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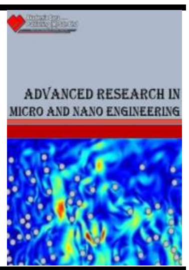

Study the Effect of Adding Malic Anhydride and Carbon Fibers to the Mechanical and Morphology Properties of Polypropylene

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ABSTRACT

Adding reinforcement materials like carbon fibers with maleic anhydride improves the strength of polypropylene. The present work aimed to study the effect of adding maleic anhydride and carbon fibers on the mechanical properties of polypropylene enhanced by presenting carbon fibers. Carbon fibers added at different ratios (0, 2, 4, 6, and 8) % and 1% of maleic anhydride were added to pure polypropylene. Standard tensile and impact test specimens were prepared per ASTM standards using an extruder technique. It was observed that increasing the carbon fiber content enhanced the tensile strength, modulus of elasticity, and hardness of polypropylene while the elongation decreased, but it enhanced after MAH addition. SEM and FTIR indicated good adhesion between fibers and polypropylene after adding maleic anhydride (MAH). UV tests showed that carbon fibers protect the composite material from the UV sunlight.

1. Introduction

Polypropylene is one of the most essential thermoplastics in the world today due to a wide range of applications like car bumpers, battery housing, carpet backing, tubes, packaging, medical equipment, bottles, films, and automobile parts [1-7]. Carbon fibers have high tensile strength, modulus of elasticity, and compressive strength [8-10]. It ensures explant fatigue characteristics and does not corrode when subjected to heat treatments above 3000°F [11]. The cost of carbon fibers depends on the strength and stiffness properties [12-14].

Malic anhydride is an organic compound with the chemical formula $C_2H_2(CO_2)_2O$, and its chemical structure is shown in Figure 1. Using maleic anhydride (MAH) with polypropylene increases the bonding between the matrix and reinforcing material by enhancing polypropylene's surface tension. Without maleic anhydride, the tensile strength and impact strength decreased with the fiber content increased [15].

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Carbon fiber surface treatments improved their surface properties by oxidation treatments, coupling agents, coating processes, plasma processing, and fluorination or oxy-fluorination to enhance interfacial adhesion and increase wet-ability due to the formation of polar groups like $C-F, -COF, -RO_2$, COOH, and C=O [1,2,16]

Polypropylene polymerized by addition polymerization has a CH_3 functional group attracted to its linear molecular channel. Polypropylene (PP) is a saturated polymer (polyolefin) with a linear hydrocarbon chain and is expressed as C_nH_{2n} [17,18]. It is an accessible processing material with low viscosity despite its semi-crystalline content and flows at a high shear rate because it is pseudoplastic. PP types are available, naming homopolymers, Block copolymers, and Random copolymers [19–21].

Polypropylene with good strength and stiffness appears when homopolymer, while block copolymer joins 5-15% ethylene with noble impact resistance, with toughness that can be increased using elastomers. Random copolymers have relatively low melting point grades, including 1-7 % ethylene [22,23].

Some drawbacks of polypropylene are brittleness and poor UV resistance. Therefore, carbon fibers are added to strengthen and protect the material from the UV sunlight. Economic polypropylene has a melting point of 160°C and is used in engineered products like turbine wind [24,25].

In external applications, especially in the case of wind turbines, cracks and crazes can show on the surface of blades; these cracks can be deeper over time and cause complete failure of wind turbine blades. To overcome this problem, carbon fibers are added to prevent crack propagation. The composite has carbon fiber carrying the load, transferring stress to the matrix [26,27]. The present work aims to enhance the mechanical properties of polypropylene reinforced with short carbon fiber and maleic anhydride and compare the mechanical properties before and after adding maleic anhydride.

