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Effect of OC CNF and BIBP chain additives on mechanical and fracture behavior

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Abstract. With the rapid development of the new energy vehicle industry, the application of lightweight materials in this field is becoming increasingly widespread. It not only helps to improve the energy efficiency of new energy vehicles, but also enhances their safety and comfort. However, finding lightweight materials that combine high strength, good stability, and environmental friendliness has always been a challenge for the industry. To further improve the mechanical properties of lightweight materials for new energy vehicles and achieve environmentally friendly applications, Bis (tert butyldioisopropyl) benzene was used as a chain extender based on Poly butyleneadipate-co-terephthalate. And a new lightweight foam material for automobiles was developed by blending with modified carbon nanofibers. These experiments confirmed that the proposed new foam material had a tensile strength of 21.0 MPa and a crack elongation of 610%. When the carbon nanofiber content reached 40% and 50%, the modulus significantly increased to over 200 MPa. The modified material's starting tensile strength was 31.8 ± 4.4 MPa. This material not only has high tensile strength, but also exhibits better stability and ductility under stress, and has good environmental significance.

Keywords: Foam material / mechanical optimization / new energy vehicles / lightweight / PBAT

1 Introduction

New energy vehicles, as a clean energy vehicle that replaces traditional fuel vehicles, have become the mainstream trend in the future development of automobiles. With the increasing acceptance of new energy vehicles by consumers and the deepening understanding of environmental protection and energy conservation, the market share of new energy vehicles is also gradually increasing. In this context, the lightweight design of New Energy Vehicle (NEV) has become a key research topic. Foam material (FM), as a lightweight, clean, environmentally friendly, and high-performance material, has shown great potential in the lightweight design of NEVs [1]. Therefore, some researchers have explored the Mechanical Properties (MPs) of FM in the NEV body structure through experiments, confirming that FM can effectively reduce the weight and crack resistance of the body structure. In addition, other researchers used numerical simulation methods to analyze the optimization effect of FM in the NEV chassis structure. These studies confirmed that FM helped improve the load-bearing capacity and stability of the overall body structure [2,3]. However, currently, the

MPs of FM in these studies have generally not reached the expected level, and the production of environmental pollutants is too high. In view of this, the study was based on Poly Butyleneadipate Co Terephthalate (PBAT) material by introducing Carbon Nanofibers (CNFs) with surface treated with octadecylamine into PBAT for co mixing, improving the material's thermosetting, hydrophobic, and lipophilic properties. PBAT's melt strength was enhanced by introducing Bis (Tert Butyldioisopropyl) Benzene (BIBP) as a chain extender. Suitable foaming agent Azodicarbonamide (AC) was selected. The optimal mix ratio of the material was explored through a series of experiments. It is expected that research can improve the lightweight and structural strength of NEV bodies, further promoting the rapid development of the automotive industry. This article mainly has four parts. Firstly, a review is conducted on the current research status of FM and lightweight materials both domestically and internationally. Secondly, a new lightweight NEV is designed based on PBAT, namely, Organized Carbon-Carbon Nanofibers (OC-CNF)/Efficient Poly Butyleneadipate-Co-Terephthalate (E-PBAT). Then, comparative experiments and mechanical optimization analysis are conducted on the optimization effect of the material. Finally, the conclusions drawn from the research and future directions for improvement are presented.

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As NEV becomes widely popular and environmental protection concepts continue to penetrate people's hearts, more and more people are paying attention to the improvement of environmental protection FM and its MPs. Flexible polymer foam needs both mechanical strength and super hydrophobicity in complex applications. In this regard, Zhang et al proposed a method to prepare superhydrophobic surfaces on polydimethylsiloxane foam using an ultra fast and environmentally friendly flame scanning strategy. These results confirmed that this surface presented perfect mechanical robustness and superhydrophobicity, could withstand various deformations and environmental tests, and was easy to deice and repairable [4]. Boonprasertpoh et al put forward the method of preparing foam by compression molding technology based on the research of PBAT foam performance, and characterized its physics, morphology, and MPs by various means. These results confirmed that the addition of PBAT had limited influence on the viscosity of the blend, but it could significantly improve foam's flexibility and toughness, while reducing its Young's modulus and Tensile Strength (TS) [5]. Yan et al proposed the use of environmentally friendly epoxidized soybean oil as a compatibilizer to address the difficulties in improving the compatibility and mechanical properties of Polyactive Acid (PLA)/PBAT blends. Compatibility was achieved through its hydroxyl reaction with PLA and PBAT. These results confirmed that the addition of ESO significantly improved TS, elongation at break, and notch impact strength of PLA/PBAT blends [6]. Pang et al proposed a method of preparing biodegradable composite materials by twin-screw extrusion using PBAT and technical lignin to address the plastic pollution in automotive manufacturing. The MPs were improved through two strategies: methylation modification and addition of compatibilizers. These results confirmed that the obtained composite materials had ideal tensile properties, and the production cost was reduced by 36% compared to pure PBAT, making them economically competitive [7]. He et al proposed a method of introducing organic modified montmorillonite through melt blending to improve PLA and PBAT blends' performance. These results confirmed that the esterification reaction between PLA and PBAT at the interface enhanced the compatibility, crystallinity, and thermal stability of the blend, while significantly improving TS of PBAT [8].

