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Thermal Behaviour of Flax Kenaf Hybrid Natural Fiber Composite

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ABSTRACT: In this work, natural fibers of flax and kenaf are used. Hybrid materials are given importance as they play very important role in all applications and characterizations. This paper deals with one of such hybrid composite made of natural fibers namely, kenaf and flax fibers. The hybrid built-up is such that one layer of kenaf is sandwiched between two layers of flax fibres by hand layup method with a volume fraction of 40% using Epoxy resin and HY951 hardener. Glass fiber reinforcement polymer (GFRP) is used for lamination on both sides. Thermal properties are investigated for single fiber composites and kenaf - flax with GFRP hybrid composites. The hybrid composites have better thermal stability than single fibre composites.

KEYWORDS: Flax, Kenaf, GFRP, Thermal behavior

1. INTRODUCTION

The usage of natural fiber- reinforced composite materials is rapidly growing both in industries and in various research activities. The advantages of fibers are cheap, recyclable and biodegradable. Plants such as flax, hemp, cotton sisal, kenaf, banana etc., are the most used reinforcements of composites. They are used widely for manufacturing composites because of their easy availability, renewability, low density, and low price. The natural fiber containing composites are more environmental friendly and are used in transportation (automobiles, railway coaches, aerospace etc.,), military applications, building and construction industries in paneling and partition boards, packaging, consumer products etc. Pickering et al [1] investigated the Optimising industrial hemp fiber for composites and concluded that the strength of the fiber was improved by alkali treatment. Sapuan et al [2] studied the mechanical properties of woven banana fiber reinforced epoxy composites and concluded that a very stable mechanical behavior of the composites under different tests. Shinji Ochi [3] studied the mechanical properties of Mechanical properties of kenaf fibers and kenaf/PLA composites and concluded that the highest temperature that does not affect the fiber strength is 160oC. Arbelaiz [4] et al studied the mechanical properties of short flax fibre bundle/polypropylene composites and concluded that the mechanical properties of the composites improved when MAPP is used as a coupling agent. Maries Idicula [5] investigated the dynamic and static mechanical properties of randomly oriented intimately mixed short banana/sisal hybrid fiber reinforced polyester composites and concluded that the hybrid composite with volume ratio of banana and sisal as 3:1 showed highest activation energy. Modniks et al. [6] investigated the model of the mechanical response of short flax fiber reinforced polymer matrix composites and concluded that elastic plastic matrix behavior as well imperfect bonding characterized by interfacial friction. {friction; have to be incorporated in the unit cell in order to model inelastic response at higher strains/ Sir please check this line; not able to understand} Libo Yan et al [7] reviewed flax fiber and concluded that tensile strength and strain of the flax fibers can be increased by a suitable chemical treatment. El-Shekeil et al[8] studied the influence of fiber content on mechanical, morphological and thermal properties of kenaf fibers reinforced polyvinylchloride/thermoplastic polyurethane poly-blend composites and concluded that impact strength was indirectly proportional to the fiber content. Shaoxiong Liang et al [9] studied the properties of flax/epoxy composites under fatigue loading and concluded that the increase in the longitudinal Young's

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modulus was noticed on the composites because of the competition between damage development and the fiber stiffening. Vincent Placet [10] studied the characterization of the thermo-mechanical behaviour of hemp fibers intended for the manufacturing of high performance composites and concluded that the variation in temperature influenced the behaviour of the hemp fiber. Z.L. Yan et al [11] investigated the reinforcement of polypropylene with hemp fibres and concluded that adhesion of fiber-PP was greatly improved by the introduction of MAPP. Kabir et al [12] studied the tensile properties of chemically treated hemp fibers as reinforcement for composites and concluded that the tensile strength of the untreated fibers is greater than the chemically treated fibers. Flax with banana, jute and kenaf fiber composite are fabricated and their mechanical and thermal characteristics are studied. [13-16].

II. EXPERIMENTAL DETAILS

An attempt has been made to analyse the thermal behavior of the natural fibers like flax, kenaf and a hybrid of flax and kenaf overlapped with glass fiber reinforced polymer on both sides of the composites using thermo gravimetric analysis. These composites are specimen 1, specimen 2 and specimen 3 respectively. In composite 1 middle layer is Flax, in composite 2 middle layer is kenaf and in composite 3 fibers are in 45^{o} orientation. (srinivasan et al 2015).

