Heliyon 10 (2024) e33869

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Research on mechanics and acoustic properties of Jute fiber composite material

Yuan Wang *, Tianqiang Du, wenkai Ma, Pengyu Song, Yiyu Chen

CATARC Component Technology (Tianjin) Co., Ltd., Tianjin, China

ARTICLE INFO

Keywords:
Composites
Amino silicone oil
Fiber content
Thermo gravimetry
Noise reduction
Sound absorption reduction

ABSTRACT

In this study, the loss of quality from the oxidative thermal decomposition of jute fiber was explored during the production of reinforced composite materials. Amino silicone oil was used to modify jute fiber, which was then subjected to thermogravimetric analysis. The modified fiber's thermal decomposition temperature was found to be 271 °C, enhancing the composite's thermal stability. The study also investigated how different jute fiber content affected the mechanical and sound absorption properties of composite materials. Results showed that jute fiber composites had better mechanical properties than pure polypropylene materials, and the average sound absorption coefficient of jute polypropylene composites increased with fiber content. Adding jute fiber to polypropylene effectively improved the sound absorption and noise reduction performance of the material. The average sound absorption coefficient of the composite material at a mass content of 20 wt% was 120 % higher than that of the polypropylene matrix material.

1. Introduction

With the rise of environmental awareness in society, hemp fiber composites, which are widely sourced, lightweight, inexpensive, environmentally friendly, and naturally degradable, are gaining increasing attention in the automotive and other industries [1]. Hemp fibers have natural plant cavities and multi-scale structures, offering superior sound absorption performance compared to synthetic fibers. Therefore, their composites have significant advantages in sound absorption, noise reduction, and thermal insulation [2]. Compared to glass fiber reinforced plastic parts, hemp fiber composite molded products have a lower density and consume less energy during use. Additionally, they have lower hardness, do not produce sharp fragments upon breakage, and do not cause skin and respiratory allergies like glass fibers, making them safer. Thus, the development and application of hemp fiber composites are of great significance to the automotive industry, which demands green, lightweight, safe, and comfortable materials [3,4].

Jute fiber offers several advantages, including excellent performance, affordability, and energy conservation, as well as environmental protection. Due to the superior stiffness and strength of jute fiber-reinforced resin composites compared to traditional resin materials, they play an important role in the lightweight, energy-saving, and environmental protection of automobiles [5]. However, jute fibers have poor temperature resistance, and the molding temperature for preparing jute fiber-reinforced resin composite materials is 180 °C. At this temperature, the jute fibers undergo thermal decomposition, which results in a loss of quality and defects in the performance of the prepared materials. Furthermore, the adhesion between jute fiber and polypropylene is poor [6]. In order to enhance the interface compatibility and overall performance of fiber-reinforced polymer matrix composites, both domestic and foreign

* Corresponding author.
E-mail address: wangyuan2020@catarc.ac.cn (Y. Wang).

https://doi.org/10.1016/j.heliyon.2024.e33869
Received 30 April 2024; Received in revised form 27 June 2024; Accepted 28 June 2024
Available online 28 June 2024
2405-8440/

scholars have proposed a range of natural fiber modification methods. These methods include cleaning with sodium hydroxide or a potassium permanganate aqueous solution [7–10]. Kabir M. M et al. investigated the use of alkaline treatment on natural plant fibers to separate fiber bundles into smaller fibers and increase the fiber surface area [11–13]. This process enhanced the mechanical properties of fiber-reinforced polypropylene composites. Veronica et al. conducted a study on amino silicone oil and discovered its favorable high-temperature resistance, low surface tension, excellent film-forming capabilities, and its non-toxic, environmentally friendly, and sustainable nature [14]. Due to its excellent properties, it is commonly used as a modifier in fiber-reinforced polypropylene composites [15].

Domestic and international experts and scholars have conducted extensive research on the combined modification treatment of various materials [16–19]. However, there is limited research on the sound absorption and noise reduction properties of natural fiber composite materials. In automotive interior materials, the sound absorption and sound insulation performance directly affect driving comfort. Fibers have a good sound absorption effect.

Adding plant fibers to chemical materials, such as polypropylene, produces materials with excellent noise reduction performance. Luo et al. [20] utilized natural plant fibers as additives to fabricate composite materials and conducted tests on sound absorption and noise reduction. Experimental results have shown that incorporating natural plant fibers can significantly enhance the sound absorption and noise reduction capabilities of the material in comparison to the original substrate.

