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Thermal Analysis for Natural Fiber (Human Hair) Composites

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ABSTRACT

The sophistications arising out of the tremendous studies on advanced material development reveal the significance and magnitude of applications to be catered by natural fiber composites in diverse industrial products. . In view of this, the present investigation is undertaken with an aim to use the human hair fiber as reinforcement with the Epoxy LY554 by hand lay-Up technique. The fiber reinforced polymer composites were subjected to thermal measurements for determining its stability at high temperature. The fabricated natural fiber reinforced composites with various compositions were subjected to microstructure analysis. The composites synthesized were subjected to various characterization techniques to evaluate the quality, strength and material integrity. The results of the characterization reveal higher strength, higher quality and good material adhesiveness and structural integrity.

Keywords:
Differential scanning calorimetry
Thermogravimetric analysis
Natural Fiber
Human Hair

1. Introduction

Thermal analysis is a adaptable techniques used for investigating the kinetics and thermophysical properties of materials. There are several methods obtainable of which in the current research we be present discussing about differential scanning calorimetry (DSC), thermogravimetric analysis (TG-DTA) and thermomechanical analysis (TMA) with dynamic mechanical analysis (DMA). The matrix material and its significance within the composites can be ascertained with the help of thermal analysis which also used to determine the thermodynamical parameters such as activation energy, enthalpy and thermal expansion coefficients. The authority of matrix on the composites can be determined with these thermodynamical parameters [1].

2. Sample Preparation

The hair used for the investigation was gathered from local resources and the resin used was EPOXY LY554. The epoxy resin

which can cure at little hotness was shared with the hardener (amino hydrocarbon) in the weight ratio of 10:1. The composites can be arranged with dissimilar compositions of fiber and polymer except among unit fiber lengths formed using lay-up process (Fig.1, Fig.2).

Fig. 1. Specimen Tested Piece

Fig. 2. Explores the composite which comprises 20% natural fiber which is used in the present investigation

3. Differential Scanning Calorimetry

One of the most important thermal techniques available is the differential scanning calorimetry (DSC) for polymer based materials. The curing of thermosetting resins, investigations on the crystallinity, compatibility of multiphase systems in the composites and to determine the degree of curing during the final product were the ones where DSC's finds its applications. The aging mechanism in the polymer during processing can also be assesses with the help of DSC analysis.

In the present study, differential scanning calorimetry (DSC) for pure epoxy resin was carried out in the temperature range 26–290^{o} C using a Netzsch DSC 204 equipment in nitrogen atmosphere with a heating rate of 10 Kmin^{-1} and is exposed in Fig. 3. The hotness of the model is plotted against the difference in the temperature stream among the reference and the present epoxy resin on the y-axis (ASTM E1356-03). From the DSC curvature of the epoxy sample, it is clear obvious that the glass transition occurs above 80^{o}C. In this temperature range, the depolymerisation takes place which is reflected in the curve as a decreasing trend. This kind of related performance is also exhibited in native starch reinforced thermoplastic starch composites [2].

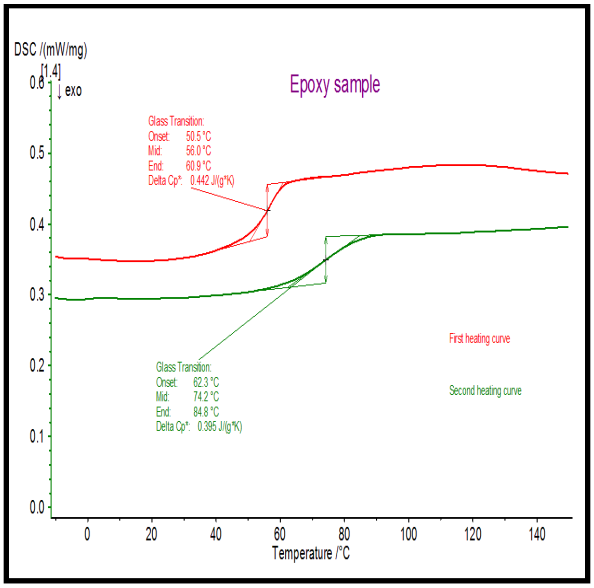

Fig.3. DSC curvature of the clean epoxy resin sample measured in the nitrogen atmosphere

4. Thermogravimetric Analysis (TGA)

Thermogravimetric analysis is one of the tool to assess the class and composition of material in these natural fiber reinforced epoxy polymer composite. The putrefaction of untreated material in the polymer matrix can be ascertained by the amount of residue left in the crucible and thereby commencing

the load of the preliminary and finishing weight of the sample the percentage of decomposition of the composites can be determined [3]. Hence the use of thermo stability is use to achieve the weight failure of the sample and thereby the information about the matrix can be evaluated from the residual weight.