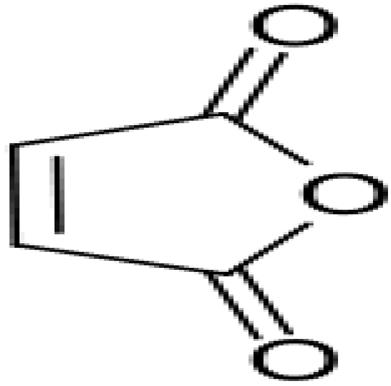
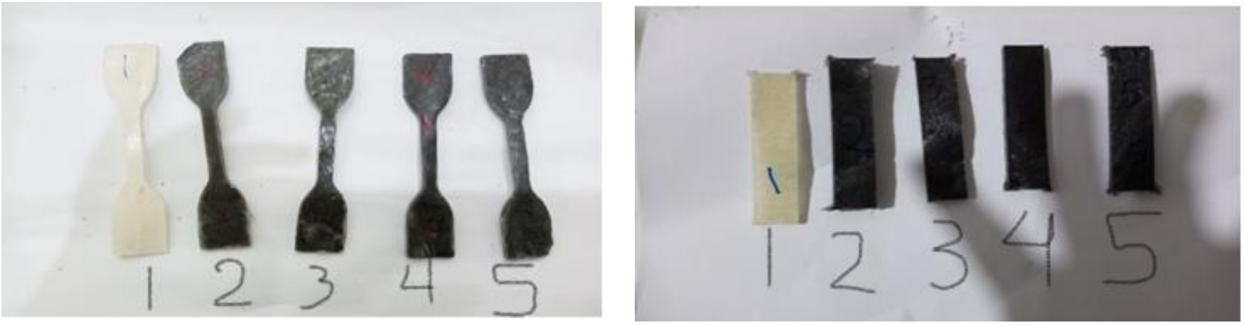


Fig. 1. Maleic anhydride structure

2. Experimental Work

The low polypropylene used as pellets from Sabic company is produced from Saudi Arabia Carbon fibers type 24 K multifilament, with a tensile strength of 700-850 KSI and a tensile Modulus of 33-41.5 MSI. It weighs 9 oz/sqyd, is 0.014 thick, and is cut into 0.5 cm. Fiber Glass Developments Corp makes it in the USA. Maleic anhydride kind CAS number 13138-45-9. Its chemical composition, C4H2O, was made in Barcelona.

The polypropylene pellets were added to the extruder with malic anhydride at 1% and carbon fibers at different ratios (0, 2, 4, 6, 8) % at a speed of 35 cycles/min at 170 o C. The components were then mixed and shaped by the roller to make sheets of 3mm and 10mm thicknesses. The samples were prepared by cutting the sheets to the required shapes according to the ASTM D638M and, for impact strength, ASTM 256B (Figure 2).



(a) (b)

Fig. 2. Slandered test samples (a) tensile strength (b) Impact strength samples

3. Result and Discussions

3.1 Mechanical Properties Result

The hardness decreased when carbon fibers increased before adding MAH until 4% of carbon fibers then increased, as shown in Figure 3, due to poor bonding between carbon fibers and polypropylene. After adding MAH, the hardness was enhanced due to good adhesion between polypropylene and carbon fibers. Also, carbon fibers have a higher aspect ratio and hardness than polypropylene because of using filament fibers with diameters equal to 6 µm.

The composite tensile strength decreased when carbon fiber contents increased before adding MAH (maleic anhydride), as shown in Figure 4, due to the lousy compatibility between carbon fibers and polypropylene. The tensile strength of the samples increased when adding 1 % MAH compared with the samples before adding MAH due to good compatibility between carbon fibers and polypropylene because the surface tension increased. The tensile strength increased with carbon fibers because the fibers have 5 µm diameters carrying most of the loads applied in the presence of Malic aldehyde and transferring the loads to the matrix, also preventing agglomeration of fibers.

The elongation increased after adding MAH, an organic compound that enhances the surface tension of polypropylene and wet the fiber surface, as shown in Figure 5. When the fiber content increased in the composite materials, the elongation decreased because the fibers decreased the polymer chain movements. The elongation increased at 8% of carbon fibers, which may be due to the high ratio of fibers, which led to an increase in the slipping of polymers' chains due to weak Vander, as shown in Figure 6, with wall bonds before adding MAH.

The impact strength decreased with the fiber content increase before adding MAH, while it increased after adding MAH, as shown in Figure 7. The surface tension of polypropylene also increases the compatibility between carbon fibers and polypropylene, which is enhanced after adding maleic anhydride. The carbon fibers reduce the energy absorption capacity, and MAH reduces the agglomerations of fibers.

The ultraviolet indicated in Figure 8 that adding carbon fibers to polypropylene increases the intensity of the peak. Most samples exhibit the same behavior when adding carbon fibers because the material becomes opaque to prevent the light from passing through. The highest shift in absorption was seen in all the samples after adding carbon fibers, which indicates good physical attraction between polymer chains and carbon fibers due to an increase in surface free energy.

