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Performance Evaluation of Chestnut Nano Particles on Tensile, Impact, Vickers Hardness of Polyester/Glass Fiber Composite

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Abstract

In this study, an industrial source(E-Glass fiber) and a natural source (chestnut filler) were combined to improve the properties of polyesters. Hand-layup technique was applied in this work. Polyester (UPE) were reinforced with E-glass fibers, then reinforced with nano chestnut particles. All composites were prepared with (10% wt.) of E-glass for all prepared sheet and this ratio applied for Nano chestnut composite to preparing nano hybrid composites, Nano chestnut particles were used to reinforce E-glass/UPE composites with weight ratio (3%, 6% and 9% wt.). The evaluated mechanical performances for E-glass/NCSP polyester composite were tensile strength, impact strength and hardness. The higher ultimate tensile strength, Young's modulus and impact strength was appeared for the E-glass/UPE composite with 3%wt nano chestnut filler only. While the composites with 6% and 9% wt. showed failure in these properties. Hardness property was high with the three percentage addition of nano powder of chestnut.

Keywords: Unsaturated polyester (UPE), Hybrid Composites, Chestnut shell, E-glass fiber, Natural fillers, Nano powder.

تقييم أداء دقائق الكستناء النانوية على الشد والصدمة وصلادة فيكرز لمتراكب ألياف البولي استر/ الياف الزجاج.

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الخلاصة:

في هذه الدراسة,تم الجمع بين مصدرصناعي(الياف الزجاج) ومصدرطبيعي(حشوة الكستناء) لتحسين خصائص البولي استر.لقد طبقت الطريقة اليدوية في هذا العمل.فقد تم تدعيم البولي استربالياف الزجاج لوحدها وثم تدعيمها بدقائق الكستناء النانوية. جميع المتراكبات حضرت بنسبة وزنية(10%) من الياف الزجاج وهذه القيمة طبقت مع متراكبات الكستناء النانوية لتحضير متراكب نانوي هجين. دقائق الكستناء النانوية استخدمت لتدعيم متراكب(E-glass/UPE) بنسب وزنية(3%,6%,9%).الخصائص الميكانيكية المقيمة لهذه المتراكبات كانت متانة الشد ,متانة الصدمة والصلادة. ظهرت اعلى قيمة لمتانة الشد ومعامل يونك ومتانة الصدمة فقط لمتراكب (E-glass/UPE) مع 3% من حشوة الكستناء النانوية. بينما اظهرت المتراكبات

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بنسب وزنية 6% و 9% فشلا في هذه الخصائص.خاصية الصلادة اظهرت حالات مختلفة بزيادة النسب الثلاثة المضافة من دقائق الكستناء النانوية.

1. Introduction

Composite materials are considered a significant discovery in the material sciences field. Many applications resort polymers composite materials such as pack ageing, furniture, paneling, fencing, assembly boards, automobile and many other industries. Therefore, polymer composites are essential in many fields that require low cost and high efficiency applications. Artificial fiber-reinforced thermoplastic composites are widely used due to their excellent physical and mechanical properties in addition to their durability to withstand different circumstances [1].

Polymer composites present the properties of two or more materials, which do not exist by either the fiber or polymer when introduced alone. Composites / fiber were successfully introduced for many years in many applications. Composites / glass fibers are mostly used in composite materials due to many benefits: high chemical resistance, low cost, high mechanical properties, and insulating properties [2]. Glass Fiber Composites (GFC) are superior to other bio-composites due to the unique characteristics of glass fibers superior than natural fibers. Glass Fibers (GF) have many properties such as strength and light weight and are considered as a robust material. Compared to carbon fiber, GFs have lower properties, less stiffness, and are less brittle. In addition, GFs raw materials are cheaper. E-glass fiber fillers are an attractive way to enhance mechanical and physical characteristics of many polymers like thermoplastics. These advanced benefits could be attributed to the excellent mechanical and physical properties, in addition to the better adhesion between both polymer matrix and the used fibers when fibers surface treatment are used [3,4].

