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TGA, DSC, DTG Properties of Epoxy Composites Reinforced with Feather Fibers of 'Emu' Bird

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Abstract: The use of composite material in engineering application is increasing. Now a day's researchers are focusing on natural fiber composites. In the present work composites were prepared with epoxy resin and emu bird feathers as fiber. The composites were prepared by varying percentage weight (P) of emu fiber ranging from 1 to 5 and length (L) of feather fibers from 1 to 5 cm. The thermal properties like Thermo Gravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC) and Degradation Temperatures for the emu feather fiber epoxy composites were analyzed.

Keywords: Epoxy composites, Emu bird feathers, thermo gravimetric analysis, peak degradation temperature properties etc.

I. INTRODUCTION

Composite materials are produced by combining two dissimilar materials into a new material that may be better suited for a specific application than the individual material alone. Important characteristics of composites are their strength, hardness, rigid, light in weight, environmental sustainability and biodegradability. They provide the required strength for all structures such as buildings, ships in combination with low weight. Due to high stiffness, the fiber composites have various structural applications. The composite materials are highly chemical resistant. Many composites are being manufactured at a lower cost compared to other materials such as steel and concrete.

The natural fiber reinforced polymer composites were used in several applications automotive, marine etc. The Studies reveals that the final properties of composites depend upon the properties of fiber and the interfacial bonding of fiber and matrix. The chemical bonding plays important role between the matrix and the fiber. Normally, the animal fiber has a poor bonding capacity with the matrix material due to low interaction with the matrix. Emu bird feathers are waste products of the poultry. Kilograms of feathers are generated every year by poultry processing plants. Disposal of these waste emu bird feathers causes negative impact to the environment. Present study is on the emu bird feather fibers.

II. LITERATURE SURVEY

The emu chicken feather contains keratin (approximately 90% by weight) which is insoluble. Keratin consists of a number of amino acids which are made of Cystine, lysine, proline, and serine [1]. The mechanical properties and effect of thickness swelling and water absorption of waste chicken feathers reinforced in cement bonded composites was studied by Menandro N.Acda[1]. The tensile behavior of chicken feathers treated with rice straw reinforced general purpose resin matrix was studied by B.Nagaraja Ganesh and B.Rekha [2]. The effect of water absorption on the mechanical properties of hemp fiber reinforced unsaturated polyester composites were presented by H.N. Dhakal [3] Sha Cheng, and KIN-tak lau investigated the mechanical and thermal properties of chicken feather fiber/ PLA green composites. A.L. Martı´nez-Herna´ndez proved that the Keratin biofiber-PMMA composites have good thermal stability and good decomposition temperatures[4]. Grafting, DSC and TG Analysis of chicken feather fibers were studied by Ana Laura Martínez-Hernández and it is observed that the grafted keratin fibers undergo only slight changes in thermal behavior.[5].

Many physical and chemical methods were developed to improve the bonding between the natural animal feathers and matrix material. These methods make the feathers free from moisture and impurities. These methods affect the bonding of fiber and matrix. A study on mechanical properties of chicken feather composites was carried by Jeffery W.Kock [6]. The Emu (Dromaius novaehollandiae) is the largest bird native to Australia and the only extant member of the genus Dromaius. It is also the second-largest extant bird in the world by height, after its ratite relative, the ostrich. There are three extant subspecies of Emus in Australia. In the present work emu feathers were selected as fibers because, Emu Chicken feathers are waste products of the poultry industry. Billions of kilograms of waste feathers are generated each year by poultry processing plants, creating a serious solid waste problem. The objective of the study is to investigate the effect weight percentage of emu feathers on thermal properties of epoxy polymer composites.

III. MATERIALS AND METHODS OF EXTRACTION OF FIBER

The composites are produced from Emu feather fibers with Epoxy (Araldite LY-556) as resin by simple hand lay up technique. The ‘Emu’ feather fiber collected from the local area is washed several times with water then soaked in 5% of NaOH concentrated water for 30 minutes. The soaked feathers then washed with detergent water followed by pure water and then is dried in sun rays. A clean fiber free from dirt and impurities are obtained.

