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Effect of Nano Graphene Fillers on Tensile and Hardness Behaviors of Waste Cow Tail Hair Polyester Bio-composites

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Abstract

This paper introduce cow hair bio-fiber as the alternative eco-friendly reinforcing material at different weight concentrations (5%, 10%, 15% and 20%) in unsaturated polyester matrix to produce a new type of bio-composites fabricated by hand lay-up technique. The animal fiber reinforced composites were divided into three groups: unfilled composites (group A), 0.2% wt graphene filled composites (group B) and 0.4% wt graphene filled composites (group C). The tensile properties and shore D hardness behavior were evaluated. The results showed that both tensile strength and hardness are increased with the increase in the concentration of fibers and more improved with graphene addition in the composites.

Keywords: graphene, cow tail hair, bio-composite, tensile strength, shore D hardness

Introduction

In the recent years, there has been an attempt by many industry sectors to lessen its dependence on commercial petroleum based products and synthetic fibers such as glass, carbon and Kevlar fibers, which are considered the main constituents in the production of polymer, based composites [1-3]. The materials named bio-composites have been found to be promising the typical solution of such attempts [4].

Generally, bio-composites can be divided according to the origin of the phases into two distinct groups. The first group which commonly called green composites refers to the material implies that all its phases (matrix and reinforcement phases) are obtained from natural sources while the second group or partly eco-friendly materials which is composed of at least one of the phases is not obtained from natural resources [5]. This group sub-divided into two forms: bio-composites made from natural fiber embedded in petroleum derived matrix material and synthetic fibers incorporated with natural polymer matrix material [6].

Natural fibers are categorized as environmental friendly materials that are not man-made or synthetic [7]. They can be divided in three types according to their origins: cellulose of plant fibers (such as cotton, kapok, jute, flax, hemp and kenaf), mineral (such as asbestos) and protein or animal fibers (such as wool, fur and secretions) [8]. In comparison with commercial synthetic fibers, the natural fibers present many advantages, which make them attractive as reinforcement in composite materials industry. They provide positive environmental benefits, easy to process, recyclable, have good properties, require lower consumption of energy for their production, easy of separation, low cost, good thermal properties, high toughness, CO_2 neutral when burned, less pollution during production resulting in minimal health hazard and biodegradability [9-12].

Animal fibers are the fibers got from animals like feathers, hair, wool, fleece, silk and alpaca [13]. Animal hair is considered a waste material that is available in all countries of the world. Nowadays, hair being one of the most important animal fibers in the field of bio-composites, which can be, applied in the automotive, aerospace and sports equipment industries [14]. This is related to its high tensile strength value (similar to that of copper wires), high compression strength, high specific strength, good corrosion and low cost [15-16]. The only disadvantage is slow or non-degradable caused an environmental problem so its usage as reinforcement material can contribution to minimize the problem.

The aim of this work is to prepare and introduce a new type of bio-composite material based on polyester matrix reinforced with waste cow tail hair fibers. The present work include study the mechanical properties of bio-composites with different fiber concentrations and study the effect of nano graphene addition as a filler material on such properties.

Materials and Methods

The waste cow tail hair is taken out from the main abattoir in Al-Shuala district – north of Baghdad – Iraq. The hair fibers were washed several times with waster to remove dirt and debris. After wish the fiber were sun dried for 7 days and then collected in the form of a braid and cut to 3-5 mm lengths (Figure 1).

Figure 1. Cow tail hair fiber.

The thermosetting matrix material investigated in this work is SIROPOL – 8341 medium viscosity unsaturated polyester resin. The resin and curing agent is manufactured by Saudi industrial resins limited.

Graphene nano platelets 20-10 nm employed in this work as a filler material were supplied by ACS material – USA.

Preparation of bio-composites

A 2-mm double sided tape mold is used for preparation of bio-composites which is cut to a size that can accommodate 3 samples as per the ISO-527 standard for tensile test (Figure). The composite samples are fabricated using hand lay-up process with different fiber weight content (5, 10, 15 and 20 wt%) unfilled (group A) and filled graphene nano filler of concentrations of 0.2 and 0.4 wt% (groups B and C) respectivly.