Nano composite is a multiphase solid material where one of the phases has one or more dimensions in the nano size (less than 100 nm) [5]. Nano composites super properties generally rely on the different materials used, especially the matrix that is present in the nanoscale dimensions, dispersion degree, loading, shape, orientation of the nanoscale second phase and finally the interactions between both the nanophase and the matrix [6, 7]. Over the last decade, composites with polymer matrix and natural fillers, which are used in industry and medical field, received wide attention in the literature [8,9]. Automobile industry has recently been replacing several parts made of plastic or glass fiber composites (GFCs) with natural filler resources [10]. The special properties of these natural fillers, such as good electrical and mechanical properties, impact resistance and especially the good thermal and acoustic characteristics made them an attractive alternative to the traditionally used materials [11]. Natural fillers could be referred to as cellulosic fillers, which can generally be classified as seed-hair, bast, leaf, cereal straw or grass fibers, depending on these materials origin [12]. Hybrid composites include a combination of two or more reinforcement materials of various types, sizes and shapes. These materials are reported to be highly dependent on the roughness of the fiber surfaces, fiber-matrix compatibility, fibers individual property and others [13-14]. Nowadays, this type of composites is more popular and is rapidly increasing owing to the capability of providing freedom to design the composites and evaluate the required properties that cannot be gained through a singular type of reinforcement [15].

Many research reported that the addition of synthetic fibers to form hybrid fibers improved the composites' quality composites [16]. Natural fillers, e.g. chestnut, are used by researchers to produce polymer composite with enhanced characteristics [17-22]. Chestnut fillers are obtained directly from natural resource; it is cheap and has advantages due to their renewable nature, available in abundance [23].

From literature review, it is obvious that only a few studies used nano chestnut as a filler with polyester resin. Further, no literature on glass fiber/ nano chestnut hybrid composite is available. Hence, this research used woven E-glass fiber/ nano chestnut shell power (NCSP)as a hybrid additive to a polyester matrix. Polyester/E-glass fiber/ nano chestnut hybrid composite is promising to be used for high-performance structural applications.

In this research hybrid polyester composite with a selected ratio of the nano-ecofriendly particles was prepared. Literature survey indicates the advantage of using natural fillers in industrial applications. Therefore, the aim of this work was to evaluate polyester/E-glass composite through the main characteristics: tensile strength, impact and Vickers hardness, which is considered as a procedure to study the efficiency of using this hybrid composite in industrial applications.

2. Materials and preparation:

2.1. Materials used:

Unsaturated Polyester resin ((SIRRESIN, SABIC KSA) as a polymeric matrix was used in this research. E- glass with continuous strand mat was selected among the many types. Fibers were sliced to the matching form of the used mould dimension. Chestnut particles were used as the third part (the scientific name of Chestnut is Aesculus Hippocastanum). Chestnut fruit shell was first extracted from the fruit. Before grinding, the shell was cleaned and chemically treated. To do so, fibers were immersed in 6% NaOH in (1liter) of distilled water for about 3 h. The fibers were dried in an oven at 60^0C for 2h. Chemical treatment is the next step to advance the bonding between the fiber and the matrix, as shown in Figure (1a). After that, a grinding machine was used to get fine particulates fillers. The produced fillers were dried in an oven at 60°in order to remove residual moisture. The ground form particulates were sieved through a mesh with 0.063μm sieve size, as shown in Figure (1b). Particle size analyzer (90-plus) was used to ensure the particles precise size after sieving, particle size analyzer (90-plus) was used. This work was carried out in the nanotechnology and advanced materials research center-UOT. Figure (2) presents the average particle size obtained to be utilized as particulate fillers. The effective diameter for the utilized nanoparticles was around (57.4) nm.

Figure 1: **a-**Chemical treatment for chestnut shell **b-**Chestnut shell before and after grinding