A. Fibers used

A.1. Flax Fiber

Flax is a member of the genus Linum in the family Linaceae. It is an erect annual plant growing to 1.2 m tall with slender stems and is extracted from the bast or skin of the stem of the flax plant. It is stronger than the cotton fiber but less elastic. The SEM photograph of flax fiber is shown in figure 1. The properties of flax fiber is listed in table 1.

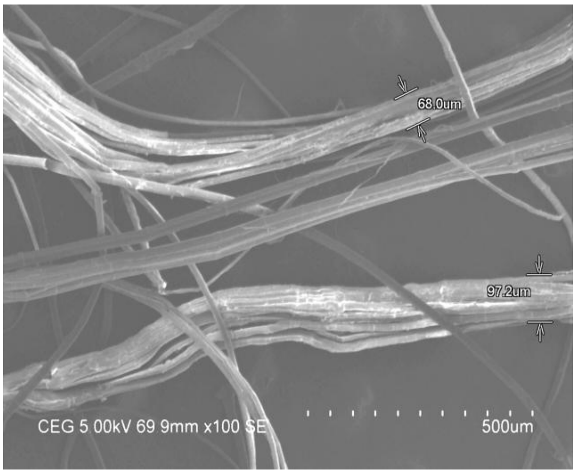

Figure 1 SEM photograph of Flax fiber

A.2. Kenaf fiber:

Kenaf is a plant in the Malvaceae family. It is one of the allied fibers of jute and shows similar characteristics. It is a high yielding tropical plant traditionally grown for the long, strong bast fibers that develop in the bark layer of the stem .Usage of bast fibers are expanding into new markets of moldable, nonwoven fabrics and reinforced composite materials in automotive, aerospace, packaging and other industrial applications. The SEM photograph of kenaf fiber is shown in figure 2. The properties of kenaf fiber is listed in table 1.

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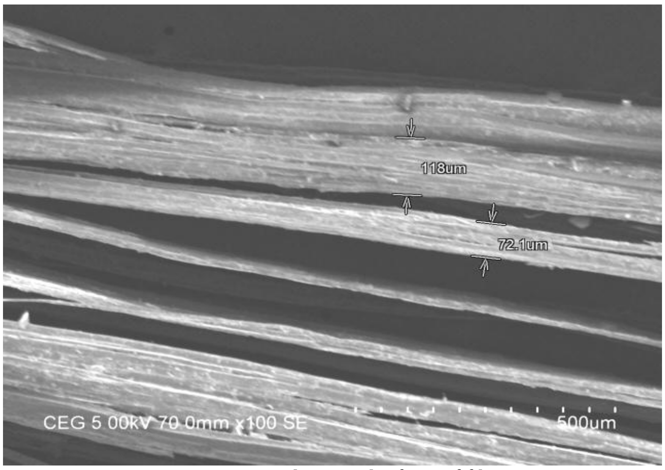

Figure 2 SEM photograph of Kenaf fiber

A.3. Glass fiber reinforced polymer

GFRP is the most used polymer which is made up of many strands of silica glass fibers. In this fabrication work, hybrids and single fiber laminates are overlapped by GFRP woven roving to achieve better finish and uniform strength.

Table 1. Properties of Flax and Kenaf fiber

Properties	Flax Fiber	Kenaf Fiber
Density kg/m^3	1500	1320
Tensile Strength MPa	345	260
Moist absorption [%]	10-11	10-12

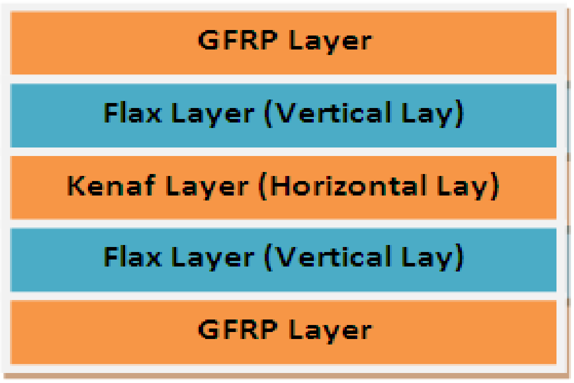

Figure 3. Schematic representation of composite 2

A.4 Epoxy Resin and hardener

The layers are binded with LY556 epoxy resin and HY951 hardener with the ratio of 9:1. The figure 3 shows the schematic diagram of composite 2.

