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Impact of coupling agent on properties of wood-plastic composite

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Abstract The impact of two coupling agents, maleic anhydride (coupling agent 1) and isocyanate (coupling agent 2) on the properties of wood-plastic composites (WPC) was studied. Wood-plastic composites were made with coupling agents 1 and 2 and properties were tested under the condition that the ratio of wood fiber to thermoplastic polymer was 7:3, target density was 0.7 g/cm³, press temperature was 175°C, press time was 8 min, and adding amount of coupling agent 2%. Results show that coupling agent 2 was superior to coupling agent 1 and had great effect on the physical and mechanical properties of WPC. When using the same coupling agent, the impact on their properties varied with different thermoplastic polymers.

Keywords wood fiber, thermoplastic polymer, coupling agent, wood-plastic composite, physical and mechanical properties

1 Introduction

In recent years, using thermoplastic polymer compounds, such as polyethylene (PE) and polypropylene (PP), with wood fibers to manufacture composite materials has become a new research field of industrial wood products. Such composites have advantages in dimensional stability, moldability, tensile strength and impact resistance (Xu et al., 2004). Polyolefin is composed of nonpolar molecules, whose molecular weights are very large, while wood fiber is composed of polar molecules. Therefore, in compounding these two materials, it is difficult to achieve great improvement in physical and mechanical properties. Some appropriate treatments must be carried out (Liao, 2003).

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Chemical modification can make wood fibers more compatible with a matrix. In our experiment, we used maleic anhydride, isocyanate and peroxide as coupling agents. Maleic anhydride has a function of inarch to thermoplastic; peroxide is used as an initiation to impel the inarch reaction of maleic anhydride. These two materials are mixed in an appropriate ratio. Isocyanate reacts with hydroxyls in wood fibers, which can improve the surface energy of wood fibers in order to modify the characteristics of the interface (Xu and Cai, 2004).

2 Materials and methods

2.1 Materials

There are many types of thermoplastic polymers, collectively four commonly used types in this experiment were polypropylene (PP), polystyrene (PS), polyethylene (PE), and acrylonitrile-butadiene-styrene (ABS). All four polymers are grains, ground in a mill. Grains are selected after screening with a 20-mesh screen. Wood fibers are selected from mixed species for medium density fiberboard (MDF) production. Two coupling agents were used: coupling agent 1 was maleic anhydride and dicumyl peroxide; as coupling agent 2 we used isocyanate. The amount of coupling agent added was 2% (Xu, 2005).

2.2 Methods

We determined that the ratio of wood fiber to thermoplastic polymer should be 7:3, the adding amount of the two coupling agent 2%, the density of the composite material 0.7 g/cm³. The hot press temperature was set at 175°C and the time to 8 min. According to different types of coupling agents, the following two methods of mixture were adopted.

First, the weighed wood fibers were put into a rotating blender and the mixing solution of acetone and isocyanate was injected at a certain ratio into the blender. After several cycles, the prepared thermoplastic polymers were added to make it fully mixed.

Second, the weighed wood fibers, which had already been adjusted to an appropriate moisture content (MC), were put into the rotating blender. At the same time, a certain amount of maleic anhydride and thermoplastic polymer were fully mixed and dicumyl peroxide was injected into this mixture. Then it was put into the rotating blender to mix completely (Li, 1989).

The mixture was formed into a 320 mm × 340 mm loose mat by hand. The mat was pre-pressed under 1 MPa at room temperature for 30 s and then moved into the hot-press machine for pressing. Pressure was applied under the following conditions: high-pressure 12 MPa, low-pressure 4 MPa, pressing time 12 min of which 3 min under high-pressure, and temperature was controlled at 175°C. To prevent the occurrence of plastic melting, a polyester film (0.5 mm thick) was affixed to the slab surface, which had the ability to resist the high temperature of 200°C (Selke and Wichman, 2004). The final thickness of the composite was controlled to about 10 mm. The hot press curve is shown in Fig. 1.