Gariba et al prepared composite materials with different ratios using powder metallurgy to investigate the microstructure and MPs of titanium-based boron doped carbon and CNF reinforced functional gradient materials. These results confirmed that CNF was uniformly distributed in the titanium matrix, with good interlayer bonding, significantly improved hardness and transverse fracture strength [9]. To solve the poor mechanical properties of CNF aerogel and difficulty in customizing 3D structure, Sun et al. proposed a method of mixing Poly Ethylene Glycol Diacrylate (PEGDA) and CNF solution to form a composite biological resin. It was prepared by stereo lithography technology. These results confirmed that different factors had different effects on the performance of aerogel, and the modified material MPs increased by

13.6% [10]. Xu et al proposed a composite cathode material using carbon coated NASICON type $\text{Na}_3\text{V}_2(\text{PO}_4)_3$ (NVP) and CNF interconnection to improve water-based zinc ion batteries' performance. These results confirmed that NVP/C/CNF had high reversible capacity and excellent cycling stability [11]. Zhang et al proposed using improved methods to prepare CNF and carboxymethyl cellulose coatings as coating materials for pulp molded food pallets to address the environmental pollution caused by petroleum-based plastic packaging. These results confirmed that the coating could obviously improve the tray's MPs and barrier properties, effectively extended the shelf life of fruits, and was environmentally friendly [12]. Mianehrow et al proposed a method for preparing cellulose nanofiber graphene oxide nanocomposites using physical mixing-drying method to address the combination of functionality and structural properties of nanocomposites. These results confirmed that the material had excellent MPs, optical transmittance, and oxygen barrier properties [13].

In summary, the application of CNF in NEV has sufficient theoretical and practical foundations, but there is little research on the mechanical optimization of blending PBAT and CNF for NEV lightweighting. Therefore, by combining modified CNF and using chain expansion and compatibilization methods to modify PBAT, a high molecular weight PBAT is obtained, and a new lightweight NEV material is ultimately designed to further develop the NEV industry.

2 Automotive lightweight materials based on PBAT and carbon nanofibers

This section is mainly divided into three sections. Firstly, E-PBAT material is obtained by modifying PBAT with tert butyldioxyisopropyl group. Secondly, CNF is modified based on acylation reaction to develop OC-CNF. Finally, E-PBAT and OC-CNF are blended.

2.1 Modified materials based on tert butyldiisopropyl PBAT

PBAT is a biodegradable polymer material widely used in NEVs to achieve lightweight vehicle body [14]. It has good processing performance and MPs, which can be easily plasticized and molded during the production process, and can also meet the requirements of NEV for material strength, toughness, and heat resistance. The crystallinity of PBAT is approximately 30%, and the Shore hardness is above 85. PBAT is a copolymer of aliphatic and aromatic compounds. PBAT belongs to thermoplastic biodegradable plastics and is a copolymer of butylene adipate and PBAT. It combines PBA and PBT's characteristics, with nice ductility and elongation at break, fine heating resistance, and impact performance. Figure 1 shows its molecular formula.

From the physical image in Figure 1, PBAT is a semi-crystalline polymer that combines aliphatic polyester's excellent degradation performance and aromatic polyester's fine MPs. But its melt strength is relatively low, which may lead to an increase in material fluidity during injection

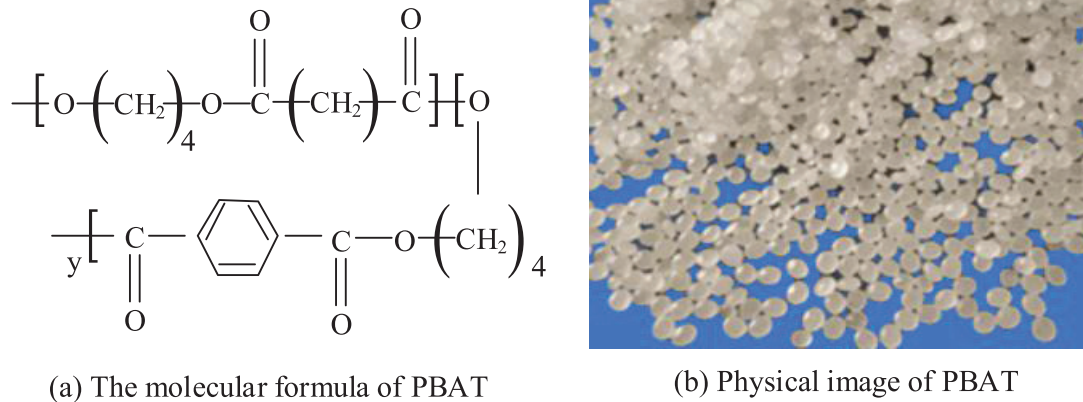


Fig. 1. Molecular formula and physical image of PBAT.

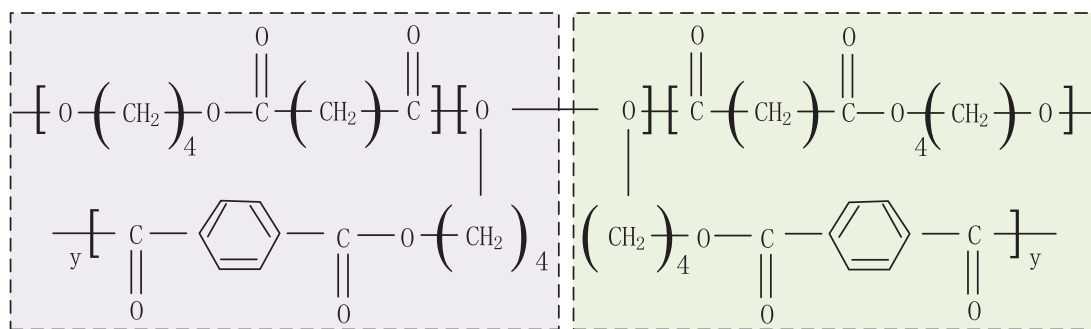


Fig. 2. Molecular formula of E-PBAT.

