on the substrate, and then apply improved flame retardant, wear-resistant paper.

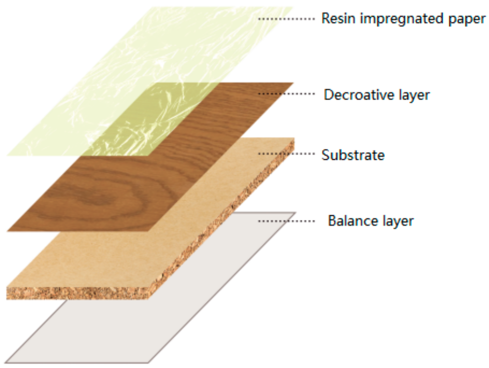

Figure 5. Structure of wood laminated flooring coated with improved flame retardant and wear-resistant paper.

Surface smoothness is a very important indicator, and special attention should be paid to control it in production. The uneven surface seriously affects the subsequent improved flame retardant and wear-resistant paper pressing and the decorative effect of the thin wood. There are many reasons for poor flatness, but most of them are caused by the defects in the substrate.The surface of the substrate artificial board is rough and uneven.The substrate is compressed unevenly in the thickness direction. After the pressure is released, the moisture absorption expansion of each part is different, resulting in an uneven surface of the substrate. The substrate absorbs the moisture in the adhesive solution and swells during the process of gluing or spraying, resulting in unevenness.

Adhesive penetration damages the appearance of the surface. Generally, the methods such as improving the bonding strength, prolonging the aging time, and spraying less water before hot-pressing can be used to prevent adhesive penetration. In addition, a small amount of pigment can be added to the adhesive to make the color of the adhesive similar to that of veneer, so that the adhesive penetration will be not conspicuous[18,19].

The cracks on the surface of the veneer are mainly attributed to the fact that the change in air humidity leads to the shrinkage and expansion of the veneer, and a stress is produced in the veneer

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since it is held back by the substrate. When the stress exceeds the cross-grain tensile strength of the veneer, the veneer will crack, producing many small cracks in the fiber direction. Cracks on the back of the veneer: The veneer with the loose side facing outward is more stable than that with the intensive side facing outward, and is less prone to cracks. The reason may be that the shrinkage and expansion of the veneer are concentrated on the original back crack, and no new cracks are generated at other places. When the intensive side is facing outward, the cracks on the back will develop into surface cracks towards the front, and the cracks will be large.Moisture content of the veneer: The veneer tends to shrink if the moisture content of the veneer is lower than that of pasting, but it is often in a state of tensile stress due to the restraint of the substrate. As a result, the veneer is prone to cracking[20].Amount of adhesive: More adhesive amount can make the surface less likely to produce cracks, but too much is prone to cause adhesive penetration[21]. Hot-pressing conditions: A higher hot-pressing temperature easily leads to production of surface cracks[22]. Combinations of the fiber directions: Whether the fiber direction of the veneer is parallel to that of the substrate or vertical has a great influence on the generation of surface cracks. Vertical laminating is an effective method to reduce surface cracks, but it is hard to operate and bonding strength is low[23]. Laminating buffer layer: A layer of paper or cloth material can be sandwiched between the veneer and the substrate as a buffer to reduce surface cracks[24].

3.4. Effects of different hot-pressing technologies on the performance of laminate improved flame retardant and wear-resistant paper

This experiment manufactured a new type of composite flooring according to orthogonal design. The relevant performance test results of the board are shown in Table 3.

Table 3. Orthogonal experimental results.

Test No.	Test parameters			
	Wear resistance rotate speed (r)	Surface bonding strength (MPa)	Static bending strength (MPa)	Formaldehyde emission （mg/m^3）
1	3950	1.61	41.0	0.029
2	4100	1.67	40.0	0.022
3	4150	1.56	37.4	0.019
4	4000	1.61	42.0	0.023
5	4200	1.63	38.9	0.019
6	4100	1.57	38.1	0.024
7	4050	1.55	41.2	0.020
8	4000	1.62	40.0	0.027
9	4100	1.57	38.2	0.020
Same batch flooring without resin impregnated paper	350	1.61	38.5	0.027

The analysis of wear resistance results of different hot-pressing technologies was shown in Table 4. When the hot-pressing temperature reached 160-180 °C, the resin adhesive could be fully cured, and the wear resistance could reach 4000 r. When the temperature was raised, the increase in the wear resistance was not prominent, and the defects such as water stains and bubbling would occur instead. In addition, the low temperature would result in bonding.

