IJIE

INTERNATIONAL JOURNAL OF INTEGRATED ENGINEERING
ISSN: 2229-838X e-ISSN: 2600-7916

Vol. 18 No. 2 (2026) 375-383
https://publisher.uthm.edu.my/ojs/index.php/ijie

Effect of Graphene Fillers on the Mechanical Properties of Kenaf Fibre Reinforced Polypropylene Composites

Nur Izzati Zulkarnain[1], Izdihar Tharazi[1], Mohamad Nazrin Hazim Ahmad Faiesal[1], Ramli Junid[2], Abdul Hakim Abdullah[1]*

1 *Faculty of Mechanical Engineering,*
Universiti Teknologi MARA (UiTM), Shah Alam, 40450, Selangor, MALAYSIA
2 *Faculty of Manufacturing and Mechatronic Engineering Technology,*
Universiti Malaysia Pahang Al-Sultan Abdullah, Pekan, 26600, Pahang, MALAYSIA

*Corresponding Author: hakimnen@uitm.edu.my
DOI: https://doi.org/10.30880/ijie.2026.18.02.030

Article Info

Received: 15 November 2025
Accepted: 31 March 2026
Available online: 8 July 2026

Keywords

Graphene-reinforced composites, Kenaf fibre, polypropylene, thermal and mechanical properties, hot press moulding

Abstract

This study investigated the influence of graphene nanoplatelet fillers on the mechanical performance of kenaf fibre reinforced polypropylene composites. Composites were fabricated with varying weight proportions of polypropylene matrix, kenaf fibre, and graphene with composition ratios of 90-10, 90-9.5-0.5, 90-9.0-1.0, and 90-8.5-1.5. Composite samples were fabricated using a hot-press compression moulding at 180°C. Thermal characterisation of each kenaf fibre, graphene and polypropylene was conducted using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). The produced composites were then subjected to tensile, flexural and impact testing. Thermal analysis: TGA and DSC revealed that graphene exhibited excellent thermal stability with no significant weight loss. In contrast, kenaf fibre showed typical degradation associated with the decomposition of its structural components. The melting point of polypropylene was confirmed at approximately 165°C. Mechanical evaluation showed that the composition with 1.5 wt.% graphene (90-8.5-1.5 specimen) exhibited the highest tensile strength (21.9 MPa), flexural strength (24.6 MPa), and impact strength (22.8 J/m^2). The enhanced mechanical properties are caused by the improved fibre-matrix interfacial bonding facilitated by the inclusion of graphene in the composites. The outcomes of this study offer a sustainable solution for automotive and load-bearing applications.

1. Introduction

In many Southeast Asian countries, kenaf fibre is emerging as a sustainable and underutilised resource with significant potential due to its unique properties and versatility. Known for its high strength and rigidity, kenaf fibre resembles a unidirectional fibre-reinforced composite with nodes along its length and is composed of cellulose fibres in a lignin matrix. Researchers are increasingly interested in kenaf because of its availability, versatility, resilience, cost-effectiveness, and high strength-to-weight ratio [1]. Combining kenaf fibre with polypropylene (PP) and enhancing the composite with graphene presents a promising approach to developing advanced materials with superior properties for diverse industrial applications [2].

Polypropylene (PP) is a thermoplastic polymer produced by polymerising propylene. It can be sourced from steam-cracking processes, gasoline refining, and propane dehydrogenation. PP's wide range of applications is due to its high thermal distortion temperature, transparency, flame resistance, dimensional stability, and impact strength. making it an excellent matrix material for creating natural-synthetic polymer composites [3].
Graphene, a single layer of carbon atoms in a two-dimensional honeycomb lattice, exhibits extraordinary mechanical, electrical, and thermal properties. Adding graphene to polymer composites can significantly enhance their performance. The combination of PP with natural fibres like kenaf, plus the addition of graphene, provides a pathway to create advanced composites with improved properties [4]. Integrating kenaf fibre with polypropylene offers numerous benefits. Kenaf fibre enhances the mechanical properties of the PP composite, including tensile strength, flexural strength, and impact resistance. A 2020 study reported that PP reinforced with aligned kenaf fibres (0° orientation) exhibited a flexural strength of 110 MPa and modulus of 8.5 GPa, approximately six times higher than pure PP [5]. Low density kenaf fibres results in lightweight composites advantageous in automotive and construction applications.