molding or extrusion molding. This makes it difficult to maintain its shape, which in turn affects the precise manufacturing and dimensional stability of the components [15]. Therefore, the study uses the method of chain extension and compatibilization to modify PBAT, obtaining high molecular weight PBAT. By using BIBP as a chain extender, pure PBAT is modified to obtain E-PBAT. During modification, BIBP reacts with the molecular chains of PBAT, increasing the molecular weight of PBAT and thus improving its melt strength. Chain extenders can also increase the intermolecular interaction force of PBAT, improve its viscosity and rigidity, and make it easier to maintain its shape during processing. The expanded E-PBAT molecule is composed of multiple PBAT molecules. This structure can improve the dimensional stability and MPs of the components in Figure 2.

2.2 OC-CNF based on amidation reaction

After preparing the modified materials for PBAT, it is necessary to prepare OC-CNF through acylation reaction. CNF is a synthetic fiber made of nylon, with a diameter of only tens of nanometers. Although the composition is ordinary, the ultra-fine fiber structure endows it with moisture absorption properties similar to cotton fibers. CNF is known for its extremely low density (about 1 g/cm³) and is suitable for manufacturing lightweight composite materials [16]. In addition, it also has excellent MPs,

including high TS, bending strength, and modulus, which can significantly improve the MPs of composite materials. CNF also exhibits excellent heat resistance and chemical stability, which can maintain performance stability in high temperatures and various chemical environments, and it is not easily affected by corrosion and oxidation. Therefore, CNF has been widely used in aerospace, automotive, construction, electronics, and medical, as a reinforcing material or filler to improve the performance of composite materials. However, there are some problems in its preparation and application, such as easy aggregation, poor dispersibility, and poor compatibility with the matrix material. In view of this, traditional methods use ODA modified CNF. Figure 3 shows its reaction principle.

The reaction principle is prepared by direct coupling reaction between the hydroxyl group of CNF and the amino group of ODA using a crosslinking agent. Specifically, an aldehyde group on the cross-linking agent molecular chain undergoes a nucleophilic addition reaction with a hydroxyl group on the surface of CNF to form a semi-acetal. The other aldehyde group and the amino group of ODA undergo covalent crosslinking by condensation to form a Schiff base. In this process, the long hydrocarbon chains of ODA are grafted onto the surface of CNF through crosslinking agents, thereby reducing the surface energy of CNF and making it hydrophobic. This reaction is carried out at 60 degrees Celsius and lasts for 4 h. But this reaction cannot fully cover the surface of CNF [17]. Therefore, studying the

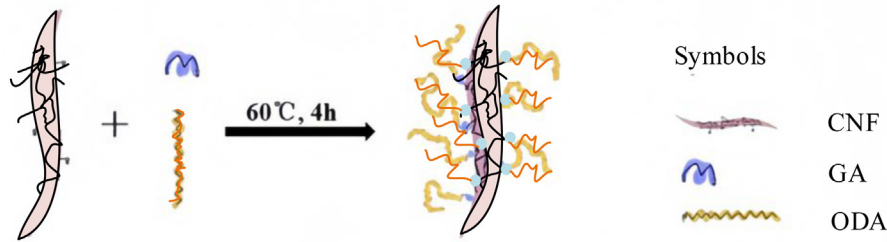


Fig. 3. Principle of ODA modified CNF reaction.

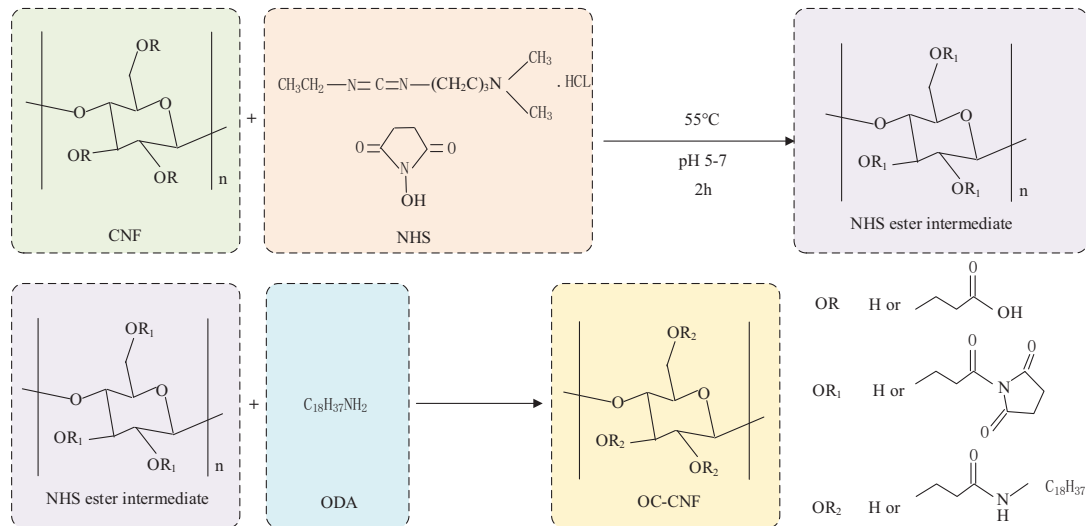


Fig. 4. Schematic diagram of ODA modified CNF through acylation reaction.

acylation reaction grafting modification of CNF can enhance CNF and polymer matrix's interfacial compatibility, thereby enhancing composite materials' MPs and thermal stability. Furthermore, by undergoing acylation reaction with carboxyl groups on the surface of CNF, it can be grafted onto the surface of CNF, thereby improving its hydrophobicity. This is very helpful for improving the waterproof performance and durability of composite materials. Figure 4 shows the specific chemical reaction formula.

