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The effect of kenaf loading on kenaf/ABS composites structure and thermal properties

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ABSTRACT

Purpose: Many manufacturers have recently become interested in using fiber-reinforced polymer composites (FRPs) in structural applications. Synthetic fibres, such as carbon and glass fibres, have been commercialised internationally for decades, but they cause environmental issues because synthetic fibres are non-biodegradable and difficult to recycle once they have served their purpose, potentially polluting the environment. Thus, natural fibre composites like kenaf is a possible replacement for synthetic fibre due to their superior physical and mechanical properties. Kenaf appears to be the best candidate for replacing synthetic fibres in order to accomplish the goal of environmental preservation while also displaying excellent properties such as equivalent specific strength, low density, and renewable resources.

Design/methodology/approach: The kenaf fiber was treated in KOH and added to ABS matrix to produce new composites at different loading (10, 15, 20 and 25 wt.%) by using Two Roll Mill machine. The influence of the fiber on the composites properties was evaluated. The produced material was subjected to SEM, MFI, TGA and DSC analysis.

Findings: The incorporation of the treated kenaf fiber has an influence on the properties of kenaf/ABS composites. The addition of 10 wt.% kenaf was found to be the best loading with MFI value, initial degradation temperature and glass transition temperature at 0.8208 g/10 min, 322.63°C and 130°C respectively. The fiber was well dispersed in the matrix and shown good adhesion to the ABS. The addition of treated fiber contribute to a reduction in the MFI, improved the thermal stability of the composites and typical effects of Tg of the composite compare to pure ABS.

Research limitations/implications: The results suggest the need to continue the study in order to further analyse higher kenaf loading and shed more light on the properties of the composites to improve understanding of kenaf/ABS composites.

Originality/value: Obtained results are a solution to alternative of synthetic fibers, which may contribute to the sustainable development of composites materials industry through the utilization of kenaf fiber with ABS matrix.

Keywords: Kenaf fibre, ABS, Polymer composites, MFI, TGA, DSC

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PROPERTIES

1. Introduction

Composites are known as advanced material with a combination of more than one group of materials. The combination effect gives ultimate properties of the combined materials. Composites offer vast opportunities to tailor the properties of products made from them, owing to their composition of several types of matrix and reinforcing materials [1]. The properties of composite also depending on the length and orientation of the fibre [2,3]. The reinforcement of composite are in the form of fibers, particles, flakes, or fillers surrounded by matrix material.

The utilization of fiber-reinforced polymer composites (FRP) in engineering industries are vastly used for automotive, structural and construction. Last few decade, synthetic fibers such as carbon and glass have been widely used as composite reinforcement fibers [4]. However, massive application of synthetic fibres caused environmental issues due to their non-biodegradability [5]. Hence, more FRPs using natural fiber resources as a substitute to synthetic fiber due to their excellent physical and comparable mechanical properties.

Recently, more studies in FRPs are using natural fibers such as wood, kenaf, hemp, sisal as fiber reinforcement. This is due to the nature of the natural fiber that are low density, less abrasiveness, low cost, and renewable and bio-degradable compared to the synthetic fiber [6]. Kenaf fiber can be considered as one of the strongest fibers among other natural fibers because of the high cellulose content that able to provide strong structural support [7].

Kenaf is a non-wood lignocellulose material that is mainly build by cellulose, hemicellulose, and lignin. Kenaf has low density, non-abrasiveness during processing, high specific mechanical properties, and biodegradability [8]. In previous studies, kenaf is applied as composite reinforcement fibre in various matrices such as polypropylene (PP) [9], high density polyethylene (HDPE) [10], epoxy (EP) [2], natural rubber (NR) [11] including poly(acrylonitrile-co-butadiene-co-styrene) (ABS) [12].

ABS has outstanding mechanical properties and low density due to the combination of co-monomers, that has an important role contributing to its ultimate properties [13]. Polyacrylonitrile components introduce polar interactions between the polymer chains, which gives higher mechanical resistance than pure polystyrene. Polybutadiene components give toughness, in consequence of their elastomeric properties. Whereas, polystyrene components provide a glossy surface and electrical insulation properties. The combination properties above make ABS applicable for automotive parts, electronic components and urban constructions. Besides that, ABS has other advantages, for instance, improved chemical resistance, toughness, dimensional stability, and processability [14].

