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Optimum Research of Hot-Pressing Technology of the Composite Board with Waste Wood and Paper

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Abstract

On the rise of global low-carbon economy with the purpose of leveraging waste wood resources efficiently, waste wood and paper was processed into new type wood-based panels. The hot-pressing technology of the 9 mm composite board with waste wood and paper was studied through an orthogonal experiment, and the effects of resin content, hot-pressing temperature, hot-pressing time and the mass ratio of waste wood and paper were discussed. Results indicated that effects of resin content on the MOR (Modulus of rupture), MOE (modulus of elasticity) and 24h TS (thickness swelling) of the composite board were remarkable, while effects of hot-pressing temperature, hot-pressing time and the mass ratio of waste wood and paper were slight. Based on the quality indicators of MOR, it was found that the optimum condition of hot-pressing for the 9 mm composite board with waste wood and paper was estimated to include resin content of 19%, hot-pressing temperature of 120 °C, hot-pressing time of 12.5min, and the mass ratio of waste wood and paper of 7 to 13. Under these conditions, the composite board could be used as new materials for furniture, interior decoration and packaging.

Key words: Waste wood; Waste paper; Composite board; Hot-pressing technology

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As in China the demand of woods consumption expanding with insufficient woods resource, the reuse of waste wood materials will be rewarding. To enhance the recycling of waste wood is not only an important measure for the development of the wood industry, but also an extremely realistic significance to solving wood resources constraints. The waste wood materials are a sort of recycled resources, including waste wood-based panel, waste paper and other wood products resources[1, 2]. Incalculable waste wood materials have been wasted every year in China. According to the official statistics, 1,200 tons of waste wood are generated every day in Hong Kong, which adding up to 438,000 tons of waste wood per year[3]. The waste paper and waste wood from processing stage are the two major sources of waste wood materials. In other countries, waste wood and waste paper have been called “the fourth forest resources” in the future which means the forest fall to the floor[4].

Applying waste wood and waste paper to new wood-based panels could greatly improve the efficiency of recycling of natural resources. This new wood-based panel would be used as new materials of furniture, interior decoration, packaging and so on, conforming to the current trend of low-carbon economy development.

1. MATERIALS AND METHODS

1.1 Materials

Waste wood: complex species, mainly Chinese fir, including tree barks, and moisture content of 8% to 10%.

Waste paper: the office waste paper scrapped into a certain size chip.

Adhesive: urea-formaldehyde resin that came from Beijing Wood Factory. Solid content of 52%, pH of 8.2, free formaldehyde content of 0.2%, F/U of 1.11.

Curing agent: ammonium chloride, the dosage was 1% of urea-formaldehyde resin solid content.

1.2 Methods

Four factors were studied in the experiment, resin content, hot-pressing temperature, hot-pressing time and the mass ratio of waste wood and paper, and four levels of each factor were selected out through a L16 (45) orthogonal experiment(Table 1).

Table 1
Experiment Factors and Levels

Level	Factors			
	Resin content (%)	Hot-pressing temperature (°C)	Hot-pressing time (min)	The mass ratio of waste wood and paper
1	15	120	8	7:13
2	17	135	9.5	1:1
3	19	150	11	3:1
4	21	165	12.5	9:1

The hot-pressing processing of the composite board was similar to that of the particleboard in the lab, which including glue blending, felting, hot-pressing and so on. The composite board was in the design of thickness of 9 mm, density of 0.8g/cm3 with the format of 300 × 300 mm, hot pressed under the pressures ranged from 1 MPa to 5 MPa. After hot-pressing, the composite board was taken out of the machine, cooled at a room temperature for 24 hours, then was taken a series of tests.

The test methods of the MOR, MOE and 24h TS of the composite board were based on the national standard GB/T 17657-1999: "Test methods of evaluating the properties of wood-based panels and surface decorated wood-based panels".

