The Influence of Graphite Filler on the Viscoelastic and Mechanical Characteristics of PC/ABS Hybrid Composite for Automotive Applications

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ABSTRACT

This work aims to enhance the viscoelastic and mechanical properties of the neat Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS) blend by incorporating graphite filler. Thermoplastic composites were prepared with PC/ABS as the matrix and graphite powder as fillers of 3, 6, and 9 wt% by injection molding. The influence of graphite particulate on the mechanical properties of PC/ABS/graphite composite was studied through tensile strength, tensile modulus, percentage elongation, impact strength, flexural strength, and modulus. The results show a 20% improvement in the tensile and flexural modulus of the PC/ABS/graphite composite compared to the neat PC/ABS blend. However, the tensile strength and percentage elongation were reduced by 11.64% and 29.63%, respectively. The storage modulus with 9 wt% of graphite in the PC/ABS blend has the highest modulus over the entire temperature range compared to the neat PC/ABS blend. The addition of graphite filler to the PC/ABS blend increased the tensile, flexural, and storage modulus, even though some mechanical attributes were compromised. The viscoelastic, mechanical, and thermal properties were enhanced by adding graphite as a filler to help plastic product designers design plastic products for automobile applications.

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Introduction

Polymeric materials and polymer matrix composites find many applications in the automotive, aerospace, electrical, and electronics industries due to their lightweight and easy processability. The processability of polycarbonate is enhanced by the inclusion of ABS and finds applications in automobiles and machinery. Previous research found that the PC/ABS (70/30) blend is the best combination with the highest possible mechanical strength [1]. The incorporation of graphene in small amounts improves the mechanical properties, decreases the thermal degradation of PC/ABS, and also improves thermal stability [1]. The addition of fillers enhances the properties of polymeric materials. Polycarbonate is a thermoplastic material with good dimensional stability and better strength. ABS also finds many applications in similar industries, but PC/ABS blend has many superior properties to neat PC and neat ABS [2]. Thermoplastic composites of PC, ABS, and PC/ABS with biocarbon/carbon fiber hybrid composite showed that impact resistance and thermal properties had been improved [3]. The dolomite filler increased the flame-retardant property. Still, the increase in filler beyond 5 wt% reduced flame retardancy, and the glass transition temperature of the composite was highest with the addition of 5 wt% of the filler [4].

A recently published paper discussed the effect of graphene in PC/ABS prepared by the Fused Deposition Modeling (FDM) process, and thermal conductivity increased with the increase in graphene content [5]. The test results were compared with established mathematical models and elaborately discussed the influence of graphene in PC/ABS. Thermoplastic composites have many applications in the industry and manufacturing processes because of the low cost of the PC/ABS blend. The mechanical and thermal characteristics of PC/ABS and Halloysite Nanotubes (HNT) possess better characteristics than pure PC/ABS [6]. The influence of modified fillers such as silica modified with alumina and bentonite modified with ammonia salt was investigated and reported that the flowability of PC/ABS increased by 254.6% with the addition of 3% Bentonite [7]. The hardness of composite material is another important property that enhances the hardness with the addition of bentonite-modified filler in the case of injection molded and 3D printed composites. Even the electrical conductivity improves by adding 3 wt% of bentonites into the polycarbonate matrix. Although the stiffness of the composite decreased with the addition of Multi Walled Nanotube (MWNT), the tensile strength and thermal stability improved. Investigation results revealed that the Electromagnetic Interference Shielding Effectiveness (EMISE) is improved with the incorporation of Carbon Black (CB) filler in

PC/ABS, and better property enhancement is possible with a higher amount of CB and PC in the PC/ABS blend [8].

The mechanical and thermal properties of PC/ABS blends were evaluated by adding graphene nanocomposites. The test results showed that the composite's tensile strength, modulus, and hardness improved due to the incorporation of graphene nanocomposites. The percentage elongation was enhanced by 2 times compared to the matrix material [9]. ABS, PC, and PC/ABS blends are extensively used in electronics, automobiles, and 3D printing applications [10]. With various compositions, blends were prepared by the melt mixing method, and a nano-indentation test analyzed the mechanical properties. The hardness and modulus were measured as the function of penetration displacement. Graphite-filled polymer blends were prepared with polypropylene (PP)/epoxy as the matrix, and graphite powder was used as the filler [11]. The PP/epoxy/graphite composites with various wt% of graphite in the matrix enhanced the flexural strength and elasticity at 70 wt% of graphite powder. It also improved the conductivity of the matrix. Through the use of a twin-screw extruder, Polytetrafluoroethylene (PTFE) flake and sphere shapes were added to pure PC/ABS (70/30), and the mechanical and wear characteristics were assessed. According to a paper, PTFE fillers were evenly distributed throughout the PC/ABS matrix, and flake PTFE particles showed superior mechanical and wear characteristics over spherical particles [12].

