

Investigation on Thermal Properties of Kenaf Fibre Reinforced Polyurethane Bio-Composites

Mathan Athmalingam¹, W V Vicki¹

¹Centre for Advance Material (CAM), College of Engineering, Universiti Tenaga Nasional, Malaysia

vignesh@uniten.edu.my

Abstract. This research focuses on the effect of Kenaf fibre on thermal properties of Polyurethane (PU) reinforced kenaf bio-composites. The samples were prepared using the polymer casting method with different percentages of kenaf fibre content (5 wt%, 10 wt%, 15 wt%). The thermal properties of Kenaf/PU bio-composite are determined through the Thermogravimetric Analysis and Differential Scanning Calorimeter test. The TGA results revealed that 10 wt% Kenaf/PU bio-composite appeared to be more stable. DSC results show that the glass transition temperature (T_g) value of 10 wt% Kenaf/PU composite is significant to pure polyurethane. It can be said that the thermal stability of 10 wt% Kenaf/PU bio-composite exhibits higher thermal stability compared to other samples.

1.Introduction

Bio-composites are the most suitable materials significant in nature for their utilization in different fields due to their eco-friendly features. Bio-composites have many advantages; they are relatively cost effective, display great thermal and stability and have low coefficient of friction and low density [1]. The utilization of sustainable sources like natural fibres in making thermal insulation board is expanding quickly in numerous enterprises. People now are venturing further to discover ways to save the earth by developing products that have high biodegradability and at the same time low energy consumption [2]. Natural fibres have a high specific heat-storage capacity and can be utilized to reduce overheating in buildings. The high density and complex microstructure of natural fibre insulations can likewise give great acoustic insulation. Natural fibre insulations are non-toxic. The utilization of natural fibres are developing in numerous areas, for example, in vehicles, furniture, and construction. This is for the most part because of their advantages in contrast with synthetic fibres, i.e. low cost, low weight, less damage to processing equipment, great relative mechanical properties, bottomless and sustainable resources [3-4]. The use of bio-composites from renewable resources has increased significantly, generally, due to their biodegradable nature. Bio-composites have many advantages; they are relatively cost effective, display great thermal stability, low coefficient of friction and low density. Bio-composites are principally utilized as part of top-line applications, for example, automotive industries, aeronautical engineering, and so on [5]. One of the problems that have been discovered from existing insulation applications is with insulation using synthetic material (e.g polyurethane) which is not very eco-friendly. It is expensive and non-biodegradable. This study was conducted to develop an eco-friendly thermal insulation material using natural fibres. This was achieved by decreasing the use of synthetic based filler materials and increasing the usage of natural fibres. Polyurethanes are a standout amongst the most adaptable materials on the planet today. It has



been connected to a wide range of ventures, for example, adaptable foam in upholstered furniture, as an inflexible foam insulation in walls, ceilings, and appliances of thermoplastic produced using polyurethane in medical devices and footwear, adhesives, sealants and plasters utilized on floors and car insides [6]. Kenaf fibres are acquired from the *Hibiscus cannabinus*, a quick growing plant ready to achieve 3.5 m of height in 2 years. The kenaf products are environment friendly and generally used in developing window frames, interior wall panels, kitchen cupboards and as a floor substitute in replacement of parquet and cement floors [7].

2. Materials

Polyurethane is a combination of both the resin and the hardener. Mirathane 6414 A/B are used for this project. The resin is known as Mirathane 6414 A and it is beige in colour with a viscosity of 2000-4000 CPS at 25°C. The hardener is known as Mirathane 6414 B and it is brown in colour with a viscosity of 30-80 CPS at 25°C. The mixing ratio of both this resin and hardener is 100:64. The Polyurethane that was used in this study was supplied by Miracon (M) Sdn. Bhd, Malaysia. Kenaf short fibre of size < 212 µm with tensile strength, modulus and elongation are 930MPa, 53GPa, and 1.6% respectively. The kenaf short fibre was purchased from Innovative Pultrusion Sdn Bhd.