2. RESULTS AND DISCUSSION

The MOR, MOE, 24h TS of the composite board were tested based on the national standard GB/T 17657-1999, and the orthogonal table was chosen to carry out the test (Table 2).

Table 2
The Scheme and Results of L_{16} (4^5) Orthogonal Experiment

Number	Resin content (%)	Hot-pressing temperature (°C)	Hot-pressing time (min)	The mass ratio of waste wood and paper	MOR (MPa)	MOE ($\times 10^3$MPa)	24h TS (%)
1	15	120	8	7:13	18.87	1.25	46.89
2	15	135	9.5	1:1	18.37	1.20	53.88
3	15	150	11	3:1	15.90	1.63	60.02
4	15	165	12.5	9:1	16.93	2.40	50.25
5	17	120	9.5	3:1	17.83	2.03	44.65
6	17	135	8	9:1	11.35	1.17	65.25
7	17	150	12.5	7:13	22.53	2.20	48.58
8	17	165	11	1:1	14.17	1.47	49.55
9	19	120	11	9:1	24.30	2.83	28.35
10	19	135	12.5	3:1	25.20	3.13	33.53
11	19	150	8	1:1	21.36	2.57	40.13
12	19	165	9.5	7:13	23.00	2.83	40.12
13	21	120	12.5	1:1	27.03	3.47	34.21
14	21	135	11	7:13	21.47	2.50	48.11
15	21	150	9.5	9:1	15.47	2.33	37.75
16	21	165	8	3:1	14.53	2.07	41.54
K1	17.52	22.01	16.53	21.47			
K2	16.47	19.10	18.67	20.23			
K3	23.47	18.82	18.96	18.37			
K4	19.63	17.16	22.92	17.01			
R	7.00	4.85	6.39	4.46			
K1	1.62	2.40	1.77	2.20			
K2	1.72	2.00	2.10	2.177			
K3	2.84	2.11	2.11	2.22			
K4	2.59	2.18	2.80	2.183			
R	1.22	0.40	1.03	0.04			
K1	52.76	38.53	48.45	45.95			
K2	52.01	50.19	44.10	44.44			
K3	35.53	46.62	46.51	44.93			
K4	40.40	45.37	41.64	45.40			
R	17.23	11.66	6.81	0.51			

Table 2 showed that:

1) Based on the quality indicators of MOR, the optimum condition of hot-pressing for the composite board was estimated to include resin content of 19%, hot-pressing temperature of 120 °C, hot-pressing time of 12.5min, and the mass ratio of waste wood and paper of 7:13.

2) Based on the quality indicators of MOE, the optimum condition of hot-pressing for the composite board was estimated to include the resin content of 19%, hot-pressing temperature of 120 °C, hot-pressing time of 12.5min, and the mass ratio of waste wood and paper of 3:1.

3) Based on the quality indicators of 24h TS, the optimum condition of hot-pressing for the composite board was estimated to include the resin content of 15%, hot-pressing temperature of 135 °C, hot-pressing time of 8min, and the mass ratio of waste wood and paper of 7:13.

2.1 The Effects of Hot-Pressing Parameters on the MOR of the Composite Board

Figure 1 showed the effects of hot-pressing parameters on the MOR of the composite board. It was evident that the MOR presented a decrease-increase-decrease tendency with the increase in resin content. Therefore, it could be concluded that resin content imposed great impact on the MOR. The shape of curve indicated that resin content of 19% was an important turning point with the MOR at its maximum of 23.47 MPa. As resin content increased from 15% to 17%, there was a small decrease in the MOR, which might be caused by uneven felting by hands. It was indicated that the MOR decreased with hot-pressing temperature increasing, and the best hot-pressing temperature was 120 °C, when the MOR reached the maximum of 22.01 MPa. However, the MOR rising with the time increasing, and the curve began to follow a smooth and gradual trend with the MOR of 22.92 MPa at 12.5min. It should be pay attention to that too long hot-pressing time or too high temperature would make urea-formaldehyde resin cured excessively to lead to embitterment, which could reduce the properties of the composite board[5, 6]. With the amount of waste wood increasing, the MOR decreased gently. It also showed that the MOR only fell about 4.46 MPa when the mass ratio of waste wood and paper changed from 7:13 to 9:1. This suggested that effects of the mass ratio of waste wood and paper were slight.