ABS is commonly used in ABS/glass fiber composites to contribute outstanding mechanical properties. Despite that, the production of glass fibers caused environmental damage, which they required higher energy from fossil fuel resources and definitely higher than those for natural fibers. In contrast to natural fibers, glass fibers are erosive that caused damage to the processing equipment and increase the maintenance costs [15].

Though, many studies were done to investigate the behaviour and effect of natural fiber as the composites reinforcement, however, the work done on kenaf/ABS combination is still limited. This paper illustrates the work done on natural fibre kenaf as reinforcement in ABS matrix at a different loading ratios of kenaf/ABS for its thermal and structural properties.

2. Materials and methodology

2.1. Materials

Kenaf fibres were supplied by National Kenaf and Tobacco Board (NKTB). The diameters of the kenaf fibres range from 10 μm to 350 μm. In this investigation, kenaf fibres with an average diameter of 112 μm were employed. ABS was supplied from Toray Plastics (Malaysia) with a specified melt flow index of 35 g/10 min (at 210°C and 10 kg).

2.2. Kenaf/ABS composites preparation

An alkali treatment was applied to the kenaf fibre surface to eliminate impurities, reduce moisture absorption, and improve surface interaction with other materials. By soaking the fibres in a 5% NaOH solution, the fibres were alkalized. After treatment, the fibers were crushed into smaller size and blended with ABS pellet using Two Roll Mill machine at 10, 15, 20, 25 wt.% loading as shown in Table 1. The process was conducted at 150°C and repeated few times until the materials were well blended. All the works done were

Table 1.
Formulation of kenaf/ABS composites

ABS, wt.%	Kenaf fiber, wt.%
100	0
90	10
85	15
80	20
75	25

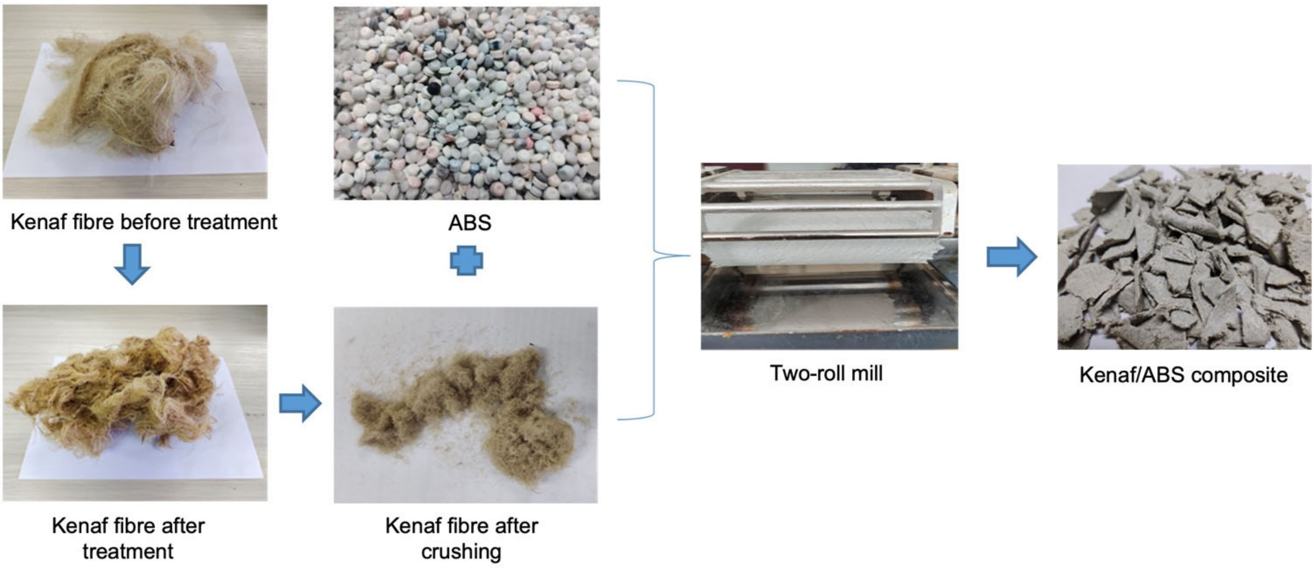

Fig. 1. Fabrication of kenaf/ABS composites

performed at University College TATI (UC TATI) workshop, Faculty of Engineering Technology laboratory. The overall step by steps fabrication of the kenaf/ABS composite is illustrated in Figure 1.

