Environment, Resource and Ecology Journal (2024)
Clausius Scientific Press, Canada
DOI: 10.23977/erej.2024.080201
ISSN 2616-3756 Vol. 8 Num. 2

Low Carbon Environmental Protection Furniture Based on Solid Waste Resources

Mengyao Xu[1,a], Wei Wang[2,b,*], Zhilong Yang[1,c]

[1]*College of Computer Science and Technology, Nantong Institute of Technology, Nantong, Jiangsu, China*
[2]*College of Basic Teaching, Nantong Institute of Technology, Nantong, Jiangsu, China*
[a]*1375782814@qq.com*, [b]*39658225@qq.com*, [c]*615809294@qq.com*
[*]*Corresponding author*

Keywords: Solid Waste Resource Utilization, Low-carbon and Environmentally Friendly Furniture, Carbon Emission Reduction, Green Environmental Protection

Abstract: Against the backdrop of increasing global environmental awareness and resource scarcity, developing green and environmentally friendly furniture products has become the mainstream trend in the field of design and manufacturing today. This article uses waste plastics, metals, paper, and other materials to process waste furniture into high-quality furniture products through physical and chemical methods. The specific approach is to classify, clean, crush, and transform garbage, and add environmentally friendly adhesives and paints to improve its functionality and aesthetics, and reduce carbon emissions. From the perspective of carbon emission reduction, wardrobes have the highest reduction, reaching 2.5 tons of CO_2 per piece, indicating that their manufacturing process has significantly reduced carbon emissions. The carbon emissions reduction of storage cabinets and sofas are also relatively high, with 2.0 tons of CO_2/piece and 1.8 tons of CO_2/piece, respectively. The research results of this article are beneficial for providing new ideas and methods for the green and low-carbon development of the furniture industry.

1. Introduction

In the context of global warming, resources are becoming increasingly scarce. How to achieve sustainable development is a major issue faced by countries around the world today. Research has shown that the proportion of furniture industry cannot be ignored worldwide. Therefore, developing green solid waste recycling furniture is of great significance for reducing environmental pollution and alleviating resource scarcity. By comparing and analyzing relevant literature from around the world, the article aims to make up for the shortcomings in the current utilization of solid waste resources.

This article uses waste plastics, waste metals, and waste paper as the main raw materials to innovatively treat and transform waste plastics, waste metals, and waste paper. This article intends to classify, clean, and crush waste materials, and use special environmentally friendly adhesives and paints to beautify them, in order to obtain a new type of furniture that combines functionality and aesthetics. The research results of this article can provide new ideas for the development of environmentally friendly furniture.

The research ideas of this article are very clear and can be divided into three main parts. Firstly, this article provides a detailed explanation of the resource utilization technology process and treatment methods of solid waste. Secondly, it elaborates on the sources, classification, treatment processes, and specific measures for reuse of waste. Finally, the physical and chemical properties of the proposed process can be tested and its performance evaluated. The purpose of this article is to provide a new approach and in-depth analysis method for promoting the research and development of solid waste resource utilization.

2. Related Work

The use of solid waste to produce low-carbon and green furniture has important environmental and economic benefits. This technology can not only alleviate the environmental impact of traditional landfilling and incineration, but also convert waste into high-value products, achieving the goal of "reduction and resource utilization". Cui Xiaolei conducted research on the design strategy and innovation of willow weaving furniture [1]. Wu Zhiqiang explored carbon reduction technologies and application solutions in the design and manufacturing of panel furniture [2]. Zhang Qianqian conducted research on modular design ideas and practical techniques for bamboo furniture [3]. Wang Gang has carried out green design and manufacturing in the environmentally friendly furniture industry park [4]. Chen Yuanyuan proposed furniture design strategies under the green concept [5]. However, existing research has mainly focused on the regeneration process and material recycling rate of waste, and there is a lack of in-depth research on the usage characteristics and market acceptance of waste, which restricts the promotion and application of environmentally friendly furniture.

Solid waste can be used to produce furniture, which can reduce dependence on raw materials, reduce environmental pollution, and promote green consumption. In order to promote circular economy and achieve a green and low-carbon production model as a demonstration, Xu Zhihao conducted an analysis of the combustion and environmental performance of furniture panels [6]. Yang Yueqian conducted data visualization analysis on the application of environmentally friendly materials in the furniture field [7]. Xiong X has conducted research on the current situation and system construction of the recycling and utilization of old furniture in China [8]. Shi Q explored the research status and development trends of polylactic acid-based composite materials applied to 3D printed furniture [9]. Hu Xing explored the development opportunities of wood plastic composite materials in the field of furniture manufacturing [10]. However, existing research has overlooked issues such as durability and safety of green building materials during use, making existing furniture products far from meeting user requirements and becoming an urgent problem to be solved in current research.