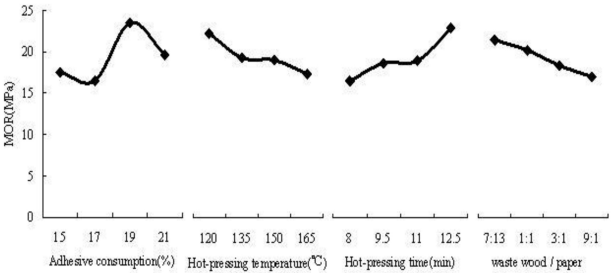

Figure 1
The Effects of Hot-Pressing Parameters on the MOR of the Composite Board

2.2 The Effects of Hot-Pressing Parameters on the MOE of the Composite Board

Figure 2 showed the effects of hot-pressing parameters on the MOE of the composite board. The MOE showed an increase-decrease tendency with resin content increasing. It was clear that the MOE reached the maximum of 2840 MPa with resin content of 19%, and it raised 1220 MPa as resin content increased from 15% to 17%, therefore resin content gave a remarkable effect on the MOE. Because the layer was too thick, resulting from the excess of resin content, the MOE decreased slightly at resin content of 21%. The MOE changed gently with temperature increasing, and reached the maximum of 2400 MPa at 120 °C. From 135 °C to 165 °C, the curve decreased slowly. It also showed that the MOE decreased with time increasing and reached the maximum of 2800 MPa at 12.5min. Although hot-pressing time of particleboard was 0.3-1.0min/mm, considering the characteristics of paper, an appropriate extension of hot-pressing time could make adhesive more fully in order to improve all the properties of the composite board. With the amount of waste wood increasing, the curve was almost a line, which meant that effects of the mass ratio of waste wood and waste paper were slight. The MOE was at the maximum of 2220 MPa when the mass ratio of waste wood and paper was 3:1, while the minimum was just 2180 MPa when at 1:1 and 9:1.

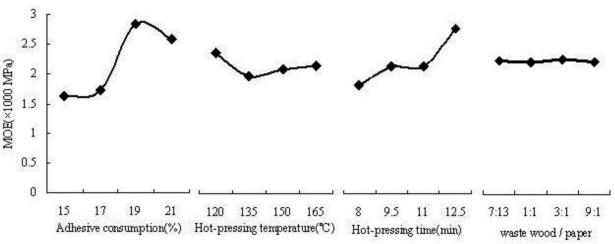

Figure 2
The Effects of Hot-Pressing Parameters on the MOE of the Composite Board

2.3 The Effects of Hot-Pressing Parameters on the 24h TS of the Composite Board

Figure 3 showed the effects of hot-pressing parameters on the 24h TS of the composite board. The 24h TS fell from 52.01% to 35.53% with resin content increased from 17% to 19%, and the minimum was reached at 19%. It can be seen that the 24h TS presented a decrease-increase tendency and resin content of 19% was an important turning point. At 120 °C, the 24h TS was at the minimum of 38.53%, then raised about 12% at 135 °C, after that point the curve dropped little. The 24h TS showed a decrease-increase-decrease tendency with time increasing without changing remarkably. The minimum of 41.46% was reached at 12.5min and only 7% of decrease was observed from 8.5min to 12.5min. Comparing to hot-pressing time, the effects of the mass ratio of waste wood and paper were slight. The curve was almost a line, as there was just about 3.3% drop from the maximum to minimum. It was not remarkable that the 24h TS came to the minimum of 44.44% at the mass ratio of waste wood and paper of 1:1.