2.3. Thermal and structural characterization

Melt flow index (MFI) is defined as the amount of extruded polymer in grams collected in 10 minutes (g/min) and conducted according to ASTM D1238 200 C/5 kg 1.8 g/10 min [12]. Samples were stored in the oven for 3-4 hours before starting the MFI. To fill up the barrel, a tiny amount of samples was extracted. A piston was introduced to act as the medium for the molten polymer to be extruded. The specimens were preheated at 240ºC before being loaded onto the piston with a specific weight. After 10 minutes, melt specimens were taken, and the weight of the specimens was accurately recorded to determine the viscosity of the specimens.

The thermal stability and degradation of the kenaf/ABS composites were determined using thermogravimetric analysis (TGA). The analysis was carried out using a thermogravimetric analysis; SDTQ600 (TA Instruments) at temperatures ranging from 50ºC to 550ºC. Samples were scanned at temperatures ranging under nitrogen atmosphere.

The analysis was done using differential scanning calorimetric (DSC) (PerkinElmer DSC-4). The specimens in the 10-12 mg range were heated at a rate of 10ºC/min from -50ºC to 350ºC. By analysing the different peaks acquired from the graphs, important properties of the samples, such as glass transition temperature (Tg) were identified.

The structure surfaces of specimens and dispersion of the fibres in the ABS matrix were explored by a JOEL Scanning Electron Microscope (SEM) combined with Energy Dispersive X-ray (EDX) JSM 7800F was used at 100, 250, and 500 magnification.

3. Results and discussion

3.1. Thermal analysis

Melt flow index

Melt Flow Index (MFI) is an indication of the degree of ease of flow of the melting thermoplastic under the application of pressure. MFI is defined as the flow rate of a mass in gram within ten minutes through a specific capillary diameter and length under applied pressure via gravimetric weights. The melt flow rate of the polymer is inversely proportional to the melt viscosity. Figure 2 shows MFI from samples of kenaf/ABS composites at different loading.

Referring to Figure 2, the value of MFI (g/10 min) increases to the maximum at 10 wt.% kenaf fibre loading in the composite. The MFI values decrease with further addition of kenaf fibers to 0.6822 and 0.3468 g/10 min at 15 and 20 wt.% loading respectively. The addition of kenaf fibers into the ABS matrix acts as a filler and caused decreases in MFI composite [16]. The contact between kenaf fibers and ABS polymer matrix causes stringent in chains' movement and lower down the composite's flow capability. In conclusion, increase incorporation of fibers in the molten ABS polymers improves the viscosity but reduces the elasticity of the system.

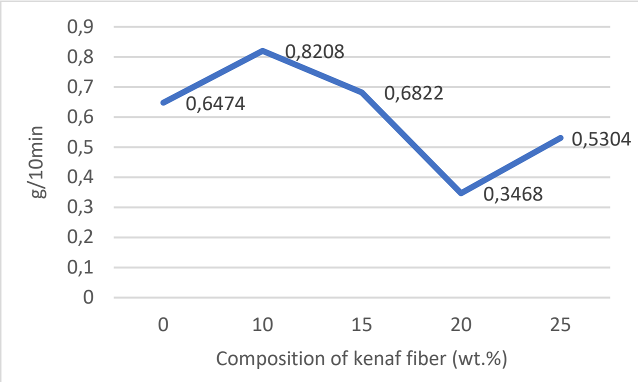

Fig. 2. MFI for kenaf/ABS composites

Higher kenaf fibre loading increased the viscosity of kenaf/ABS composites due to low MFI value of the composite. Previous study stated that; the the main reason for reduced MFI value and increasing in viscosity are because of the rheological properties of polymer blends such as viscosity which is generally a replication of the molecular weight change and the component interaction [16].The two roll mill process of kenaf/ABS composites introduce the thermal degradation effects, and high shear reduces the polymer chains size and also MFI. From the results, it can be seen that incorporation of 25 wt.% kenaf fiber has resulted in an increase of MFI. This could probably have contributed by the agglomeration of kenaf of more than 20 wt.%. Kenaf fiber starts to agglomerate at a higher loading and forms voids around its fibers [17]. As a result, less interaction occured between the fiber and the matrix hence increased the MFI value. Therefore 10 wt.% loading is chosen as the best MFI value.