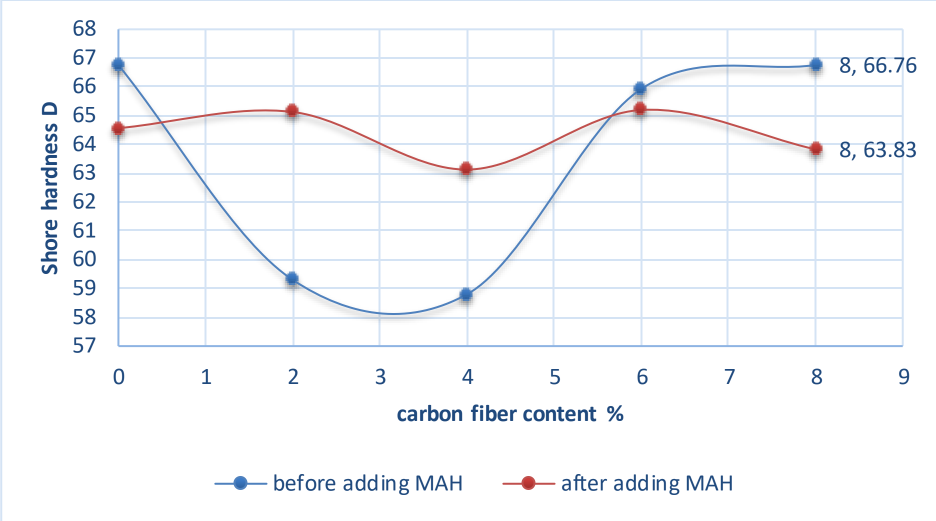


Fig. 3. Represents hardness versus carbon fiber contents

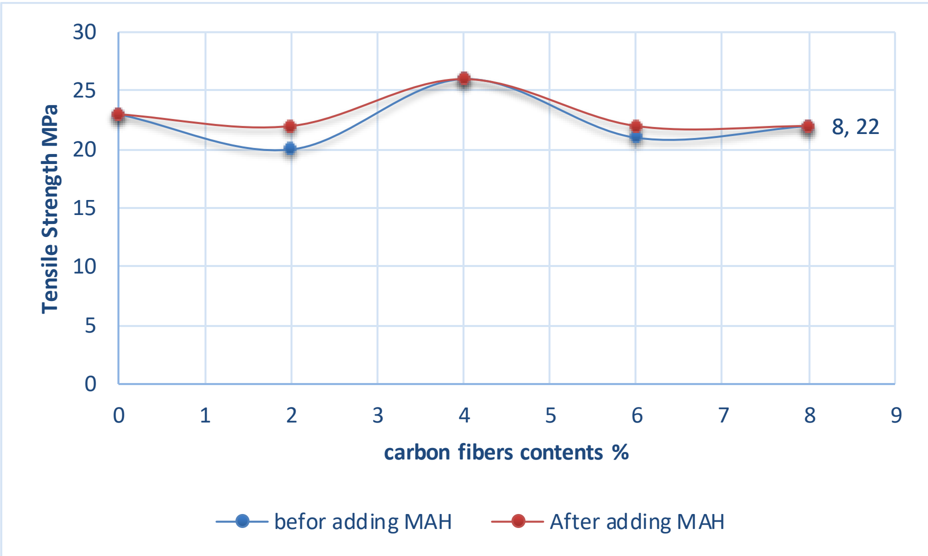


Fig. 4. Represents tensile strength versus carbon fiber contents

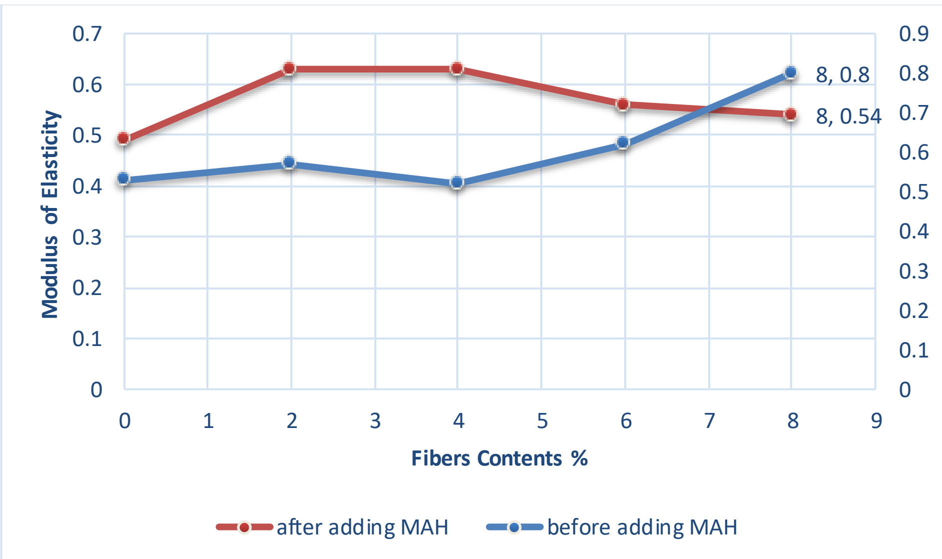


Fig. 5. Represents the modulus of elasticity versus carbon fiber contents

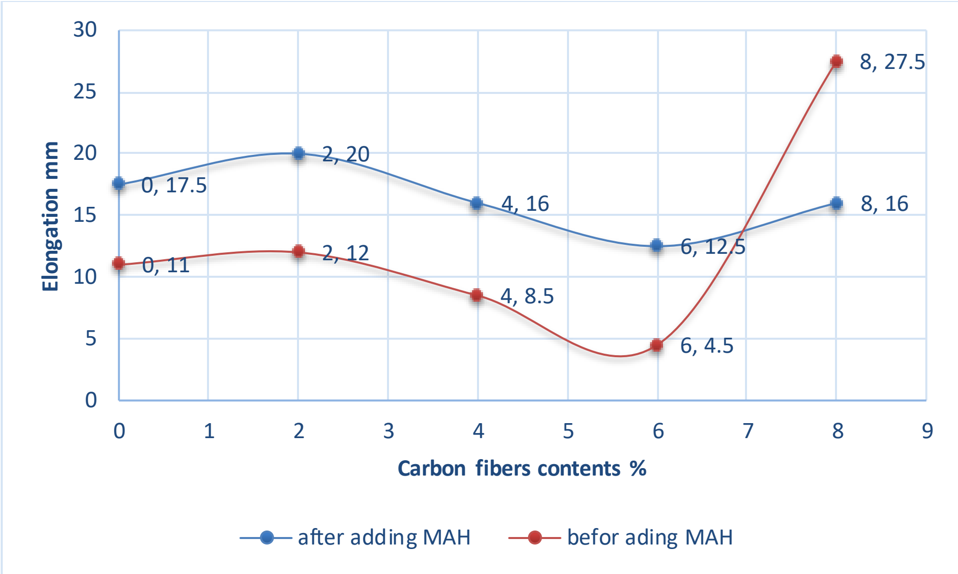


Fig. 6. Represents elongation versus carbon fiber contents

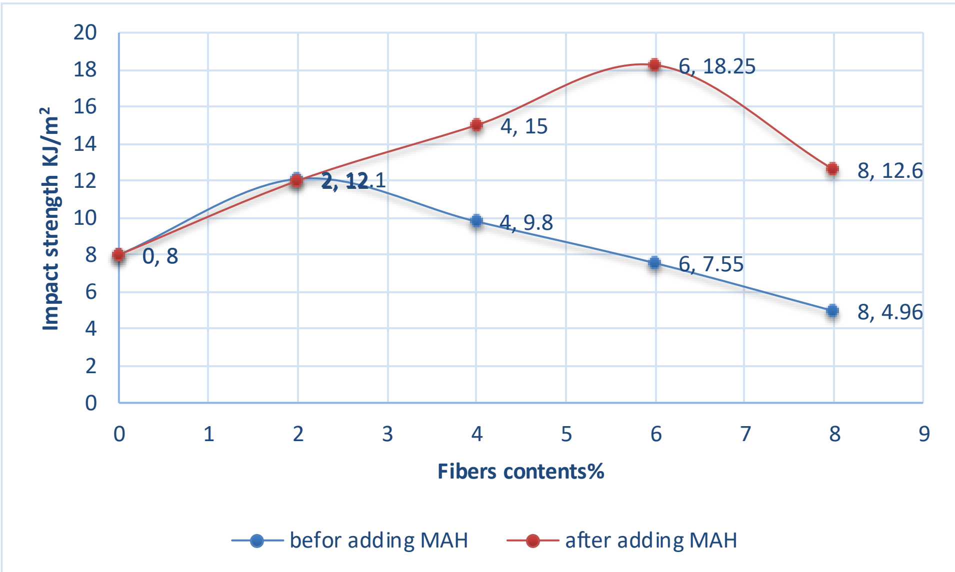


Fig. 7. Represents impact strength versus carbon fiber contents

3.2 FTIR Result

The FTIR result before MAH addition, as shown in Figure 9, indicates physical attraction between carbon fibers and polypropylene. The bonds are expressed in Table 1. Sample (1) represents pure polypropylene. When the carbon fiber content increases, the intensity of transparency decreases because when carbon fiber increases, the distance between chains increases. Generally, the bond intensity increases by adding 1% of maleic anhydride because it enhances the wettability between carbon fibers and polypropylene. Also, the adhesion of fibers with the matrix is enhanced. There are new bonds (1165,1157) cm_{-1}, which may be C-F bonds that appeared after the MAH addition (Figure 10). Oxyfluorination is done by interfacial adhesion, as shown in Table 1.

Table 1
FTIR Bonds before and after adding MAH

The bonds before the MAH addition		The bonds after the MAH addition	
1. 3433.29 cm^{-1}	OH	3433.29 cm^{-1}	OH
2. 2954.95 cm^{-1}	CH	2954.95 cm^{-1}	CH
3. 1635.64 cm^{-1}	C=O	1635.64 cm^{-1}	C=O
4. 1111,107.4,1033.8 cm^{-1}	C-O	1111 cm^{-1}	C-O
5. 1234.44 cm^{-1}	C-C	1249 cm^{-1}	C-C
6. Not Found		1165, 1157 cm^{-1}	C-F