In automobile industries, metallic parts of automotive structures are replaced by polymer composites due to their lightweight. These lightweight composites are prepared by injection molding, and the mechanical and flexural properties are enhanced by adding suitable fillers based on the application and requirement [13]. Investigations were conducted with hybrid mesoporous silica incorporated into a PC/ABS blend, and the mechanical and flame-retardant attributes were evaluated. It was revealed that the hybrid mesoporous silica elevated the thermal stability of PC/ABS and behaved as a synergistic agent in Triphenyl Phosphate (TPP) [14]. Through a twin-screw extrusion method, graphene nanoplatelets were added to PC/ABS in varying amounts (1, 3, and 5 wt%) to study the composites' mechanical, structural, and thermal properties. The tensile and flexural strength was raised to 3 wt% of Grapheme Nanoplatelets (GNPs) before beginning to decline. However, Young's and flexural modulus improved by 30% and 54%, respectively. The authors suggested using the composites in automotive, electric equipment, and household products after the FTIR data showed the existence of GNPs in PC/ABS [15].

The viscoelastic properties of thermoplastic materials were enhanced with the addition of graphite filler in PVC and polypropylene and PP/epoxy matrix [16]-[17]. The mechanical properties improved, but the impact strength of the matrix decreased due to the increase in graphite content. The inclusion of expanded graphite in the epoxy matrix showed good dispersion, which resulted in increased degradation temperature and tensile strength (30%) due to the good dispersion of expanded graphite in epoxy [18]. By including graphite filler (5 to 15 wt%), the mechanical, electrical, and tribological characteristics of nylon-6 composites were examined [19]. The samples were made by injection molding, and the test results showed that while the hardness and elastic modulus increased with the amount of graphite in nylon-6, the tensile strength, impact strength, and specific wear rate were reduced. Mechanical characteristics increased up to 10 wt% percent of graphite in nylon-6 before beginning to decline. Research showed that graphite reinforcement in High-Density Polyethylene (HDPE) enhanced the storage modulus, loss modulus, and flexural modulus [20]. It also increases the thermal degradation temperature of the matrix. In addition to the mechanical, viscoelastic, and thermal characteristics, graphite filler also improved the wear characteristics of polymer composites. It was found that the optimum result was achieved with 10 wt% of graphite in epoxy resin [21].

To the best of our knowledge, no such publications were found in the literature review where graphite was used as a filler material in PC/ABS blend to develop thermoplastic composites, even though fillers including graphene, dolomite, bentonite, carbon black, and mica [1], [4]-[5], [7]-[8], [13] were used as fillers in PC/ABS blend to achieve better attributes. According to a report, high-density polyethylene and polypropylene are filled with graphite, which boosts the viscoelastic characteristics and other mechanical features to make them viable for automotive applications. Since no other researcher had attempted to develop such composites, it was decided to use twin screw extrusion and injection molding to create PC/ABS/graphite composites with varying amounts of graphite (0 - 9 wt%). The current study investigates how the viscoelastic, mechanical, and thermal properties of the PC/ABS blend are influenced by the graphite content. The pure PC/ABS blend's homogeneous dispersion of graphite powder was apparent in the SEM images. Dynamic Mechanical Analysis (DMA), Universal Testing Machine (UTM), and Heat Deflection Temperature (HDT) instruments were used to analyze the dynamic mechanical, mechanical, and thermal characteristics. The findings demonstrated that incorporating graphite filler enhanced the storage modulus, mechanical characteristics, and thermal stability of virgin PC/ABS.

Methods

Materials

The PC/ABS blend of 70:30 ratios was procured from Bhansali Polymers, Mumbai, India in the form of granules [6]. The graphite powder of sizes 70 μm was procured from Chem – o – Chem, a Chemical supplier, in Chennai, India.