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Table 4. Wear resistance results of laminated flooring coated with improved flame retardant and wear-resistant paper.

Item	A Hot-pressing pressure	B Hot-pressing temperature	C Hot-pressing time
K_1	4067	4000	4017
K_2	4100	4100	4067
K_3	4050	4117	4133
R	50	117	116

Even if the hot-pressing time was in a short cycle of 30 s, the wear-resistant rotate speed of 4000 r could still be maintained, while the wear-resistant rotate speed did not increase significantly when the cycle was extended to 50 s. This is because under the condition that the hot-pressing temperature and time can ensure the full curing of the resin adhesive, the Al_2O_3 wear-resistant particles have been firmly adhered by the cured adhesive layer, and then raising the hot-pressing temperature and extending the time cannot increase its wear-resistant rotate speed. Therefore, when designing the hot-pressing technology of the laminate floorboard, the main consideration should be the full curing of the adhesive to ensure the physical and chemical properties of the board surface[25]. However, if the production volume is pursued and the hot-pressing cycle is shortened, other properties such as hardness and water vapor resistance of the board surface may be affected.

In this test, the hot-pressing technology did not show a significant impact on the wear resistance of the product. The design of the hot-pressing technology should focus on the full curing of the adhesive to ensure the physical and chemical properties of the plate surface.

The effects of hot-pressing parameters on surface bonding strength was shown in Table 5. When the hot-pressing pressure increased from 3.0 MPa to 3.5 MPa, the surface bonding strength did not change largely; when it rose from 3.5 MPa to 4.0 MPa, the surface bonding strength did not change much when the hot-pressing temperature was low, and decreased when the hot-pressing temperature was high. The higher the hot-pressing pressure, the faster the heat transfer. As a result, the surface of the slab quickly reached a higher temperature. The time spent at higher temperatures was increased compared to that at lower pressure. The continuous high temperature causes embrittlement of the adhesive, which reduces the surface bond strength[26].

Table 5. Surface bonding strength results of laminated flooring coated with improved flame retardant and wear-resistant paper.

Item	A Hot-pressing pressure	B Hot-pressing temperature	C Hot-pressing time
K_1	1.61	1.59	1.60
K_2	1.60	1.64	1.62
K_3	1.58	1.57	1.58
R	0.03	0.07	0.04

When the hot-pressing temperature rose from 160 °C to 180 °C, the surface bonding strength increased. This is because as the temperature rises, the adhesive flows faster due to the effect of heat, the contact between the slab and the improved flame retardant and wear-resistant paper is better, and the adhesive can be cured better. However, when the temperature rose to 200 °C, the surface bonding strength decreased, which may be ascribed to the embitterment of the adhesive layer at a higher temperature, which affects the bonding between materials and reduces the surface bonding strength[27].

When the hot-pressing time was extended from 30 s to 40 s, the surface bonding strength increased slightly. It is because as the temperature increases, the adhesive can be cured better. When it was extended from 40 s to 50 s, the surface bonding strength decreased instead. It can be seen from

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Table 5 that the hot-pressing temperature had the greatest effect on the bonding strength of the product surface, followed by hot-pressing time and then hot-pressing pressure.

The effects of hot-pressing parameters on static bending strength was shown in Tab. 6. The hot-pressing pressure had little effect on the static bending strength within the designed pressure range[28,29].When the hot-pressing temperature rose from 160 °C to 180 °C, the static bending strength decreased slightly, and when it rose from 180 °C to 200 °C, the static bending strength still decreased. This is because the increase in the hot-pressing temperature improves the internal temperature of the slab. A high temperature of the core layer will affect the original cured adhesive layer inside the substrate, making the adhesive layer brittle and affecting the strength, so the hot-pressing temperature should not be too high.

Table 6. Static bending strength results of laminated flooring coated with improved flame retardant and wear-resistant paper.