There is a relative lack of research on the sound absorption and noise reduction characteristics of composite materials, as well as the thermal stability analysis of modified jute fibers. Therefore, this study prepared treated and untreated jute fibers with amino silicone oil and conducted surface microstructure analysis, thermogravimetric testing, and other research aspects to investigate the effectiveness of amino silicone oil treatment in enhancing the thermal stability of the fibers. Different composite materials with varying jute fiber contents were also prepared to investigate the influence of different jute fiber contents on their mechanical properties, as well as their sound absorption and noise reduction performance.

2. Materials and methods

2.1. Materials

The raw jute fibers are cleaned to remove surface dirt and impurities, then placed in a drying oven for heating and drying. The drying time is 6 h, and the drying temperature is between 90 and 110 °C. The dried jute is then soaked in an emulsion and subjected to ultrasonic vibration for a period of time to ensure thorough interaction between the emulsion and the jute fibers. After this, the jute fibers are dried and set aside for later use. Additionally, an equal amount of clean, dry, unmodified jute fibers is prepared for comparison. First, the dried jute fibers and polypropylene are fed into an extruder (model: TDS-300) in the required proportions. The jute fibers are fed through the traction section of the machine, while the polypropylene pellets are added through the hopper. Under specific temperature conditions and a twin-screw rotation speed of 50 r/min, with a melt pressure of PV1.6 MPa and SV12.0 MPa, and a main motor current of 15A, a cylindrical jute fiber-reinforced polypropylene composite material is extruded from the machine head. After cooling and shearing, composite materials with different jute fiber mass fractions are prepared, with mass fractions of 0 %, 5 %, 10 %, 15 %, and 20 %. The main chemical materials for the surface modification solution of the jute fibers are listed in the Tables 1 and 2 below.

The test specimens for the bending test, sound absorption and noise reduction test, and tensile test are shown in Fig. 1, respectively.

2.2. Methods

2.2.1. Thermogravimetric analysis

Thermogravimetric analysis (TGA) is one of the methods used to study the thermal stability and composition of materials. In this paper, a constant pressure variable temperature analysis method was employed using a simultaneous analyzer (NETZSCH STA449C, Germany) to test treated and untreated natural hemp fibers in an argon environment. The testing standard followed was BS EN ISO 11358–1997 ″Plastics. Thermogravimetric analysis of polymers.” The experimental procedure involved placing a crucible containing the sample on a thermal balance. Gas was introduced, and the initial mass was recorded. The program temperature was set to gradually increase the temperature of the treated and untreated hemp fibers from room temperature (23 °C) to 600 °C at a heating rate of 23.2 K/10.00 min, ensuring that the thermal analysis curve eventually reached a stable state. The surface observation of jute fibers was conducted using a scanning electron microscope (JSM-5610) to analyze the surface morphology of the jute fibers before and after treatment.

Table 1
Main materials for jute fiber surface treatment solution.

Material	Supplier	Grade
Jute	Changsha Zhongnong Institute	Industrial
Amino Silicone Oil	Zhuangjie Chemical Co., Ltd.	Industrial
Anhydrous Ethanol	Sinopharm Group	Sinopharm Group
n-Butanol	Sinopharm Group	Sinopharm Group

Table 2
Extrusion-injection molding processing equipment.

Name	Company	Mode
Precision Balance	Shanghai Guangzheng Medical Instrument Co., Ltd.	YP1002
Electric Blast Drying Oven	Shanghai Experimental Instrument Factory Co., Ltd.	101
Granulator	Nanjing Yuesheng Extrusion Machinery Co., Ltd.	TDS-30D
Injection Molding Machine	Zhejiang Jinying Plastic Machinery Co., Ltd.	GEK80
Plastic Pelletizer	Kehao Plastic Machinery Factory	180
CNC Ultrasonic Cleaner	Kunshan Ultrasonic Instrument Co., Ltd.	KQ-300DB

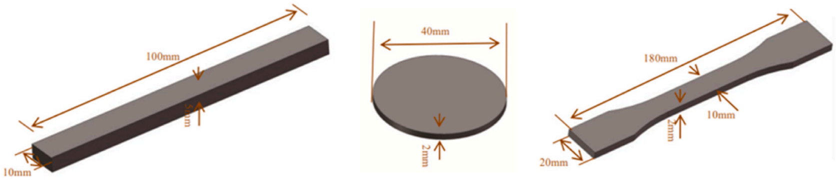

Fig. 1. Size of specimens: (left)Bending test specimen.(middle)Sound absorption test specimen. (right)Tensile test specimen.