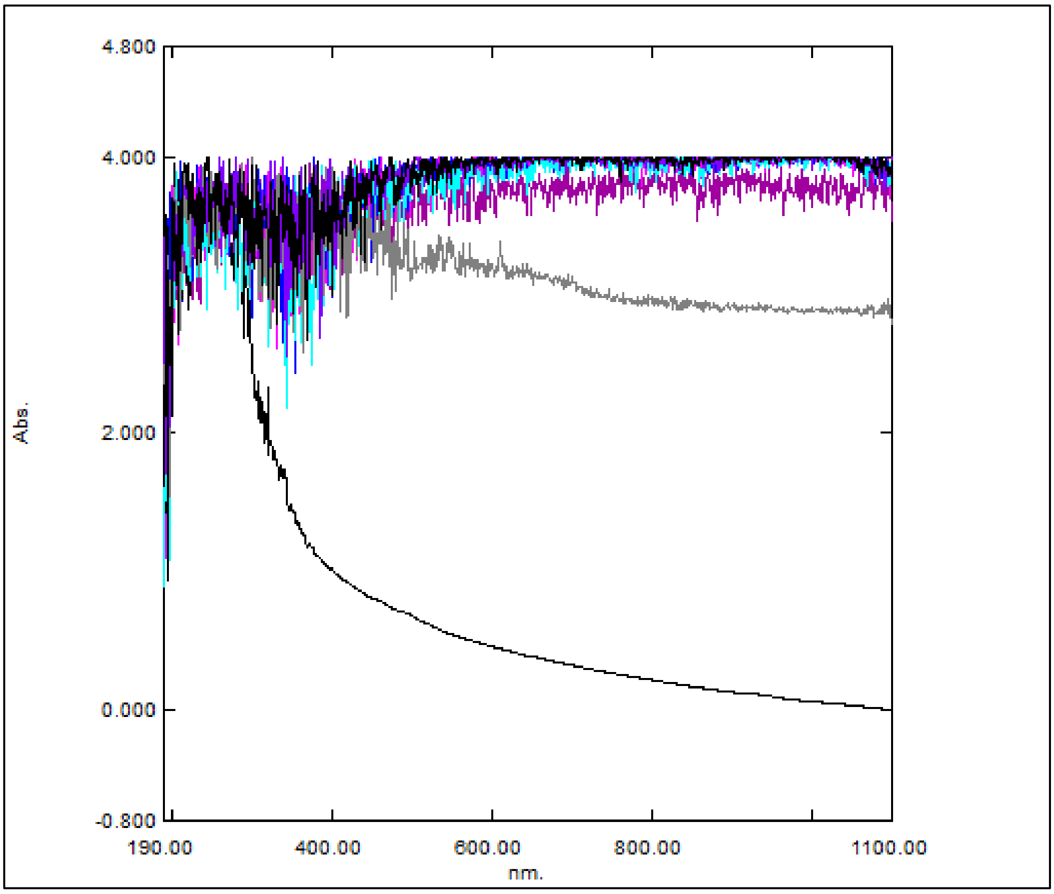


Fig. 8. Represents impact strength versus carbon fiber contents