Compounding and injection molding

The PC/ABS blend was preheated in an oven at a temperature of 80 ℃ for 5 hours to remove the moisture, and then the graphite powder (3, 6, and 9 wt%) was added manually to the blend. The compounding of the PC/ABS blend and the graphite filler was performed using a twin-screw extruder at a speed of 80 rpm; the length-to-diameter ratio of the extruder was 40:1. Throughout the three zones, composites were fabricated using a twin-screw extruder at a temperature between 220 and 260 °C. The output from the extruder was in the form of strands and cut into granule form with a pelletizer. Then the granules were heated in a hot air oven at 80 ℃ for 4 hours to remove the moisture before injection molding in a two-plate injection molding machine. The plate size of the two-plate mold was 300 x 300 mm.

Characterizations

Dynamic Mechanical Analysis (DMA)

The viscoelastic behaviour of the PC/ABS blend and the PC/ABS/graphite composites were analysed by dynamic mechanical analysis (DMA) using Dynamic Mechanical Analyzer (DMS 6100, SII Nano Technology, Japan). The sinusoidal force was applied in three-point bending mode to determine the storage and loss modulus, and the specimen size was 55 x 10 x 3 mm. The test results were obtained with a frequency of 20 Hz from 30 – 150 ℃ at a ramp of 3 ℃ per minute in a nitrogen atmosphere, and the flow rate of nitrogen liquid was maintained at 50 mL/min.

Fourier Transform Infrared Spectroscopy (FTIR)

The chemical bonds and the presence of functional groups in the composites were analyzed by the Fourier Transform Infrared (FTIR). The Fourier Transform Infrared (FTIR) spectra were recorded over a wave number of 4000 – 400 cm^{-1} using a thermo-scientific spectrometer with a resolution of 4 cm^{-1} and 32 scans.

Mechanical characterizations

The mechanical characteristics of the composites were determined as per the ASTM D638 standard in a universal testing machine (Instron Limited, UK) of 1kN capacity in an atmospheric condition. The dimensions of the test specimen were 60 mm (gauge length) x 10 mm width x 3 mm thickness and the crosshead speed in UTM was maintained at a speed of 50 mm/min. The composite samples' tensile strength, tensile modulus, and percentage elongation of the samples were measured from the data recorded in the universal testing machine which was connected to a computer. The flexural strength and flexural modulus were measured using the same universal testing machine and the ASTM D790 was used for the flexural test. The dimensions of the flexural test samples were 100 x 10 x 3 mm. The average of three samples was taken as the flexural strength and flexural modulus of the composites.

SEM analysis

The composites' morphological study was carried out using a Scanning Electron Microscope (SEM; Carl Zeiss, USA; Bruker, Germany) and all the samples were gold-coated before analysis. The fractured samples of tensile testing were used for the morphological characterization. The purpose of the SEM analysis was to check the dispersion of graphite filler in the pure PC/ABS matrix.

Heat Deflection Temperature (HDT) analysis

The HDT measures the stiffness and thermal properties of plastic materials as per ASTM standard D648 with a change in temperature of 3 ℃/minute using a laboratory scale HDT instrument available in the Department of Polymer Engineering, B S Abdur Rahman Crescent Institute of Science and Technology, Chennai. The sample was kept between the two supports, and the load was applied in the middle. As per ASTM standard, the temperature was noted as the sample deflected 0.25 mm in the middle. The average value of 3 samples for each composition was considered as the HDT of the composite.

Results and Discussion

Dynamic Mechanical Analysis

The viscoelastic characteristics of the matrix and PC/ABS/graphite composites were investigated by DMA. This is a dynamic mechanical characterization technique to measure the damping properties of polymers. The storage modulus of any viscoelastic material is the amount of energy absorbed and estimates the stiffness changes of the composite materials. The storage modulus of any viscoelastic material represents the elastic component, and the loss modulus represents the viscous component in the material. It was observed from Figure 1 that the graphite content in the PC/ABS blend enhanced the storage modulus.