Additionally, kenaf fibres are more sustainable and cost-effective than synthetic fibres [3]. Incorporating graphene into kenaf fibre-PP composites further enhances their properties. Graphene's exceptional strength and stiffness can improve the composite's mechanical properties. Its high thermal conductivity enhances thermal stability and heat dissipation, while its electrical conductivity introduces new functionalities, such as electromagnetic interference (EMI) shielding and sensing capabilities [4].
Despite the promising potential of kenaf fibre-PP composites with graphene, several challenges must be addressed. Ensuring good adhesion between kenaf fibres, graphene, and the PP matrix is crucial for composite performance. Furthermore, a recent study reported by Tharazi et al. [6] has shown that optimizing hot pressing parameters such as temperature, pressure, and heating time can significantly influence the mechanical properties of kenaf-reinforced composites. Surface treatments of kenaf fibres and the use of coupling agents can improve compatibility. Additionally, while kenaf fibres are inexpensive, the cost and scalability of producing high-quality graphene must be considered for commercial applications [7].

The incorporation of graphene nanoplatelets (GNPs) in natural fibre composites has been extensively explored in recent years. Mohd et al. [4] reported that adding GNPs into hybrid non-woven kenaf fibre reinforced polypropylene composites enhanced thermal stability and improved mechanical strength. Similarly, a study from Idumah and Hassan showed that GNPs improved the electrical conductivity and stiffness of kenaf/PP composites, demonstrating multifunctional performance [8]. A study by Mirzaei et al. [9] further confirmed that optimized combinations of kenaf fibres and graphene significantly enhanced tensile and flexural properties, particularly when compatibilizers were employed to improve interfacial adhesion. More recently, Taghipoor et al. [10] emphasized the need to optimise filler loading and processing parameters, since poor dispersion of graphene can lead to agglomeration and defects within the polymer matrix.

However, the specific impact of graphene fillers on the mechanical properties of kenaf fibre reinforced polypropylene composites is not well understood [4]. It is crucial to investigate how different concentrations and dispersions of graphene fillers affect the tensile strength, flexural strength, impact resistance, and overall mechanical performance of these composites. Therefore, this research aimed to study the influence of graphene filler content on the mechanical properties of kenaf fibre reinforced polypropylene composites.

2. Methodology

2.1 Materials

In this study, polypropylene pellets with an average diameter of approximately 4 mm were used as the matrix for the composites. Kenaf fibre, ground to a fineness of 625 mesh (≈20 μm), served as the fibre reinforcement. Graphene nanoplatelets (xGnP M-5, 5 μm particle size) purchased from Sigma-Aldrich were employed as the filler.

2.2 Composite Fabrication

2.2.1 Polypropylene, Kenaf Fibre and Graphene Composition

The preparation of composite specimens began with precise mass calculations (wt.%) for each formulation, following established protocols from prior studies [10]. Subsequently, the materials were subjected to a process involving mixing and blending. This allows uniform dispersion of the graphene fillers. A crushing process was done later to obtain the desired particle size distribution. Four formulations with varying compositions were developed as shown in Table 1. The control sample containing 90% polypropylene and 10% kenaf fibre served as a baseline to evaluate the effects of graphene addition. The incremental incorporation of graphene at 0.5%, 1.0%, and 1.5% was developed.

Int. Journal of Integrated Engineering Vol. 18 No. 2 (2026) p. 375-383

Table 1 *Sample designation for the composites*

Sample Designation	PP (wt.%)	Kenaf (wt.%)	Graphene (wt.%)
90-10	90	10	0
90-9.5-0.5	90	9.5	0.5
90-9.0-1.0	90	9.0	1.0
90-8.5-1.5	90	8.5	1.5