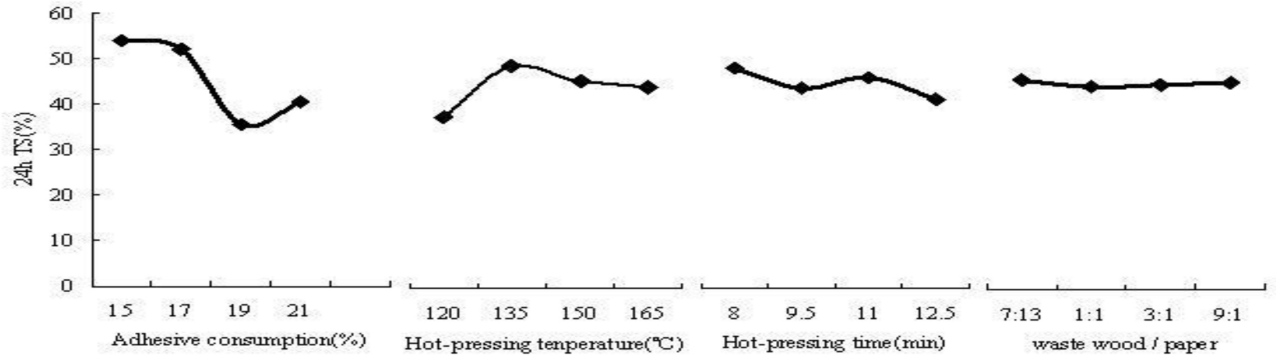

Figure 3
The Effects of Hot-Pressing Parameters on the 24h TS of the Composite Board

It can be obtained from the above analysis that resin content had the greatest effects on the MOR, MOE, 24h TS, while the **hot-pressing** temperature and **hot-pressing** time was relatively insignificant, and the mass ratio of waste wood and paper only created the least effect.

2.4 Verification Experiment

Considering the uses of the composite board, the optimum condition was picked out based on the quality indicators of the MOR for the verification experiment, which was estimated to include the resin content of 19%, hot-pressing temperature of 120 °C, hot-pressing time of 12.5min, and the mass ratio of waste wood and paper of 7:13.

The table 3 showed results of the verification experiment. The MOR and MOE met the relevant national standards in China, such as GB/T 4897.2-2003: "Requirements for general purpose boards for use in dry conditions" and GB/T 4897.3-2003: "Requirements for boards for interior fitments (including furniture) for use in dry conditions".

Table 3
Verification Experiment Results Table

Resin content (%)	Hot-pressing temperature (°C)	Hot-pressing time (min)	The mass ratio of waste wood and paper	MOR (MPa)	MOE ($\times 10^3$MPa)	24h TS (%)
19	120	12.5	7:13	27.40	3.50	48.87

CONCLUSIONS AND SUGGESTIONS

1) Through orthogonal test, it is observed that resin content had the greatest effect on the MOR, MOE, 24h TS of the composite board. Comparing to resin content, the MOR, MOE, 24h TS were affected relatively insignificant by the hot-pressing temperature and hot-pressing time, while the mass ratio of waste wood and paper just created the least effect on the MOR, MOE, 24h TS.

2) Through the verification experiment and considering the uses of the composite board, the optimum condition of hot-pressing was picked out based on the quality indicators of the MOR. It was estimated to include the resin content of 19%, hot-pressing temperature of 120 °C, hot-pressing time of 12.5min, and the mass ratio of waste wood and paper of 7:13. Under these conditions, the composite bard was able to meet several relevant national standards, hence, it can be used as new materials of furniture, interior decoration, and packaging.

3) As the thickness swelling of the composite board was relatively large, in the later studies, it would be better to add a suitable waterproofing agent or taking decorative

finishes, such as veneer materials and paint, in order to improve its properties and practicality and widen its application spectrum.

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