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III. TESTING OF THERMAL BEHAVIOR OF COMPOSITES

Thermal Analysis (TA) is a group of techniques that study the properties of materials as they change with temperature. In practice thermal analysis gives properties like enthalpy, thermal capacity, mass changes and the coefficient of heat expansion. Solid state chemistry uses thermal analysis for studying reactions in the solid state, thermal degradation reactions, phase transitions and phase diagrams. The following methods are used to find different parameters as listed below:
1) Thermo gravimetric analysis (TGA): mass
2) Differential thermal analysis (DTA): temperature difference
3) Differential scanning calorimetry (DSC): heat difference
4) Pressurized TGA (PTGA): mass changes as function of pressure.
5) Thermo mechanical analysis (TMA): deformations and dimension
6) Dilatometer (DIL): volume
7) Evolved gas analysis (EGA): gaseous decomposition products

In this research work, Thermo Gravimetric Analysis (TGA) instrument is used for finding the thermal behavior of the composites. It offers a more precise control of heating conditions such as variable temperature range and accurate heating rate and needs only a small quantity of sample for analysis. The analyses are performed under nitrogen atmosphere at a heating rate of 20^0C /min.

IV RESULTS AND DISCUSSION

The thermal behavior has been investigated for single fiber laminates of flax-GFRP (Srinivasan et al 2014).Thermal analysis of epoxy composite materials provides some basic information regarding thermal stability of materials. The values of initial decomposition temperature and final decomposition temperature for epoxy composites have been found out for flax and GFRP, kenaf and GFRP and Flax kenaf and GFRP hybrid composite using Thermo Gravimetric Analyser (TGA). The studies are carried out in nitrogen atmosphere at a heating rate of 20^oC /min. TGA is used to characterize the decomposition and thermal stability of material under a variety of conditions. Principally in TGA analysis a change in thermal stability is examined in terms of percentage weight loss as a function of temperature. Initial decomposition temperature (IDT) and final decomposition temperature (FDT) for flax-GFRP, kenaf-GFRP and hybrid composites of flax-kenaf -GFRP the temperatures have been found out . The table 2 shows the entire details on TGA.

Table 2. LOI values of composites

Composites Sample	Initial decomposition temperature (IDT) C	Limiting Oxygen Index (LOI) values	Char Yield (%)
Composite 1	370	22	11.31
Composite 2	372	21	9.690
Composite 3	377	34	41.19

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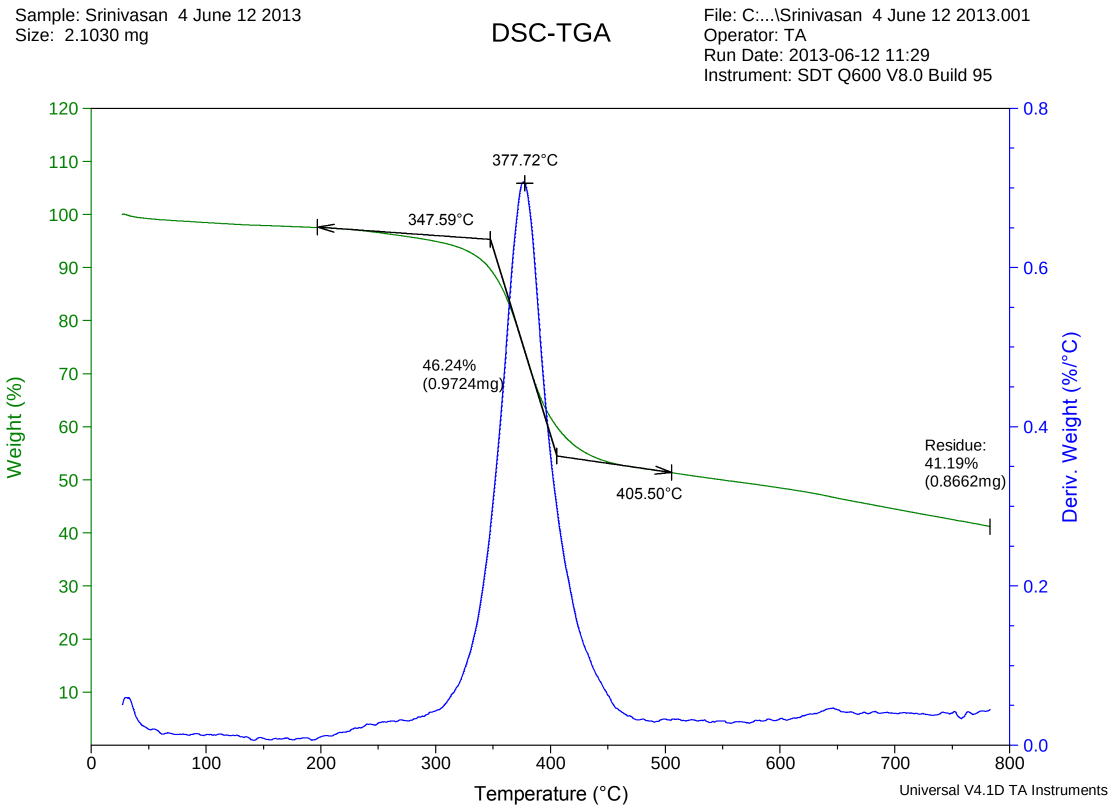