In the present investigation thermogravimetric analysis (TGA) was performed in the temperature range 25-800^{o}C in a nitrogen atmosphere using a Nezsch STA 409 analyzer. The thermogravimetric analysis (TGA) was carried out for the 20 % natural hair fiber reinforced epoxy reinforced composites with a heating rate of 20Kmin^{-1} is revealed in Fig. 4.

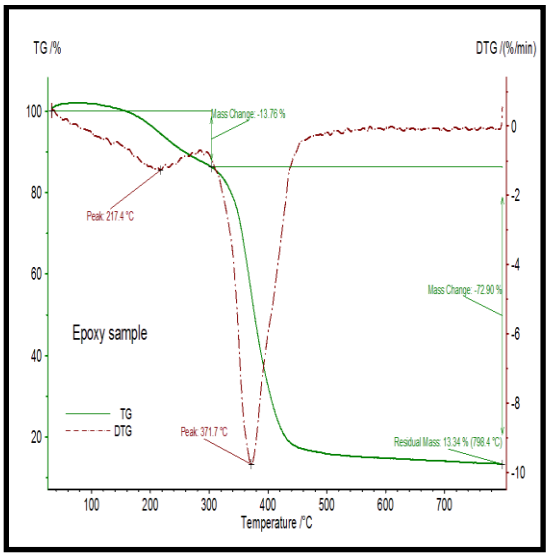

Fig.4. Simultaneous TG-DTA measurement of the 20 % mixed natural fiber reinforced epoxy composite measured in the nitrogen atmosphere

The TG curve for the various natural hair fiber reinforcements of 5, 10, 15, 20 and 25 % epoxy composites shows a weight loss of about 14 % mass change which may be due to the loss of organic bonding that exists in the epoxy polymers and the natural hair fiber melting. The peak at 217^{o}C that reflects in the DTA confirms this nature which may be due to the loss of organic binding that exists between the natural fiber and the polymer composites. The mass failure is improved as the increase in temperature for all the compositions of fiber reinforcement and shows a related trend of two stage decomposition [4], which reflects in the Fig. 5.

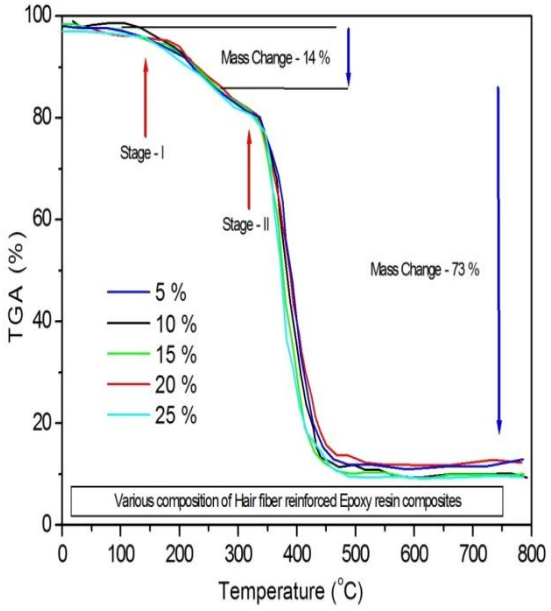

Fig.5. Thermo gravimetric curve natural hair fiber reinforced epoxy composites at various percentages measured in the nitrogen atmosphere

As the heating is further continued beyond 300^{o}C, there is a further loss of weight of about 74 % in the TG curve for all the compositions of fiber reinforcement which may be due to the decomposition of organic bonding such as breakage of C-O bonding N-H bonding and other hydrogen bonding that exists in the natural hair fiber and in the resins matrix. This weight loss is continued till 371^{o}C where the composite completely loses its behavior. Beyond this temperature only approximately 14 % of the residue is left over which is only the carbon reside left in the crucible. Thus this is related to the previous reported ones of the normal filament resistant composites. Several of the reported hair fiber such as 'emu' feather fiber showed a stability of about 354^{o}C, where as in the present investigations the fibers withstand of about 370^{o}C and

considerable increase in the stability which can facilitate the mechanical behavior such as fracture and toughness behavior during the component fabrication [5].