2.2.2. Mechanical tests

Mechanical testing was conducted using a WDW20 electronic universal testing machine (Changchun New Testing Machine Co., Ltd.). Tests were performed three times at room temperature, and the average value was taken. The tensile performance test was carried out according to GB/T 1447–2005 ″Test Method for Tensile Properties of Fiber-Reinforced Plastics." The testing method involved placing the specimen of specified dimensions on the operating table of the electronic universal testing machine, loading it slowly and uniformly until the specimen broke. The machine was then turned off, and the maximum load value at the time of breakage was recorded. The bending performance test was conducted according to GB/T 1449–2005 ″Test Method for Bending Properties of Fiber-Reinforced Plastics." The testing method involved placing the specimen of specified dimensions on the operating table of the electronic universal testing machine, with the center indenter of the machine pressing down at a speed of 2 mm/min. The indenter and supports were kept parallel.

2.2.3. Transfer function measurement method

The transfer function measurement method is used to calculate the sound absorption coefficient of acoustic materials by obtaining the reflection coefficient from the sound pressure collected by two microphones in front of the sample [21,22], as shown in Fig. 2.

The test principle of transfer function method is shown in formula (1), where P_i is the base plane (the amplitude of P_I on x = 0; Pr is the amplitude of P_R on the datum plane (x = 0); k_0 is the complex wave number.。

$$P_I = P_i e^{jk_0 x}$$
$$P_R = P_r e^{-jk_0 x} \tag{1}$$

Let the distance between the two microphones and the material be x_1 and x_2, then two The sound pressure P_1 and P_2 at the microphone position are calculated by formula (2), respectively.

$$P_1 = P_i e^{jk_0 x_1} + P_r e^{-jk_0 x_1}$$
$$P_2 = P_i e^{jk_0 x_2} + P_r e^{-jk_0 x_2} \tag{2}$$

Where P_I and P_R are the amplitudes of the incident and reflected sound waves, respectively, at the reference plane (x = 0); k_0 is the complex wave number; x_1 and x_2 are the distances from the material to the microphones; P_1 and P_2 are the sound pressures at the microphones.

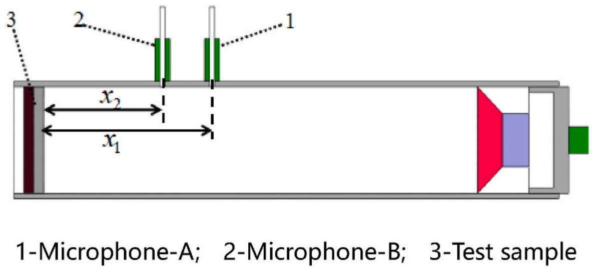

Fig. 2. Diagram of transfer function measurement method.

In formula (3) the transfer functions for the incident wave and reflected wave are denoted as H_1 and H_2, respectively.

$$H_1 = \frac{P_{1I}}{P_{2I}} = e^{jk_0(x_1 - x_2)}$$
$$H_2 = \frac{P_{1R}}{P_{2R}} = e^{-jk_0(x_1 - x_2)} \tag{3}$$

In formula (4) since $P_R = rP_I$ (r is the normal reflection factor), the transfer function of the total field, H_{12}, can be calculated using Equation (2):

$$H_{12} = \frac{P_2}{P_1} = \frac{e^{jk_0x_2} + re^{-jk_0x_2}}{e^{jk_0x_1} + re^{-jk_0x_1}} \tag{4}$$

In formula (5) based on the expressions for H_1, H_2 and H_{12}, r can be obtained.

$$r = \frac{H_{12} - H_I}{H_R - H_{12}} e^{2jk_0x_1} \tag{5}$$

In formula (6) expression for the normal incident sound absorption coefficient α can be derived, allowing for the calculation of the sound absorption coefficient.

$$\alpha = 1 - |r|^2 \tag{6}$$

2.2.4. Sound absorption and noise reduction experimental test system

Currently, there are two methods for measuring sound absorption and noise reduction: the reverberation chamber method and the impedance tube method. In this experiment, the impedance tube method was used to test the sound absorption coefficient of the prepared plant fiber composite materials, as shown in Fig. 3.

A stable white signal source was outputted from the computer to the TP60 power amplifier. The amplified white signal was then transmitted to the AFD1000 impedance tube, where the built-in speaker emitted sound waves. The M370 pressure sensor detected the internal sound wave signal in the impedance tube and transmitted it to the data collector. Finally, the AFD1001 analysis software was used to calculate the sound absorption coefficient of the materials. This experiment tested and analyzed composite materials with varying jute fiber contents. The experimental setup is shown in Fig. 4.

