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Process and Structure of Electromagnetic Shielding Plywood Composite Laminated with Carbon Fiber Paper

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Abstract: Carbon fiber paper (CFP), a type of flexible planer electromagnetic shielding material with thin thickness, low density, and good adhesion property and permeability, was laminated with wood veneer to produce a plywood composite with good shielding effectiveness (SE). It was found that a hot-press pressure of 1.2 MPa and a double-sized adhesive concentration of 380 g/m^2 were most appropriate for the production of CFP plywood composites. SE of plywood composite laminated with single layer CFP was better than that before hot pressed, which result from the formation of three-dimensional and smaller conductive carbon fiber circuitries. The space between two-layer CFPs and the thickness of the surface-layer veneer had significant influence on SE. The SE of the composites laminated with two-layer CFPs was significantly higher than those with one-layer CFPs. The SE in the frequency range of 30 MHz to 1 GHz reached above 30 dB depending on the space between two-layer CFPs and the thickness of the surface veneer, which was sufficient SE for commercialization and the use of plywood composites.

Keywords: Carbon fiber paper, electromagnetic shielding, hot-press process, laminate structure, plywood composite.

1. INTRODUCTION

Wood is one of the most abundant biological materials, and timber products have been widely used in both structural and nonstructural applications such as furniture and building construction. However, timber products remain low-value added materials, especially for the products of fast-growing plantation wood, and many physical technologies have been attempted for the production of higher-value added products for the industry. One of the methods is to modify wood products in terms of their electromagnetic shielding functionality, and thus replace expensive and heavy metal shielding materials. This wooden functional material could also be used as shielding material to reduce harmful electromagnetic interference in the fields of military, precision instruments, and hospital equipment.

Electromagnetic shielding wooden composites have been studied for about 30 years, with concentration mainly on combining the conductive shielding with wooden elements and/or by high-temperature carbonization of wood constituents. Wood particles were coated with a layer of nickel by electroless plating technology [1-3], and the coated particles were then used for the production of particleboards, the SE of which could reach 40 dB in the frequency range of 10 MHz to 1 GHz [4]. Veneer has also been electroless-plated with nickel on its surface, and can reach an SE of 55-60 dB in the frequency range of 9 kHz to 1.5 GHz [5, 6]. The plywood made with the modified veneers by the γ-aminopropyltri-hydroxysilane (APTHS) before being plated with nickel could achieve an SE of higher than 60 dB in the frequency range of 10 MHz to 1.5 GHz [7].

Metal nets [8], metal fiber [9-11], and conductive powder [12] have also been mixed with wooden materials to prepare shielding composites. Among them, the fiberboard versions with two layers of 60 mesh copper wire nets placed on the top and bottom surfaces, respectively, have achieved the highest SE of 60 dB in the frequency range of 9 kHz to 1.5 GHz. It was also reported that the SE was higher when the metal nets were laminated on the surface layer than when they were laminated on the interlayer [8]. Conducting polymers, such as polyaniline and polypyrrole, were also applied in the wooden shielding material by in situ polymerization, and had an SE level above 10 dB in the frequency range of 100 MHz to 3 GHz [13]. Power coal carbon material was used to modify wood wool-cement boards. When the concentration of carbon material was 5wt% and 25wt%, the total insertion loss of electromagnetic wave in the frequency range of 2.5 GHz to 6 GHz could reach 20 dB to 40 dB [14]. Carbonized wooden material, such as solid wood panel [15] and fiberboard [16] could also improve SE, which could be further improved with structural designing. It was reported that the fiberboard composite designed with the metal net and conductive coating as reflective material on the two surface layers and barite powder and magnetite powder as an absorbing material in the core layer [17] could obtain an SE of more than 60 dB in the frequency range of 18.85 MHz to 1.46 GHz. The above studies on wooden shielding material could more or less enhance SE. However, further research is required to reduce costs and weight and improve processing efficiency.

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3.3.2. Two-layer CFPs Plywood Composites Laminated with Surface Veneers of Different Thickness

It can be seen from Figs. (**16**, **17**) that the thickness of surface veneer had a remarkable influence on its SE. The SE of plywood composites in the frequency range of 30 MHz to 1 GHz increased as the thickness of surface veneer decreased from 2.4 mm to 0.4 mm, which could be seen in both the five-layer plywood composites and the seven-layer plywood composites. The maximum difference reached about 10 dB. Overall, all SE in the frequency range of 30 MHz to 1 GHz reached above 30 dB when the thickness of surface veneer of five-layer plywood composites was 0.4 mm and that of seven-layer plywood composites was 0.4 mm and 0.8 mm, which met the requirement for commercial uses [25]. The SE in the seven-layer plywood composite with a surface veneer of 0.4 mm thickness had a maximum of 39 dB and a minimum of 34 dB in the frequency range. The dosage of carbon fiber was only 42 g/m^2, much lower than in previous studies, about 430 g/m^2 [19].

Fig. (16). SE of five-layer plywood composites laminated with surface veneer of different thickness.

Fig. (17). SE of seven-layer plywood composites laminated with surface veneer of different thickness.

Wood material consists of polar materials, *i.e.*, moisture, cellulose, hemicellulose, lignin, and a small amount of mineral material, and has some dielectric property [26]. Its wave impedance is greater than that of air; when an electromagnetic wave passes from air into the surface veneer, it gives rise to a refraction, the angle of which is less than that of incidence. As shown in Fig. (**13**), l_1 as surface veneer, also l_2 and l_3 as veneer, with the increase of the thickness of surface veneer the incident position (A_1) should move down and the incident position (A_2) also move down, so the distance of multiple reflection between two shielding material in finite width becomes shorter, which resulted in less SE.

CONCLUSION

(1) Electromagnetic shielding plywood composites laminated with CFP were investigated, illustrating that CFP is a promising material for realizing an industrial production of wooden composites with sufficient SE.

(2) It was demonstrated that CFP paper and wood veneer can appropriately laminate with a pressure of 1.2 MPa, a modified UF adhesive concentration of 380 g/m^2 (surface of veneer contacted with CFP), a press time of 1.2 min/mm, and a platen temperature of 110±5 °C.

(3) Both the space between two-layer CFPs in plywood composite and thickness of surface veneer had a remarkable influence on its SE, with the SE increasing as space increased and thickness decreased.

(4) The SE of the five-layer plywood composites laminated with two-layer CFPs (dosage of carbon fiber 42 g/m^2) reached above 30 dB in the frequency range of 30 MHz to 1 GHz when the thickness of its surface veneer was 0.4 mm; and the SE of the seven-layer plywood composites reached above 30 dB in the frequency range of 30 MHz to 1 GHz when the thickness of surface veneer was 0.4 mm and 0.8 mm. Therefore, both could be applied in commercial uses.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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