The effects of CaCO₃ on the properties of PCL wood-plastic composites

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Abstract. The effects of CaCO₃ on the properties of PCL wood-plastic composites were studied in this paper. The strength and the melt flow rate of the composites increased first and then decreased with the content of CaCO₃, and up to maximum while the content of CaCO₃ is 30%. Gaps and holes could be seen from the SEM figure in the composites when the content of CaCO₃ is more than 30%. Above all, the best content of CaCO₃ in the composites is 30%.

1. Introduction
Wood plastic composites (WPCs) have become a successful commercial building material with an increasing market potential during the past years due to their recyclability, low density, low cost, low maintenance, good mechanical properties, and biological performance. WPCs consist of varying contents of wood, plastics and additives, and are processed by thermoplastic shaping techniques such as extrusion, injection molding, and compression molding. WPCs have been used in increasingly widespread applications, including siding, roofing, windows, door frames, and outdoor furniture industry [1-4].

CaCO₃ particles have been widely compounded into polymer matrices to enhance the impact toughness of polymers. Researchers usually agree that the impact strength depends on the particle dispersion such as particle shape, particle size and aspect ratio, owing to their great impact on the particle–matrix interaction and the overall structure [5].

Poly(ε-caprolactone)(PCL) is widely adopted as synthetic polymer for medical applications due to its several desirable features, such as good stability under ambient conditions and ease of process ability with different techniques and morphologies.

PCL is an aliphatic linear polyester, with a glass transition temperature of 62°C and a melting point of 55°C~60°C depending on the degree of crystallinity, which in turn is dictated by the molecular weight. Which allow it to be formed from a wide range of scaffold fabrication technologies.

PCL and its copolymers have demonstrated this utility by being successfully used in electrospinning, gravity spinning, solid freeform fabrication and microparticles, in part due to the low melting temperature, very good blend-compatibility, FDA approval and low cost [6-8].

Here, we report a study of the effects of CaCO₃ in PCL wood plastic composites. This research can provide a reference for the study of the application of PCL wood plastic composites.
2. Experimental section

2.1. Materials
Poly(ε-caprolactone) PCL (Solvay 6500), the powder of plant fiber, CaCO₃, AR, coupling agent(KH 550), AR, antioxidants, AR, plasticizer, AR. The components of the composites were listed in Table 1.

| Specimen | PCL | The powder of plant fiber | CaCO₃ | KH 550 | Antioxidants | Plasticizer |
|----------|-----|---------------------------|-------|--------|--------------|-------------|
| 1        | 100 | 30                        | 10    | 0.01   | 0.01         | 0.01        |
| 2        | 100 | 30                        | 20    | 0.01   | 0.01         | 0.01        |
| 3        | 100 | 30                        | 30    | 0.01   | 0.01         | 0.01        |
| 4        | 100 | 30                        | 40    | 0.01   | 0.01         | 0.01        |

2.2. The preparation of the powder of plant fiber and CaCO₃
The powder of plant fiber and CaCO₃ were put in the high-speed mixer, with 600~900R/min, which were stirring 15 minutes. The ethanol solution of the coupling agent was added in the high-speed mixer while the materials were stirring.

2.3. The preparation of the composites
PCL, the powder of plant fiber, CaCO₃, KH 550, antioxidants and plasticizer were put in the internal mixer, stirring 10 minutes in 90°C.

2.4. Properties of the composites

2.4.1. Test of mechanical properties
The tensile strength, elongation, compression strength, bending strength and other mechanical properties were tested by ETM104C electronic universal testing machine. Five samples of each composite were tested.

2.4.2. Melt flow rate
The melt flow rate was measured using a Melt Flow Indexer XNR-400C machine.

2.4.3. Morphology
The morphology of composites was tested by INSPECT S50 scanning electron microscopy (SEM) after the composites were covered with gold.

3. Results and discussion

3.1 Mechanical properties of the composites
The strength of the composites is changed with the increased of CaCO₃, which is shown in Figure 1. The strength of the composites is 7.1MPa, 7.8MPa, 8.6MPa, 7.7MPa while the content of CaCO₃ is 10%, 20%, 30%, 40%. It can be seen that the strength of the composites increase with the content of the CaCO₃ first, and up to the maximum when the content of CaCO₃ is 30%, then decrease with the content of CaCO₃. The results turn out that a small amount of CaCO₃ could enhance the strength. The strength will decrease with too much amount of CaCO₃.
3.2 Melt flow rate
The melt flow rate of the composites is 11.694g, 12.252g, 14.628g, 22.976g while the content of CaCO$_3$ is 10%, 20%, 30%, 40%, which is shown in Figure 2. CaCO$_3$ could disperse in the molecular chain of PCL with a small amount, which could reduce the frictional resistance of the chain of PCL. So the melt flow rate of the composites is increased with the content of CaCO$_3$, and up to the maximum while the content of CaCO$_3$ is 30%. Then the melt flow rate of the composites is decreased because the activity space of molecular chain was reduced when the content of CaCO$_3$ is more than 30%.
3.3 *The morphology of the composites*

The morphology of the composites is shown in the Figure 3. It can be seen from the picture that the PCL matrix is connected with each other closely and doesn’t have fault when the content of CaCO$_3$ is 10%, 20%. The PCL matrix is saturated when the content is 30%, and have fault when the content is 40%. The matrix has large gaps and holes, which reduce the strength and the melt flow rate.

![Fig.3 SEM morphology of the composites filled with different contents of CaCO$_3$](image)

- (a) 10%; (b) 20%; (c) 30%; (d) 40%

4. **Conclusions**

1. A small amount of CaCO$_3$ could enhance the strength of the PCL composites. The strength is up to maximum when the content is 30%. The matrix will have fault, and the strength of the composite decrease when the content of CaCO$_3$ is more than 30%.

2. A small amount of CaCO$_3$ could reduce the frictional resistance of the chain of PCL, and enhance the melt flow rate and the processing performance. Excessive content of CaCO$_3$ reduce the activity space of molecular chain and the melt flow rate, which demonstrate that the optimal content of CaCO$_3$ is 30%.

3. As shown in SEM figure, the matrix will have fault when the content of CaCO$_3$ is more than 30%.
Above all, the best content of CaCO$_3$ in the composites is 30%.

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