STUDY ON SOUND INSULATION PROPERTIES OF FLAX FIBER REINFORCED POLYPROPYLENE MATRIX COMPOSITES

by

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Original scientific paper
https://doi.org/10.2298/TSCI2503705Z

Fiber reinforced composites with fiber contents of 0%, 10%, 20%, 30%, and 40% were prepared using flax fiber as the raw material and polypropylene as the matrix. The effects of fiber content and surface treatment on the sound insulation of flax fiber reinforced composites were investigated by alkali treatment and coupling agent treatment. The results show that when the fiber content exceeds 10%, the sound insulation of the composite initially increases and then decreases with increasing voicing frequency. At the same intonation frequency, the lower the fiber content, the worse the sound insulation performance. When the fiber content exceeds 30%, the peak damping rate decreases. After surface treatment, the sound insulation performance of the composite was improved, and the sound insulation performance of the composite after coupling agent treatment was better than that of the composite after alkali treatment.

Key words: *flax fiber, polypropylene, content, surface treatment, sound insulation*

Introduction

Natural fibers possess a multitude of remarkable properties, including excellent mechanical properties [1, 2], high solar energy absorption [3], excellent sound absorption [4, 5], and excellent thermal insulation [4]. With the strengthening of global environmental awareness and the rise of *green projects*, as well as the continuous understanding of the excellent properties of hemp fiber, the development and application of hemp fiber reinforced thermoplastic composites have attracted more and more attention from the textile industry [6, 7]. Hemp fiber has the characteristics of high strength, high elastic modulus, friction resistance, high temperature resistance, rapid heat dissipation, low dust absorption rate, no static electricity, acid and alkali resistance, and non-perishableness in water. It meets the characteristics of composite materials. High orientation and high crystallinity make the fiber strong and tough, and the tensile strength is high, which can be used as a toughening fiber of composite materials. In addition, flax is easy to cultivate, has a short growth cycle, low price, biode-

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gradable and easy to recycle, and is the preferred raw material for reinforced fiber for the pursuit of green environmental protection [8]. Flax has sufficient resources in China, and as an industrial raw material, it is beneficial to environmental protection and sustainable development.

In this paper, flax staple fiber was used as the reinforcing body and polypropylene as the matrix, and flax fiber-reinforced polypropylene composite material was prepared by moulding technology [9], and flax fiber was surface-treated to investigate the influence of fiber content and surface treatment on the sound insulation performance [10] of flax fiber/polypropylene composite material.

Experiment

Flax fiber was provided by Zhejiang Golden Eagle Co., Ltd., polypropylene fiber was provided by Yancheng Weibang Engineering Materials Co., Ltd., NaOH was provided by Shanghai Nanxiang Reagent Co., Ltd., the KH-570 was provided by Shanghai Yanyu Biotechnology Co., Ltd., Y101 Raw cotton impurity Analyzer was bought from Changzhou First Textile Equipment Co., Ltd., A181AS27 Cotton carding net small prototype from Suzhou Huafei Textile Technology Co., Ltd., Plate vulcanizing machine from Qingdao Xincheng Yiming Rubber Machinery Co., Ltd., scanning electron microscope was made through JSM-5600 LV; Self-made testing device was used for sound insulation performance of composite materials.

The flax fiber was cut into 30 mm, placed in NaOH solution with 7.5% concentration and soaked for 1 hour at room temperature. After treatment, the fiber was washed and neutralized with dilute acid solution, and washed with clean water to become neutral, and dried in oven at 80 °C to constant weight for use.

Take an appropriate amount of ethanol solution, add formic acid solution and adjust the pH to 4-4.5. Add KH-570 silane coupling agent at a concentration of 3% to the above prepared solution, hydrolyze for 5 minutes, add fibers to the solution according to the bath ratio of 1:50, soak for 1 hour at room temperature, dry and set aside.

Preparation of sound insulation performance test device is illustrated in fig. 1.