Item	A Hot-pressing pressure	B Hot-pressing temperature	C Hot-pressing time
K_1	39.47	41.40	39.70
K_2	39.67	39.63	40.07
K_3	39.80	37.90	39.17
R	0.33	3.50	0.90

When the hot-pressing time was extended from 30 s to 40 s, there was little effect on the static bending strength[30,31]. With the extension of the hot-pressing time, the static bending strength decreased slightly. It may also be attributed to the fact that the original cured adhesive layer inside the substrate is affected with the extension of time, causing the adhesive layer to become brittle and thus affecting its strength.According to Table 4, hot-pressing temperature displayed the greatest effect on the bonding strength of the product surface, followed by hot-pressing time and then hot-pressing pressure. The influence of hot pressing parameters on formaldehyde release is shown in Table 7. Both hot pressing time and temperature have a significant effect on reducing formaldehyde release. It can be seen that when the hot pressing time exceeds 40 seconds, low formaldehyde release can be obtained.

Table 7. Formaldehyde emission results of laminated flooring coated with improved flame retardant and wear-resistant paper.

Item	A Hot-pressing pressure	B Hot-pressing temperature	C Hot-pressing time
K_1	0.023	0.024	0.027
K_2	0.022	0.023	0.022
K_3	0.022	0.021	0.019
R	0.001	0.003	0.008

In summary, the hot-pressing temperature is the most important factor affecting the laminating of the improved flame retardant, wear-resistant paper. The hot-pressing pressure of 3.5 MPa, the temperature of 180 °C, and the time of 40 s should be selected as the optimal hot-pressing technology parameters.

3.5. Performance of the Improved Flame Retardant and Wear-Resistant Paper Veneer Solid Wood Composite Flooring

It is stipulated in the GB/T 18102-2020 that the surface bonding strength of the impregnated paper laminated wood floorboard shall be ≥1.0 MPa, and the measured value of the surface bonding strength of all experiment pieces shall be not less than 80 % of the standard value; the surface wear-resistant rotate speed shall be ≥4000 r (wear-resistant Level II). GB/T 24507-2020 also stipulates that the static bending strength of the solid wood laminate floorboard shall be ≥30MPa. The arithmetic mean of the surface bonding strength, surface wear-resistant rotate speed and static bending strength of the improved flame retardant, wear-resistant paper veneer solid wood composite flooring was 1.60 MPa, 4072 r, and 39.6 MPa, respectively, indicating that it is feasible to paste the improved flame retardant, wear-resistant paper on the plywood for solid wood composite flooring with thin wood veneer. The products fully combine the advantages of the solid wood composite flooring and the laminate wood flooring, which maximize their strengths and are highly cost-effective. By re pressing and sealing the surface with impregnated film paper veneer, the formaldehyde emission of the floor can be reduced again. The floor trial produced in this experiment meets the optimal level specified in GB/T 39600-2021, namely ENF level.

For general household floorboards, a wear-resistant rotate speed of 4000 r or above is far enough. In the experiment, therefore, improved flame retardant and wear-resistant paper with Al_2O_3 content of 38 g/m^2 was used in the experiment for laminating to reduce production costs[32,33]. If a floorboard with special requirements for wear resistance, such as for public places, is to be developed, products with a higher grade of wear resistance can be produced by simply laminating a improved flame retardant, wear-resistant paper with Al_2O_3 content of 46 g/m^2 or 62 g/m^2.

4. Conclusions

The laminating technology of the substrate with decorative veneer and balance layer is similar to that used in the production of the veneer solid wood laminate floorboard, where the slab is first pre-laminated before laminated by hot-pressing. The material, thickness and moisture content of the decorative veneer and the balance layer should be comprehensively considered during laminating.Factors affecting the quality of the veneer decorative layer include surface flatness, adhesive penetration, and surface cracks. The uneven surface will seriously affect the subsequent laminating of improved flame retardant, wear-resistant paper and the decorative effect of the veneer, and attention should be especially paid to controlling of surface flatness in the production.

The hot-pressing temperature is the most important factor affecting the laminating of improved flame retardant, wear-resistant paper[34,35]. The hot-pressing pressure of 3.5 MPa, the temperature of 180 °C, and the time of 40 s were selected as the best hot-pressing technology parameters, under which cost-effective floorboard products with better quality can be produced.The improved flame retardant, wear-resistant paper veneer solid wood composite flooring combines the advantages of the solid wood composite flooring and the laminate wood flooring. If there are special requirements for wear resistance, replacement with improved flame retardant, high Al_2O_3 content wear-resistant paper is required.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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