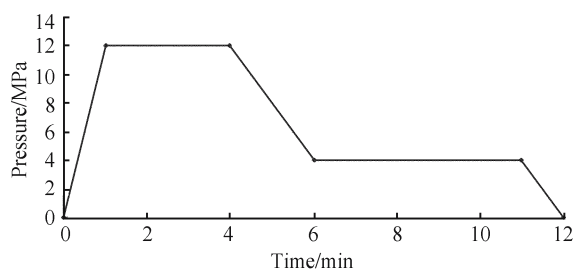


Fig. 1 Hot press curve of wood-plastic composite

The composite sheet must meet the national standards of MDF (GB 11718. 1-11718.10-89), used to compare different properties of mechanically produced composite materials, such as polymers, i.e. internal bond (IB) strength, modulus of rupture (MOR), modulus of elasticity (MOE) and thickness swelling (TS).

3 Results and analysis

Figures 2 to 5 show the various strengths of the polymers PP, PS, PE, and ABS mixed with wood fibers in the composite materials produced. These are, respectively, *IB*, *MOR*, *MOE* and *TS* under the conditions of using different coupling agents.

3.1 Internal bond

Figure 2 shows the *IB* of the mixture of the polymers PP, PS, PE and ABS with wood fibers in the production of composite materials under different conditions. The results are shown as follows.

As seen from Fig. 2, *IB* of the composite materials from different polymers and wood fibers clearly vary. The addition

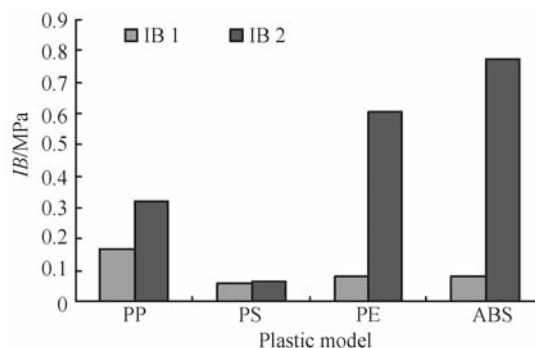


Fig. 2 *IB* of composite materials from different polymers and wood fibers

of coupling agent 1 to the PP composite material obviously resulted in a higher *IB* than to the other plastic combinations. The main reason is different molecular structures and nature of the four polymers. The addition of coupling agent 1 in the thermoplastic polymer results in a maleic anhydride grafting action and combines with wood fibers to form hydrogen bonds and cause esterification. Among these four polymers, the hydrogen bonding of PP is the strongest. Its combination is the best and its *IB* the highest.

We can also see from the figure that the addition of coupling agent 2 produces clearly a higher *IB* than that of coupling agent 1. It indicates that isocyanate not only plays the role of coupling agent, but also has a role as an adhesive.

3.2 Modulus of rupture

Figure 3 shows that the addition of coupling agent 1 results in similar *MOR* of the composite materials, made of the four different polymers and wood fibers. However, when coupling agent 2 is added, the *MORs* are very different. The composite material using ABS has maximum *MOR* followed by the PP composite material. The four polymers do not have the same molecular structure. The role of coupling agent 1, maleic anhydride, in combination with wood fibers results in a grafting reaction, where the polymer performance is weaker and the *MORs* are not much different. The major role of coupling agent 2 in composite materials is the same as that of adhesive, so the physical performance of the polymer is fully shown. There are few branches in PE macromolecular chains, the chains are flexible and the material rather soft. So their *MOR* is poor. The side of the benzene ring of PS makes for a difficult macromolecular structure and molecules move with difficulty. The stiffness of the material and its rigidity makes for a high performance in *MOR*. There are many side cymenes in macromolecules and the existence of side cymenes forms the molecular structure into a spiral shape. The arrangement is more regular and the rigidity of macromolecules is markedly enhanced. So, the stiffness and *MOR* of the material is higher. Acrylonitrile-butadiene-styrene is a copolymer mixture, with the common properties of three components: an acrylonitrile copolymer mixture has characteristics of

chemical resistance such as a certain surface rigidity; a butadiene copolymer makes rubber mixtures show toughness; and styrene make copolymer mixtures show thermoplastic polymer process characteristics. The synergy of every component makes the physical-mechanical properties of ABS excellent with the highest *MOR*.