Firstly, CNF and NHS are placed in an environment at 55 degrees Celsius and reacted for 2 h at a pH of 2. During the reaction, NHS ester intermediates are generated. Next, C18H37NH2 is added to the reaction system. The amino group of C18H37NH2 can undergo acylation reaction with the carboxyl group on the surface of CNF, forming stable amide bonds. In this way, the long hydrocarbon chains of C18H37NH2 are successfully grafted onto the surface of CNF. This extra long hydrocarbon chain can also provide additional functions for CNF, such as increasing its dispersibility in organic solvents or serving as anchoring points for other functional groups. In the synthesis of OC-CNF, the amino group of ODA interacts with the carboxyl group on the surface of C-CNF, forming stable amide bonds. The long hydrocarbon chains of ODA are successfully grafted onto the surface of C-CNF, resulting in a change in the properties of C-CNF.

2.3 Production of E-PBAT/OC-CNF blend materials

The MPs of PBAT are relatively weak, while CNF has high strength and rigidity, which can significantly improve the MPs of PBAT and make it more durable. For environmental and safety reasons, PBAT is a biodegradable polymer, whose degradation rate is relatively slow. By adding CNF, the degradation performance of PBAT can be improved, allowing it to completely decompose in a shorter time. The production cost of PBAT is relatively high, while CNF can be obtained from natural fibers at a lower cost. By combining CNF with PBAT, it is possible to reduce production costs while maintaining the excellent performance of PBAT. The study combines OC-CNF with E-PBAT. Figure 5 shows its interaction mechanism.

The interaction mechanism between OC-CNF and PBAT involves multiple levels, including physical and chemical interactions. In terms of physical interactions, the long hydrocarbon chains of OC-CNF increase its dispersibility in the organic phase, allowing OC-CNF to be more uniformly dispersed in the PBAT matrix. This uniform dispersion helps to enhance OC-CNF and PBAT's interfacial interaction. Secondly, due to the enhanced hydrophobicity of OC-CNF, the interfacial adhesion between it and PBAT is also improved. This helps to improve the MPs of composite materials. In terms of chemical interactions, the amide bonds on the surface of

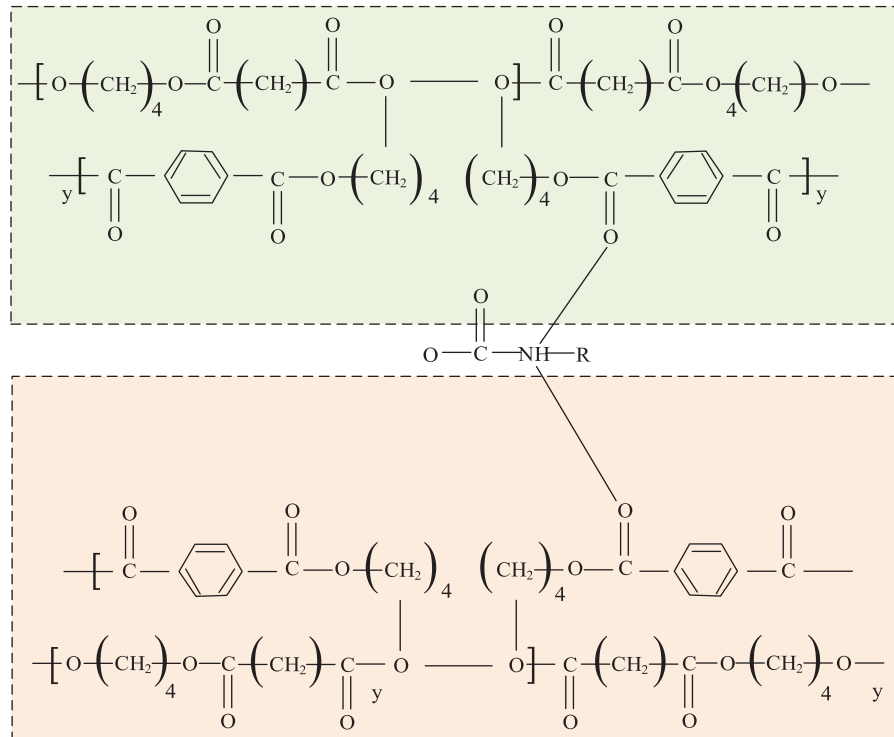


Fig. 5. Mechanism of interaction between OC-CNF and PBAT.