Preparation of composites

Laminates are prepared by hand layup technique. Composites are prepared from epoxy and hardener mixed in the ratio of 10:1 by weight [7] as recommended. To prepare the composite specimens, these fibers in pre determined weight proportion and length (maximum of 05% & 5 cm) are reinforced into the epoxy resin. Blocks of size (200mmX20mmX3mm) for tensile, (127mmX13mmX3mm) for flexural, (65mmX13mmX3mm) for impact test were cast with hand layup technique in a rubber mould.

Initially, the rubber mould is gently cleansed and is set free from moisture and dirt. Later a thin layer of wax is applied on inner walls of the mould along with its base plate, for easy removal of cast after curing. The control parameters used and their levels chosen are given in the below table 1.

Table 1. Control parameters and their levels

S. No.	Description	Level 1	Level 2	Level 3	Level 4	Level 5
1	Percentage of fiber (P) in %	1	2	3	4	5
2	Fiber length (L) in cm	1	2	3	4	5

After wax is applied, the proportionate mixture of resin and hardener (10:1 by weight percentage) is taken and is poured into the mould to form a uniform layer and later fiber was taken and is placed with uniform spacing. After the fiber gets wet on early layer of matrix, another layer of resin and hardener mixture is poured over it until desired thickness is obtained. In the present work, only one layer of fiber is layed because of thin slab thickness. The specimens were prepared by varying the fiber length from 1 to 5 cm and percentage weight of fiber from 1 to 5 percent.

Curing

The specimens thus prepared were put under load for about 24 hours for proper curing at room temperature. After this, the specimens were removed from the moulds and cured further at a constant temperature of upto 70^{o}C for 3 hours. Sample specimens prepared are shown in figure 1.

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Fig. 1 Sample Specimens of ‘Emu’ feather fiber epoxy composites

IV. TESTS AND RESULTS

The above ‘Emu’ feather fiber epoxy composites (with various percentage weights and lengths of fiber) were subjected to TGA, DSC and DTG tests and the following results were drawn.

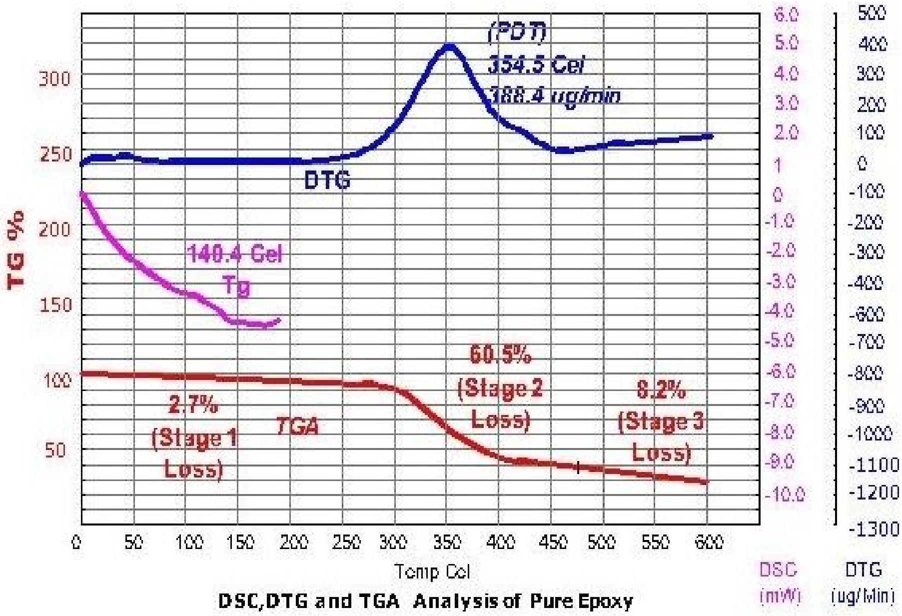

Fig. 2 (a) DSC, DTG and TGA curves for pure epoxy specimen

The DSC, DTG and TGA curves of pure epoxy are shown in Figure 2 (a). For pure Epoxy, the glass transition temperature is 140.4 °C. The specimen is getting decomposed in three stages and In the first stage there is 2.7%, in the second stage there is 60.5% of loss and finally in the third stage 8.2% loss taking place in the sample. The peak degradation temperature is 354.5 ºC and the material loss at this point is 388.4 µg/min. Epoxy has the lowest residue due to the absence of char.