3. Method

3.1 Collection and Pretreatment of Waste Materials

The primary step in solid waste reuse is the collection and pretreatment of waste. At this stage, it is necessary to classify, clean, and crush the plastics, waste paper, and metals recovered from urban waste. For example, waste plastic needs to be cleaned with hot water, while waste paper needs to remove impurities such as oil stains. To remove non-metallic impurities from metal materials, methods such as magnetic separation and cyclone separation are used. Processed materials must undergo quality evaluation to ensure that their reuse standards meet the requirements of furniture manufacturing.

Total carbon footprint C:

$$C = \sum_{i=1}^{n}(m_i \times EF_i) \quad (1)$$

Among them, m_i is the quality of the ith material (such as waste wood, plastic, etc.), EF_i is the carbon emission factor of the ith material.

3.2 Material Reconstruction Technology

Reengineering technology is the process of transforming pre-treated solid waste into usable furniture materials. For plastics and metals, common processes include melt shaping and casting, while waste paper sheets can be processed into paper-based composite materials through pulp processing. In the melting and reshaping process, waste plastic is heated to a melting point or higher, and then molded into the required furniture parts. Metal raw materials are cast at high temperatures, and waste pulp can be added with natural resin as a binder to increase hardness and durability. It is suitable for making tables, chairs, etc.

Resource utilization rate R:

$$R = \frac{W_{used}}{W_{available}} \times 100\% \quad (2)$$

Among them, $Wused$ is the amount of waste used, $Wavailable$ is the total amount of available waste.

3.3 Environmental Design and Manufacturing

In the furniture production process, environmental protection is an important link in achieving the organic combination of functionality and aesthetics. On the premise of ensuring that the design meets the requirements of ergonomics and aesthetics, designers must fully consider the physical properties of materials, such as strength, durability, weight, etc. Simulate and optimize furniture using CAD (Computer Aided Design) software to ensure its greenness and practicality. In the manufacturing process, use low-energy machines and minimize the use of chemicals to minimize environmental impact.

Energy efficiency E:

$$E = \frac{U}{E_{total}} \quad (3)$$

Among them, U is the useful energy required to complete the product during the production process, E_{total} is the total energy consumed during the production process.

3.4 Performance Evaluation and Market Adaptability

The finished product must undergo strict performance evaluation, including durability testing, safety testing, and environmental protection testing. Through these experiments, it can be determined whether the quality of furniture meets commercial standards and ensure their safe use over a long period of time. In addition, it is necessary to analyze the market acceptance of the product, and study its acceptance level, willingness to pay, and usage effectiveness, which are all key aspects of its marketing.

The detailed implementation and system optimization of the above technologies can effectively convert solid waste into low-carbon and environmentally friendly furniture. This not only increases the value of waste, but also contributes to the cause of environmental protection, demonstrating the practical application prospects of circular economy in modern industry [11].

Environmental Impact Assessment Index EI:

$$EI = \frac{\sum_{j=1}^{k}(I_j \times A_j)}{P} \tag{4}$$

Among them, I_j is the intensity of the jth environmental impact (such as chemical spills, noise, etc.), A_j is the area where the jth impact occurs, P is the quantity of products produced.

4. Results and Discussion

4.1 Experimental Setup for Environmental Furniture Evaluation

Experimental environment and parameter settings:

Experiments can be conducted in a professional furniture testing laboratory equipped with comprehensive mechanical testing equipment, environmental simulation equipment, and consumer research tools. Environmental parameters such as temperature, humidity, and lighting are controlled according to international standards to ensure consistency in experimental conditions. The main parameters used in the experiment include:

Material types: waste plastic, waste metal, waste paper.

Processing techniques: melt reshaping, die-casting, and pulp lamination.

Product types: chairs, tables, bookshelves.

4.2 Test Results of Low-carbon and Environmentally Friendly Furniture

(1) Durability testing

Here, the initial load-bearing capacity refers to the load-bearing capacity of the furniture during the initial testing phase. The load-bearing capacity after load is the load-bearing performance of furniture after multiple load tests. After use, the load-bearing capacity is simulated for furniture after long-term use.