3. Results

3.1. Thermogravimetric analysis

Thermogravimetric analysis was used to investigate the thermal properties of jute fibers treated with amino silicone oil and untreated jute fibers.

The thermal decomposition temperature of jute fibers is 150 °C. As shown in Fig. 5, the TG curve of jute fibers indicates that the untreated jute fibers experience a weight loss rate of 6.5 % at 150 °C, whereas the jute fibers treated with amino silicone oil exhibit a weight loss rate of 6.5 % at a temperature of 271 °C. The jute fibers treated with amino silicone oil have an increased charring decomposition temperature of 121 °C compared to untreated jute fibers. This is because the active hydroxyl groups in jute fibers react

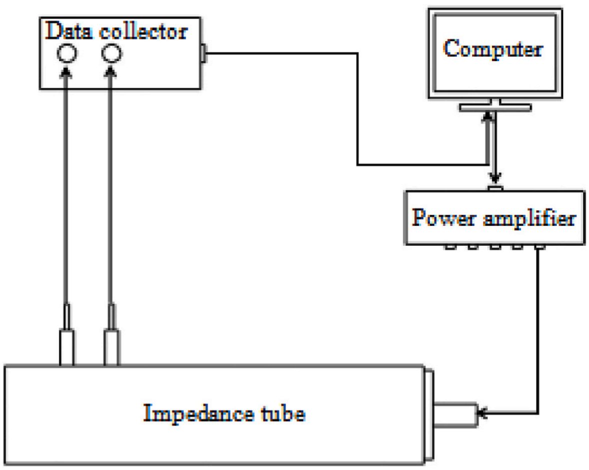

Fig. 3. Schematic diagram of sound absorption and noise reduction experimental test system.

Fig. 4. Composition of sound absorption and noise reduction experimental test system.

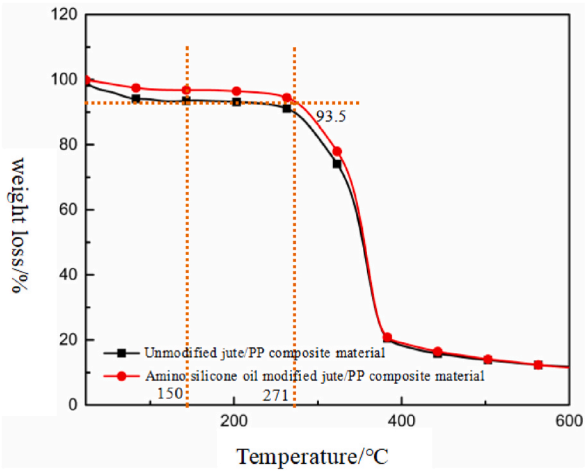

Fig. 5. Thermogravimetric analysis test result graph.

with the amino groups in amino silicone oil, which reduces the hydroxyl value of natural fibers and alters their water absorption properties from hydrophilic to hydrophobic. As a result, jute fibers absorb less moisture in the air. Therefore, the loss of moisture mass is reduced during heating. Additionally, amino silicone oil can form a protective film on the surface of jute fibers, enhancing their heat resistance and consequently raising the thermal decomposition temperature of the fibers.

As shown in Fig. 6 untreated jute fibers have a rough and uneven surface with more impurities. In contrast, Fig. 7 depicts jute fibers treated with amino silicone oil. After treating the jute fibers with amino silicone oil, the impurities on their surface are eliminated. This is because the amino silicone oil dissolves the small organic impurities, effectively removing any fine impurities. Additionally, a thin film of amino silicone oil is formed on the surface of the fibers [23,24], which effectively enhances the thermal stability of the fibers

Fig. 6. SEM image of untreated jute fiber surface.

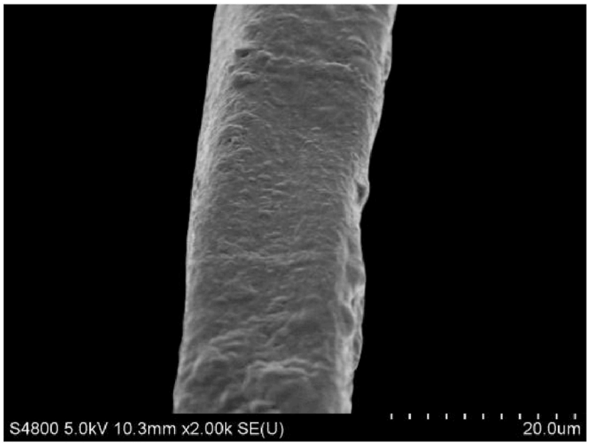

Fig. 7. SEM image of treated jute fiber surface.

internally.