It was reported that Exfoliated Graphite (EG) filler in an ABS matrix [16] reduced the amplitude of molecular vibrations due to the strengthening effect between the matrix and filler which enhanced the storage modulus. The storage modulus of the PC/ABS blend and the PC/ABS/graphite composite (3 and 6 wt%) decreased slowly over the temperature range of 45 – 100 ℃. Then it decreased suddenly, whereas increasing the graphite content of wt% in the PC/ABS composite slowly decreased the storage modulus to 120 ℃. It was observed that the storage modulus of the prepared composite with 9 wt% of graphite incorporated PC/ABS blend has the highest modulus over the entire temperature range compared to the other compositions and earlier researchers had similar results [19]. It was reported that the storage modulus of thermoplastic matrices improved with the addition of fillers [23]-[24], [27], [28]. An interesting result was found that the storage modulus decreased correspondingly to 3 wt% of graphite in the PC/ABS blend, but it improved at 6 and 9 wt% of graphite content in the same matrix. At all temperatures, the effect of the filler content (except 3 wt% of graphite) on the viscoelastic characteristics led to a significant increase in storage modulus. The composites prepared with neat ABS and textile fiber also showed a similar trend [30]. The superior mechanical inequalities between the matrix (PC/ABS) and filler predominantly induce the reinforcing action between the two materials (graphite). Due to the restriction effect on the segmental mobility of PC/ABS chains, the graphite particles might have helped to improve the storage modulus.

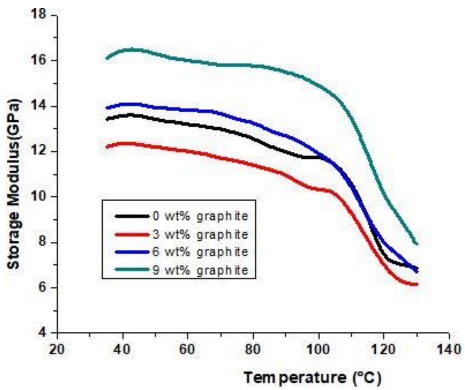

Figure 1: Influence of the graphite filler on the storage modulus of PC/ABS blend

The effect of graphite content on the loss modulus of the PC/ABS blend is presented in Figure 2. The test results presented in the figure showed an improvement in the loss modulus of the pristine matrix. Although the loss modulus decreased corresponding to 3 wt% of graphite in PC/ABS but increased as the filler content raised to 6 and 9 wt%. The maximum improvement in loss modulus was observed at 9 wt% of graphite in PC/ABS [16], [19].

The effect of graphite content on the Tan Delta of the PC/ABS blend is depicted in Figure 3. The peak in a Tan Delta vs. temperature represents the glass temperature of polymer materials. The graph showed two different peaks because a neat PC/ABS blend is a copolymer consisting of polycarbonate and acrylobutadiene styrene. So, it showed 2 peaks in the graph and the addition of graphite content in the PC/ABS blend shifted the peaks in the graph towards the right side increasing the glass transition temperature (T_g). The increased value of T_g for the PC/ABS/graphite composites enhanced the thermal stability of the composite. By the inclusion of graphite in the PC/ABS blend, the composite becomes stiffer and reduces the mobility of the polymer chains and the peak of the graph is shifted to raise the glass transition temperature [16], [19], [30].

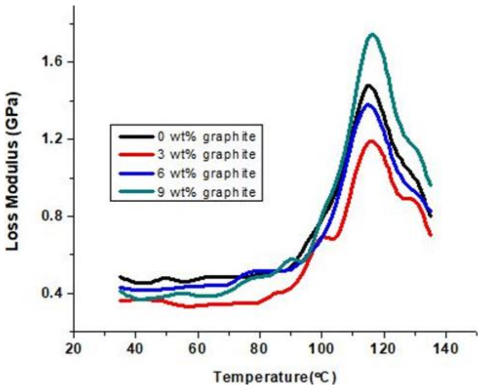

Figure 2: Effect of graphite content in the loss modulus of PC/ABS blend

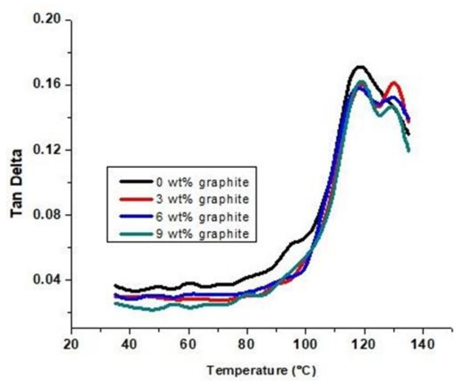

Figure 3: Effect of graphite content in the Tan Delta of PC/ABS blend

FTIR analysis

The FTIR spectra of the matrix and the prepared composites with 3%, 6%, and 9% of graphite in the PC/ABS matrix are shown in Figure 4. PC/ABS and graphite-filled PC/ABS composites show peaks at 2970-2924 cm^{-1}, and 1460 cm^{-1} are attributed to the vibration of aliphatic components R- CH_2 - R and R-CH_3, respectively. The peaks that appeared around 1769 cm^{-1} and 1502 cm^{-1} are due to the C=O and C-O. The dominant peaks 1190 cm^{-1} and 1222 cm^{-1}