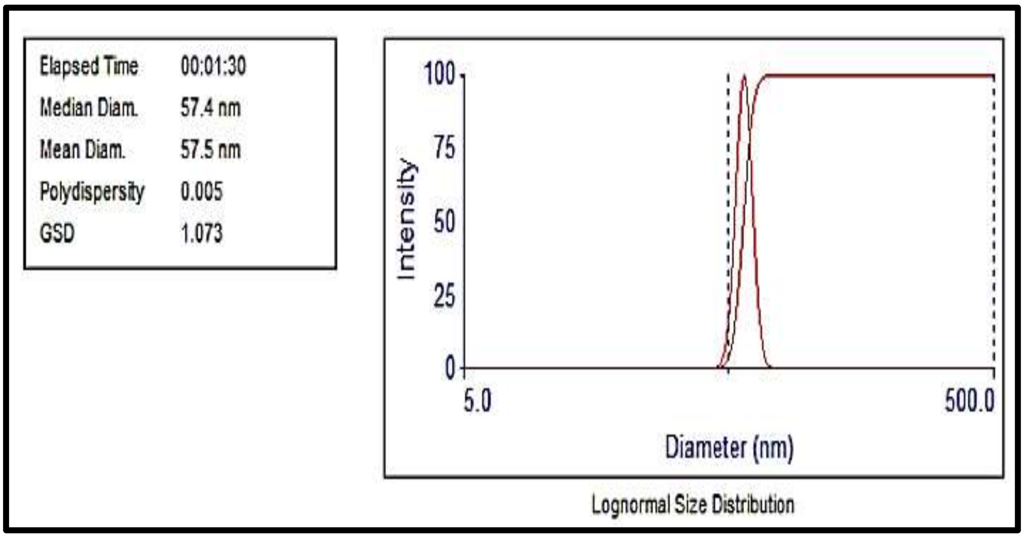

Figure 2: The lognormal size distribution of nano chestnut shell particles (NCSP)**.**

2.2. Preparation of hybrid composites:

The prepared polyesters were grouped into five group samples, as shown in Table (1). Sample A presents the polyester as the control sample; sample B was polyester reinforced with E-glass. Sample C, sample D and sample E are the prepared nanohybrid composites with different percentage weight ratios of nano-chestnut particles of 3%, 6% and 9%, respectively.

The ratio of E-glass fiber was fixed at 10% wt for samples B, C, D, and E.

As shown in Figure (3), the prepared blend (polyester/ Nano-chestnut particles) were poured on the E-glass laminated in a specific mould to prepare the hybrid composites. The casted sheets were cut according to the related ASTM, for testing the samples. An identical procedure was used for preparing the composite samples (hand lay- up technique).

Table 1: Weight percentage for all prepared samples

Sample	Polyester ratio %	E-glass fiber ratio %	Nano-Particle ratio %
A	100	0	0
B	90	10	0
C	87	10	3
D	84	10	6
E	81	10	9

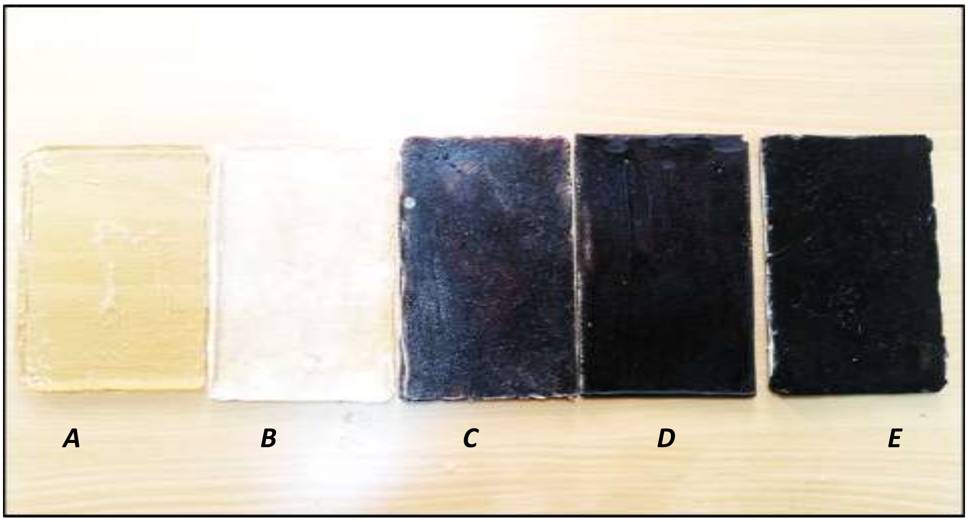

Figure 3: Cast sheet for E-glass /NCSP polyester composites.

3. Testing procedure.

3.1. Tensile test:

Tensile load was applied to the prepared samples after fixing them longitudinally using equipment upper jaw and lower jaw with an applied load of (5KN) with (2mm/min) as machine velocity. Utilizing the connected graphic plotter (Model 1195; INSTRON), the relationship of (ρ-ΔL) was obtained, which was modified to stress–strain (σ-ε) relationship. The (σ-ε) relationship was used to determine the ultimate tensile strength (UTS) and Young's modulus for the prepared composite [24]. The samples prepared for the tensile test are illustrated in Figure (4). The strain and stress can be calculated using the following equations:

$$\sigma = p / A \qquad \text{.......(1)}$$

$$\varepsilon = \Delta L / L \qquad \text{..........(2)}$$

Where: P is the applied force to the sample (N), A is the cross sectional area of the sample (m^2), and ΔL is the elongation of the original length (L) before the fracture occurs

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3.2. Impact strength test.