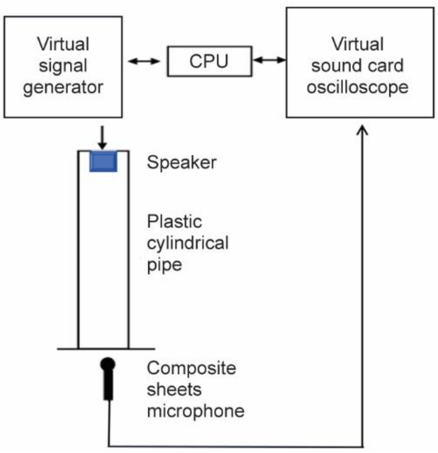

Figure 1. Testing device of acoustic property about composite

As shown in fig. 1, a set of simple measuring equipment is self-made to test the sound absorption and sound insulation performance of composite materials. The acoustic emission device is mainly composed of signal generator and loudspeaker (sound box) in the virtual sound card instrument, and the acoustic detection device is mainly composed of acoustic sensor (microphone), oscilloscope and computer in the virtual sound card instrument, forming the acoustic signal acquisition and processing system. The distance between the composite material and the microphone in the figure should be kept constant. Obviously, the greater the sound energy detected by the sound detector, the stronger the voltage signal will be. When the test result is stable, the voltage peak is displayed on the test interface. The sound insulation performance index is characterized by the peak attenuation rate of the sound voltage, namely ΔU. The larger ΔU is, the greater the attenuation amount and the better the sound insulation performance of the composite material. The ΔU is calculated by:

$$\Delta U = \frac{\Delta U_0 - \Delta U_1}{\Delta U_0} \times 100\% \tag{1}$$

where ΔU_0 is the peak voltage in the absence of composite material, ΔU_1 – the peak voltage in the presence of composite material, and ΔU – the peak voltage decay rate.

The polypropylene fiber is simply opened by hand and the appropriate amount of water is sprayed to avoid the influence of static electricity during combing. In order to evenly mix the alkali-treated flax fiber and the polypropylene fiber, the sandwich network is fed, *i.e.* the polypropylene fiber is divided into two layers and the flax fiber is evenly distributed in the middle of the polypropylene. The flax fiber contents are, respectively, 10%, 20%, 30%, and 40% to prepare the flax fiber/polypropylene fiber mixed fiber net each 100 g, and then the mixed fiber net is put on the plate vulcanization machine. The molding pressure is 10 Mpa, the molding time is 8 minutes, the molding temperature is 190 °C to prepare composite materials. For comparison, 100 g of pure polypropylene sheet was prepared at the same time. The sound insulation performance of the composite material was tested using the home-made sound insulation performance tester. The microscopic morphology of the fibers was examined using a Nippon Electron JSM-5600 LV type scanning electron microscope.

Results and discussion

Flax fiber microstructure after surface treatment is shown in fig. 2.

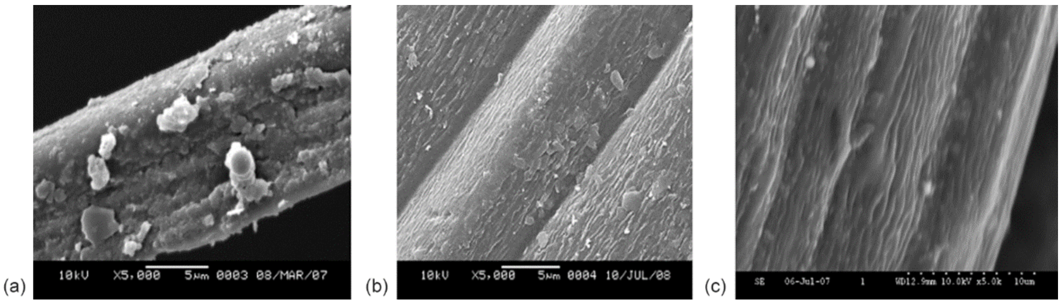

Figure 2. The SEM photographs of different modified flax fibers (a) untreated, (b) alkali treated, and (c) KH-570 treated

As can be seen from fig. 2, there is a large amount of colloid attached to the surface of untreated flax fiber, and the compatibility between the matrix and the fiber is poor, so there are many gaps between the fiber and the matrix. After alkali treatment at room temperature, the surface of flax fiber becomes rough after partial etching and the surface colloid is significantly reduced. The main reason is that NaOH reacts with flax cellulose to form alkali cellulose, which dissolves some of the low molecular substances such as pectin, lignin and hemicellulose on the surface of the fiber and improves the bond between the fiber and the matrix material. The gap between the matrix and the fiber is reduced. After the surface treatment with the silane coupling agent KH-570, the gum on the surface of the flax fiber was obviously removed and many grooves appeared on the surface. Compared with the alkali treatment, the roughness of the flax fiber surface was deepened. The reason was that the silane reacted with water to form silanol and ethanol, and the silanol and the hydroxyl group on the surface of the flax fiber were dehydrated to realize the bond between the silane and the flax fiber cell wall. Obviously, the bond between the matrix and the fiber is better and the gap is greatly reduced.