correspond to C-H_3 bonding, and medium peaks around 829 cm^{-1} were assigned to C-H wagging vibration. When comparing PC/ABS/graphite composites to neat PC/ABS, no significant change in peak positions was detected, implying that the addition of various graphite compositions did not result in any substantial change in the chemical structure of the PC/ABS matrix. However, compared to pure PC/ABS blends, the position of the 3400-3028 cm^{-1} bands intensities of PC/ABS/graphite composites migrated to lower wavenumbers. It was also observed that the addition of graphite onto the PC/ABS blend slightly decreases the intensity of the C=O band approximately at 1769 cm^{-1} due to the formation of π-π stacking between PC aromatic rings and graphite. The high shear stress produced during extrusion forms many closely aligned phenyl rings parallel to graphite [24], [26]. Thus, FTIR confirmed the interaction between graphite and PC/ABS blends.

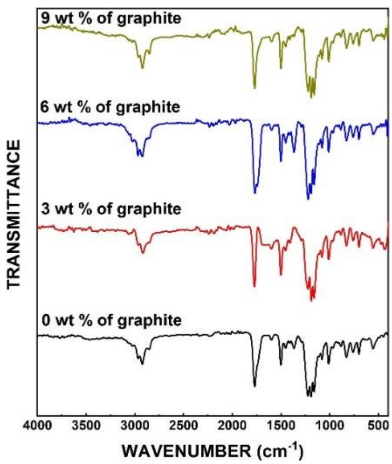

Figure 4: FTIR spectra of neat PC/ABS and the PC/ABS/graphite composites

Mechanical Characteristics

Tensile strength and tensile modulus

The tensile strength and tensile modulus of the PC/ABS blend and the PC/ABS composite with various wt% of graphite content are presented in Figure 5 and Figure 6, respectively. From the tensile strength vs. wt% of graphite graph, it is evident that the tensile strength of composite decreases with the increase in wt% of graphite filler. The tensile strength of the matrix and the composite with 3, 6, and 9 wt% of graphite contents in the matrix are 51, 46, 47, and 45 MPa, respectively. There is a slight increase in the tensile strength of the composite at 6 wt% of graphite compared to 3 wt% of graphite, but again it decreases at 9 wt% of graphite fillers incorporated into PC/ABS blends. The reduction in tensile strength of the PC/ABS/graphite composite at 9 wt% of filler is 12.53% compared to the neat PC/ABS blend. A similar result was reported as the filler content increased and the thermoplastic composites' tensile strength decreased [29]. They have identified that increased agglomeration reduces tensile strength. The addition of graphite content in the PC/ABS blend made the crystal structure smoother and a heterogeneous mixture at a higher filler ratio might have been the reason for reducing the tensile strength. This finding is consistent with prior research showing that tensile strength was diminished when mica and dolomite fillers were added to a PC/ABS (70/30) blend [4], [13]. They ascertained that the polymer matrix disconnected from the filler particle and voids were created as the filler loading ratio in PC/ABS blends increased. The tensile strength was reduced due to the aggregation of dispersed filler particles.

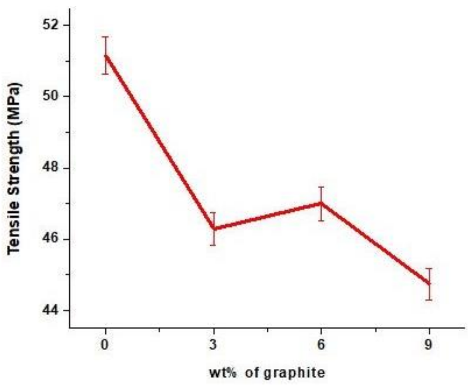

Figure 5: Influence of graphite content on the tensile strength of PC/ABS blend

But the tensile modulus of the PC/ABS/graphite composite increases from 2115 MPa (Neat PC/ABS) to 2645 MPa (PC/ABS blend with 9 wt% of graphite particulates), which is a 25% increase in the tensile modulus compared to pure PC/ABS blend. The tensile modulus of the composite at 9 wt %age of graphite increased by 25% for the neat PC/ABS blend [2]-[3], [27], [29]. It was found that the tensile modulus of PC/ABS improved as the weight percentage of graphite filler increased. The increased stiffness of PC/ABS composite that results from adding filler may be attributed to the organic filler's inherent stiffness, which is comparatively larger than that of the polymer matrix. According to reports, incorporating more dolomite into PC/ABS and polypropylene (PP) boosted the composites' tensile modulus [4], [22]. So, a similar trend was found by adding graphite with the PC/ABS matrix. The findings are consistent with adding graphite to nylon-6 composites [29].