Table 1: Basic performance information of tested furniture

Serial number	Waste material type	Furniture type	Repeated load times	Long term use simulation (months)
1	Recycled waste article board	Desk	1000	24
2	Plastic recycled particles	Dining chairs	2000	36
3	Reuse of glass fragments	Tea table	1500	24
4	Wood waste composite board	Wardrobe	500	12
5	Rubber tire regeneration	Sofa	800	48
6	Metal waste recycling	Bed frame	600	36
7	Reuse of ceramic fragments	Side cabinet	3000	18
8	Mixed waste composite materials	Storage cabinet	1200	24

The waste material types in the test are 8 categories, corresponding to 8 categories of furniture.

The range of repeated load times is 500-3000. The basic performance information of the tested furniture is shown in Table 1.

The initial, load, and post use bearing capacity under different serial numbers are shown in Figure 1.

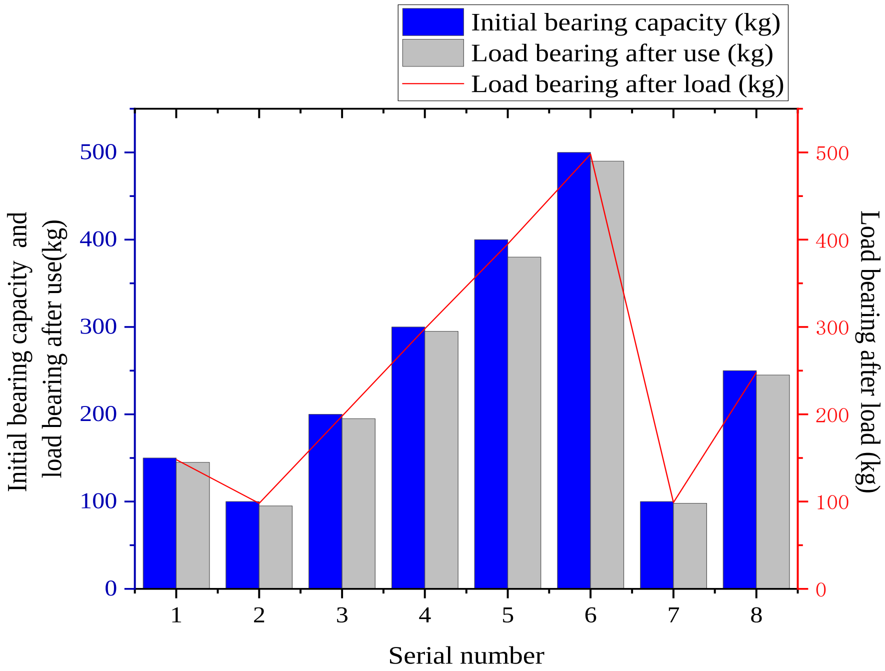

Figure 1: Initial, load, and post use load under different serial numbers

Solid waste resource utilization technology has broad application prospects in the field of furniture manufacturing. Different types of waste materials are effectively converted into furniture components, which not only reduces waste generation but also promotes environmental protection and sustainable development.

The data on initial load-bearing, post load load-bearing, and post use load-bearing demonstrate the load-bearing capacity of furniture at different stages. These numerical changes reveal the load-bearing performance of furniture during use. The load-bearing capacity of furniture slightly decreases from initial load-bearing to load-bearing after loading, but the change is not significant, which may be caused by slight deformation or measurement errors during loading. From load-bearing after loading to load-bearing after use, the load-bearing capacity of some furniture further decreases, but the overall amplitude is small, indicating that the furniture has some wear and tear during normal use, but the overall structure is still stable.

The sofa with serial number 5 is made of recycled rubber tires, with an initial load-bearing capacity of 400kg. After use, it drops to 380kg, making it the furniture with the greatest decrease in load-bearing capacity among all furniture items. This may be due to high load-bearing requirements in the design and manufacturing process of sofas, or significant deformation or wear of rubber tire recycled materials during long-term use. The side cabinet with serial number 7 uses ceramic debris reuse materials, with a load-bearing capacity reduced from 100kg to 98kg (after use), indicating that ceramic debris reuse materials have good stability and durability in furniture manufacturing.