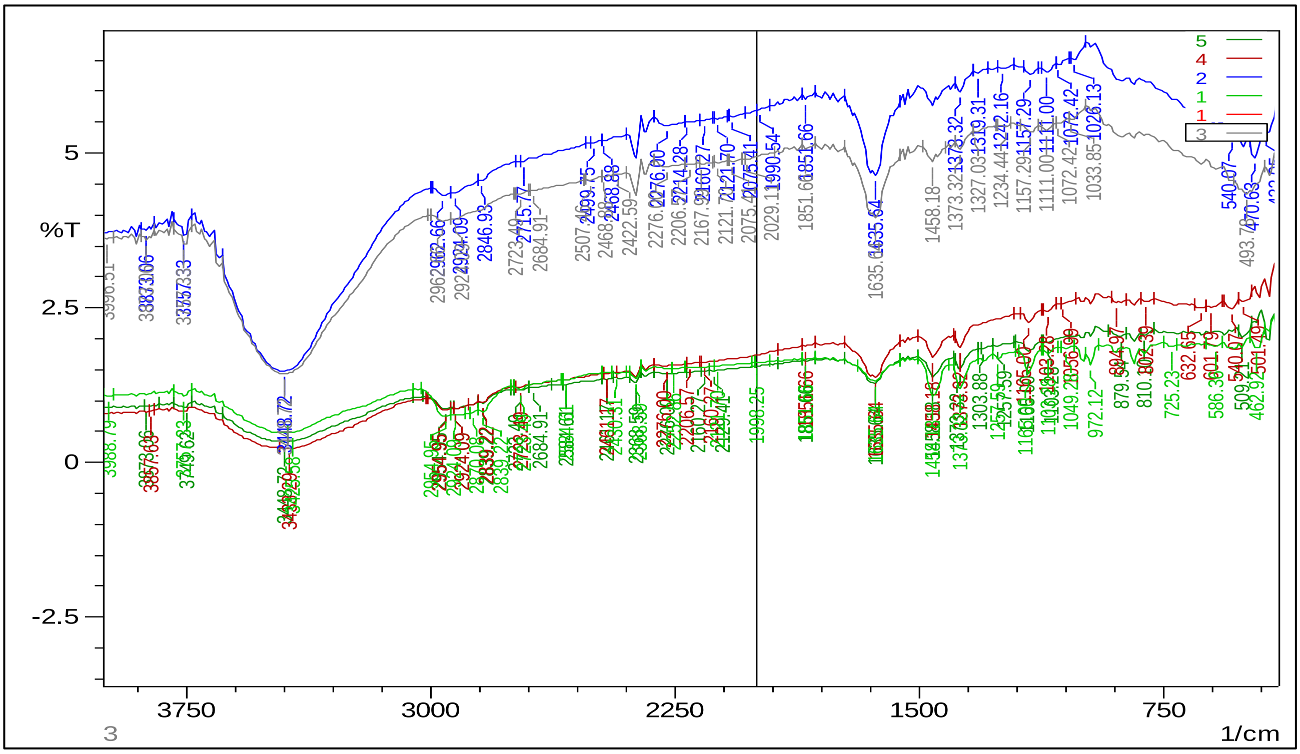


Fig. 9. Represents the samples' FTIR test before adding MAH