Perhaps the inclusion of graphite particles improves the crystal structure, but a heterogeneous combination may evolve at higher graphite ratios. Similar results were found when the tensile modulus of a PC/ABS blend was increased by incorporating mica particulates [13]. One possible explanation is that the composite's tensile modulus was increased because the filler was stiffer than the matrix.

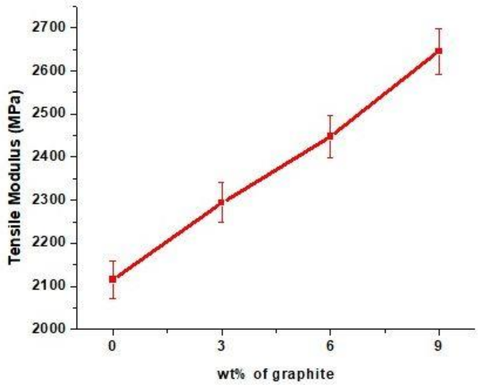

Figure 6: Influence of graphite content in tensile modulus of PC/ABS blend

Percentage elongation

The percentage elongation is shown in Figure 7, and it is evident from the curve that the percentage elongation of the composite decreased with the rise in the filler content percentage in PC/ABS. It made the composite more brittle and the reduction in percentage elongation from 4.15% to 2.92%.

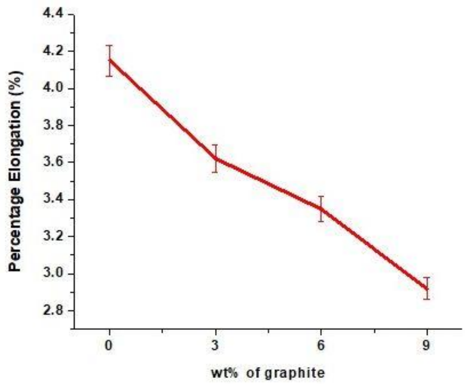

Figure 7: Effect of graphite wt% on the percentage elongation of PC/ABS blend

As the filler proportion in the PC/ABS blend rose, the elongation percentage decreased. The stress concentration tendency of graphite demonstrates that the composite gets more brittle as the weight percentage increases. Earlier investigations discovered a resemblance by including dolomite and mica in PC/ABS [4], [13]. It was reported that the inclusion of graphite in Nylon-6 decreased the percentage of elongation [29]. The increase in fractures surrounding the filler particles and potential agglomeration and void formation that could lead to local dissociation of the matrix from the filler particles may be the causes of the decline in percentage elongation.

SEM Analysis

SEM analysis was used to examine the interfacial bonding, filler dispersion, and mix compatibility between the PC/ABS matrix and graphite filler. The micrographs of 3, 6, and 9 wt% of graphite in PC/ABS were shown in Figures 8(a), 8(b), and 8(c). It was noticed that the PC/ABS mixture and the graphite filler were equally distributed. Since there was good interfacial adhesion between the matrix and filler, as shown in Figures 8(a) and 8(b), the tensile and flexural strengths were maximum at 6 wt% of graphite in PC/ABS. However, PC/ABS that included 9 wt% of graphite revealed voids and had poor matrix-filler compatibility.

