The effect of recycled WPC on the performance of composite materials

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Abstract. In order to improve the comprehensive utilization of waste Wood-Plastic Composites (WPC), high-density polyethylene (PE) and polypropylene (PP) WPC composites filled with recycled WPC were prepared. The effects of different recycled WPC content on the processing performance, mechanical properties and artificial accelerated aging performance of composite materials were studied. The results show that when the quality fraction of recycled WPC is less than 20%, it has little influence on the properties of composite materials. With the increase of the quality fraction of recycled WPC by more than 20%, all the processability, mechanical properties and artificial accelerated aging property of composite materials show a significant decline.

1. Introduction
Wood-plastic composite (WPC) is a new type of energy-saving and environment-friendly composite materials that is widely used in landscape, automobile and construction industries [1]. With the increasing awareness of environmental protection, the production and market of WPC are continuously expanding [2]. WPC has excellent properties such as water resistance, acid and alkali resistance, easy forming and processing, and recyclability [3], which has been increasingly favored by scientific researchers, production enterprises and consumers. However, with the expansion of the WPC market and the replacement of products, the number of discarded WPC has gradually increased. The waste WPC contains non-degradable components, which is not only a pity but also pollutes the environment by direct burial [4]. Therefore, this study used high-density polyethylene (PE) and polypropylene (PP) as the matrix, wood flour and recycled WPC as reinforcement and filler materials, and investigated the effects of different recycled WPC mass fractions on the processing performance, mechanical properties and accelerated aging performance of the composite materials.

2. Materials and methods
2.1. Preparation of composite materials
First, the recycled WPC material are dried and crushed to meet the processing conditions. The recycled WPC, wood powder, PE, PP, talcum powder, active calcium, additives and condiments are mixed in a fixed ratio and mixed evenly with a high-speed mixer. Then, plasticized and granulated by parallel twin-screws to obtain plasticized pellets of new materials, which are extruded with conical twin-screws to obtain test samples. The quality ratio of WPC materials is shown in Table 1.
Table 1. Raw material ratio.

| number | PE/kg | PP/kg | Talcum powder/kg | Wood powder/kg | Active calcium/kg | Additives/kg | Condiments/kg | Recycled WPC/% |
|--------|-------|-------|------------------|----------------|------------------|--------------|---------------|----------------|
| 1      | 12.5  | 7.5   | 12.5             | 32.5           | 16.5             | 7            | 10.8          | 0              |
| 2      | 12.5  | 7.5   | 12.5             | 32.5           | 16.5             | 7            | 10.8          | 10             |
| 3      | 12.5  | 7.5   | 12.5             | 32.5           | 16.5             | 7            | 10.8          | 20             |
| 4      | 12.5  | 7.5   | 12.5             | 32.5           | 16.5             | 7            | 10.8          | 30             |
| 5      | 12.5  | 7.5   | 12.5             | 32.5           | 16.5             | 7            | 10.8          | 40             |
| 6      | 12.5  | 7.5   | 12.5             | 32.5           | 16.5             | 7            | 10.8          | 50             |

Note: PE+PP+ talcum powder + wood powder + active calcium + additives + condiments are 100%. On this basis, add recycled WPC according to the mass percentage content.

2.2. Characterization and testing

2.2.1. Torque rheology test. The processing performance of the composite materials was tested on a torque rheometer with a test temperature of 180°C and a speed of 50 r/min.

2.2.2. Mechanical properties test. The tensile strength, bending strength and impact strength of the composite materials are tested in accordance with ASTM D638, ASTM D790 and GB/T 1043-2008.

2.2.3. Accelerated aging performance test. The accelerated aging performance test refers to ASTM D 2565-2016 to test the color difference and mechanical property changes of the samples after 400h and 800h.

3. Results and discussions

3.1. Processing performance of recycled WPC material

For the reuse of recycled waste WPC material, the processing performance of the material is the decisive factor for its recycling. The torque-time curve of recycled WPC material with different dosages is shown in Figure 1, and the rheological curve data is shown in Figure 2.

![Figure 1. Torque-time curve.](image1)

![Figure 2. Torque rheological curve data.](image2)
It can be seen from Figures 1 and 2 that with the increase in the amount of recycled WPC, the changes of the composite materials in the melt plasticization stage and the melt homogenization stage are more regular. It can also be seen from the melting and plasticizing stage of the curve that as the amount of recycled WPC increases, the curve goes to the upper right, indicating that the composite materials show a trend of increasing melting time and increasing activation energy of viscous flow, and the change trend is more obvious. When the recycled WPC content is less than or equal to 20%, the torque of the test samples tends to be stable within 60s, and the change trend is small. When the recycled WPC content is more than 30%, the time required for the composite materials to reach the equilibrium torque increases. And the increasing trend of the curing time is more obvious. The plasticizing time of the recycled WPC with 30% content is increased by 27% and 15.6% compared with the 0 and 20% content samples. It can be seen from the balance torque of the test samples that as the amount of recycled WPC increases from 0 to 50%, the curve position increases sequentially and the torque increases sequentially. Compared with the sample without added recycled wood plastic, the balance torque of the composite materials increased by 8.1% and 45.6% when the recycled WPC content was 20% and 50%, respectively. In addition, all curves did not fluctuate significantly during the homogenization stage. The results show that with the increase in the amount of recycled WPC, the viscosity of the composite melt will show a significant increase trend, which affects its processing fluidity.