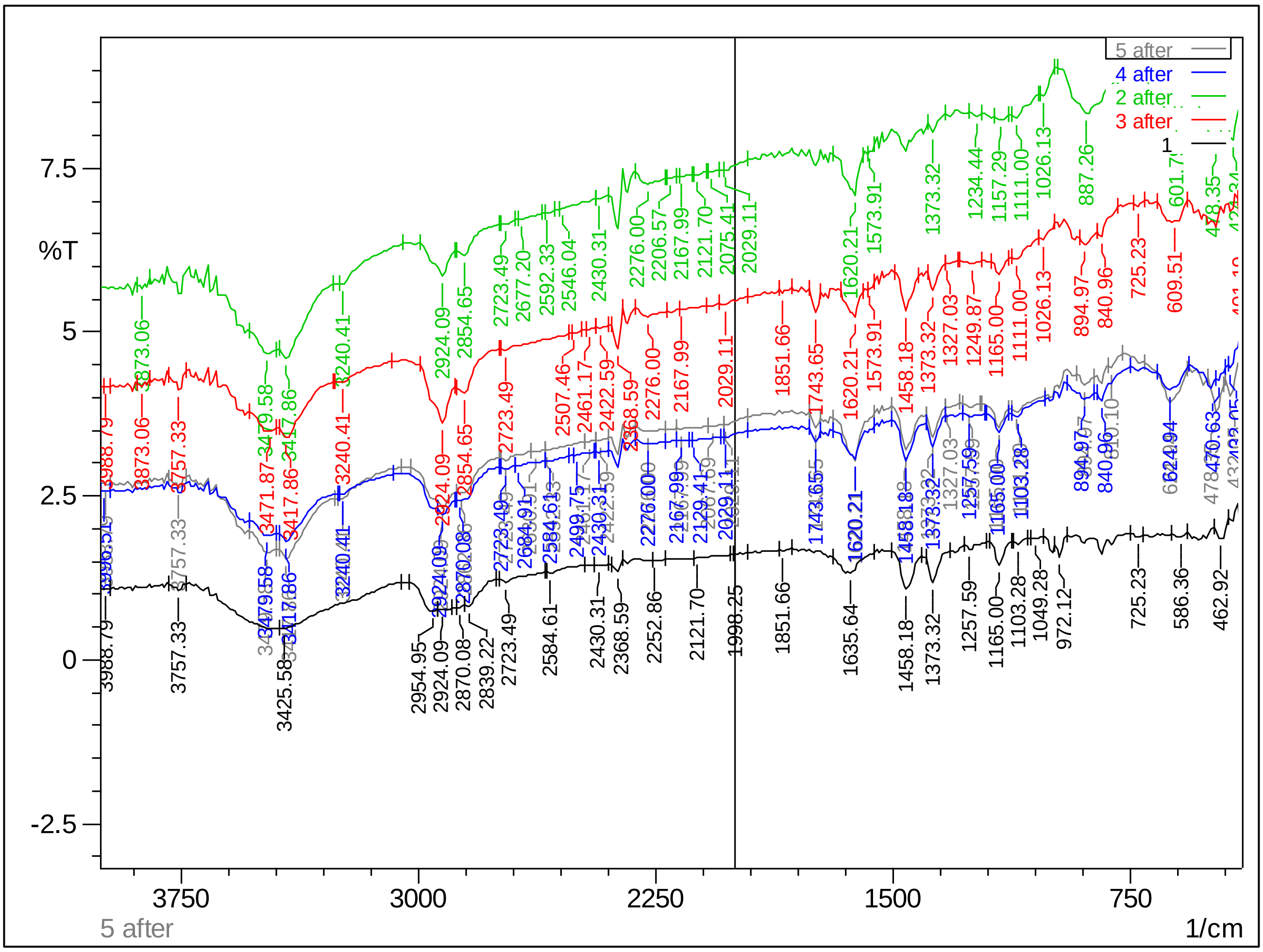
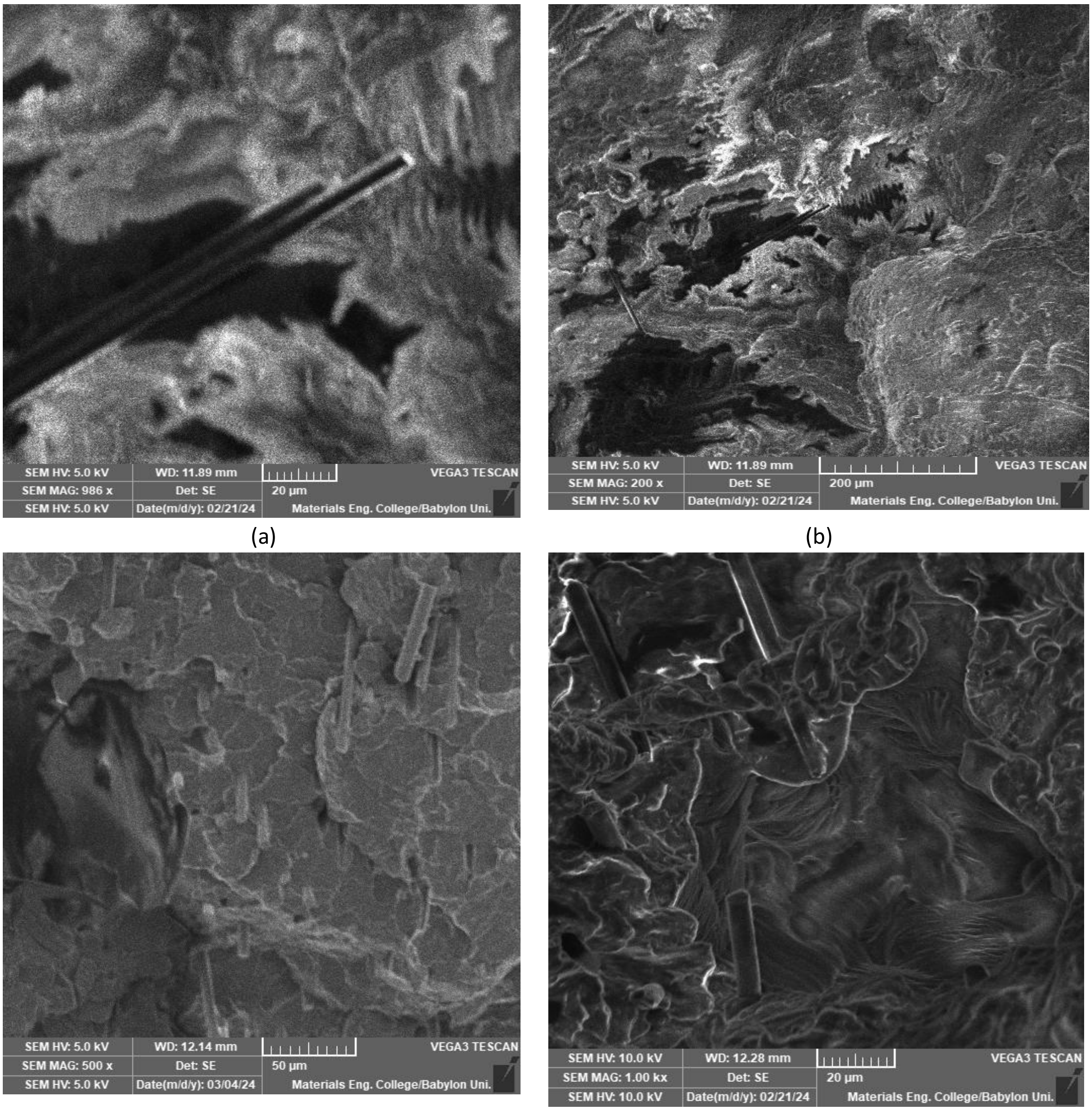