For unfilled graphene natural fiber bio-composites (group A), the blend of unsaturated polyester resin and hardener was poured into the mold then fiber incorporated with the matrix material.

For group B and C, dispersion of graphene, unsaturated polyester resin with hardener are blended by the basic mechanical mixing. This process is done for certain amount of time till the mixture becomes homogenous. The fibers were added after put the blend into the mold. The samples of each composite group were removed from the molds after curing at room temperature for 24 hours. The designation and composition of the test samples of each composite group are listed in Table 1.

Table 1. Composition and designation of the test samples.

Group	Sample Constitution
0	Pure polyester
A	Polyester + 5 wt% cow tail hair fiber
A	Polyester + 10 wt% cow tail hair fiber
A	Polyester + 15 wt% cow tail hair fiber
A	Polyester + 20 wt% cow tail hair fiber
B	Polyester + 5 wt% cow tail hair fiber + 0.2 wt% graphene
B	Polyester + 10 wt% cow tail hair fiber + 0.2 wt% graphene
B	Polyester + 15 wt% cow tail hair fiber + 0.2 wt% graphene
B	Polyester + 20 wt% cow tail hair fiber + 0.2 wt% graphene
C	Polyester + 5 wt% cow tail hair fiber + 0.4 wt% graphene
C	Polyester + 10 wt% cow tail hair fiber + 0.4 wt% graphene
C	Polyester + 15 wt% cow tail hair fiber + 0.4 wt% graphene
C	Polyester + 20 wt% cow tail hair fiber + 0.4 wt% graphene

Tensile test

Tensile tests were done using machine. Samples were prepared and machined according to ISO-527 standard with dimensions of 150 mm x 22 mm x 4 mm using automatic dumbbell shape sample machine LYDS-250 (Figure 2).

Hardness test

Shore D hardness testing were determined according to ASTM D2240 standard and five measurements were taken for each set of samples.

Figure 2. Tensile test samples.

Results and Discussion

Results of tensile tests

Figures (3-5) shows the stress – strain curves of selected unfilled and graphene filled natural fiber composites. In all cases, the composites samples exhibited brittle behavior with no apparent yielding. In addition, it was observed that the tensile strength rises with increasing strain until the point of ultimate load. At this point the composite samples broke and failure.

The effect of animal fiber concentration on tensile strength of composites (group A) is shown in Figure 6. It was found that, the greater the concentration of fiber incorporated in the matrix, the more increased in tensile strength values. As expected, there was increase in tensile strength for 0.2 wt% graphene filled natural composites (group B) compared to the unfilled natural composites (group A) based on the charts presented in Figure 7. Furthermore, the increase in the amount of nano filler resulted in significantly increase in strength (group C). The 0.4 wt% graphene filled natural composite exhibited the highest tensile strength 31 MPa with 20 wt% fiber compared to 27 MPa and 19.6 MPa for unfilled composites (group A) 0.2% wt graphene filled composite (group B) of the same fiber concentration respectively. The improvement in tensile strength may be due to good particle dispersion and strong polymer/filler interface adhesion for effective stress transfer. The results show that the values of shore D hardness was enhanced in all natural fiber composites filled with 0.2 wt% and 0.4 wt% graphene. This is may be due to high hardness of nano ceramic particles dispersed in polymer matrix.