3.2. Mechanical tests

Fig. 8 shows strength performance is a measure of a material's resistance to external forces. As shown in Figure, the jute fiber-reinforced polypropylene composite material with a fiber content of 20 wt% exhibits an increase in tensile strength and bending strength of 51.4 % and 37.97 %, respectively, compared to pure polypropylene material. As shown in Fig. 8(left), the tensile strength of the composite materials with fiber contents of 5 %, 10 %, 15 %, and 20 % is 21.3 MPa, 23.2 MPa, and 34.5 MPa, respectively, which is higher than that of pure polypropylene material (17.9 MPa). As shown in Fig. 8(right), the bending strength of the composite materials with fiber contents of 5 %, 10 %, and 15 % is 35 MPa, 37.4 MPa, and 38 MPa, respectively, which is higher than that of the original material (29.5 MPa).

Fig. 9 shows the cross-sectional morphology of the jute/polypropylene composite material, indicating a strong adhesion between the jute fibers and polypropylene. When subjected to stress, the stress is transferred from the matrix to the fibers. The strength of jute fibers is much higher than that of polypropylene, thereby enhancing the mechanical performance of the material.

The elastic modulus is a fundamental property that reflects a material's ability to resist deformation under stress. As shown in Fig. 10(a), the performance results of the elastic modulus for different fiber contents are presented. When the fiber mass fraction is 0 %, 5 %, 10 %, 15 %, and 20 %, the elastic modulus is 1.352 GPa, 1.52 GPa, 1.646 GPa, 1.78 GPa, and 1.952 GPa, respectively. It can be observed that the addition of jute fibers effectively enhances the elastic modulus performance of polypropylene. The jute fiber-reinforced polypropylene composite material, with a fiber content of 20 wt%, has an elastic modulus that is 44.38 % higher than that of pure polypropylene material. Due to the relatively high elastic modulus of jute fibers, incorporating them into the matrix effectively enhances the overall elastic modulus. Furthermore, the higher the jute fiber content, the greater the improvement in performance.

As shown in Fig. 10(b), the elongation of the fracture in the composite materials decreases as the fiber content increases. This is because jute fibers are rigid and brittle materials, and a higher fiber content makes the composite material more brittle [21].

3.3. Sound absorption coefficient

When sound waves encounter obstacles, some of the waves will transmit through the object, some will be reflected, and a small portion will be converted into thermal energy. The sound absorption performance is not only related to the properties of the material itself but also to the wavelength of the sound wave. In engineering applications, the average sound absorption coefficient of a material is determined by measuring its absorption at six frequencies: 4000Hz, 2000Hz, 1000Hz, 500Hz, 250Hz, and 125Hz. This average value is commonly referred to as the material's average sound absorption coefficient [25]. Fig. 11 shows the sound absorption coefficient at various fiber contents and sound wave frequencies. At the same frequency, a higher fiber content results in a greater sound absorption coefficient, leading to improved sound absorption and noise reduction effects.

As shown in Fig. 12, the average sound absorption coefficients of the composite materials with jute fiber contents of 5 %, 10 %, 15 %, and 20 % are 0.2675, 0.3003, 0.3895, and 0.4435, respectively. These values are 32.7 %, 49.0 %, 93.2 %, and 120.0 % higher than the average sound absorption coefficient of pure PP material (0.2016). The average sound absorption coefficient increases with an increase in jute fiber content. The jute plant fibers have a central channel called the "cell lumen," which transports nutrients through the plant's cell wall. Each jute fiber cell wall consists of the middle lamella, primary wall, and secondary wall, which can be further divided into the outer layer, middle layer, and inner layer [26,27]. When sound waves enter the jute fiber-reinforced resin composite, some of the sound waves are reflected, while others penetrate into the interior of the plant fibers. The sound waves that enter the interior of the fibers cause them to vibrate. This vibration leads to friction between the fibers and between the fibers and the matrix. As