The overall evaluation shows that solid waste resource utilization furniture performs excellently in terms of load-bearing capacity and can maintain structural stability during normal use. Although the load-bearing capacity of some furniture has decreased after use, the magnitude is relatively small, and the overall structure is still stable. This validates the effectiveness of solid waste resource utilization technology in manufacturing high-quality and environmentally friendly furniture.

Suggestion:

For furniture with high load-bearing requirements such as sofas made from recycled rubber tire materials, it is recommended to further consider the mechanical properties and stability of the materials in the design and manufacturing process. For other types of furniture, it should continue to explore and optimize solid waste resource utilization technologies to improve the environmental performance and overall quality of furniture. In addition, furniture can be regularly maintained and inspected to promptly identify and address potential issues, ensuring its safe and stable use.

(2) Environmental impact testing

The Life cycle Assessment (LCA) method is used here to analyze the environmental impact of various types of furniture throughout the life cycle, covering carbon footprint and resource consumption.

The results of the environmental impact test are shown in Figure 2 (Figure 2 (a) carbon emission reduction rate and resource consumption reduction rate, Figure 2 (b) carbon emission reduction).

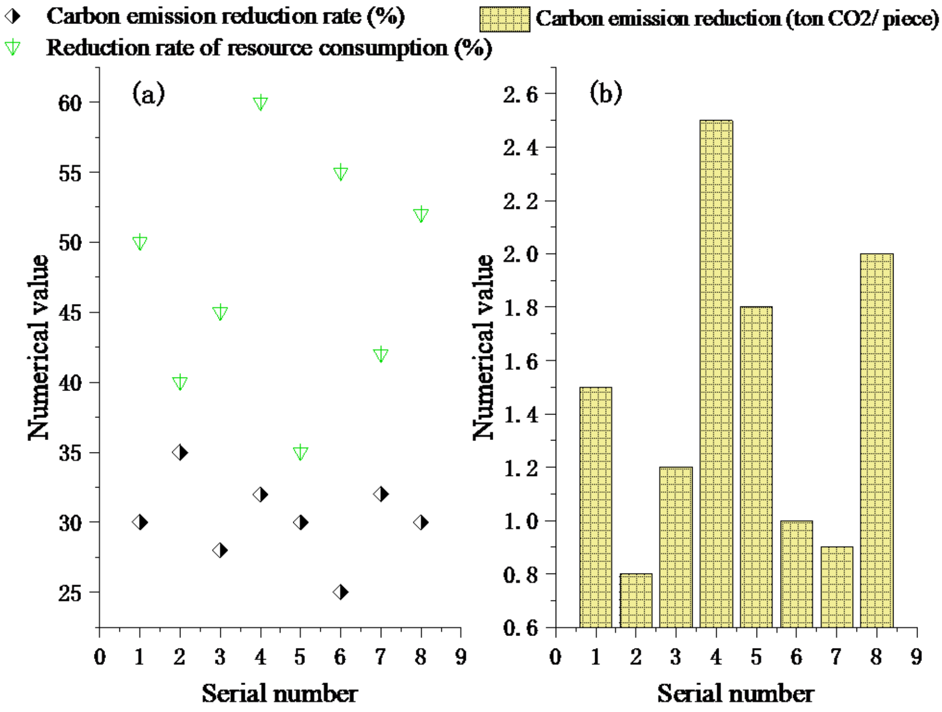

Figure 2: Environmental impact test results

Judging from the reduction in carbon emissions (tons of CO_2/piece), the wardrobe has the highest reduction, reaching 2.5 tons of CO_2/piece, indicating that its manufacturing process has significantly reduced carbon emissions. The carbon emission reductions of lockers and sofas are also relatively high, at 2.0 tons of CO_2/piece and 1.8 tons of CO_2/piece, respectively. Relatively speaking, the carbon emission reduction of dining chairs and side cabinets is small, but it still reduces carbon emissions to a certain extent; in terms of carbon emission reduction rate (%), the dining chair has the highest reduction rate, reaching 35%, which shows that it performs well in carbon emission control in the manufacturing process. Furniture such as desks, wardrobes, sofas and side cabinets have also achieved good results in reducing carbon emissions. The reduction rate of coffee tables and bed frames is slightly lower, but it also shows the efforts to reduce carbon emissions; in terms of the reduction rate of resource consumption (%), the wardrobe has the highest reduction rate, reaching 60%, indicating that its manufacturing process is more efficient in resource utilization. The resource consumption reduction rate of bed frames and lockers is also relatively high, at 55% and 52%, respectively. The reduction rate of resource consumption of other furniture types shows varying degrees of resource conservation effects.