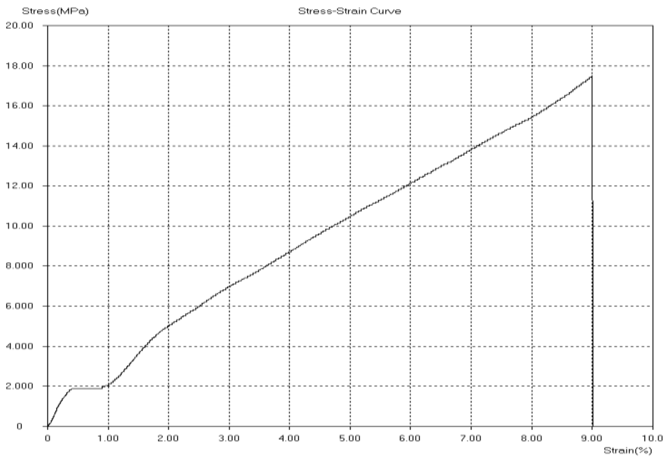

Figure 3. Stress-strain curve for unfilled 20 cow hair/80 polyester composite (group A).

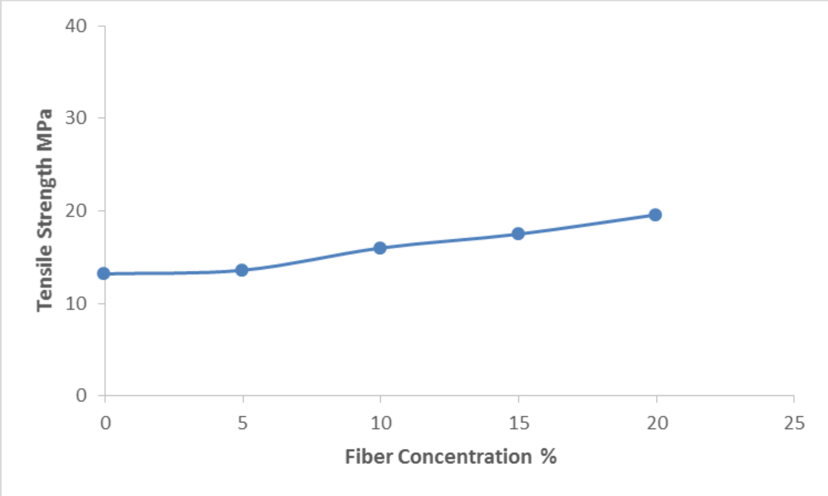

Figure 4. Stress-strain curve for 0.2 wt% graphene filled 20 cow hair/80 polyester composite (group B).

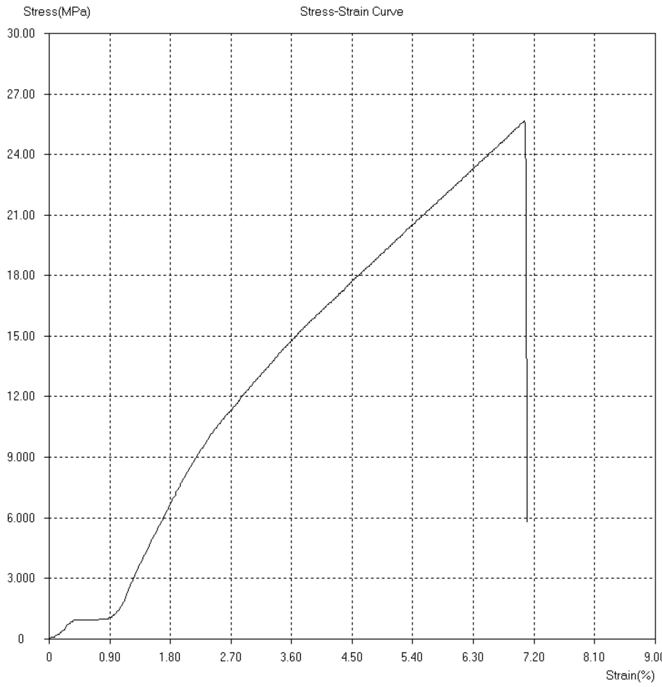

Figure 5. Stress-strain curve for 0.4 wt% graphene filled 20 cow hair/80 polyester composite (group C).