3. Bio-composite Preparation

Polyurethane and kenaf composition were prepared using the polymer casting method. Three different fiber loading composition were prepared with 5, 10 and 15 %wt of kenaf fibre. The desired weight in grams of the Polyurethane resin, hardener and Kenaf fibre were measured using a digital weighing scale and mixed. The mixture was then stirred thoroughly to obtain uniform mixture of polyurethane and kenaf fibre. Then, the mixture was poured into mould and left to cure for 24 hours at room temperature. Hardened samples were removed from the mould and proceeded for testing

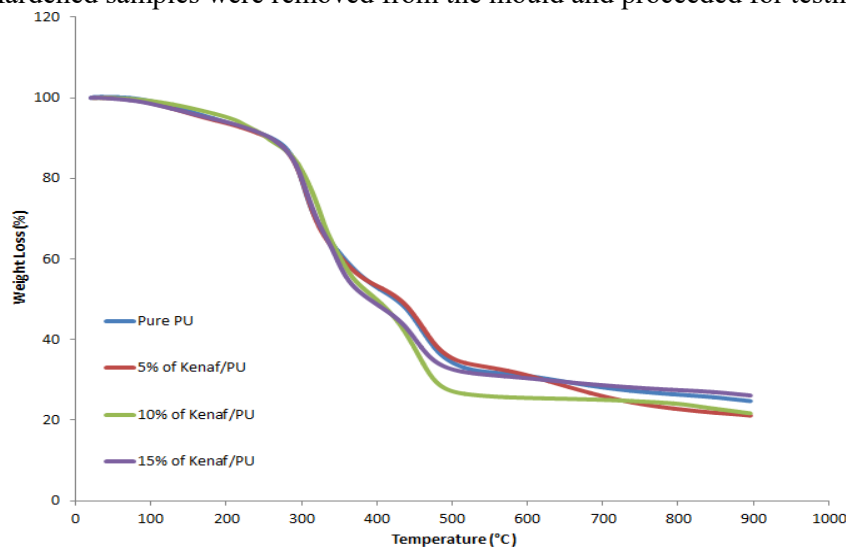


Figure 1. TGA curves for Kenaf/PU bio-composite with different fibre loading

4. Results and discussion

4.1 Thermogravimetric Analysis (TGA).

Thermogravimetric analysis was done to measure changes in the weight reduction (mass) of samples that were subjected to a steady increment of temperature to evaluate reactions including gaseous emissions. At temperatures lower than 100°C, the samples lost weight by undergoing water evaporation. Table 1 shows the decomposition temperature range, residue percentage and weight loss

percentage for kenaf/PU bio-composite with different fibre loading. The TGA and DTG curves of pure PU, and Kenaf/PU bio-composite with 5, 10, and 15 wt% fibre loading are represented in figure 1 and figure 2.

The initial mass loss for every composite occurred approximately around 200 – 400°C with a maximum loss at 300°C corresponding to a weight loss of about 50%. 10 wt% Kenaf/PU bio-composite had an initial mass loss at 253.33°C which is much earlier than PU, 5 wt% Kenaf/PU and 15 wt% Kenaf/PU. This is attributed to the higher thermal stability of fibre and phase compatibility between polyurethane and kenaf. The reason for the mass loss is because there is a deterioration of the hemicellulose from kenaf and also a disturbance in the urethane bond. When temperature increases, more raw materials vaporize or decompose, so mass continues to reduce. This denoted a reduction in thermal stability from the addition of kenaf fibre into the matrix. Norshahida Sarifuddin et. al (2013) [8] concluded that it is best to say the reduction in weight loss was the result of improvement in thermal stability [8]. It is also said from the previous studies conducted by Sunny M. Ogbomo et. al 2013 [9], natural fibres with hemicellulose tend to have low thermal stability.