2.2.2 Mixing and Blending

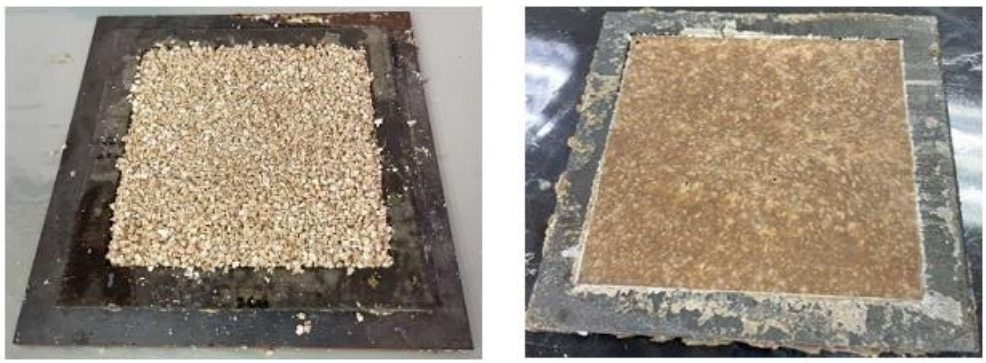
Kenaf fibre, polypropylene and graphene nanoplatelets were mixed in the Sigma blade mixer. Proper mixing is essential to ensure homogeneity, minimize air entrapment, and promote effective interfacial interactions among the composite constituents. The blending duration varies according to the formulation, particularly with changes in the kenaf fibre content. An increase in kenaf fibre loading results in a corresponding increase in the time required to achieve uniform dispersion and complete mixing.

2.2.3 Crushing

The mixed sample from the Sigma blade mixer undergoes a crushing process to break it into particles, facilitating its effective loading into the mould. The crushed particles were then evenly distributed inside the mould's cavity. Any gaps and air pockets in the mould's cavity were identified and eliminated.

2.2.4 Hot Press Compression

The filled mould was then positioned between the hot press compression moulding machine and subjected to a pressure of 5 MPa at a temperature of 180 °C. This application of heat softens the material, making it more flexible and enabling it to adopt the dog bone and square shapes. The pressure of 5 MPa ensures that the material is compacted within the mould, ensuring it conforms to the mould's shape and achieves the desired density and consistency [11]. The samples are held under this pressure for 20 minutes to allow them to fully conform to the mould's shape and undergo physical transformation. Following the heating process, the specimen undergoes a cooling process by being exposed to ambient room temperature for 20 minutes, allowing a gradual cooling scheme. The total time taken for this hot press process is 45 minutes per sample. Fig. 1(a) and Fig. 1(b) depict the composite panel before and after the hot press process.



(a) **(b)**

Fig. 1 *Composite specimens during the hot-pressing process: (a) Before pressing; and (b) After pressing*

2.3 Materials Characterization and Mechanical Testing

2.3.1 Thermogravimetric Analysis (TGA)

The thermal degradation behaviour of kenaf fibre, polypropylene, and graphene was analysed using a Mettler Toledo thermogravimetric analyser (TGA). Approximately 10-15 mg of each sample was acquired and then heated from room temperature to 600 °C at a constant heating rate of 10 °C min^{-1} under a nitrogen atmosphere.

2.3.2 Differential Scanning Calorimetry (DSC)

DSC analysis was carried out on kenaf fibre, polypropylene, and graphene using a Mettler Toledo DSC model machine. Samples of about 10-15 mg were heated from room temperature to 350 °C at a rate of 10 °C/min under a nitrogen atmosphere. The DSC analysis data is valuable for determining the permissible temperature range suitable for the injection moulding process.

2.3.3 Tensile Test

A ServoPulser Shimadzu Universal Testing Machine (UTM) was used to conduct tensile tests in accordance with ASTM D638 standard. Composites were loaded to a crosshead speed of 5 mm/min up to failure. The testing was done at room temperature with a relative humidity of around 60%. Tensile strength and tensile modulus were calculated from stress-strain curves and the results were analysed accordingly.

2.3.4 Flexural Test

The flexural test was conducted according to the ASTM D790 standard using a ServoPulser Shimadzu Universal Testing Machine (UTM). Rectangular specimens measuring 80 mm in length,12.7 mm in width and 3.2 mm in depth were employed for two-point bending configurations. Samples were loaded at a rate of 5 mm/min up to failure. Flexural strength and flexural modulus values were evaluated from the experimental data.

2.3.5 Izod Impact Test

The impact test was conducted to measure the maximum impact strength by the test specimen. Samples were cut into a rectangular dimension; 60 mm in length, 12.7 mm in width and 2.3 mm in depth. A V-shaped notch was machined samples according to the ASTM D25. Composites were impacted using an Izod impact test machine at room temperature.