In summary, the data show that various furniture types have contributed to the reduction of carbon emissions and resource consumption, reflecting the efforts of the furniture manufacturing industry in environmental protection and sustainable development.

(3) Consumer acceptance survey

The survey results of consumer acceptance are shown in Table 2.

Table 2: Consumer acceptance survey results

Survey items	Investigation details	Result
Acceptance of environmental protection furniture	Very willing	40%
	Be willing	30%
	Be neutral	20%
	Unwilling	10%
Use feeling	Quality feeling	Excellent:40%,Good:50%,General:10%
	Comfort feeling	Excellent:45%,Good:45%,General:10%

First of all, environmentally friendly furniture is actively recognized among most consumers. 40% of respondents said they were “very willing” to accept environmentally friendly furniture, indicating that environmental awareness has spread widely among consumers. At the same time, 30% of respondents said they were “willing” to accept it, further reflecting the potential of the environmentally friendly furniture market. Only 10% of respondents expressed “unwillingness”, which may be due to insufficient understanding of environmentally friendly furniture or price factors.

Secondly, most respondents gave positive feedback on their feelings after using environmentally friendly furniture, whether it is quality or comfort. In terms of quality, 40% of respondents think it is excellent, 50% think it is good, and only 10% think it is average.In terms of comfort, 45% of respondents thought it was excellent, 45% thought it was good, and only 10% thought it was average. These data show that environmentally friendly furniture can meet the needs of most consumers in terms of quality and comfort.

In summary, environmentally friendly furniture has a high degree of acceptance among consumers, and most consumers have a positive attitude towards its use. This provides strong support for the development of the environmentally friendly furniture market. At the same time, it also reminds companies that they need to further strengthen publicity and raise consumers' awareness of environmentally friendly furniture to meet the needs of more consumers.

(4) Cost-benefit analysis

The production cost of different furniture varies significantly. The production cost of the wardrobe (serial number 4) is the highest, reaching 2000 yuan per piece, while the cost of the dining chair is the lowest, only 800 yuan per piece. This suggests that differences in materials, processes and manufacturing difficulties affect production costs.

The market price is usually higher than the cost of production, so the furniture industry has a certain profit margin. The price of wardrobe is the highest, reaching 3,000 yuan per piece, and the dining chair is relatively low, at 1,200 yuan per piece, which may be related to factors such as furniture function, design and brand.

Consumers' willingness to pay also varies significantly. The willingness to pay for wardrobes was the highest, reaching 3,500 yuan per piece, while the willingness to pay for dining chairs was lower, at 1,300 yuan per piece. This shows that consumers can weigh in on factors such as practicality, aesthetics and brand when buying furniture.

The cost-benefit analysis results are shown in Figure 3.