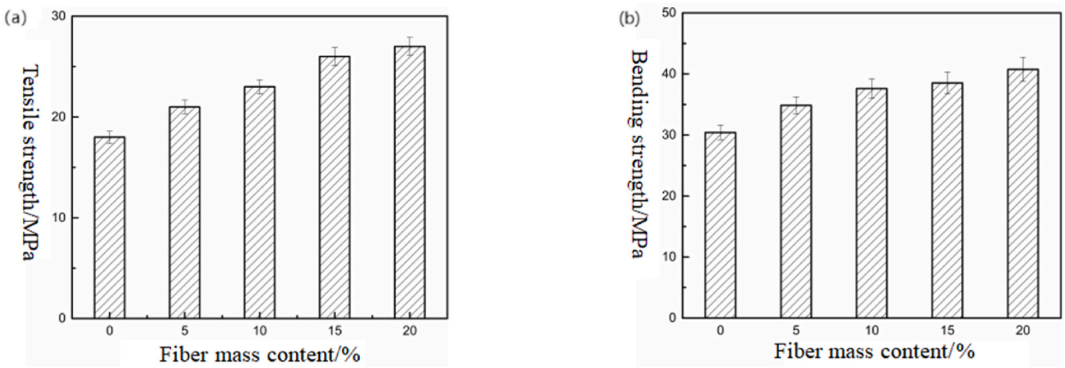

Fig. 8. Tensile mechanical properties with different fiber contents: Tensile strength(a) and Bending strength(b).

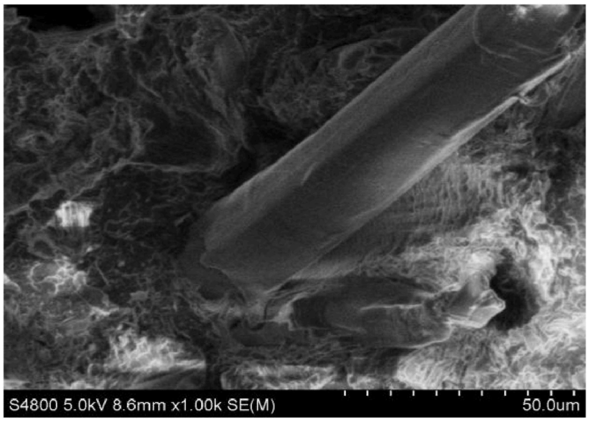

Fig. 9. SEM image of the cross-section of the composite material.

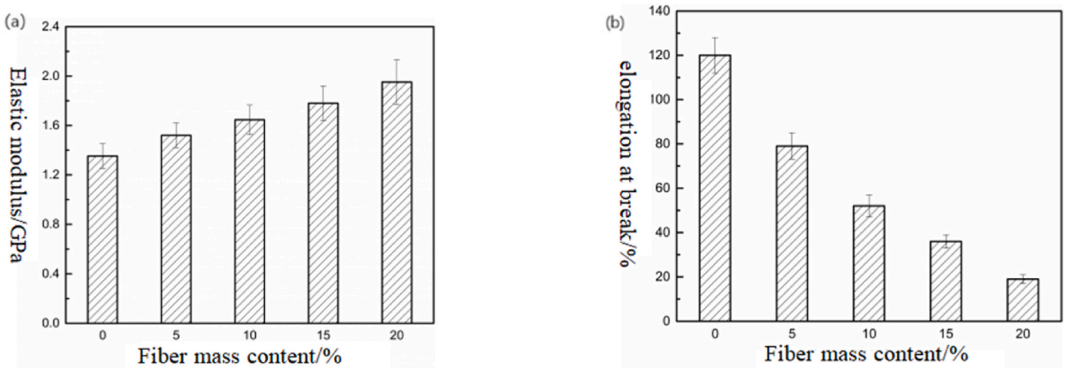

Fig. 10. Tensile mechanical properties with different fiber contents: Elastic modulus(a) and Fracture elongation(b).

a result, viscous resistance is formed, converting sound energy into thermal energy and ultimately reducing the sound. At the same time, multiple reflections and refractions occur between the fiber-matrix interface and within the fibers, which further attenuate the sound energy. On the other hand, compared to pure PP material, jute fibers have plant tissue pores and fiber cavities, making it easier for sound waves to transmit through the material [28]. Therefore, the fiber-reinforced composite material enhances its sound absorption coefficient.