3. Results and Discussion

3.1 Thermogravimetric Analysis (TGA) of Fibre, Graphene and Polypropylene

Fig. 2 shows the weight loss of samples subjected to temperature elevation in TGA analysis. Kenaf fibre began to decompose at a lower temperature (~90°C) primarily due to the evaporation of moisture and volatile compounds. As the temperature increased, another significant weight loss occurred between 200-260°C. This suggests hemicellulose degradation had occurred. This is followed by the decomposition of cellulose between 300–370°C in the TGA curve [9]. The thermogravimetric curve for pure polypropylene showed the onset of decomposition at approximately 350°C marked by a sharp drop in mass. In contrast, it is interesting to observe that graphene remains stable throughout the temperature range and does not decompose, unlike the kenaf fibre and polypropylene matrix.

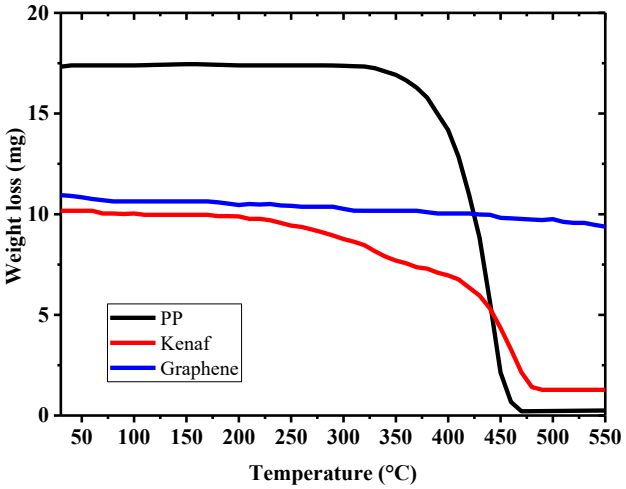


Fig. 2 *TGA traces for kenaf, graphene and polypropylene*

Int. Journal of Integrated Engineering Vol. 18 No. 2 (2026) p. 375-383

3.2 Differential Scanning Calorimetry (DSC) of Fibre, Graphene and Polypropylene

Fig. 3 shows the heat flows of the composites using differential scanning calorimetry analysis. Polypropylene shows a melting point temperature, T_m during heating at 143 °C, which is typical for semicrystalline polypropylene. It can be observed that kenaf fibre exhibits a broad endothermic region within the temperature range of 45–250 °C. The primary cause could be the evaporation of moisture and the release of volatile components. The DSC thermograph indicates that graphene remains stable with only minimal changes, showing its strong thermal stability over a wide range of temperatures. These results highlight the melting behaviour of PP, the decomposition behaviour of kenaf, and the stability of graphene.

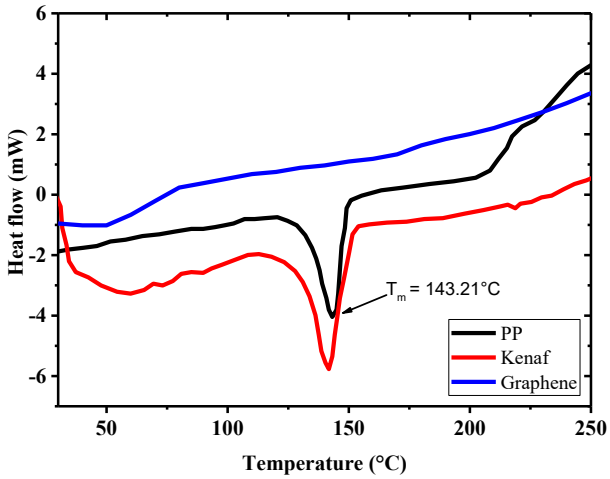


Fig. 3 *DSC traces for kenaf, graphene and polypropylene*

3.3 Tensile Properties of Composites

Fig. 4(a) shows the tensile strength of composites with and without graphene filler. The bar chart shows that the composite containing 90% polypropylene and 10% kenaf fibre exhibits a tensile strength of 15.06 MPa. The data clearly indicate that the addition of graphene filler enhances the tensile properties of the composites. Incorporation of 0.5 wt.% graphene resulted in an increase in tensile strength to 23.61 MPa, demonstrating a significant improvement of 23.6% over the reference composite. A higher graphene content in the composites resulted in improved tensile strength. The specimen containing 1.5 wt.% graphene exhibited a 45.5% improvement, achieving the highest tensile strength of 21.91 MPa among all tested composites.