TGA analysis

TGA is a thermal analysis that measures the mass of a sample over time as the temperature changes. The thermal stability of various composites was evaluated to identify the impact of kenaf fibers loading on the thermal degradation of the ABS matrix. Figure 3 shows the TGA thermogram for the neat ABS and kenaf/ABS composites. The TGA properties of kenaf/ABS are presented in Table 2.

Table 2.
TGA properties of kenaf/ABS composites

Kenaf fiber, wt.%	Initial degradation temperature, °C
0	278.86
10	322.63
15	316.78
20	316.39
25	346.40

The neat ABS begins to degrade at temperature approximately 278.86°C. This degradation is due to the breakage of the long ABS molecular chains. Referring to the data tabulated in Table 2, the addition of kenaf fibers in the ABS matrix shows increment in the initial degradation temperature of the kenaf/ABS composites. This implies that the addition of kenaf fiber in the ABS matrix enhanced the composites thermal stability and acts as an important parameter in delaying the decomposition temperature. It contributes to the higher thermal stability of polymeric composites by enhancement of interaction between fibre and the matrix from the fiber treatment, resulting in additional intermolecular bonding between them [18].

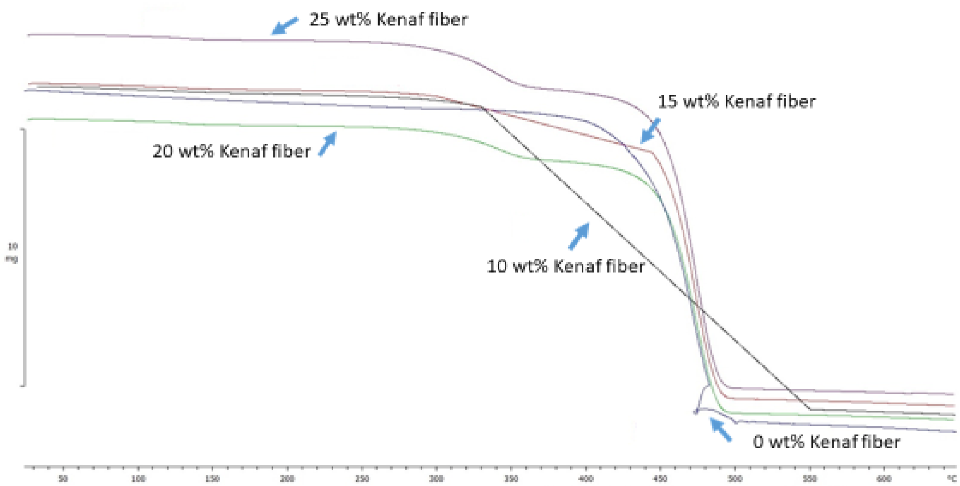

Fig. 3. TGA thermogram curves of kenaf/ABS composites

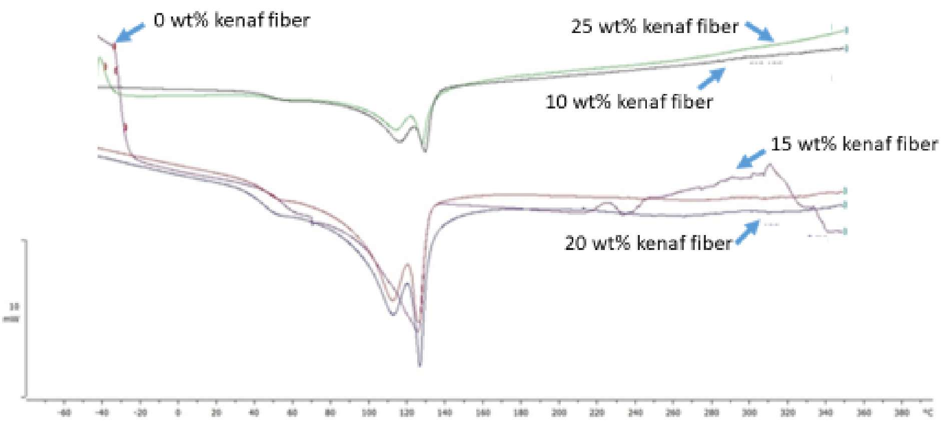

Fig. 4. DSC thermograms of kenaf/ABS composites

DSC analysis

DSC thermograms data for kenaf/ABS composites is illustrated in Figure 4 and tabulated in Table 3 respectively. The DSC results shows glass transition temperature (Tg) of the composites between 120ºC to 130ºC. It is noteworthy that the DSC studies of kenaf/ABS composites is significance in Tg since ABS being amorphous polymer which is characterized by its Tg. The Tg of virgin ABS was at 120ºC. The addition of kenaf fibers at 10 wt.% loading showed increment in Tg value, but further addition of kenaf fiber dropped the value to 110ºC but increased again to 130ºC for 25 wt.% loading. The findings are parallel to the results of Rahman et al. [19] who mentioned the decrease of Tg value with the increment of fiber loading. However, due to fiber agglomeration at 25 wt.%, the contact between the fibre and the matrix was minimal hence increased the value.