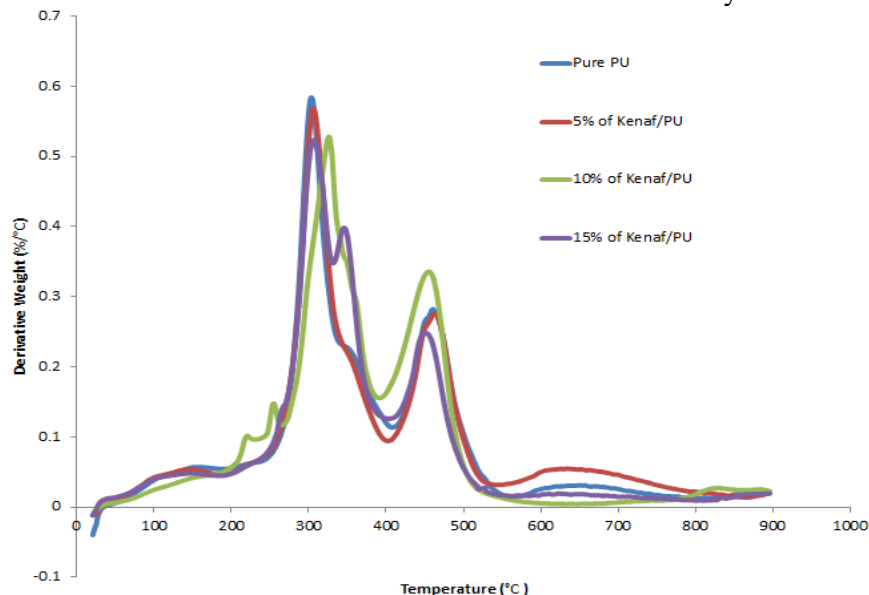


Figure 2. Differential Thermal Analysis (DTA) curves

This was due to the early decomposition of kenaf in the composition while the pure PU decomposes awhile later compared to kenaf/PU composites. The second decomposition occurred in a range of 350–500 °C with the main peak picturized at around 450 °C with a weight loss of about 70%. This two-step degradation process demonstrated that the incorporation of Kenaf fibre did not affect the decomposition behavior of pure PU. The percentage of weight at 900°C reflects the amount of residue left after the samples were completely degraded. Pure PU and 15% wt Kenaf/PU composite has the highest residue percentages of 24.74% and 26.13% than 5% and 10% wt Kenaf/PU composite. It can be said from previous studies conducted by Y.A. El-Shekeil et al 2012 [10] that the lowest weight loss percentage has the highest thermal stability.

Table 1. TGA results of kenaf/PU bio-composite with different fibre loading.

Sample	Decomposition temperature range (°C)	DTGmax (°C)	Maximum Decomposition	
			Residue (%)	Weight loss (%)
Pure PU	270.40 - 544.00	303.42	24.74	75.26
5 wt% Kenaf	267.29 - 584.88	306.08	21.13	78.87

10 wt% Kenaf	253.33 -7 77.22	325.20	21.71	78.29
15 % wt Kenaf	242.42 - 618.50	306.08	26.13	73.87

DTG curves of PU/kenaf composites is illustrated in figure 2. Maximum weight loss occurred at temperature T_{max} and was determined from the DTG curves. It can be seen that the main peaks of kenaf composites have lower values compared to pure polyurethane composites. From these results, it is clear that the thermal stability and decomposition temperature of the composites are affected by the percentage of kenaf composition in polyurethane. Good interfacial adhesion between the kenaf fibre and polyurethane would result in good compatibility between fibre and matrix where it shows an increase in degradation temperature of composites compared to pure PU.

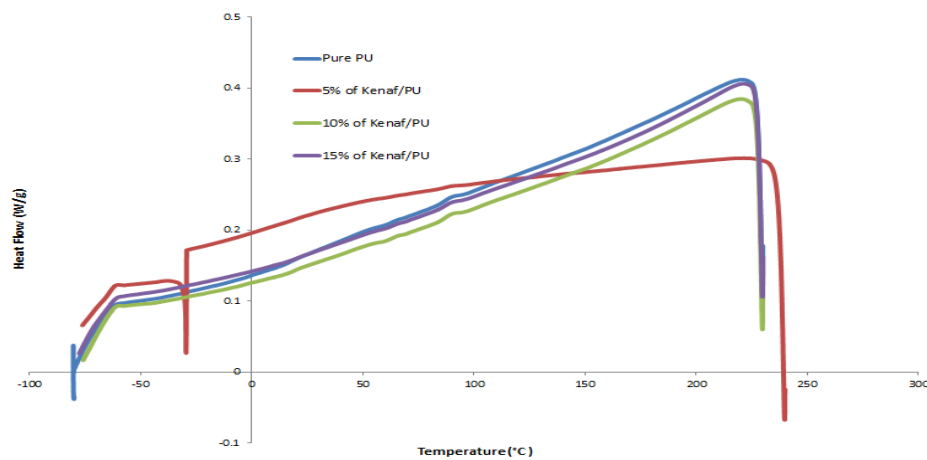


Figure 3. DSC thermograms (heating-step)