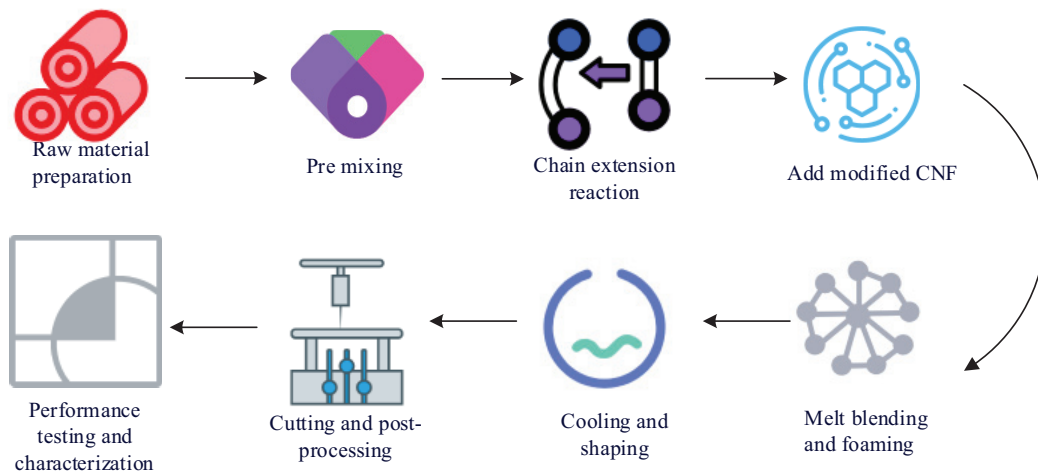


Fig. 6. Improved foaming process flow of PBAT.

OC-CNF and the ester bonds in the PBAT molecular chain are both polar groups. They can form hydrogen bonds or dipole-dipole interactions between them, thereby enhancing the interfacial bonding between the two. In blending or processing, limited chemical reactions may occur between the amide bonds of OC-CNF and the ester bonds of PBAT, such as ester exchange reactions. However, this reaction may not be significant under normal processing conditions. The improved foaming process of PBAT includes the following eight steps in Figure 6.

Firstly, the preparation of raw materials ensures that the quality of PBAT, BIBP, modified CNF, and other additives meets the requirements, and they are accurately weighed according to the formula ratio. PBAT and

modified CNF are dried to remove moisture and impurities. Then, PBAT, BIBP, and other additives are pre-mixed in a high-speed mixer to ensure uniform distribution of each component. Next, a chain expansion reaction is carried out, using the SWAR-100 high-speed mixer of Qiwei technology machinery to feed the pre-mixed materials into the twin-screw extruder. Melt blending is carried out at the set temperature and shear force. The temperature and time of the chain extension reaction should be adjusted according to the specific formula and equipment parameters to ensure that the molecular chains of BIBP and PBAT fully react. In the third part, the study will confirm its optimal mix ratio. Then modified CNF is added. After the chain expansion reaction reaches a certain degree, the modified

Table 1. Experimental instruments and equipment.

Name	Model	Manufacturer
Electric blast drying oven	DGF-9050A	Shanghai Yiheng Scientific Instrument Co., Ltd
DSC	DSC-6000	Seiko Corporation of Japan
Scanning electron microscope	JSM-7610F	JEOL
Rotational rheometer	HR-2	TA Instruments Corporation USA
Single-screw extruder	SJ-45	Nanjing Jiente Electromechanical Co., Ltd
Mixer	XM-500	Guangdong Hongji Rubber Machinery Co., Ltd
Single (double) series extruder	DH-S(D)20/25	Beijing Chemical Machinery Factory
Twin screw extruder	LT-DZ-20	Lanzhou Xinlan Plastic Machinery Co., Ltd
Dynamic thermomechanical Analyzer	DMA-Q800	TA Instruments Corporation USA

CNF (such as OC-CNF) is added to the extruder through the side feeding port. Attention should be paid to controlling the amount and speed of CNF addition to ensure that CNF is uniformly dispersed in the PBAT matrix. The fifth step is to melt blend and foam, and continue to melt blend in the extruder. The pneumatic diaphragm pump from GASTSA company in the United States is used to inject foaming agent, and the foaming agent used in the study is AC. The sixth step is cooling and shaping, by rapidly cooling the foamed composite material through a cooling water tank or air cooling device to fix the foam cell structure. The seventh step is cutting and post-processing, which involves cutting and trimming the cooled and solidified FM as needed. Finally, performance testing and characterization are conducted on the improved PBATFM, including MPs, thermal stability, biodegradability, and other performance tests. The pore structure and interfacial compatibility are characterized by microscopy, Scanning Electron Microscopy (SEM), and other means. These results are compared with the original PBATFM to evaluate the modification effects.

3 Characterization observation and mechanical optimization analysis of E-PBAT/OC-CNF

This section mainly consists of two sections. First, the preparation and experimental instruments used for E-PBAT/OC-CNF were mainly elaborated, and their surface characteristics were observed. Second, it was subjected to MPs testing and compared with other new energy materials.

3.1 Experimental equipment and E-PBAT/OC-CNF characterization observation

Various instruments were used in this experiment, including an electric hot air drying oven (DGF-9050A) for drying experimental materials, and a scanning electron microscope (JSM-7610F) for observing and studying the microstructure of materials, a rotary rheometer (HR-2) for measuring materials' rheological properties, such as viscosity and modulus, the required single-screw extruders

(SJ-45), internal mixers (XM-500), single (double) series extruders (DH-S(D)20/25), and double screw extruders (LT-DZ-20) for sample preparation in Table 1.

SEM images of pure PBAT and PBAT composite materials with different contents of OC-CNF were first scanned using a scanning JSM-7610F electron microscope. Figure 7 shows the experimental results to explore and understand the microstructure and interface interactions of the material, providing a basis for subsequent performance analysis and mechanism exploration.