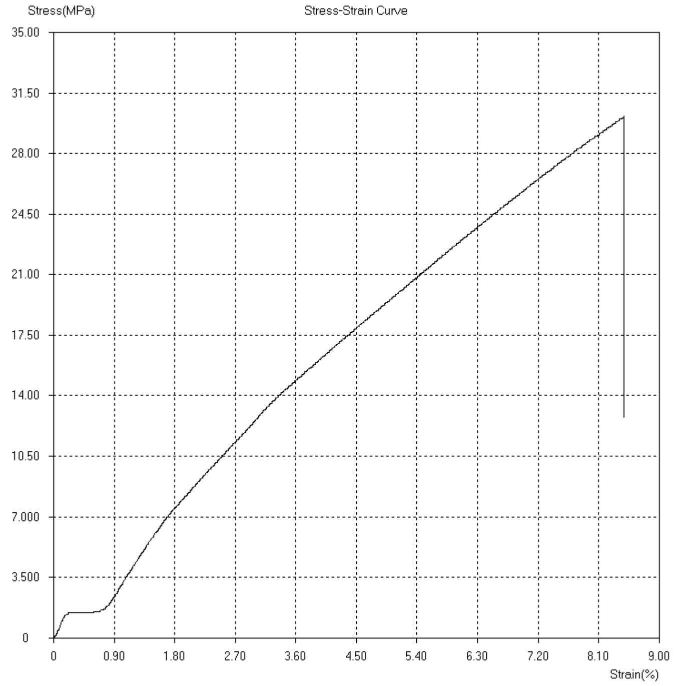

Figure 6. The effect of cow hair concentration on tensile strength of polyester based composites (group A).