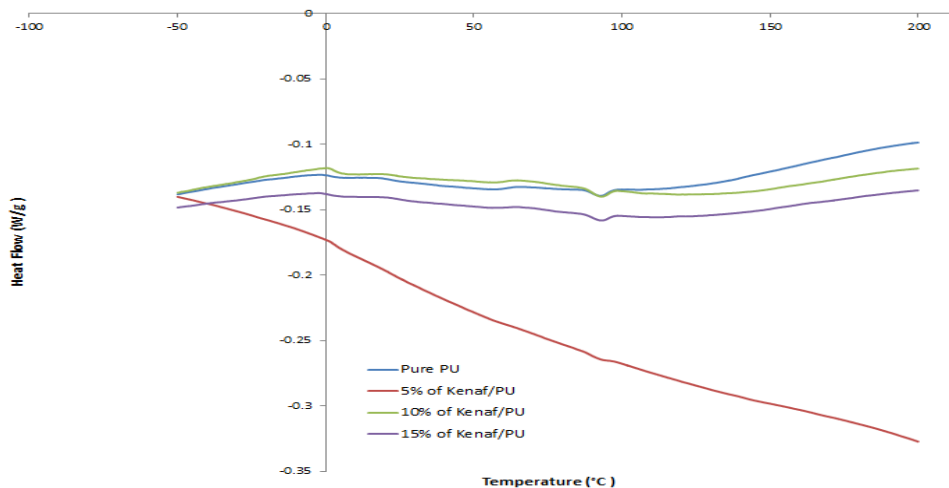


Figure 4. DSC thermograms (cooling-step)

4.2 Differential Scanning Calorimeter (DSC) analysis

DSC analysis gives the flow rate associated with a thermal event as a function of time and temperature to obtain quantitative information about melting and phase transition of polymeric materials. As can be seen in the figure 3 and figure 4, the glass transition temperature (T_g) for pure polyurethane occurred at 95.27°C, and there was no significant change in T_g for other composites. The cold crystallization peak temperature appears at 90 °C. A decrease in the cold crystallization temperature

indicates enhancement in crystallinity. The T_m of the crystalline component in a blend is dependent on both morphological and thermodynamic factors. The crystallinity of 5 wt% Kenaf/PU bio-composite was higher with lower fibre content than the 10 wt% and 15 wt% composite, indicating that the presence of a small amount of fibre increases the crystallization of the composite.

5. Conclusion

From the present study, it can be concluded that kenaf fibre reinforced polyurethane bio-composite was successfully prepared. Based on analysis, the thermal test results have shown good positive trends. TGA and DTG curves revealed that (10 wt% Kenaf/PU) appeared to be more stable because the higher DTG max is noticed from the resulted graph. DSC results show that the T_g value of (10 wt% Kenaf/PU) is similar to polyurethane. It can be said that the thermal stability neither improved nor deteriorated. Therefore, the addition of natural fibres does not have significant negative effects to the PU bio-composite and this can be a strong evidence to develop bio-composites with high thermal stability.

6. Acknowledgement

The authors would like to acknowledge the financial support provided by Universiti Tenaga Nasional under the BOLD 2025 research grant scheme to promote research excellence that supports both nation's and TNB needs.

7. References

- [1] Keynakli O 2012 *Renewable and Sustainable Energy Reviews* **16** 415–425
- [2] Korjenic A, Zach J, and Hroudová J 2016 *Energy and Buildings* **116** 45-58
- [3] Sanjay M R., Arpitha G R, Naik L L, Gopalakrishna K and Yogesha B *Natural Resources* **07(03)** 108-114
- [4] Mohamed Amine Laadila, Krishnamoorthy Hegde, Tarek Rouissi, Satinder Kaur Brar, Rosa Galvez, Luca Sorelli, Ridha Ben Cheikh, Maria Paiva, Kofi Abokitse 2017 *Journal of Cleaner Production* **164** 575-586
- [5] P Asokan, M Firdoous and W Sonal 2012. *Rev.Adv.Mater. Sci.* **30** 254-261
- [6] Mawarnie Ismail, Farhana Mohd and Abdul Rahim Bahari 2016 *Journal of Engineering and Applied Sciences* **11** No. 16
- [7] Edynoor bin Osman, Toshihiro Moriga, Kei-ichiro Murai, Mohd Warikh bin Abd Rashid 2017 *Industrial Crops and Products* **100** 171-175
- [8] Sarifuddin, N, Ismail H, and Ahmad Z 2013 *Journal of Thermoplastic Composite Materials* **28(4)** 445-460
- [9] Ogbomo S M, Ayre B, Webber C L, and D'Souza N A. *Polymer Composites*, **35(5)** 915- 924
- [10] El-Shekeil Y, Sapuan S, Zainudin E, and Khalina A 2011 **471** 58–63