Figure 4 Sample graph of flax-kenaf-GFRP hybrid composite tested by TGA instrument

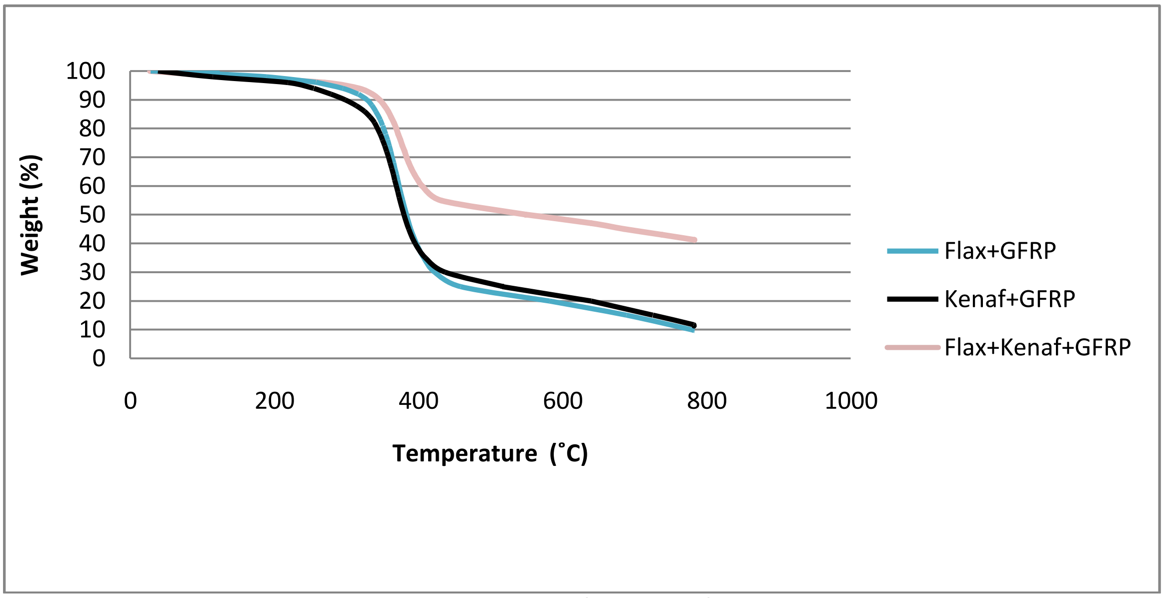

Figure 5 Weight Vs Temperature graph for TGA test for Composite specimens 1, 2and 3

The thermogravimetric analysis of (a) kenaf, (b) flax and (c) hybrid composite are shown in Figure 4. The pristine kenaf showed the degradation at 370 °C and the final weight residue content was 11.31% at 800 °C. The pristine flax showed the degradation at 373 °C and the final residue content was 9.820% at 800 °C. The hybrid composite showed the only one degradation at 378 °C and it confirms that the slight improvement in thermal stability. And also the final weight residue was 41.19% at 800 °C, confirms that the formation of composite of both flax and kenaf compound. Based on char yield percentage , limiting oxygen index (LOI) values can be found and shown in table 2 The TGA data confirms that composite 3 has higher flame resistance and thermal stability over the composite 1 and 2 single fiber composites. According to Krevelen's equation for finding the LOI =17.5+0.4 [σ] and if the value of LOI is greater than 26, it will be having better flame resistance. By investigation on all the three samples, composite 3 is found to be having the LOI value of 34 . Hence, it is evident that composite 3 which is a combination of both flax and kenaf has good flame resistance.

V CONCLUSIONS

The hybrid composites fabricated are very useful in applications like building of ships and constructional work. For the want of their applications, the composites are tested for thermal behavior with TGA instrument. The IDT and FDT are measured for all the composites. The TGA data confirms that composite 3 (flax-kenaf-GFRP) has better thermal stability and flame resistance. Hence it is evident that the hybrid composite 3 can be applied for the above said applications.

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