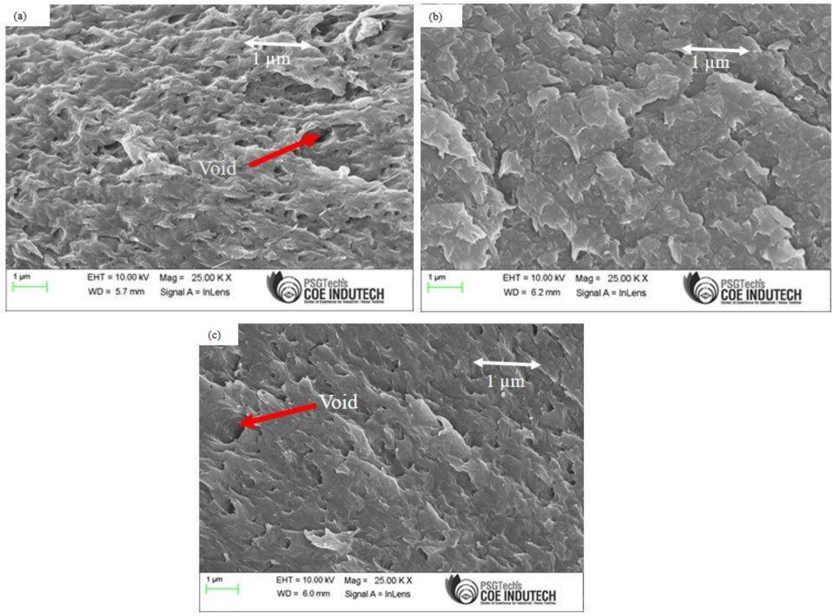

Figure 8: SEM images; (a) PC/ABS and 3 wt% graphite, (b) PC/ABS and 6 wt% graphite, and (c) PC/ABS and 9 wt% graphite

Shore hardness

The shore hardness is presented in Figure 9, and the hardness of the composites increased with the rise in the mass percentage of graphite in the PC/ABS blend. The increase in the shore hardness is 4.22% at the 9 wt% of graphite compared to the neat PC/ABS blend, and a similar trend was observed by researchers [3], [12], [29]. The composites' shore hardness increased, likely because of the rigidity of the graphite filler and the increased modulus that allowed them to withstand a greater depth of penetration as the hardness of neat ABS increased with the rise in the ZnO filler content [31].

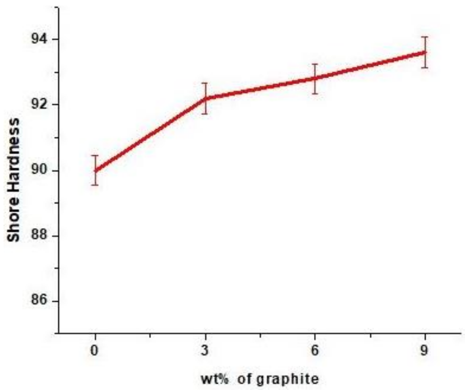

Figure 9: Effect of wt% of graphite in shore hardness of PC/ABS blend

Flexural strength and flexural modulus

Figures 10 and 11 represent the influence of graphite content on the flexural strength and flexural modulus of pure PC/ABS blend and the PC/ABS/graphite composites. It is noticed from Figure 10 that the flexural strength decreased at 3 wt% of graphite and again increased when the wt% of filler is 6%, but the flexural strength at the 9 wt% is the least value compared to all other wt% of graphite filler in the composite. The effects of the wt% of graphite in the flexural modulus of pure PC/ABS blend are shown in Figure 11. The flexural modulus increased with the gradual filler content up to 6 wt% of graphite in the PC/ABS blend and then decreased. The highest flexural modulus is achieved at the 6 wt% of filler content. The maximum flexural strength and modulus are 79.48 MPa and 2542.86 MPa, respectively. Although the flexural strength is increased only by 1.34%, in agreement with the previous investigation [28], the flexural modulus increases by 21.55%. So, it is very clear that both tensile modulus and flexural modulus increase significantly as the wt% of graphite increases in the PC/ABS blend. Similar results were reported by other researchers by adding fillers in thermoplastic matrices [6], [10], [12], [28]-[29].