4. Conclusions

In conclusion, the mechanical properties of polypropylene composite materials with added jute fibers improve with increasing fiber

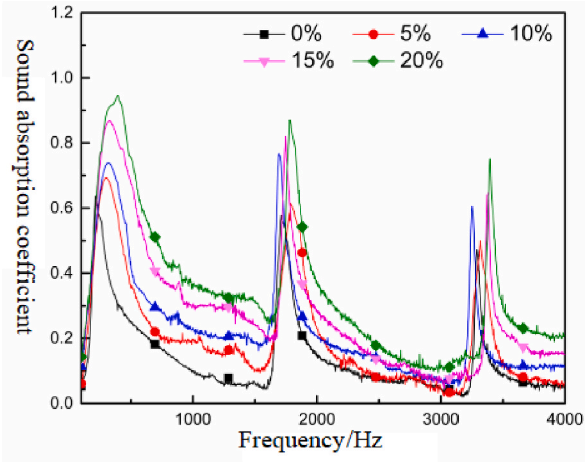

Fig. 11. Relation diagram of sound absorption coefficient and frequency.

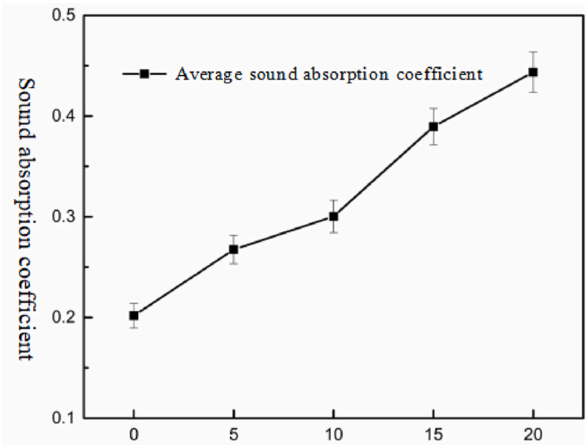

Fig. 12. Relation diagram of average sound absorption coefficient and jute content.

content. Yellow jute fibers treated with amino silicone oil exhibit a 121 °C increase in char decomposition temperature compared to untreated jute fibers, effectively raising the fiber's carbonization temperature and expanding the potential applications of yellow jute fibers in various fields and products. The average sound absorption coefficient of yellow jute polypropylene composite materials increases with the fiber content. Adding jute fibers to polypropylene effectively enhances the material's sound absorption and noise reduction performance. At a mass fraction of 20 wt%, the average sound absorption coefficient of the composite material is 120 % higher than that of the polypropylene base material. Jute fibers, when applied in composite materials with thermoplastic resin as the matrix, offer advantages such as high modulus and strength, long continuity, light weight, good reprocessing performance, and biodegradability. The resulting composite materials have broad application prospects in industries such as packaging, automotive, construction, and home furnishings.

Funding

None.

Data availability

The raw/processed data required to reproduce these findings cannot be shared at this time as the data also forms part of an ongoing study.