Table 3.
DSC data for kenaf/ABS composites

Kenaf fiber, wt.%	Tg, °C
0	120
10	130
15	110
20	110
25	130

There are no major effects of Tg for kenaf/ABS composite compare to pure ABS and it is indicating that this blend showed a typical melting temperature of virgin ABS. Substantial increase in Tg for the composites implies that kenaf was able to increase the service temperature by limiting the mobility of ABS polymer chains.

3.2. Structural analysis

The variation of kenaf fibre loading in the composite has affect on the overall kenaf/ABS properties, and this can be analysed by observing the morphologies of the kenaf/ABS composites. The best kenaf loading of 10 wt.% is investigated using JOEL Scanning Electron Microscope (SEM) coupled with Energy Dispersive X-ray (EDX) JSM 7800F at 100, 250 and 500 magnifications as shown in Figures 5, 6 and 7.

Figure 5 shown that the kenaf fibers were well distributed in the ABS matrix without any agglomeration. Otherwise, surface morphology of kenaf/ABS shown that the distribution of kenaf fibers concentrated in certain part of the composites or agglomeration. These findings suggest for future manufacturing composites using kenaf fibers incorporated into ABS polymer need to be treated to improve the interaction between fiber and ABS and utilization of two-roll-mill is also recommended for composites preparation, since no agglomeration is observed in the composites as shown in the SEM micrograph.

The addition of kenaf fibres can introduce voids in the composite of kenaf/ABS. Micrographs in Figure 6 shown some voids in the composite. These could lead to the reduction in properties of the composites. These also could happen during the processing of the sample using two-roll-mill, that initiate voids in the composites.

However at higher magnification in Figure 7 the voids are actually very superficial and not deep enough to cause deterioration in the mechanical properties. Thus, it can conclude that even though no coupling agent were used in the composites, good interaction between the fiber and the matrix were revealed, and this is contributed by the treatment of the fiber before incorporation in the matrix.