Izod impact test (I.S.) was carried out in this work to evaluate the impact strength value before and after the reinforcing polyester resin with the selected fillers. All samples were cut according to the standard ISO-179. The samples prepared for the test are illustrated in Figure (4). The main Izod impact test principle is to evaluate the amount of energy absorbed by a material sample during the fracture, which refers to the material toughness [25], according to the following equation:

$$\text{Impact Strength (I .S)} = \frac{Energy\ of\ fracture(KJoul)}{Cross{-}Sectional\ area(m^2\ )} \qquad \text{..... (3)}$$

Figure 4: The prepared samples for the tensile and impact test.

3.3 Vickers Hardness Test.

Material hardness is the measurement of its resistance to surface deformation. The samples were exposed to Vickers hardness test, also called micro-hardness, where the hardness of the surface (HV) is evaluated. A digital Vickers hardness device (HVS -1000, Laryree technology Co.Ltd, China) was used. The applied load was 200g which was applied for 15 seconds (according to ADA Specification No.27). For each sample, the average magnitude of three teats was registered.

4. Result and discussion:

4.1 Tensile test evaluation

Stress –strain curves of all composites samples for all cases declared that these samples display plastic deformation. Despite the fact that a high percentage of brittle material polyester (UPE) still present, the composite curves did not display the yield points. The proof of the ductile behaviors was in the necking area, followed by the homogeneous drawing of the sample (Figure (5)).

Tensile characteristics are considered the most exceedingly properties determined for any material before its use in any application. The tensile strength is the maximum applied load the specimen can bear before breaking under the gradual increase during the tensile test [26]. The stress–strain curves for the five samples are shown in Figure (5). From the figure, it can be noticed that the tensile strengths of all filled composites are of higher values compared to the polyester only sample polyester (UPE) expect for the composite of sample E, with 9% nano chestnut shell powder(NCSP),that showed a noticeable failure. Table (2) presents the mean values of Young's Modulus, tensile strength, and strain for all the samples. Higher values of ultimate tensile strength, Young's modulus and strain were noticed for sample C (the hybrid composites at 3% weight percentage of nano chestnut). This could be due to the mobility restriction and matrix deformability with the introduction of mechanical restraint and the filler dimension. Additionally, this increase could be due to the high strength and stiffness of E-glass fiber. In addition, the adhesion between the group of fiber, nanopowder and the polymer matrix had an appreciable influence on the mechanical properties of the polymer composite with fiber reinforcement. Thus, interfacial adhesion plays the main role in improving the composite properties, particularly tensile strength, which is generally affected by the load transfer efficiency from the polymer matrix to added fibers via shearing at the interface [19]. Sample E, the hybrid composite prepared with 9% nano chestnut particles, showed noticeable failure, which could be due to the reduction of adhesion with increasing the weight ratio of the nano chestnut and agglomeration of nanoparticles [27].

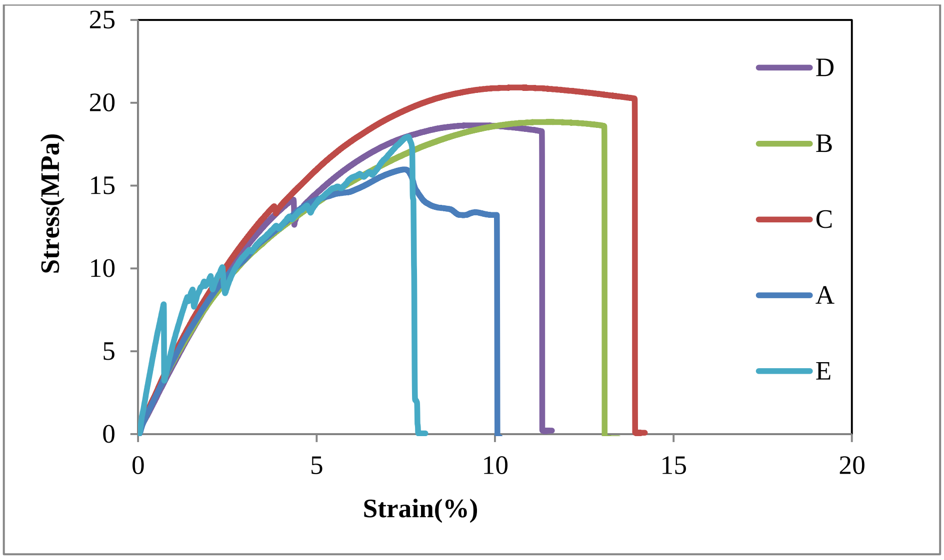

Figure 5: Stress-Strain Curve for all specimens.