CRediT authorship contribution statement

Yuan Wang: Writing – original draft. **Tianqiang Du:** Writing – review & editing, Conceptualization. **wenkai Ma:** Data curation. **Pengyu Song:** Formal analysis. **Yiyu Chen:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] H. Bahrambeygi, N. Sabetzadeh, A. Rabbi, K. Nasouri, A.M. Shoushtari, M.R. Babaei, Nanofibers (PU and PAN) and nanopar ticles (Nanoclay and MWNTs) simultaneous effects on polyure thane foam sound absorption, J. Polym. Res. 20 (2) (2013).
[2] A.O. Sanches, G.F. Teixeira, M.A. Zaghete, et al., Influence of polymer insertion on the dielectric, piezoelectric and acoustic properties of 1–0–3 polyurethane/cement-based piezo compos ite, Mater. Res. Bull. 119 (2019).
[3] Y. Li, X. Yi, T. Yu, G. Xian, An overview of structural functional-integrated composites based on the hierarchical microstructures of plant fibers, Adv. Compos. Hybrid Mater. 1 (2) (2018) 231–246.
[4] J. Shen, X. Li, X. Yan, Mechanical and acoustic properties of jute fiber-reinforced polypropylene composites, ACS Omega 6 (46) (2021) 31154–31160.
[5] L.P. He, C.X. Pi, D.C. Chen, et al., Effect of fiber content on mechanical properties and vibration damping characteristics of bast fiber reinforced composites, J. Hunan Univ. 45 (12) (2018) 66–72 (in Chinese).
[6] L. Yan, C. Nawawi, J. Krishnan, Flax fibre and its composites – A review, Composites, Part B 56 (1) (2014) 296–317.
[7] L.P. He, W.J. Li, D.C. Chen, Microscopic mechanism of amino silicone oil modification and modification effect with different amino group contents based on molecular dynamics simulation, Appl. Surf. Sci. 440 (2018) 331–340.
[8] A. Demir, Y. Seki, E. Bozaci, Effect of the atmospheric plasma treatment parameters on jute fabric: the effect on mechanical properties of jute fabric/polyester composites, J. Appl. Polym. Sci. 121 (2) (2011) 634–638.
[9] J.M. Cervantesuc, et al., Effect of fiber surface treatment on the fiber-matrix bond strength of natural fiber reinforced composites, Compos. B Eng. 30 (3) (1999) 309–320.
[10] Y. Xie, C.A.S. Hill, Z. Xiao, Silane coupling agents used for natural fiber/polymer composites: a review, Composites Part A 41 (7) (2010) 806–819.
[11] L.P. He, W.J. Li, D.C. Chen, et al., Investigation on the microscopic mechanism of potassium permanganate modification and the properties of ramie fiber/polypropylene composites, Polym. Compos. 39 (9) (2018) P3353–P3362.
[12] M.M. Kabir, H. Wang, K.T. Lau, Chemical treatments on plant-based natural fibre reinforced polymer composites: an overview, Composites, Part B 43 (7) (2012) 2883–2892.
[13] B. Lu, L.W. Zhang, J.C. Zeng, et al., Natural Fiber Reinforced composites[M], Chemical Industry Press, Beijing, 2005, pp. 34–50 (in Chinese).
[14] S.N. Monteiro, V. Calado, R.J.S. Rodriguez, Thermogravimetric behavior of natural fibers reinforced polymer composites—an overview, Mater. Sci. Eng., A 557 (none) (2012) 17–28.
[15] N. Saba, M. Jawaid, M.T. Paridah, Mechanical properties of kenaf fibre reinforced polymer composite: a review, Construct. Build. Mater. 76 (2014) 87–96.
[16] L. Marrot, A. Lefeuvre, B. Pontoire, Analysis of the hemp fiber mechanical properties and their scattering (Fedora 17), Ind. Crops Prod. 51 (6) (2013) 317–327.
[17] W. Li, H.Y. Huang, Y.Q. Wu, Preparation of jute fibers reinforced epoxy resin composites by VARTM, J. Hunan Univ. 42 (12) (2015) 15–20 (in Chinese).
[18] H. Fang, Y. Zhang, J. Deng, Effect of fiber treatment on the water absorption and mechanical properties of hemp fiber/polyethylene composites, J. Appl. Polym. Sci. 127 (2) (2012) 942–949.
[19] Y. Luo, Y. Li, Acoustical studies of natural fiber reinforced composites, J. Mater. Eng. (4) (2010) 51–54 (in Chinese).
[20] L.P. He, W.J. Li, D.C. Chen, et al., Effects of amino silicone oil modification on properties of ramie fiber and ramie fiber/polypropylene composites, Mater. Des. 77 (2015) 142–148.
[21] J. Yuan, S. Lin, C.C. He, Transfer function measurement method of sound absorption coefficient in impedance tube, Noise and Vibration Control 26 (1) (2006) 68–70 (in Chinese).
[22] Y.A. EL-Shekeil, S.M. Sapuan, M. Jawaid, Influence of fiber content on mechanical, morphological and thermal properties of kenaf fibers reinforced poly(vinyl chloride)/thermoplastic polyurethane poly-blend composites, Mater. Des. 58 (6) (2014) 130–135.
[23] Y. Xu, H. Yin, H. Zheng, et al., Application performance and surface morphologies of amino polysiloxanes with different amino values and amino types, J. Appl. Polym. Sci. 119 (4) (2011) 2326–2333.
[24] H.E.D. Bree, F.J.M.V.D. Eerden, J.W.V. Honschoten, A Novel Technique for Measuring the Reflection Coefficient of Sound Absorbing materials[J], Isma, 2000.
[25] M. Zuber, K.M. Zia, S. Tabassum, Preparation of rich handles soft cellulosic fabric using amino silicone based softener, part II: colorfastness properties, Int. J. Biol. Macromol. 49 (1) (2011) 1–6.
[26] L.H. Ren, Environmental Physical Pollution Control Engineering [M], Chemical Industry Press, Beijing, 2008, pp. 42–43 (in Chinese).
[27] G.Y. Meng, B. Wu, J. Zhou, et al., Relationship between morphological structure and economic traits and physical properties of cytoplasmic wild plant fiber cells, Acta Bot. Sin. 33 (4) (2013) 712–719 (in Chinese).
[28] A. Bourmaud, C. Morvan, A. Bouali, et al., Relationships between micro-fibrillar angle, mechanical properties and biochemical composition of flax fibers, Ind. Crop. Prod. 44 (2013) 343–351.