5. Estimation of Activation Energy (EA)

In the present investigation DTG curve for the hair thread resistant epoxy composites in the temperature range 25-800^{o}C in a nitrogen atmosphere using a Nezsch STA 409 analyzer for various heating rate of 5. 10, 15, 20 and 25 K (or ^{o}C). Fig. 6 shows a two stage decomposition which is observed in DSC curve also.

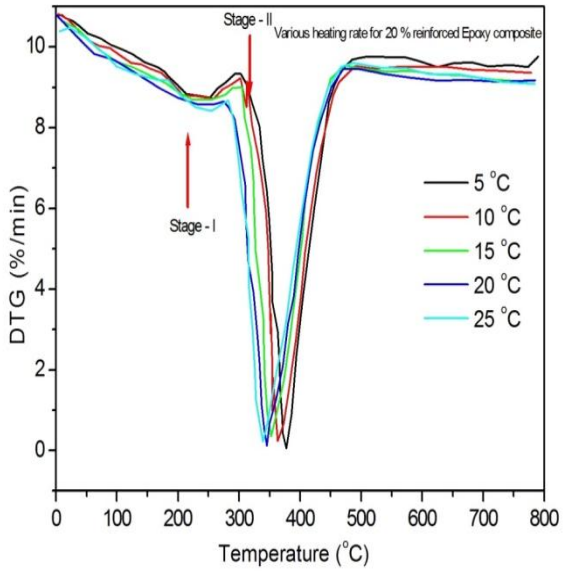

Fig.6. DTG derivative at different heating rate for 20 % mixed natural fiber reinforced epoxy composite measured in the nitrogen atmosphere

The maximum peak position from the DTG curve for 20 % thread resistant epoxy composite shows a decreasing trend which is in agreement among to the previous observed behavior in thermo gravimetric analysis [6]. The value of maximum (peak) temperature is noted as Tm and is listed in Table 1.

Table 1. Heating rate (β) and the corresponding maximum temperature (Tm) for 20% fiber reinforced epoxy composites.

Heating rate (β) (K)	Peak or Maximum Temperature (T_m) for HE20
5	378
10	361
15	352
20	345
25	339

The activation energy is the energy which is absorbed by the atoms in the molecules to reach to the excited state from the metastable state which involves molecular motion and rearrangement during crystallization. Here in the current analysis, the activation power (Ea) was found to be 49.9 kJ/mol. Fig. 7 shows the evaluation of opening power getting by plotting $\ln(K/T_m^2)$ against $((1/T_m)$ which resulted in a straight line $(= - E_a/R)$. The values for ordinary thread strengthening were in superior conformity among that of the standards reported for similar polymer composites [7]. Here R is the general gas steady value (8.314 J/molK).

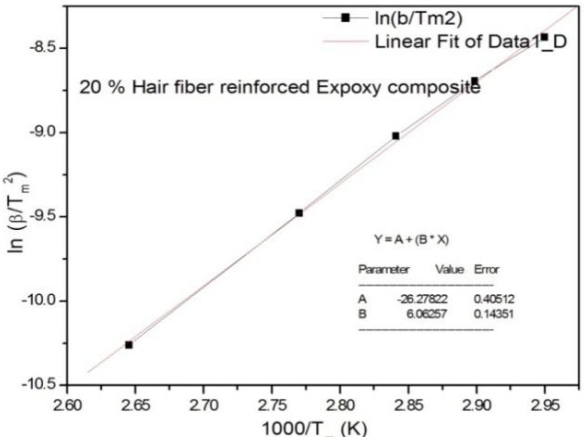

Fig.7. Activation energy determination from rate of heating and maximum temperature obtained from DTG curve for 20 % mixed natural fiber reinforced epoxy composite

6. Conclusion

Thermal analysis is an adaptable techniques used for investigating the kinetics and thermophysical properties of materials. There are abundant methods accessible of which in the current analysis we converse regarding differential scanning calorimetry (DSC), thermogravimetric analysis (TG-DTA) and thermomechanical analysis (TMA) with dynamic mechanical analysis (DMA). The matrix material and its significance in the natural fiber composites can be determined by the help of thermal analysis which also used to determine the thermodynamical parameters such as activation energy, enthalpy and thermal expansion (Ta). Presently the natural fiber reinforced polymer/plastic composite system is in rising trend. Their durability and flexibility makes them a low cost material for manufacturers a viable raw material. Hence, this thermodynamical investigation would be a crucial factor in determining its phase and phase stability while making it to the large scale. Hence these thermo physical properties would definitely provide a fruitful suggestion to improve its thermal stability and endurance while manufacturing.

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