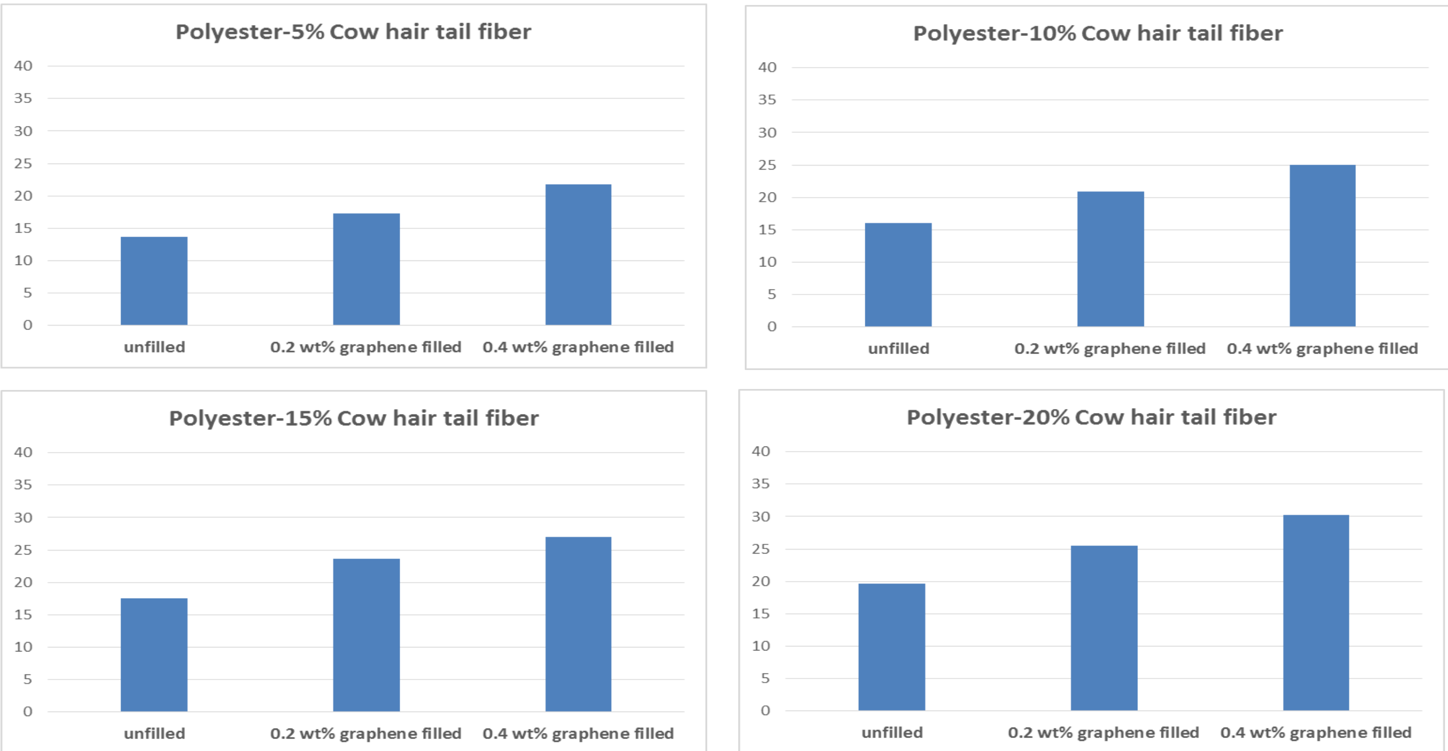

Figure 7. Tensile test results of unfilled and filled graphene natural fiber composites groups A, B and C.

Results of shore D hardness tests

Shore D hardness test was applied to pure polyester, unfilled cow hair fiber/unsaturated polyester composites (group A), 0.2% wt graphene filled cow hair fiber/unsaturated polyester composites (group B) and 0.4% wt graphene filled cow hair fiber/unsaturated polyester composites (group C). The average of these measured five hardness values was accepted as the hardness of the samples of each group. From Figure 8, it can be seen that the value of the hardness slightly increased with the increase in fiber concentrations (group A). In cooperation with value of 72 for pure polyester, the minimum hardness value were measured as 73 for composites containing 5% wt cow hair fiber. While the maximum hardness value were measured as 79.75 for composites containing 20% wt cow hair fiber. This increase may be related, as animal fibers are harder material than polymer matrix material. The composites filled with 0.2% wt graphene (group B) show better values of hardness than unfilled composites (group A) as shown in Figure 9. Also, it was found that 0.4w % wt filled graphene composites (group C) have highest hardness values compared with unfilled composites (group A) and 0.2% wt graphene filled composites (group B). Based on the charts presented in Figure 9, it can be observed that 0.4% wt graphene filled composite samples (group C) have the maximum hardness value than unfilled composites (group A) and 0.2% wt graphene filled composites (group B). The maximum hardness vale were measured as 87.25 for 0.4% wt graphene filled composite containing 20% wt cow hair fiber compared with 79.75 and 86.5 for unfilled composites (group A) 0.2% wt graphene filled composites (group B) of the same fiber concentration respectively.

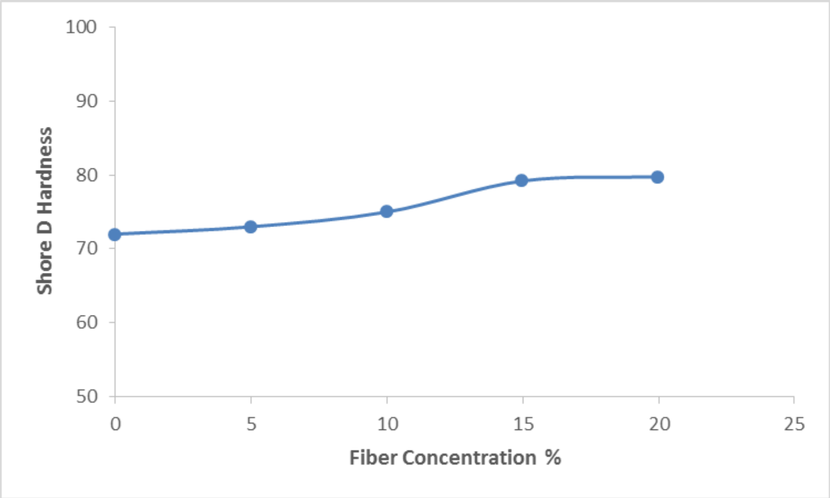

Figure 8. The effect of cow hair concentration on hardness of polyester based composites (group A).