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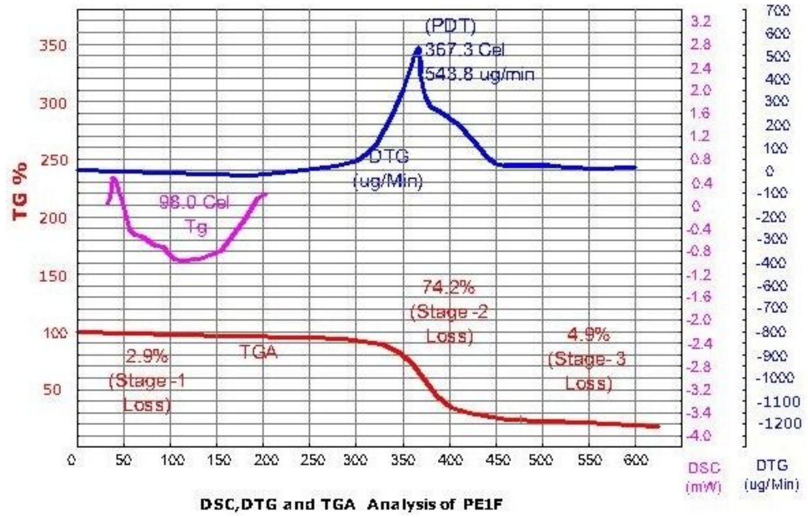

Fig. 2 (b) DSC, DTG and TGA Analysis of Epoxy Composites with 1% fiber

The DSC, DTG and TGA curves of the epoxy composites with 1% emu feather fiber are shown in Figure 2 (b). When 1% of emu feathers are added to the pure epoxy, the glass transition temperature is reduced to 98 ºC. The specimen is getting decomposed in three stages and In the first stage there is 2.9%, in the second stage there is 74.2% of loss and finally in the third stage 4.9% loss taking place in the sample. The peak degradation temperature is 367.3 ºC and the material loss at this point is 543.8 µg/min.

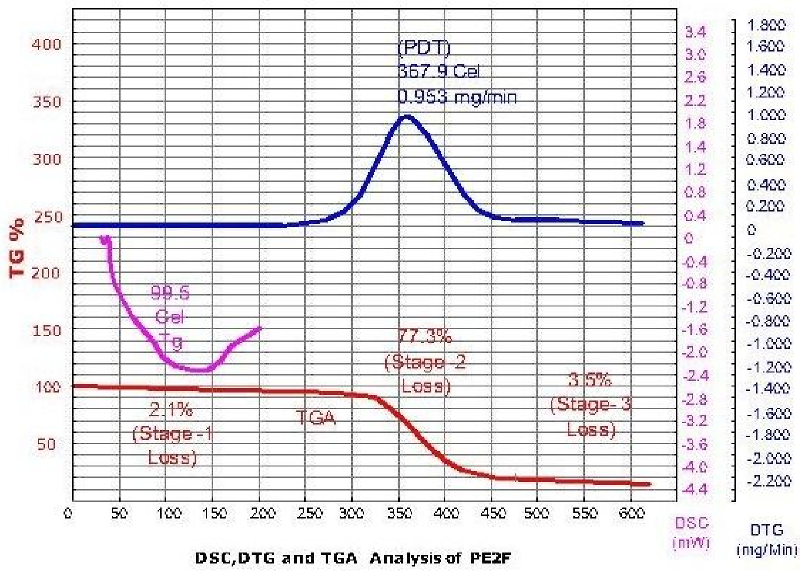

Fig. 2 (c) DSC, DTG and TGA Analysis of Epoxy Composites with 2%fiber

The DSC, DTG and TGA curves of the epoxy composites with 2% emu feather fiber are shown in Figure 2 (c). When 2% of emu feathers are added to the pure epoxy, the glass transition temperature is reduced to 99.5 ºC. The specimen is getting decomposed in three stages and In the first stage there is 2.1%, in the second stage there is 77.3% of loss and

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finally in the third stage 3.5% loss taking place in the sample. The peak degradation temperature is 367.9 ºC and the material loss at this point is 0.953 mg/min.