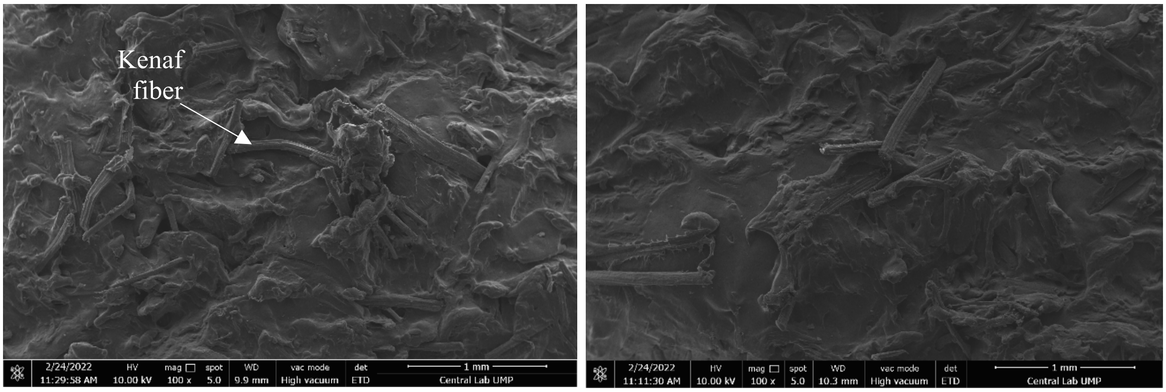

Fig. 5. Micrograph of kenaf/ABS composites by SEM at 100X magnification

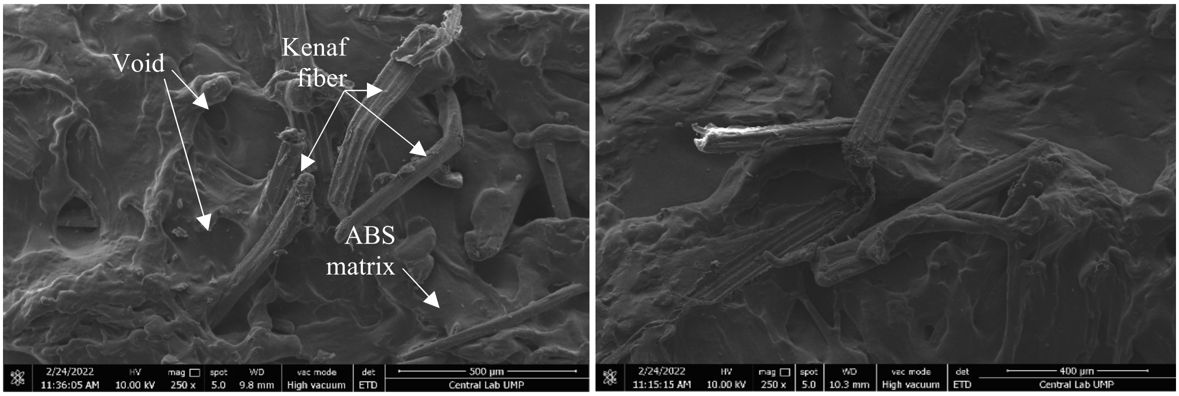

Fig. 6. Micrograph of kenaf/ABS composites by SEM at 250X magnification

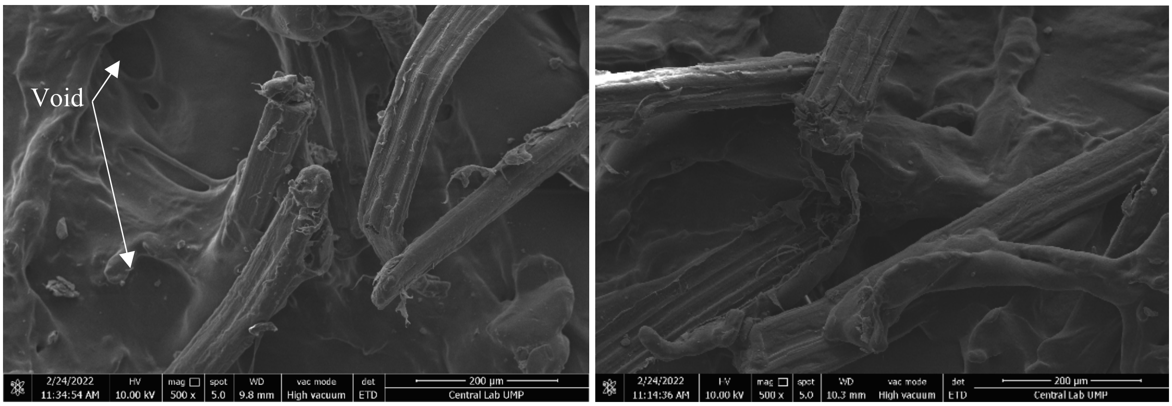

Fig. 7. Micrograph of kenaf/ABS composites by SEM at 500X magnification

4. Conclusions

Fiber reinforced plastics composites are increasingly popular in manufacturing industry especially with the application of natural fibre, such as kenaf, as substitute to the synthetic fibre. The work done on natural fibre kenaf as reinforcement in ABS matrix at a different loading ratios of kenaf/ABS is investigated for its thermal and structural properties.

MFI shown reduction in value with the addition of fiber loading but improved the thermal stability of the composites. It is found that 10 wt.% loading is the best MFI value since the higher loading caused less interaction between the fiber and the matrix. The TGA shows that the neat ABS begins to degrade at temperature approximately 278.86°C due to the breakage of the long ABS molecular chains and the addition of kenaf fibers in the ABS matrix shows increment in the initial degradation temperature of the kenaf/ABS composites.

DSC analysis shows there are only slightly change in Tg between all the formulations tested. The best obtained kenaf fibre loading is at 10 wt.% and this is comparable to the previous studies where it stated 10 wt.% of kenaf fibre could be the most suitable formulation in the improvement of the composites properties. Meanwhile, the SEM micrographs showed that the kenaf fibers were well distributed in the ABS matrix without any agglomeration. There were voids within the composites which were developed during the processing of the sample using the two-roll-mill.

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Additional information

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