Assessment of Thermo-Mechanically Treated Chicken Feather Fibre Reinforced Epoxy Composites for Automobile Application

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Abstract

This research was carried out to assess the viability of chemical modification on the mechanical and abrasion properties of treated chicken feather fibre as reinforcement in epoxy resin to develop composites for automobile applications. The composites were developed using waste chicken feather fibre from poultry after been treated with NaOH to reinforced epoxy resin. The short fibres were randomly dispersed in an open mould and allowed to solidify at room temperature. Tests were carried out on the cured samples to ascertain the aptness of the materials. From the results, it was observed that the developed composites have the potentials that are expedient in automobile materials. The mechanical and abrasion properties were improved by the addition of these chemically modified chicken feather fibre into the epoxy. These properties were enhanced at the application of 2-8 wt% reinforcements. While 2 wt% produced the overall best performance for mechanical properties, 4-6 wt% gave the best results for abrasion property.

Keywords: Thermo-mechanical treatment; Chicken feather fibre; Epoxy; Reinforcement; Composites; Automobile application

1. Introduction

The need to clean our environments and made them void of environmental pollution has contributed immensely to the necessity to look for alternative means of handling most commonly generated wastes in our environments. The use of natural fibers as reinforcing materials in both thermoplastic and thermoset matrix composites provides positive environmental benefits with respect to ultimate disposal and best utilization of raw materials. The advantages of natural fibers over traditional reinforcing materials are their specific strength properties, availability, light weight, ease of production, enhanced energy recovery, high toughness, non-corrosive nature, low
density, low cost, reduced tool wear, renewability and bio-degradability. However, the main disadvantages of natural fibers in composites are the poor compatibility between fiber and matrix and the relative high moisture sorption (Ghali et al. 2011). Hence, chemical treatments that are usually considered to modify the fiber surfaces properties include alkali, silane, acrylation, maleated coupling agents, acetylation, and benzoylation. The chemical treatments in most cases eliminate the lignin and hemicelluloses thereby enhancing the fiber strength and reducing water absorption properties (Oladele et al. 2010; Saw et al. 2013). Mammalian hairs especially the human hair have been reported by many authors and researchers to exhibit very good physical and mechanical properties, which in turn account for their intrinsic ability to undergo appreciable mechanical stressing and various types of chemical and thermal treatments without sustaining permanent damage (Valesco et al. 2009; Dias, 2015). This unique behaviour of hair has been attributed to the presence of structural proteins which are essentially keratin in the hair fibre (Khan et al. 2014). Hair has been defined as a filamentous biomaterial consisting principally of proteins, most especially keratin. These keratins are scaffolding proteins that combine to form a network of intermediate filaments in the cytoplasm of epithelial cells and their foremost function is fundamentally to provide structural maintenance for cells and tissues (Ramot and Zlotogorski, 2015). Remarkable works of some researchers have shown that the response of hair fibres to mechanical stresses is highly dependent on the stability of the structure of the cortical keratin of hair fibre and this stability is at times affected by heat and chemical treatments depending on the degree of application (Sinclair, 2007; McMullen and Jachowicz, 1998). Recent research findings have also shown that appropriate chemical treatments can significantly improve the structural integrity of hair fibres without deteriorating their intrinsic properties (Nagasawa et al. 2013; Oladele et al. 2015a). In recent times, these attractive properties of hair fibres have impelled materials scientists especially from the developing countries to reassess the economic importance of hair fibres, and in doing so, they are able to unlock a new vista for the industrial applications of hair fibres, as reinforcements for the synthesis of novel composite materials (Batebi et al. 2013; Oladele et al. 2014).

Epoxy resins are regarded as compounds which contain more than one epoxy group which are capable of being converted to cured form with the help of hardener as curing agents. Most of the commercially available epoxy resins are formed by the reaction of Bisphenol-A (Diphenylol propane, DPP) and epichlorohydrin in the alkaline medium. The main features of these resins are that they maintain their properties at high temperatures and possess high heat deflection temperature (HDT) and high glass transition temperature (Tg). The resin is used as matrix in this work. The main characteristics of epoxy resins that induced the interest of using it for this research was that it has the ability of being processed by varieties of techniques. Researchers have focused most attention on the use of plant fibres and has been highly utilised from past decades. However, the use of animal fibres has not been adequately employed and the reason for using this readily available animal fibre in modified status as reinforcement in epoxy matrix in this work.

2. Materials and Method

2.1 Chicken Feather Fibre Extraction

The required fibres were obtained from boiler chicken feathers which were considered as waste in the poultry industry. The average age of the chicken that their feathers were used was 6 months.
The feathers when collected from the chicken processing plants are always dirty and contain various foreign materials, such as dust, blood and faeces. Therefore, the feathers were washed many times with water and detergent before sun dried for 3 days. After drying, quills were separated by stripping from barbs, since they differ physically.