From Figure 7, the fracture surface's SEM images of pure PBAT showed a smooth and even surface. In the SEM images of PBAT composite materials with 0.5 wt.% OC-CNF added, a significant amount of fiber structures were observed. This indicated that after modification, the compatibility and interfacial adhesion between fibers and PBAT matrix were significantly enhanced. When the OC-CNF content increasing, a denser OC-CNF cross-linked network was formed in the PBAT matrix. Cracks generated by PBAT matrix under exceeding ultimate stress.

3.2 Mechanical optimization analysis of E-PBAT/OC-CNF lightweight materials

To investigate the effect of OC-CNF addition on E-PBATMPs and obtain the optimal blending ratio to optimize material properties, E-PBAT/OC-CNF blends with different ratios were experimentally prepared. Then, MPs tests were conducted on these blends in Table 2.

In Table 2, E-PBAT/OC-CNF/10, E-PBAT/OC-CNF/20, E-PBAT/OC-CNF/30, E-PBAT/OC-CNF/40, and E-PBAT/OC-CNF/50 indicate that the OC-CNF content in the E-PBAT/OC-CNF blend is 10%, 20%, 30%, 40%, and 50%, respectively. PBAT and its blends with OC CNF exhibited unique MPs. Firstly, for the yield strength, the benchmark value of E-PBAT was 7.3 ± 0.4 MPa. As OC-CNF was gradually added, the overall yield strength of the blend increased, reaching a peak of 11.1 ± 0.9 MPa at the E-PBAT/OC-CNF/30 ratio, followed by a slight decrease. However, all blends containing OC-CNF exhibited superior yield strength to pure E-PBAT, highlighting the enhancing effect of OC-CNF on the material's yield performance. E-PBAT's initial TS was 31.8 ± 4.4 MPa. But with the addition of OC-CNF, this value gradually

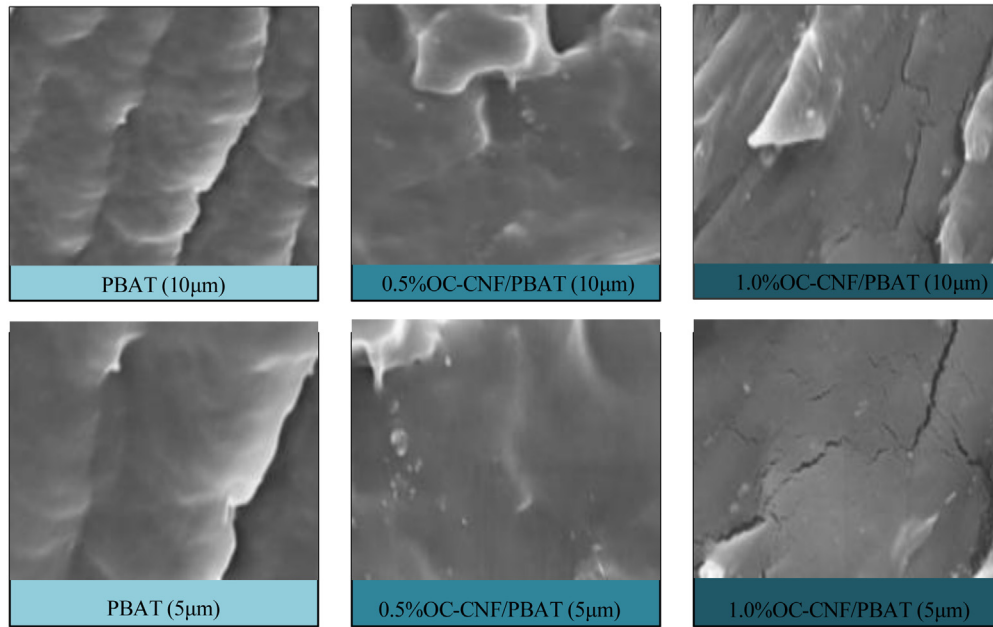


Fig. 7. SEM images of PBAT composite materials with different contents of OC-CNF.

Table 2. E-PBAT/OC-CNF blend's mechanical properties.

Samples	Yielding strength	TS	Elongation at	Young's modulus
/	(MPa)	(MPa)	Break(%)	(MPa)
E-PBAT	7.3 ± 0.4	31.8 ± 4.4	401.0 ± 33.0	59.8 ± 7.0
E-PBAT/OC-CNF/10	8.6 ± 0.1	27.4 ± 5.2	1011.1 ± 24.1	98.8 ± 8.0
E-PBAT/OC-CNF/20	10.2 ± 1.6	28.4 ± 5.5	1222.5 ± 26.1	137.6 ± 10.0
E-PBAT/OC-CNF/30	11.1 ± 0.9	17.2 ± 2.4	4891.4 ± 20.1	86.7 ± 12.0
E-PBAT/OC-CNF/40	10.6 ± 0.8	9.3 ± 3.6	67.2 ± 36	244.8 ± 8.0
E-PBAT/OC-CNF/50	9.2 ± 0.8	9.3 ± 4.8	81.1 ± 47	224.7 ± 6.0
OC-CNF	10.7 ± 1.0	10.2 ± 4.1	95.3 ± 4	299.1 ± 8.0

decreased, especially when the OC-CNF content exceeded 20%, the downward trend was more obvious, even dropping to close to or below 10 MPa. This may be due to the introduction of OC-CNF affecting the internal structure and continuity of the material. For the elongation at break, E-PBAT itself had an elongation of $401.0 \pm 33.0\%$, but the addition of OC-CNF caused significant fluctuations in this value. As the content of OC-CNF continued to increase, the elongation at break sharply decreased. Finally, for Young's modulus, the initial modulus of E-PBAT was 59.8 ± 7.0 MPa. The addition of OC-CNF led to increasing the blend's Young's modulus in overall, indicating an increase in material stiffness. Especially when the OC-CNF content reached 40% and 50%, its modulus significantly increased to over 200 MPa, indicating that the material was more rigid under these ratios. The molecular chain reaction between BIBP and PBAT increased the molecular weight of PBAT, thereby enhancing its melt strength. The study investigated the effects of different BIBP contents on E-PBAT's TS, elongation at break, and strain in Figure 8.