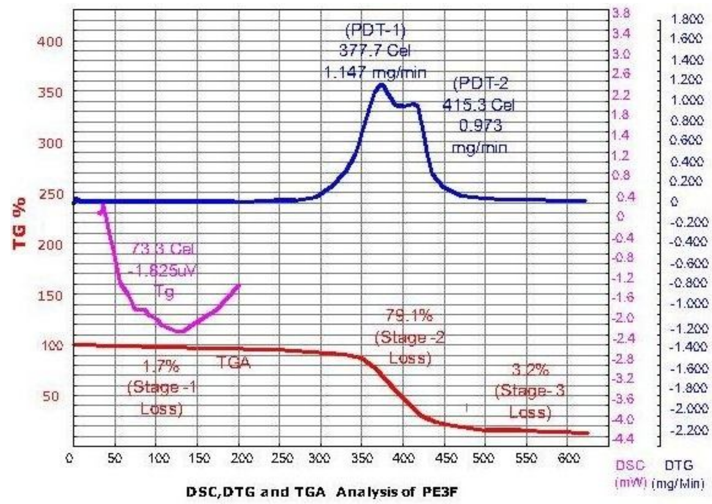

Fig. 2 (d) DSC, DTG and TGA Analysis of Epoxy composites with 3% fiber

The DSC, DTG and TGA curves of the epoxy composites with 3% emu feather fiber are shown in Figure 2 (d). When 3% of emu feathers are added to the pure epoxy, the glass transition temperature is reduced to 73.3 ºC. The specimen is getting decomposed in three stages and In the first stage there is 1.7%, in the second stage there is 79.1% of loss and finally in the third stage 3.2% loss taking place in the sample. The peak degradation is taking place at two temperatures initially at 377.7 ºC the material lose is 1.14mg/min. followed by the second stage at 415.3 ºC where the rate of material loss is 0.973 mg/min..

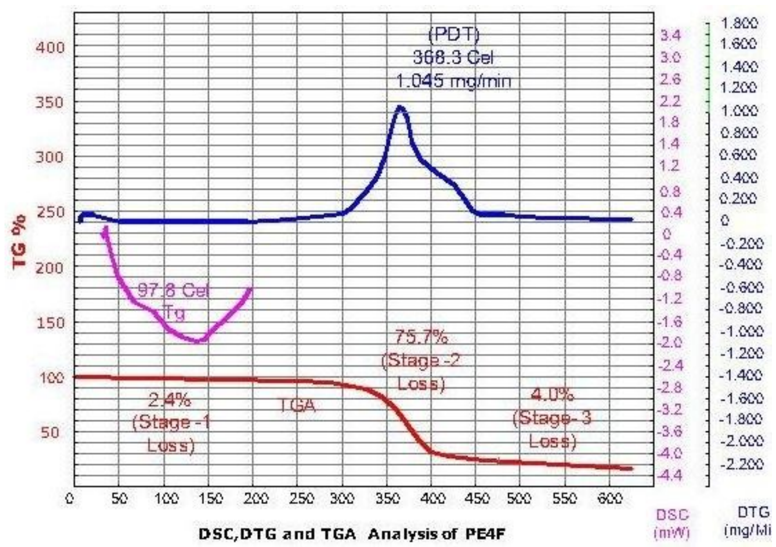

Fig. 2 (e) DSC, DTG and TGA Analysis of Epoxy Composites with 4%fiber

The DSC, DTG and TGA curves of the epoxy composites with 4% emu feather fiber are shown in Figure 2 (e). When 4% of emu feathers are added to the pure epoxy, the glass transition temperature is reduced to 97.8 ºC. The specimen

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is getting decomposed in three stages and In the first stage there is 2.4%, in the second stage there is 75.7% of loss and finally in the third stage 4.0% loss taking place in the sample. The peak degradation temperature is 368.3 ºC and the material loss at this point is 1.045 mg/min.