2.1.1 Chemical Treatment

A solution of 1M KOH was prepared in a glass beaker by adding 6% KOH to distilled water. Thermo-mechanical treatment treatment was carried out on the dried fibres by soaking in the solution for 3 hours in a shaker water bath maintained at 50 °C. The treated fibre was washed thoroughly with tap water and rinsed with distilled water until neutral status was obtained followed by sun drying for 5 days as shown in Fig. 1. The SEM of the treated fibres was as shown in Fig. 2 where it was revealed that the fibre contains barbs and barbules in its structure that aid proper bonding after treatment. Chemical treatment with KOH stabilizes the molecular orientation thereby reducing the moisture content and also increases the fibre strength.

Fig. 1. Chemically treated chicken fibre

Fig. 2. Scanning Electron Microscopy Image of brown (E) and white (F) chicken fibres
2.2 Production of Composites

The composites were developed with the base material which comprise of the epoxy resin and the hardener in ratio 2:1. The basis of the matrix for production was 60 g. The proportions of the fibre added were determined using 2, 4, 6, 8, 10, 15 and 20 wt%, respectively. After proper stirring, the homogenous mixture were poured into the moulds and allowed to cure at room temperature before they were removed from the moulds. The cured samples as shown in Fig. 3 were left for 27 days before the mechanical tests were carried out.

![Fig. 3. Dried Tensile, Flexural and Wear Samples](image)

2.3 Mechanical Testing and Structural Characterization of the Prepared Samples

Following the production of the composites, samples were prepared for tensile, flexural and wear tests. These tests were carried out as follows:

2.3.1 Determination of Tensile Properties

The tensile strength of the sample was determined according to the American Standard Testing and Measurement method ASTM D412, (1983). The tests were performed on INSTRON 1195 universal testing machine at a fixed Crosshead speed of 10 mm min\(^{-1}\). To carry out this test, the test piece was fixed on the jaws of the universal tensile testing machine and the load was applied. The material is extended as the load increases until the material is fractured. The tensile properties for each composition and the average values were documented on the system. The procedure was repeated for each of the variations.

2.3.2 Determination of the Flexural Property

Three point bend test was carried out using INSTRON 1195 universal testing machine at a fixed Crosshead speed of 100 mm min\(^{-1}\). To carry out the test, the grip for the test was fixed on the machine and the sample with dimension 115 x 25 x 3 mm was hooked on the grip and the test commenced. As the specimen is stretched due to bending load applied at the middle of test piece, the computer generates the required data and graphs and as well record the values until the sample
break. The procedure was repeated for each of the variations.

2.3.3 Determination of the Abrasion Property

The wear resistance test was carried out with Taber Abrasers, Model ISE-AO16. This involves mounting the specimen to a turn table platform that rotates at a fixed speed. The sample was weighed using an analytical weighing balance for the initial weight of the sample before being fixed on the turn table. The platform rotates at 1000 r.p.m for 5 hours and removed followed by weighed to obtain the final weight of the sample. The values of the initials and final weight of the sample were used to determine the difference in weight of the sample. This procedure was carried out for all the samples variation to determine the effect of abrasion on the material.

3. Results and discussion

3.1 Tensile Properties

![Graph of the response of the developed composites and neat sample to the ultimate tensile strength](image)

Fig. 4. Graph of the response of the developed composites and neat sample to the ultimate tensile strength

The response of the materials to ultimate tensile stress for the determination of the ultimate tensile strength (UTS) was as shown in Fig. 4. It was observed from the results that, reinforcement with 2 wt% of the chemically modified chicken feather fibre (CMCFF) produce the best result with a value of about 11.40 MPa ahead of the neat sample with a value of 9.71 MPa. The result was in agreement with the findings of Oladele et al. (2014) where low fibre weight fraction was discovered to be good for the improvement of the mechanical properties of high density polyethylene reinforced composites. The improvement of UTS in this work culminated to about 17 % increment in this property. Though, other weight fraction gave less value but there was an increase from 4-8 wt% followed by decrease at 10 wt % reinforcement. This decrease was observed to also follow increasing trend
from 10-20 wt%. The enhancement achieved by the addition of 2 wt% CMCFF was due to proper wetting of the fibre by the matrix and the presence of well dispersed fibre within the matrix without fibre touching or twisting. Fibre touching and twisting are likely to occur when the amount of fibre present within the matrix is much. This usually resulted in poor interfacial bonding strength and weak strength in the developed composites due to inability of the matrix to transfer load to the fibre adequately.