From Figure 8a, when the BIBP content was 1%, E-PBAT's TS and elongation at break showed the best performance, 25 MPa and 870%, respectively. Subsequently, when BIBP increasing, these two indicators actually deteriorated. This may be due to excessive BIBP disrupting the regularity of E-PBAT molecular chains, leading to decreasing the material's strength and toughness. From Figure 8b, when the amount of BIBP added exceeded 2 wt%, the stress yield point of E-PBAT material disappeared. This indicated that adding BIBP reduced E-PBAT's yield strength, causing the material to begin plastic deformation at lower stresses. In addition, this study further explored the dynamic MPs of blends with different proportions after introducing different contents of BIBP. The storage modulus and loss factor were used as key evaluation criteria in Figure 9.

From Figure 9a, the storage modulus of E-PBAT/OC-CNF/BIBPD with a ratio of 90:10:1 performed the worst, while the storage modulus with a ratio of 90:10:3 performed the best. The storage modulus increased steadily

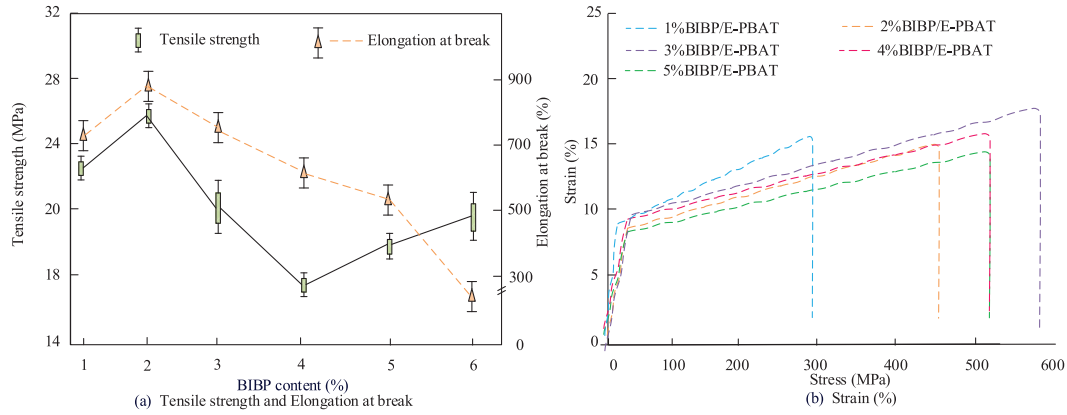


Fig. 8. Mechanical properties of E-PBAT composite materials as a function of BIBP dosage.

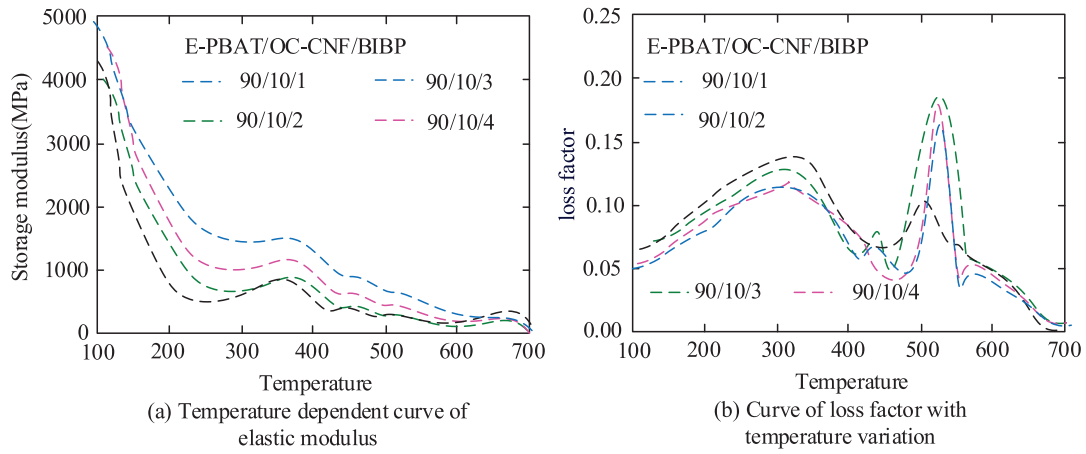


Fig. 9. Dynamic mechanical properties of blends with different proportions after introducing different contents of CNF fibers.