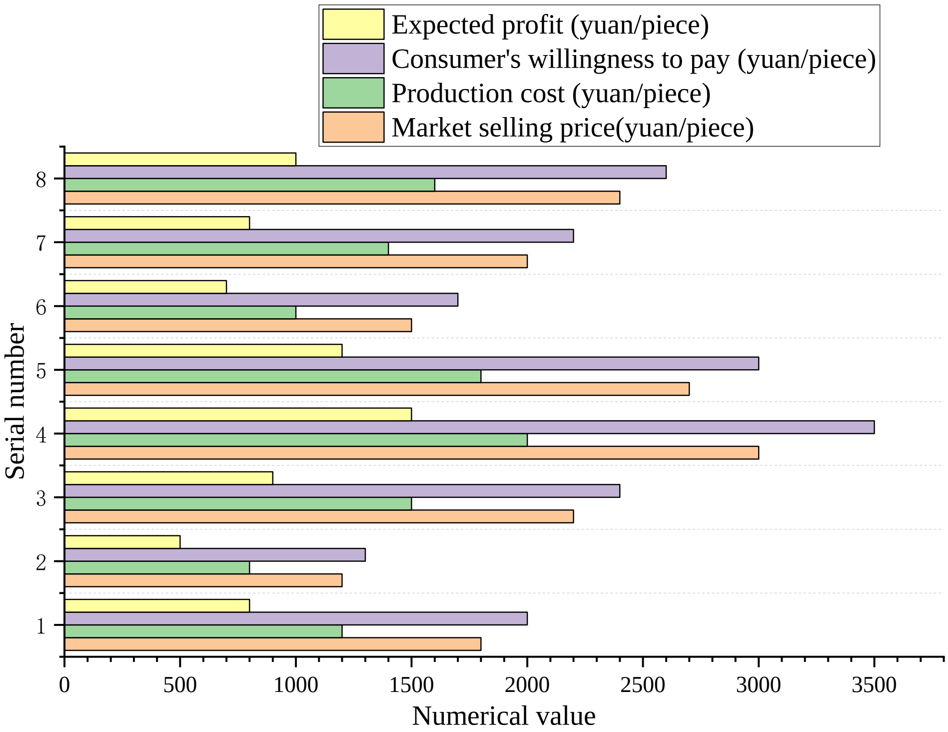

Figure 3: Results of cost-benefit analysis

5. Conclusions

This article intends to study and evaluate the process of making low-carbon environmental furniture from solid waste resource utilization. The research includes waste collection and pre-treatment, material modification technology, environmentally friendly design and production, product performance evaluation and market evaluation. Through experiment and market investigation, the practicality of this concept is tested, and its feasibility and benefits in practical application are evaluated. The experiment proves that the waste plastic, scrap metal, waste article and other materials can be processed into environmentally friendly furniture with practical value and aesthetic value by using the appropriate pretreatment and transformation technology. The results of the consumer acceptance survey show that most people are open to environmentally friendly furniture, especially those who are environmentally conscious young people. In addition, although the manufacturing cost of the product is high, but from the market feedback, consumers are still willing to buy, which is also a very potential market. While encouraging results have been achieved, there are certain limitations. First of all, the existing waste pretreatment and material restructuring technologies still need to be further improved in terms of cost and efficiency. Secondly, this article takes a certain kind of solid waste as the research object, and researches less on the more general methods of solid waste reuse. In the future research, it is necessary to recycle different types of solid waste to expand the source and utilization efficiency of solid waste resources. On this basis, this article focuses on the research and development of raw material processing and processing technology with high cost performance, in order to reduce the production cost of environment-friendly furniture and improve its competitiveness in the market.

Acknowledgement

This work was supported by Jiangsu Province College Student Innovation and Entrepreneurship Training Program Project, Project Number: 202312056026Y, Project Name: Creative Green Furniture in Low Carbon Environment - Based on Environmental Protection and Solid Waste Resource Utilization Technology.

References

[1] Cui Xiaolei. Research on wicker furniture design strategy and Innovation [J]. Forest industry, 2020, 57(10): 31-35.
[2] Wu Zhiqiang. Carbon reduction technology and application in the design and manufacture of panel furniture [J]. Forest industry, 2020, 57(3): 96-98.
[3] Zhang Qianqian, Chen Siyu, Ye Lei, etc. Modular design ideas and practices of bamboo furniture [J]. World Bamboo and Rattan Newsletter, 2023, 20(6): 74-78.
[4] Wang Gang. Greening design in environmental protection furniture industrial park [J]. Forest industry, 2020, 57(2): 92-94.
[5] Chen Yuanyuan. Furniture design strategy under the green concept [J]. Packaging Engineering Art Edition, 2022, 43(2): 286-289.
[6] Xu Zhihao, He Lihui, Zhong Wenhan, etc. Analysis of the combustion performance and environmental protection performance of furniture plates [J]. Fire science and Technology, 2020, 39(2): 170-173.
[7] Yang Yueqian, Xu Wei. Visual analysis of data on the application of environmentally friendly materials in the field of furniture [J]. Forestry and grassland machinery, 2021, 2(05): 73-77.
[8] Xiong X, Yue X, Dong W, et al. Current status and system construction of used-furniture recycling in China[J]. Environmental Science and Pollution Research, 2022, 29(55): 82729-82739.
[9] Shi Q. Research Status and Development Trend of Polylactic Acid Matrix Composites Applied to 3D Printed Furniture [J]. International Journal of Frontiers in Sociology, 2021, 3(11): 3-11.
[10] Hu Xing. The development opportunities of wood-plastic composite materials in the field of furniture manufacturing [J]. Architectural design and research, 2023, 4(6): 103-105.
[11] Lao W L, Li X L, Gong Y C, et al. Carbon Dioxide Emission Evaluations in the Chinese Furniture Manufacturing Industry Using the IPCC Tier-2 Methodology[J]. Forest Products Journal, 2023, 73(1): 6-12.