3.2. Mechanical properties of recycled WPC

The effect of different recycled WPC mass fractions on the mechanical properties of composite materials is shown in Table 2. It can be seen from Table 2 that with the increase of the recycled WPC content, the bending strength, tensile strength and impact strength show a downward trend. When the recycled WPC content is 20%, the bending strength is 15.2MPa, the tensile strength is 7.35MPa, and the impact strength is 2.7KJ/m², which is decreased by 6.86%, 10.07% and 8.52% compared with the sample without the recycled WPC. When the amount of recycled WPC is 50%, its bending strength is 7.5MPa, tensile strength is 3.27MPa, impact strength is 1.9KJ/m², which is decreased by 57.14%, 58.87% and 40.63% compared with the sample without the recycled WPC. The results show that when the amount of recycled WPC is not large, the amount of recycled WPC has little effect on the mechanical properties of the composites, but when the amount of recycled WPC exceeds 20%, the recycled WPC will greatly reduce the mechanical properties of the composite. This is because in the used and repeated processing of recycled WPC, the wood powder and plastic matrix are degraded, the wood fibers are shortened, and the load cannot be effectively transferred, which causes the mechanical properties to decrease [5].

| Recycled WPC/% | Bending strength /MPa | Tensile Strength /MPa | Impact strength /KJ/m² |
|---------------|------------------------|----------------------|-----------------------|
| 0             | 17.5                   | 8.84                 | 3.5                   |
| 10            | 17.1                   | 8.51                 | 3.4                   |
| 20            | 16.3                   | 7.95                 | 3.2                   |
| 30            | 12.5                   | 4.24                 | 2.8                   |
| 40            | 10.7                   | 3.75                 | 2.4                   |
| 50            | 7.5                    | 3.27                 | 1.9                   |

3.3. Aging properties of recycled WPC composites

The color difference and tensile strength performance of the recycled WPC composite materials after accelerated aging performance test is shown in Table 3.
### Table 3. Aging resistance of composite materials.

| Recycled WPC/% | Color difference | Tensile Strength |
|----------------|------------------|------------------|
|                | Original value/MPa | 400h aging test value/MPa | Retention rate % | 800h aging test value/MPa | Retention rate % |
| 0              | 8.8              | 8.84             | 8.79             | 99.43             | 8.24             | 93.21             |
| 10             | 9.5              | 13.5             | 8.78             | 93.85             | 7.89             | 89.86             |
| 20             | 11.7             | 16.8             | 7.95             | 91.32             | 6.28             | 78.99             |
| 30             | 17.1             | 21.6             | 5.24             | 73.28             | 3.01             | 57.44             |
| 40             | 22.9             | 28.4             | 3.75             | 68.80             | 1.85             | 49.33             |
| 50             | 29.6             | 36.8             | 3.27             | 53.21             | 1.32             | 40.37             |

It can be seen from Table 3 that with the increase in the amount of recycled WPC, the color difference of the composite materials increases significantly. The color difference of the composite materials with 20% recycled WPC after 400h aging is 11.7 and the color difference of the sample after 800h is 16.8, which increased by 44.32% and 48.67% compared with the experimental sample without added recycled WPC. Compared with the samples without added recycled WPC, the sample with 50% recycled WPC increased by 236.36% and 225.66% respectively. Due to the relationship between color difference and vision, when the color difference is greater than 12.0, the human visual perception will be very obvious, which seriously affects the appearance of the product.

It can be seen from the tensile properties and retention rate of the composite materials that after the accelerated aging test, as the recycled WPC content increases, the tensile strength and strength retention rate of the samples gradually decrease, and the downward trend is obvious. After undergoing the aging test for 400h and 800h, the tensile strength retention rate of the composite materials is 91.32% and 78.99%, when the recycled WPC content is 20%. When the recycled WPC content is 50%, the tensile strength of the composite materials the strength retention rates were 53.21% and 40.37%, after undergoing the aging test for 400h and 800h. The results show that the incorporation of recycled WPC will promote the aging process of the composite materials, because the recycled WPC base material was oxidatively degraded to a certain extent when the recycled WPC was processed or used outdoors. Recycled WPC materials basically do not carry free radicals, the addition of recycled WPC will significantly reduce the oxidation induction time of the composite materials, reduce the anti-aging properties of the material.

### 4. Conclusion

The research in this article shows that the processing properties, mechanical properties and accelerated aging properties of recycled WPC decrease with the increase of recycled WPC content. When the content of recycled WPC is 20% or less, the processing performance, mechanical properties and accelerated aging performance of the composite materials decrease to a lesser extent, which is the optimal value of the recycled WPC content and meets the various properties of the composite materials. At the same time to ensure the maximum amount of recycled WPC. The incorporation of recycled WPC will accelerate the aging of the composite materials, so additional antioxidants should be introduced into the recycled WPC system to delay the aging of the composite materials.

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### References

[1] Qingwen Wang, Weihong Wang. Wood-plastic composites and products[M]. Beijing: Chemical Industry Press, 2007.

[2] Li Jing, Trends in China’s Wood Plastic Composite Market[J]. China Wood-based Panels, 2014,
21(02):1-3.

[3] Taneli Väisänen, Oisik Das, Laura Tomppo. A review on new bio-based constituents for natural fiber-polymer composites[J]. Journal of Cleaner Production, 2017, 149.

[4] Denni Kurniawan, Byung Sun Kim, Ho Yong Lee, Joong Yeon Lim. Effects of repetitive processing, wood content, and coupling agent on the mechanical, thermal, and water absorption properties of wood/polypropylene green composites[J]. Journal of Adhesion Science and Technology, 2013, 27(12).

[5] Ran Cheng, Haigang Wang, Tian Liu, Qingwen Wang. The Mechanical properties and water absorption of polyethylene fiber reinforced wood /HDPE composites[J]. New Building Materials, 2014, 41(04): 79-82.