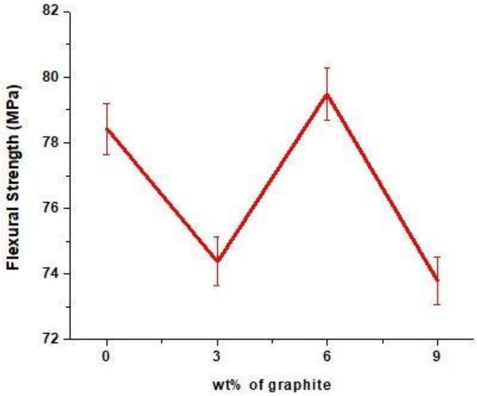

Figure 10: Effect of wt% of graphite in flexural strength of PC/ABS blend

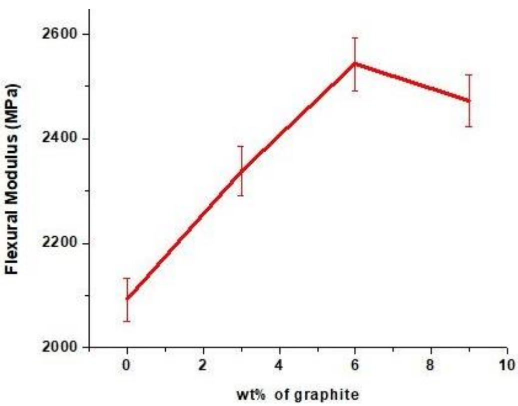

Figure 11: Effect of wt% of graphite in flexural modulus of PC/ABS blend

As the loading of graphite content in PC/ABS was elevated further (beyond 6 wt%), flexural strength and flexural modulus were also reduced. As filler-filler attraction forces inside the graphite particles result in an agglomeration that decreases the surface area available for stress transfer, this may be attributed to graphite restacking after a certain proportion of graphite in the PC/ABS matrix. The interaction between graphite and PC/ABS was good at 6 wt% of graphite due to better dispersion, which might be linked with boosting flexural strength and modulus up to 6 wt% of graphite in the matrix and then decreased at 9 wt% of graphite due to agglomeration of filler when more quantity was added.

Heat Deflection Temperature (HDT) analysis

Figure 12 represents the influence of graphite content on the heat deflection temperature of the PC/ABS blend. The heat deflection temperature (HDT) of the PC/ABS was enhanced with the increase in the wt% of the graphite. The graph represents the rise in HDT by 7.6 ℃ corresponding to 9 wt% of graphite in PC/ABS (approximately 10% increase in HDT). The inclusion of the graphite filler in the neat PC/ABS blend made it stiffer (was observed from the result of percentage elongation), so as the composite becomes stiffer it resists load up to a higher temperature and it showed an increase in the heat deflection temperature by 7.6 ℃.

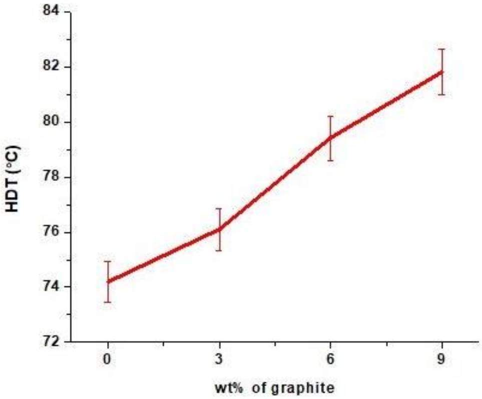

Figure 12: Effect of wt% of graphite on heat deflection temperature of PC/ABS blend

Conclusion

PC, ABS, and PC/ABS blend polymers are widely used in automobiles and other industries. Thermoplastic composite of PC/ABS (70/30) as the matrix and graphite as filler with mass ratios (3, 6, and 9 wt%) were prepared through the extrusion process and sample preparation by two plate injection molding. The mechanical and thermal characteristics were investigated, and the following are some of the important conclusions arrived:

1. The DMA studies confirmed that the storage modulus of the pure PC/ABS matrix was enhanced with the addition of graphite content over a wide range of temperatures. The storage modulus is improved by more than 70% over a wide range of temperatures.
2. The addition of graphite contents improves the tensile and flexural properties of PC/ABS/graphite composite. Both tensile and flexural modulus increased by 20% compared to the neat PC/ABS polymer.

3. The tensile strength and percentage elongation were reduced by 12.53% and 2.96%, respectively. As the prepared composite became more brittle than the PC/ABS blend, the hardness increased by 4.22% at 9 wt% of graphite particles in PC/ABS.
4. Flexural strength initially decreased at 3 wt%, increased at 6 wt%, and again decreased at 9 wt% of graphite. So, the highest flexural strength of 79.48 MPa was achieved at 6 wt% of graphite content in the PC/ABS blend.

This thermoplastic composite can be used as a bearing and gear in automotive, electrical, and medical instrument applications.

Contributions of Authors

The authors confirm the equal contribution in each part of this work. All authors reviewed and approved the final version of this work.

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Conflict of Interests

All authors declare that they have no conflicts of interest.

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