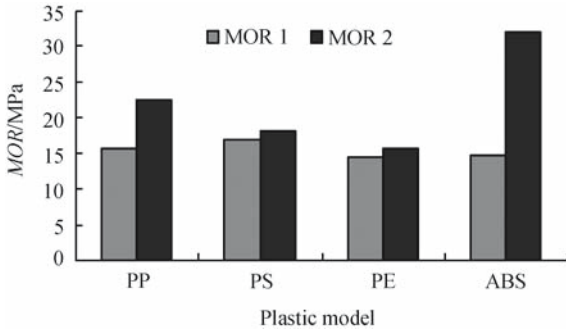


Fig. 3 *MOR* of plastic/wood-fiber composites

3.3 Modulus of elasticity

Figure 4 shows *MOE* of plastic/wood-fiber composites. The figure indicates that the four polymer materials are better, for *MOE* incorporates the rigidity of the materials which are not destroyed and is largely related to the constitution of a material. Comparing the four polymer materials, when coupling agent 2 is added, *MOE* is superior to that after the addition of agent 1. The addition of coupling agent 1 to the composite shows that the *MOE* of PS and ABS is superior to that of the other two polymers. Adding coupling agent 2 to the composite again shows the *MOE* of ABS is superior to the others. These are all related to the configuration of the polymer itself.

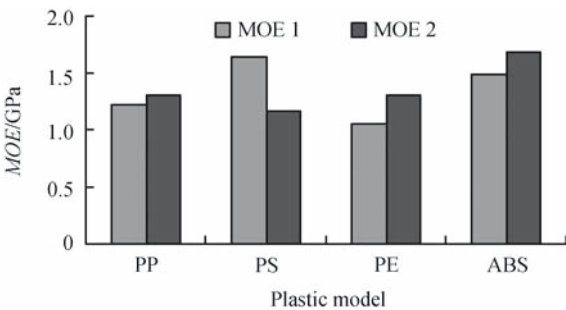


Fig. 4 *MOE* of plastic/wood-fiber composites

3.4 Thickness swelling

From Fig. 5, we can see that any composite in this experiment can meet *TS* value of the GB standards of MDF, because these polymers are water-repellent materials. When compounded

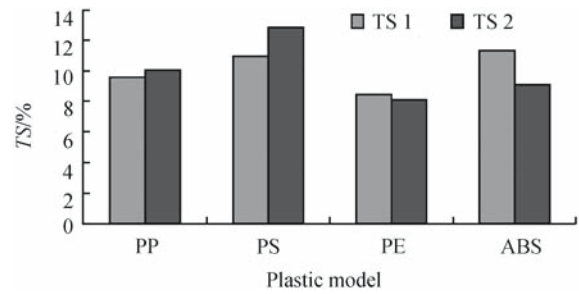


Fig. 5 *TS* of plastic/wood-fiber composites

with wood fibers, owing to the function of coupling agents, hydrogen bonds on fiber surfaces reduce and part of the fiber molecules are enwrapped by polymers. So compared with wood, *TS* of the composites has improved significantly.

4 Conclusions

1) When using the hot press technology to produce plastic/wood-fiber composites, the mixing ratio of wood fiber to plastic is 7:3. Under certain conditions, through adding maleic anhydride or isocyanate, plastic/wood-fiber composite materials can be produced.

2) Plastic/wood-fiber composite materials prepared with two coupling agents can meet the performance requirements set by national standards of MDF. From our comprehensive evaluation, we concluded that the performance of plastic/wood-fiber composite materials with the addition of coupling agent 2 is superior to that of coupling agent 1.

3) When other conditions are the same, different thermoplastic polymer composite materials show different impacts in their performances. These different impacts are inherent in the structure of the polymer itself.

References

- Li J (1989). Characteristic of Interface and Self-bonding Technology of Wood Materials. Harbin: Northeast Forestry University Press, 16–35 (in Chinese)
- Liao J P (2003). Holding history opportunity, accelerating the development of WPC industry. House Mater Appl, 5: 25–26 (in Chinese)
- Selke S E, Wichman I (2004). Wood fiber/polyolefin composites. Composites A, 35: 321–326
- Xu M, Cai Z (2004). Research of different modifiers affecting on wood-polymer composites properties. J For Res, 15(1): 77–79
- Xu M, Jiang X B, Wang K Q (2004). Research situation and application prospect of wood-plastic composites. For Sci Tech, 29(3): 41–43 (in Chinese)
- Xu M (2005). Study about compound technology of wood fiber/polymer. Dissertation for the Doctoral Degree. Harbin: Northeast Forestry University, 81–83 (in Chinese)