Figure 3 shows the effect of different flax fiber contents on the sound insulation performance of the composite, and a higher peak attenuation rate of the acoustic voltage indicates a better sound insulation performance. The flax fiber reinforced polypropylene composites with 0%, 10%, 20%, and 30%, 40% fiber content were designated as PP, FPP10, FPP20, FPP30, and FPP40, respectively. It can be seen from fig. 4 that the sound insulation performance of pure polypropylene and composites with 10% fiber content increases with increasing frequency, which shows that they have a better effect on the high frequency attenuation of composites. When the fiber content is more than 10%, the sound insulation performance of the composite first increases and then decreases with the increase of sound frequency, and the blocking effect of the frequency of 6000 Hz is the best. In addition, it can be seen from fig. 4 that when the fiber content is low, the sound insulation performance is worse for the same sound frequency; the lower the content, the worse the sound insulation performance. The main reason for this is that the flax fiber has a sound absorbing function, but when the fiber content exceeds 30%, the stress peak attenuation rate decreases instead. The main reason for this is that the addition of flax fiber can effectively provide sound insulation when the content is too high. However, the increased voids within the composite allow some of the sound to pass through completely.

Figure 4 shows the effect of surface treatment on the acoustic properties of the composite. The fiber reinforced composites with 30% fiber content treated with alkali and coupling agent were named AFPP30 and SFPP30, respectively. It can be seen from fig. 4 that after surface treatment, the sound insulation performance of the composite material increases significantly, and the sound insulation performance of the composite material treated with coupling agent is better than that of the composite material treated with alkali. The main reasons for this are: the surface roughness of the flax fiber is improved after the surface treatment, and the surface roughness of the fiber after the coupling agent treatment is higher than that of the alkali treatment. Therefore, the bonding effect between the matrix and the flax fiber is better, and the gap between the matrix and the fiber is smaller. When the sound is projected

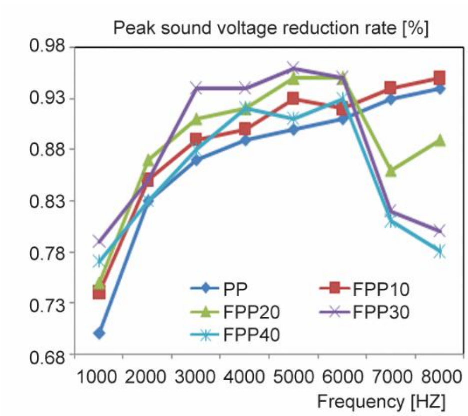

Figure 3. Effect of fiber content on elongation of flax/polypropylene composites

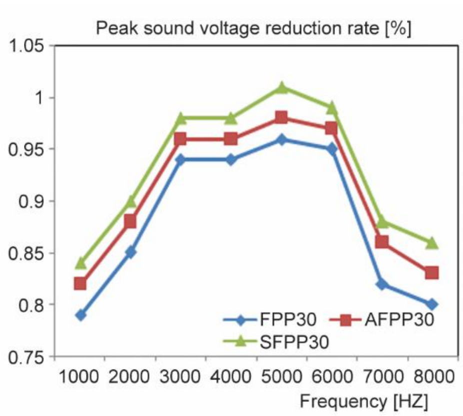

Figure 4. Effects of surface modification on acoustic property of flax/polypropylene composites

onto the surface of the flax fiber, the gap provides a good reflection path for the sound. The roughness of the flax fiber surface provided a good reflecting surface, and the sound could not pass through the composite after many reflections, which was consistent with the microstructure of the fiber surface after flax treatment.

Discussion and conclusion

Here is a large amount of colloid on the surface of untreated flax fiber. After alkali treatment at room temperature, the surface of flax fiber is hairy. The raw part became rough after etching, and the surface of flax fiber became rougher after surface treatment with silane coupling agent KH-570.

When the fiber content exceeds 10%, the sound insulation of the composite initially increases and then decreases as the voicing frequency increases. At the same intonation frequency, the lower the content, the worse the sound insulation performance. When the fiber content exceeds 30%, the voltage peak damping rate decreases.

After surface treatment, the sound insulation performance of the composite material is improved, and the sound insulation performance of the composite material treated with coupling agent is better than that of the composite material treated with alkali.

Our work can be extended to the nanofiber reinforced honeycomb structure and the fractal sandwich structure, as discussed in [11, 12].

Acknowledgment

This work is supported by Provincial Scientific Research Platform Open Project Funding of Yancheng Polytechnic College (YGKF202011), Jiangsu Higher Vocational College Teachers' Professional Leaders' High and Training (2022TDFX008), Qing Lan Project of Jiangsu Colleges and Universities for Excellent Teaching Team (2023 No. 27), the doctoral research initiation fund project of Yancheng Polytechnic College (2023), Jiangsu Province Higher Vocational Education High-level Major Group Construction Project (2020 No. 31), Brand Major Construction Project of International Talent Training in Colleges and Universities (2022 No. 8), Key technology innovation platform for flame retardant fiber and functional textiles in Jiangsu Province (2022JMRH-003).

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Paper submitted: April 18, 2024
Paper revised: June 20, 2024
Paper accepted: June 25, 2024