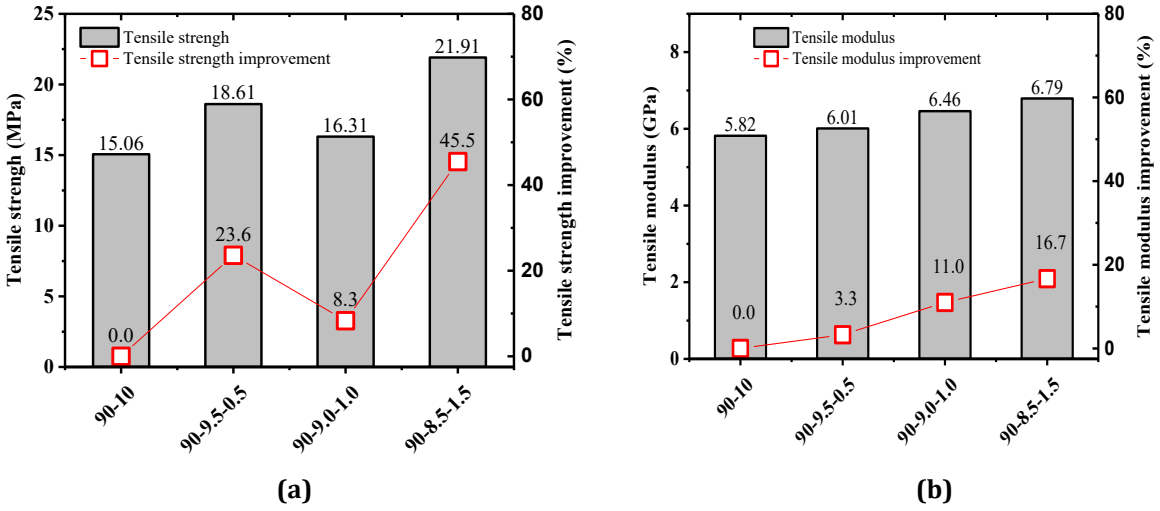


Fig. 4 *Tensile properties of composites; (a) Tensile strength; and (b) Tensile modulus*

Fig. 4(b) presents the tensile modulus of the composites produced with and without graphene. In agreement with the tensile strength behaviour, the tensile modulus exhibits a clear increasing trend as the graphene content

increases. The 90-10% composite without graphene shows the lowest tensile modulus of 5.82 GPa, reflecting the reduced rigidity typical of materials lacking reinforcing fillers like graphene. Although the addition of graphene filler resulted in an increase in tensile modulus, the percentage of improvement ranged only between 3.3% and 16.7%, which is comparatively lower than the enhancement observed in tensile strength. The small amount of graphene (0.5 wt.%) might not be enough to provide a significant increase in stiffness, but subsequent increases in graphene concentrations contribute to a higher percentage of improvement. For the composites developed in this work, the graphene concentration was found to be optimal at 1.5 wt.%, resulting in a 45.5% increase in tensile strength and 16.7% relative to the specimen produced without graphene inclusions. The improved tensile properties in the present investigation are a result of the enhanced fibre matrix interface. Graphene's high surface area and exceptional mechanical properties enable it to act as an effective coupling agent, significantly enhancing interfacial adhesion and mechanical performance [9].

3.4 Flexural Properties of Composites

Fig. 5(a) displays the flexural strength of composites produced with varying graphene content. With the inclusion of 0.5% wt.% graphene filler in polypropylene matrix, the flexural strength of this composite rose to 18.22 MPa from 15.89 MPa, presenting 14.7% improvement over the specimen without graphene. The improvement in flexural strength with increasing graphene content can be linked to the enhanced interfacial bonding and stress transfer efficiency between the polymer matrix and the fillers, which restricts deformation under bending loads. Although increasing the graphene content from 0.5 wt.% to 1.5 wt.% is beneficial for improving tensile properties as shown in Fig. 4, the enhancement in resistance to bending forces appears to be limited to composites containing up to 1.0 wt.% graphene. The tensile modulus remains nearly constant at 24 GPa (equivalent to 54% of improvement) even with the addition of 1.5 wt.% graphene to the composite.