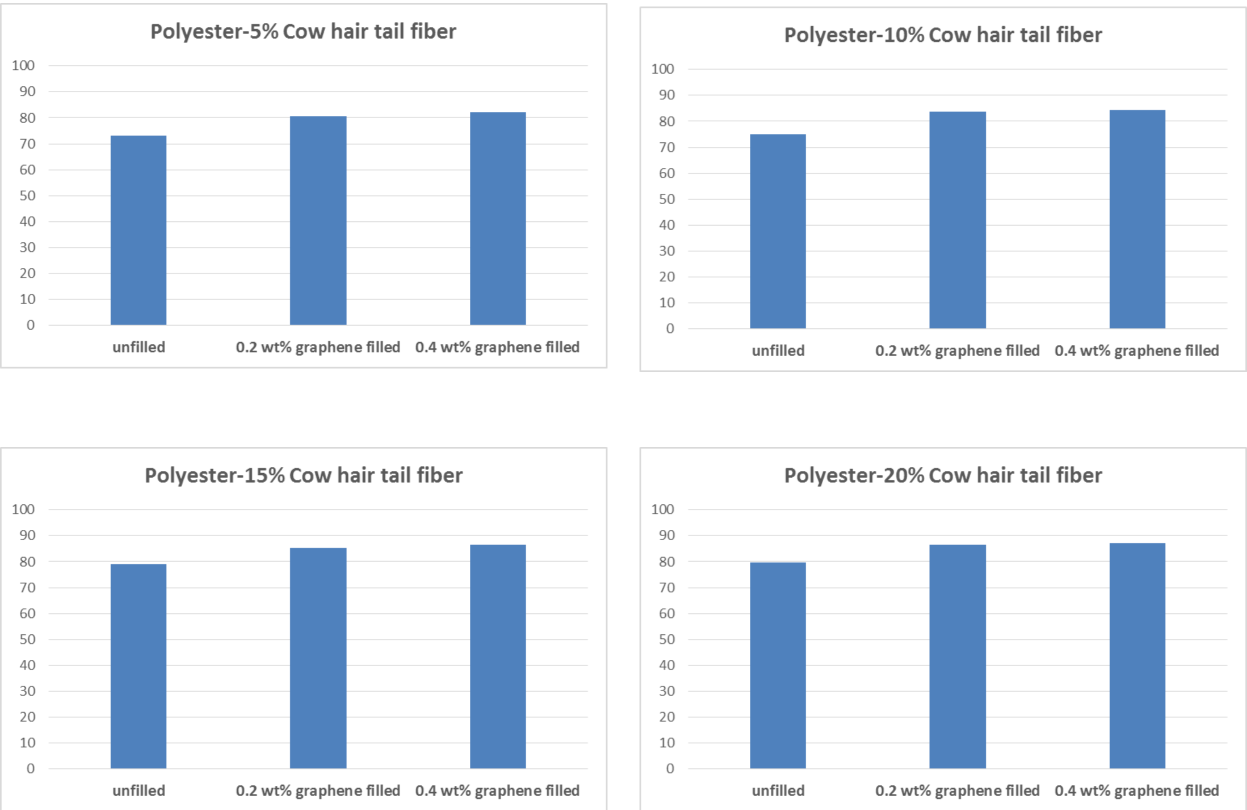

Figure 9. Shore D hardness test results of unfilled and filled graphene natural fiber composites groups A, B and C

Conclusions

1. The effect of animal fiber concentration on the mechanical properties of unsaturated polyester based composites was investigated. Both tensile strength and hardness of composites increased with increase in fiber concentration.
2. In corporation of waste cow hair fibers at 2 wt% and 4 wt% nano graphene platelets resulted in improvement of tensile strength and hardness behaviors of composites.
3. At 4 wt% graphene filled composites containing 20 wt5 waste cow hair fiber, the highest value of the mechanical properties is recorded.

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