Fig. 5. Graph of the response of the developed composites and neat sample to the tensile modulus

Fig. 5 depicts the response of the developed composites as well as the neat sample to the tensile modulus. The results revealed similar trend to that of the ultimate tensile strength, however, the slight difference was that, 8 wt% reinforcement gave better result more than the neat sample. From the results, it was observed that 2 wt% followed by 8 wt% reinforcements gave the values 65.85 MPa and 59.16 MPa, respectively above the neat sample with a value of 30.74 MPa. These gave increments of about 114 % and 92 %, respectively. The results showed that the stiffness of the matrix; epoxy can be improved with the use of CMCFF as reinforce

The tensile strains of the developed composites as well as the neat sample were shown in Fig. 6. The results also followed the same trend with other tensile properties of these developed composites as well as the neat sample as shown in Figs. 4-5 in an antithetical manner. It was observed from the results that 2-8 wt% reinforcements were grouped separately from 10-20 wt% as displayed in Figs. 4-5. The strain properties of 2 wt% and 8 wt% reinforcements were seen to be low compared to others due to their high stiffness as shown in Fig. 5. The best straining properties were obtained from 10 wt% and 15 wt% with values 0.44 mm/mm and 0.36 mm/mm. These are the best among the developed composites that possess better straining tendency than the neat sample that has a straining value of 0.32 mm/mm which implies that the straining property of the epoxy after reinforcement has been enhanced by 38%. The use of CMCFF as reinforcement in this matrix prove to be more effective by enhancing the tensile properties contrary to the behaviour of the untreated CFF used for the reinforcement of HDPE composites reported by Oladele et al. (2014).
3.2 Flexural Properties

Fig. 6. Graph of the response of the developed composites and neat sample to the strain at maximum tensile stress.

Fig. 7. Graph of the response of the developed composites and neat sample to the flexural strength at peak.

Fig. 7 show the behaviour of the materials under the influence of flexural strength at peak. The response of the developed composites to flexural strength at peak was similiar to that of UTS in Fig. 4 in which only 2 wt% reinforcement was able to yield enhancement. The reinforcement with the best flexural strength at peak was 2 wt% with a value of 65.95 MPa above the neat sample that has
a value of 32.86 MPa. The enhancement achieved was about 100 %. However, unlike the UTS, reinforcement within 10-20 wt% gave a decreasing trend. Oladele et al. (2015b) showed that the use of animal fibres has the potential for the enhancement of flexural properties of animal fibre reinforced polymer composites.

Fig. 8. Graph of the response of the developed composites and neat sample to the flexural modulus

The flexural modulus of the materials was as shown in Fig. 8. All the developed composites except 8-10 wt% reinforcement gave better performance compared to the neat sample. The best results were obtained from 2-6 wt% in a decreasing trend. From the results, 2 wt% followed by 4 wt% reinforcements gave the best results with values 174.10 MPa and 150.69 MPa, respectively. The neat sample was with a value of 53.10 MPa. The enhancement was more than 100 %. Comparing the enhancement achieved in tensile and flexural properties of the developed composites, it is obvious that the flexural properties of the composites were better improved than that of the tensile properties, though, both were enhanced. This also agreed with the findings of Oladele et al. (2014) in which high density polyethylene was reinforced with cow hair and chicken feather fiber. It follows therefore, that the use of these animal fibers as reinforcement in polymeric materials is a potential means to improve on the bending strength and obtained good resistance to bending load in service. These reinforcement materials serve as good replacement for synthetic fibres in this regards being eco-friendly, available and cheap.

3.3 Abrasion Property

The reaction of the materials to abrasion behaviour was as shown in Figure 9. It was observed from the results that composites with good abrasion behaviour in comparison with the neat sample fall within 2-8 wt% while those composites within 10-20 wt% reinforcement were seen wear at higher rate than the neat sample. The results showed that 6 wt% followed by 4 wt% CMCFF reinforced epoxy composites gave the best results with values 0.074 g and 0.098 g, respectively better than the
neat with a value of 0.110 g. This feat led to 49% enhancement.

![Graph](image)

Fig. 9. Graph of the response of the developed composites and neat sample to the abrasion property

4. Conclusion

The work shows that chemically modified chicken feather fibre can be utilized in epoxy matrix in order to enhance the mechanical and abrasion properties of the developed composites. All the properties were enhanced by the introduction of CMCFF into the epoxy matrix. The mechanical as well as the abrasion properties were enhanced within the range of 2-8 wt% CMCFF reinforcement additions. While mechanical properties were enhanced by the addition of 2 wt%, the abrasion property was enhanced by the addition of 4-6 wt%. Since the weight fraction used was up to 20 wt% and better performance are achieved at low weight fractions, it can be established that low weight fraction is good for the development of composites materials with good mechanical and abrasion properties.

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None

**Conflict of Interest**

None

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