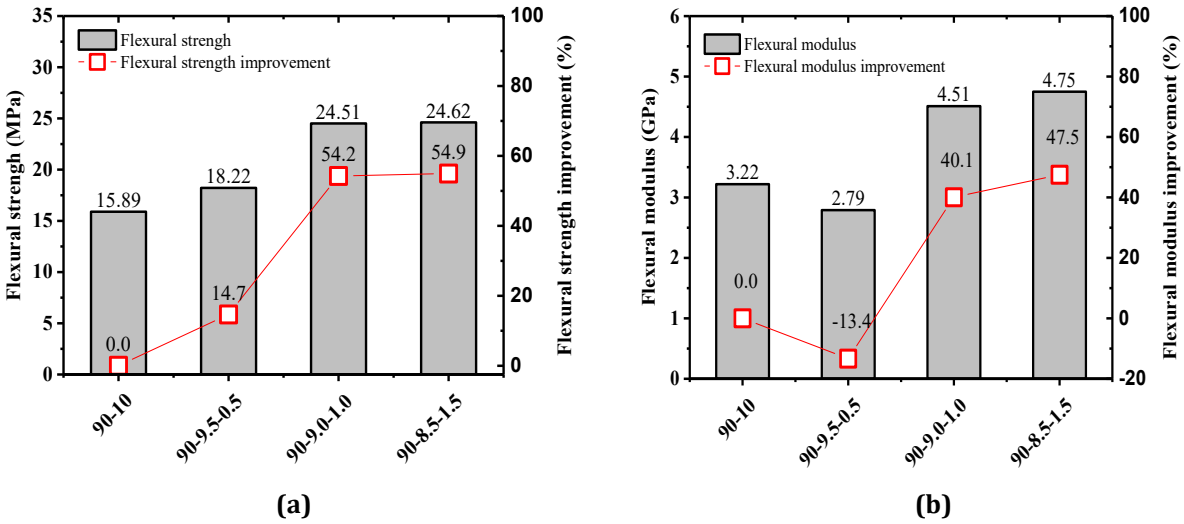


Fig. 5 *Flexural properties of composites; (a) Flexural strength; and (b) Flexural modulus*

Fig 5(b) compares the flexural modulus of composites with varying graphene content. The composition made entirely of polypropylene and kenaf fibre had the lowest flexural modulus because graphene is not present to provide reinforcement [12]. Except for the composite containing 0.5 wt.% graphene, which exhibits a flexural modulus lower than that of the control specimen, the 1.0 wt.% graphene composite shows a remarkable improvement of 40.1%, exceeding the enhancement observed in the tensile modulus (3.3% - 16.7%) as shown in Fig. 4(b). The flexural modulus of the 90-9.0-1.0 specimen has increased to 4.51 GPa. This behaviour can be explained by the fact that flexural strength and modulus are predominantly matrix-controlled properties. During bending, the polypropylene matrix experiences substantial deformation, but the inclusion of graphene in the matrix region can resist this deformation owing to its superior strength and modulus. These findings corroborate previous research, confirming that graphene acts as a strong reinforcement in polymer composites and markedly improves their flexural behaviour [13][14]. It appears that the addition of graphene with 1.5 wt.% content showed a smaller flexural modulus improvement of about 0.24 GPa than that of the graphene 1.0 wt.% specimen, suggesting the effectiveness of the graphene filler has been achieved for the flexural modulus.

Int. Journal of Integrated Engineering Vol. 18 No. 2 (2026) p. 375-383

3.5 Impact Strength of Composites

Fig. 6 shows the impact strength of composites produced with and without graphene filler. It determines how much a material can absorb energy under applied load. In general, the impact strength of the composites increased with the addition of graphene content, except for the specimen containing 0.5 wt.% of graphene. A possible explanation is that the graphene concentration (0.5 wt.%) in the polypropylene matrix is too low to effectively compensate for the reduced fibre content (from 10 wt.% to 9.5 wt.%) in this type of specimen and thus, limiting its ability to absorb and dissipate energy under sudden impact. As expected, the composite without graphene exhibited a low impact strength of 14.41 J/m^2. The incorporation of 1.0 wt.% and 1.5 wt.% graphene resulted in 27.3% and 58.4% enhancements against the 90-10 specimen, corresponding to impact strengths of 18.35 J/m^2 and 22.83 J/m^2, respectively. This means that adding more graphene fillers did not make the polypropylene composite crack easily. The increase in impact strength depends on several factors, including the toughness of the composite, the compatibility between the fibre and matrix, and the proper dispersion of the filler within the matrix [15]. Therefore, the incorporation of 1.5 wt.% graphene in this study ensures adequate interfacial interlocking between the fibre and matrix, as well as uniform dispersion of the filler throughout the matrix. The results are consistent with previous studies showing that the impact strength increases with higher graphene filler content in kenaf composites [16].