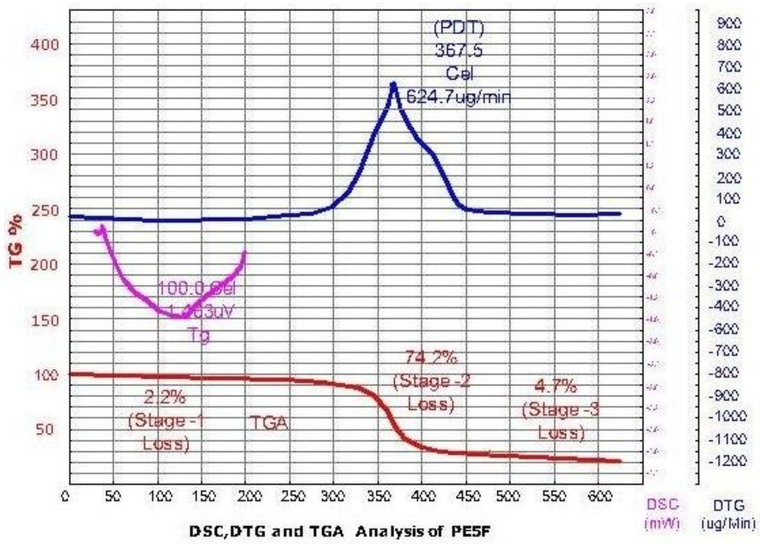

Fig. 2 (f) DSC, DTG and TGA Analysis of Epoxy composites with 5%fiber

The DSC, DTG and TGA curves of the epoxy composites with 4% emu feather fiber are shown in Figure 2 (e). When 5% of emu feathers are added to the pure epoxy, the glass transition temperature is reduced to 100 ºC. The specimen is getting decomposed in three stages and In the first stage there is 2.2%, in the second stage there is 74.2% of loss and finally in the third stage 4.7% loss taking place in the sample. The peak degradation temperature is 367.5 ºC and the material loss at this point is 624.7 µg/min.

V. CONCLUSIONS

Glass Transition Behavior

The DSC curves of the pure epoxy and the emu feather fiber are shown in Figure 2 (a) - 2 (f). The T_g of pure epoxy was observed at 140.4 °C. All the DSC curves of epoxy and emu feather fiber epoxy composites systems had a single glass transition temperature in the experimental temperature range. Obviously, the presence of a single T_g indicates that ring-open reactions occurred between the epoxy groups in fiber epoxy composites. In the fiber epoxy composites systems, the T_g values are lower than that of pure epoxy, and the T_g of the fiber epoxy composites decreased with increasing of length of the fiber upto 3 cm and then T_g increases with increase of fiber epoxy composite length upto 5 cm . T_g of fiber epoxy composite of length 1 cm to 3 cm varies from 96 °C to 73.3 °C and then it again reaches to 100 °C for the epoxy fiber length of 5 cm. The fall of T_g in fiber epoxy composites can be attributed to two factors: the incomplete curing reaction and the increase in the free volume of the system. The decrease in the free volume is proposed to be responsible for the increased T_g values because of the addition of emu feather fiber epoxy composite. In addition, the composites with different loadings of emu feather fiber epoxy composite had higher T_g, which may be attributed to the nano-reinforcement effect and the segmental level restriction of the motion by the incorporation of emu feather fiber epoxy composite into the epoxy matrix leads to increase in T_g [8, 9].

Thermal Stability

Thermogravimetric analysis (TGA) was used to investigate the thermal stability of emu feather fiber epoxy composite. As shown in Figure 2 (a) – 2 (f), the TGA curves of the pure epoxy and emu feather fiber epoxy composite were recorded under nitrogen at 10 °C/min from 50 °C to 600 °C.

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From Figure 2 (a) - 2 (f) , it can be seen that the emu feather fiber /epoxy composite starts to lose weight which is attributed to the higher moisture content of untreated Moisture evaporates from the fibers starting at 80 ºC. The percentage of weight reduction at 600°C reflects the amount of residues left after the composites were degraded. Epoxy has the lowest residue due to the absence of char. The peaks of the DTA curves correspond to the decomposition temperature of each constituent of the composites. However, from 2 (a) - 2 (f), only one peak is obvious for all curves due to the overlapping peaks of the feather fiber and epoxy. It seems that neat epoxy has the lowest decomposition temperature at 345.5 ºC while the addition of feather fibers had shifted the curves to higher temperatures. Some researchers have found that the addition of natural fibers causes reduction in the thermal stability of the composite due to the influence of the less stable fibers [10, 11]. It seems that in this study, the emu feather fiber epoxy composite plays a synergistic role in improving the thermal resistance of the composite. Covalent bonds can be assumed to have been formed in the composite systems, although dispersion of emu feather fiber in the epoxy matrix is also an important factor contributing to the enhanced thermal stability. Apparently, as the length of the emu feather fiber increases the epoxy emu feather composites becomes more stable at higher temperatures.

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