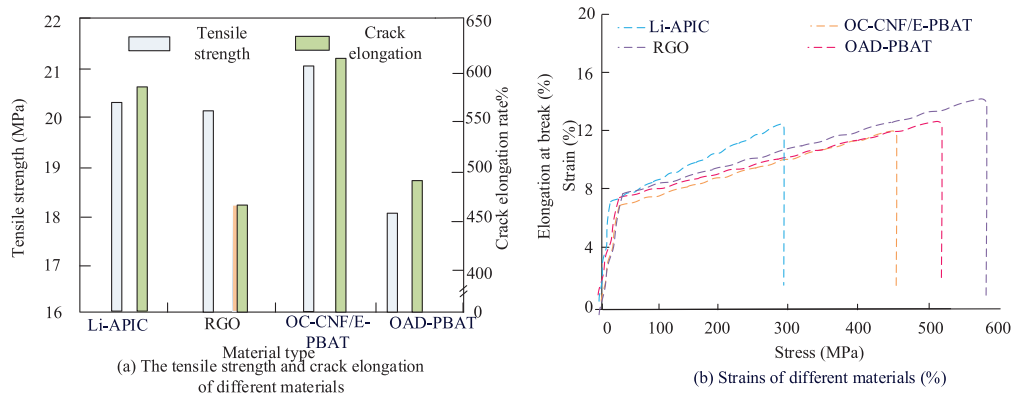


Fig. 10. Comparison of mechanical properties of various materials.

when BIBPD increasing, meaning that adding BIBPD effectively improved the composite material's stiffness and elasticity. From Figure 9b, the loss factor with a ratio of 90:10:1 for E-PBAT/OC-CNF/BIBPD performed the worst, while the loss factor with a ratio of 90:10:3 performed the best. The ratio of loss modulus to storage modulus is defined as the loss factor, which reflects the damping performance of the material. The addition of BIBPD reduced the loss factor of composite

materials, indicating that BIBPD helped to reduce energy loss and improve the damping performance of materials. Finally, the Li-APIC material from reference [18], the NEV lightweight RGO material from reference [19], and the NEV lightweight OAD-PBAT material from reference [20] were introduced to compare with the OC-CNF/E-PBAT material under the optimal mix ratio conditions. Figure 10 shows the experimental results.

From Figure 10a, TS of Li APIC material was 21.1 MPa, and the crack elongation was 590%. RGO material had a TS of 22.6 MPa and a crack elongation of 460%. OAD-PBAT material had a TS of 18.6 MPa and a crack elongation of 490%. The proposed OC-CNF/E-PBAT material had a TS of 21.0 MPa and a crack elongation of 610%. Its TS is not significantly different from Li APIC material and RGO material, while its crack elongation is significantly higher than the other two materials. In addition, Figure 10b further confirmed the superiority of OC-CNF/E-PBAT materials in stress performance. This material not only had high TS, but also exhibited better stability and ductility under stress.

4 Conclusion

The study modified PBAT materials by introducing OC-CNF fibers and BIBP chain extenders, and prepared OC-CNF/E-PBAT composite materials. The MPs and mechanical optimization effects were analyzed through a series of experiments. These results confirmed that the addition of OC-CNF significantly increased the yield strength and Young's modulus of PBAT, while also having an impact on the corresponding denaturation energy. When the OC-CNF was 30%, the yield strength of E-PBAT/OC-CNF blend reached a peak of 11.1 ± 0.9 MPa. However, TS gradually decreased with OC-CNF increasing, and the elongation at break also showed a fluctuating downward trend. In addition, the appropriate addition of BIBP could improve E-PBAT's TS and elongation at break. Excessive BIBP could disrupt the regularity of molecular chains, leading to a decrease in performance. Dynamic MPs testing had confirmed that the appropriate addition of BIBP could significantly improve the storage modulus and damping performance of composite materials. When the E-PBAT/OC-CNF/BIBPD ratio was 90:10:3, the storage modulus performed best and the loss factor decreased, indicating that the material had better rigidity and damping characteristics. In comparison experiments with other materials, OC-CNF/E-PBAT showed good TS and crack elongation, with values of 21.0 MPa and 610%, respectively. It had a certain competitive advantage compared to Li-APIC, RGO, and OAD-PBAT materials. In addition, OC-CNF/E-PBAT exhibited excellent stability and ductility under stress. In summary, the study proposes that the OC-CNF/E-PBAT composite materials in NEV have the advantages of environmental protection, high TS, and high crack elongation. In summary, the study has shown that under appropriate ratios, OC-CNF/E-PBAT composite materials in new energy vehicles have the advantages of high TS and high crack elongation. At the same time, the material also has clean and environmentally friendly characteristics. However, it should be noted that although OC-CNF/E-PBAT materials exhibit good MPs, factors such as processing performance, durability, and cost need to be considered in practical applications. This is also an aspect that needs to be followed up in subsequent research.

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Conflict of interest

The authors declare no conflict of interests.

Data availability statement

All data generated or analysed during this study are included in this published article.

Authors contributions statement

H. Zhang To further improve the mechanical properties of lightweight materials for new energy vehicles and achieve environmentally friendly applications, Bis (tert butyldioisopropyl) benzene was used as a chain extender based on Poly butyleneadipate-co-terephthalate. And a new lightweight foam material for automobiles was developed by blending with modified carbon nanofibers. H. Zhang Conducted a series of experiments. In summary, the study proposes that the OC-CNF/E-PBAT composite materials in NEV have the advantages of environmental protection, high TS, and high crack elongation. In summary, the study has shown that under appropriate ratios, OC-CNF/E-PBAT composite materials in new energy vehicles have the advantages of high TS and high crack elongation. At the same time, the material also has clean and environmentally friendly characteristics. However, it should be noted that although OC-CNF/E-PBAT materials exhibit good MPs, factors such as processing performance, durability, and cost need to be considered in practical applications. This is also an aspect that needs to be followed up in subsequent research.

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