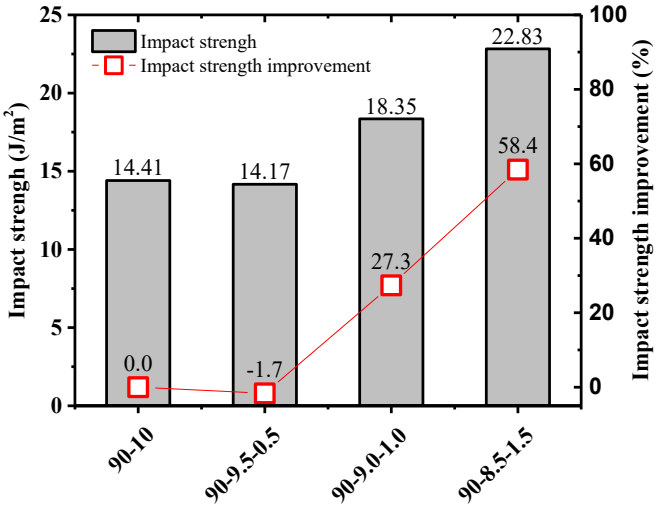


Fig. 6 *Impact strength of composites*

4. Conclusions

Kenaf fibre reinforced polypropylene composites were fabricated with varying graphene fillers; 0.5 wt.%, 1.0 wt.% and 1.5 wt.%, respectively. Thermal properties of individual polypropylene, kenaf fibre and graphene were initially conducted using thermogravimetric analysis and differential scanning calorimetry to assess the permissible temperature range suitable for the injection moulding process. Mechanical properties such as tensile properties, flexural properties and impact strength of produced composites were subsequently determined. TGA analysis indicates the kenaf fibres start to decompose at lower temperatures whilst graphene remains stable across the temperatures. The DSC analysis showed that the melting behaviour of polypropylene was confirmed at 143.21°C and the moulding temperature set at 180 °C was ideal for composite fabrications. Tensile strength, tensile modulus, flexural strength, flexural modulus and impact strength were found to improve with a higher amount of graphene, showing improvements of up to 16%-55%. Therefore, the increase in mechanical properties is due to strong interfacial adhesion effects by the inclusion of graphene fillers in the composites.

Acknowledgement

This research article was financially supported by the Faculty of Mechanical Engineering, Universiti Teknologi MARA and the Institute of Postgraduate Studies, Universiti Teknologi MARA.

Conflict of Interest

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

Author Contribution

*Nur Izzati Zulkarnain is responsible for the **visualising and initial draft preparations**. Izdihar Tharazi is responsible for the **conceptualization of the study**. Mohamad Nazrin Hazim Ahmad Faiesal is responsible for the **experimental works**. Ramli Junid is responsible for the **materials characterization and result analysis**. Abdul Hakim Abdullah is responsible for the **supervision, review and final draft of the manuscript**.*

References

[1] Nazir, Muhammad Hamza, Ali H. Al-Marzouqi, Waleed Ahmed, and Essam Zaneldin (2023). The potential of adopting natural fibers reinforcements for fused deposition modeling: Characterization and implications. *Heliyon*, *9*(4). https://doi.org/10.1016/j.heliyon.2023.e15023

[2] Fawad, M., Alabduljabbar, H., Farooq, F., Najeh, T., Gamil, Y., & Ahmed, B. (2024). Indirect prediction of graphene nanoplatelets-reinforced cementitious composites compressive strength by using machine learning approaches. *Scientific Reports*, *14*(1), 14252. https://doi.org/10.1038/s41598-024-64204-3

[3] Idumah, C. I., Ogbu, J. E., Ndem, J. U., & Obiana, V. (2019). Influence of chemical modification of kenaf fiber on xGNP-PP nano-biocomposites. *SN Applied Sciences*, *1*(10), 1261. https://doi.org/10.1038/s41598-024-64204-3

[4] Mohd, H. A., Abu Bakar, M. B., Masri, M. N., Sulaiman, M. A., Amini, M. H. M., Mamat, S., & Mohamed, M. (2020, October). Mechanical and thermal properties of hybrid non-woven kenaf fibre mat-graphene nanoplatelets reinforced polypropylene composites. In *Materials Science Forum* (Vol. 1010, pp. 124-129). Trans Tech Publications Ltd. https://doi.org/10.4028/www.scientific.net/MSF.1010.124