Fig. 10. Represents the samples' FTIR test after adding MAH

3.3 SEM Result

The SEM image is given in Figure 11 before adding MAH, as shown in Figure 11 (a) and (b), where polypropylene has poor bonds with carbon fibers. After adding MAH, as shown in Figure 11 (d) and (c), there is a good bonding between polypropylene and carbon fibers. It is found from SEM micrographs of the fracture surface of the composite after the impact test that when adding MAH, the Interfacial adhesion enhanced between the fibers and the matrix forms a bridge between fibers and matrix and reduces delamination and agglomeration of fibers.



(a) (b)

(c) (d)

Fig. 11. Represents the SEM image before adding MAH (a, b) and after adding MAH (c, d)

4. Conclusion

The present study indicates the effect of adding 1% of MAH on mechanical properties, and FTIR, SEM, and UV tests also compare the samples before and after the addition of MAH to produce composite materials suitable for many applications like car pumpers, tubes, and battery housings which require good impact strength, tensile strength, and hardness. After adding MAH, the tensile strength, hardness, modulus of elasticity, and impact strength increased due to the enhancement of the surface tension between the matrix and carbon fibers. Also, SEM and FTIR specify that there is a good bond between them, and the matrix forms bridge-like fibers. UV explained that the composite material turns opaque when carbon fibers are added, protecting the material from UV sunlight.

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