[5] Radzuan, N. A. M., Tholibon, D., Sulong, A. B., Muhamad, N., & Che Haron, C. H. (2020). Effects of high-temperature exposure on the mechanical properties of kenaf composites. *Polymers*, *12*(8), 1643. https://doi.org/10.3390/polym12081643

[6] Tharazi, I., Sulong, A. B., & Mohd Salleh, F. (2020). Application of response surface methodology for parameters optimization in hot pressing kenaf reinforced biocomposites. *Journal of Mechanical Engineering (JMechE)*, *17*(3), 131-144. https://doi.org/10.24191/jmeche.v17i3.15318

[7] Arsad, A., Suradi, N. L., Rahmat, A. R., & Danlami, J. M. (2013). The influence of kenaf fiber as reinforcement on recycled polypropylene/recycled polyamide-6 composites. *International Journal of Plastics Technology*, *17*(2), 149-162. https://doi.org/10.1007/s12588-013-9055-7

[8] Khan, Z. H., Kermany, A. R., Öchsner, A., & Iacopi, F. (2017). Mechanical and electromechanical properties of graphene and their potential application in MEMS. *Journal of Physics D: Applied Physics*, *50*(5), 053003. https://doi.org/10.1088/1361-6463/50/5/053003

[9] Mirzaei, J., Fereidoon, A., & Ghasemi-Ghalebahman, A. (2021). Experimental study on mechanical properties of polypropylene nanocomposites reinforced with a hybrid graphene/PP-g-MA/kenaf fiber by response surface methodology. *Journal of Elastomers & Plastics*, *53*(8), 1063-1089. https://doi.org/10.1177/00952443211015362

[10] Taghipoor, H., & Mirzaei, J. (2024). Analysis and Optimization of Mechanical Properties of Biocomposites Reinforced with Kenaf Fibers/Graphene in the Presence of Compatibilizers. *Amirkabir Journal of Mechanical Engineering*, *56*(2), 241-272. https://doi.org/10.22060/mej.2024.22798.7679

[11] Tajvidi, M. (2005). Static and dynamic mechanical properties of a kenaf fiber–wood flour/polypropylene hybrid composite. *Journal of applied polymer science*, *98*(2), 665-672. https://doi.org/10.1002/app.22093

[12] Malik, K., Ahmad, F., Dawood, M. S., Islam, M. S., Ali, S., Raza, A., & Shahed, C. A. (2024). Mechanical property enhancement of graphene-kenaf-epoxy multiphase composites for automotive applications. *Composites Part A: Applied Science and Manufacturing*, *177*, 107916. https://doi.org/10.1016/j.compositesa.2023.107916

[13] Sayeed, M. A., Sayem, A. S. M., Haider, J., Akter, S., Habib, M. M., Rahman, H., & Shahinur, S. (2023). Assessing mechanical properties of jute, kenaf, and pineapple leaf fiber-reinforced polypropylene composites: Experiment and modelling. *Polymers*, *15*(4), 830. https://doi.org/10.3390/polym15040830

[14] Oun, A., Manalo, A., Alajarmeh, O., Abousnina, R., & Gerdes, A. (2022). Influence of elevated temperature on the mechanical properties of hybrid flax-fiber-epoxy composites incorporating graphene. *Polymers*, *14*(9), 1841. https://doi.org/10.3390/polym14091841

[15] Ganapathy, T., Sathiskumar, R., Sanjay, M. R., Senthamaraikannan, P., Saravanakumar, S. S., Parameswaranpillai, J., & Siengchin, S. (2021). Effect of graphene powder on banyan aerial root fibers reinforced epoxy composites. *Journal of Natural Fibers*, *18*(7), 1029-1036. https://doi.org/10.1080/15440478.2019.1675219

[16] Raj, R. R., Sathish, S., Mansadevi, T. L. D., Supriya, R., Sekar, S., Patil, P. P., & Tonmoy, M. M. (2022). Effect of Graphene Fillers on the Water Absorption and Mechanical Properties of NaOH-Treated Kenaf Fiber-Reinforced Epoxy Composites. *Journal of Nanomaterials*, *2022*(1), 1748121. https://doi.org/10.1155/2022/1748121