Table 2: Value of mean (Tensile strength, Young's Modulus and Strain)for samples.

Sample Code	Ultimate Tensile Strength(MPa)	Strain (%)	Young's Modulus(MPa)
A	15.987	10.136	262.670
B	18.593	13.486	378.192
C	20.923	14.198	387.598
D	18.637	11.594	376.772
E	17.953	8.048	377.882

4.2 Impact test evaluation.

From Figure (6), it is clear that the maximum impact strength (13.61 KJ/mm2) was of sample (C), which contains 3% wt nano-chestnut particles, compared to the other samples. This behavior was similar to that of the tensile test. This could be explained by the decrease of inter-particle spacing, which often slows down the nucleation of cracks by absorbing some fraction of energy [23]. In addition, E-glass fiber distributes the stress over a larger volume, reducing the possibility of stress concentration in a particular area, as well as it acts as inhibitory to fractures and prevents the growth of small cracks that occur as a result of impact[28].

While the samples (D and E) with 6% and 9% nano chestnut particles, respectively, showed a reduction in the impact strength value with the increase of weight fraction of nano chestnut shell powder (NCSP), which led to a decrease of matrix elasticity and also decrease of the adhesion with E-glass/UPE composite. (NCSP) concentration inside these composite decreases the capability to absorb energy and reduces the value of toughness; therefore, the fraction impact strength decreases [18].

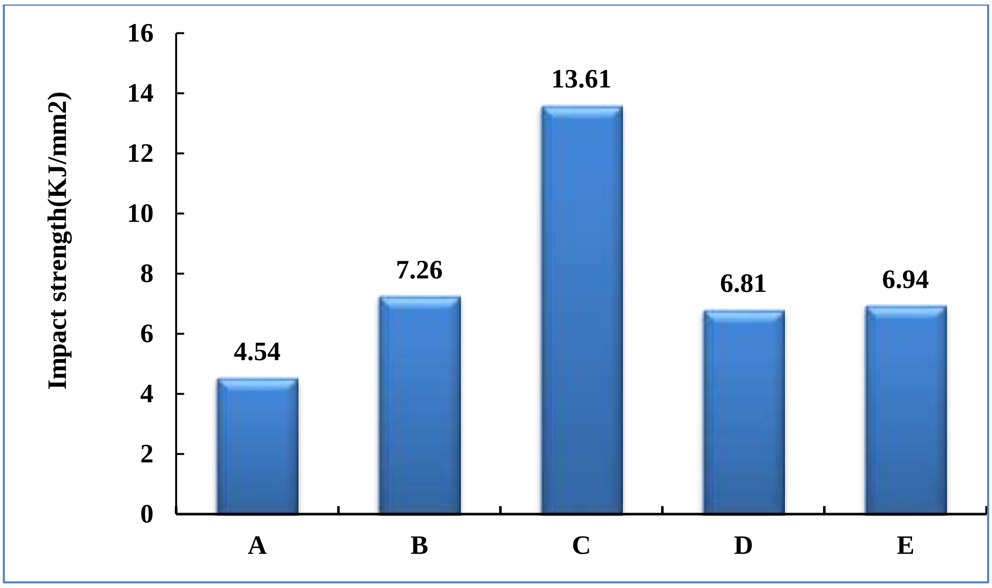

Figure 6: Mean impact strength fo the different samples of composites.

4.3 Vickers hardness evaluation.

Generally, polymer materials may be penetrated by hardened equipment while they are in use. In the application fields, hardness is an important surface mechanical property that can be defined as the material's resistance to plastic deformation or penetration [26]. Figure (7) shows that the hardness values of samples reinforced with glass fibers and NCSP increase with increasing weight percentage for the nano chestnut particles, as these particles have high hardness [23]. The values for the samples (C, D and E) were almost the same. Yet, there was a noticeable difference between the virgin polyester sample A and E-glass fiber/ polyester sample B. This could be explained because the chestnut particles emerge with the matrix. Hardness depends on the bonding nature of the particles with the resin [27]. The interface plays a pivotal role in determining the mechanical properties, e.g. transferring the stress and distributing the bond; it is among the least understood components of the composite . Table (3) presents the percentage improvement of micro hardness between the prepared hybrid composite and neat polyester. Interestingly, a gradual increase in the percentage improvement of micro hardness was observed as the nano-fillers weight percentage was increased. The maximum was found for samples d and E of 6wt % and 9wt % Polyester/ GF- nano chestnut particles, respectively.

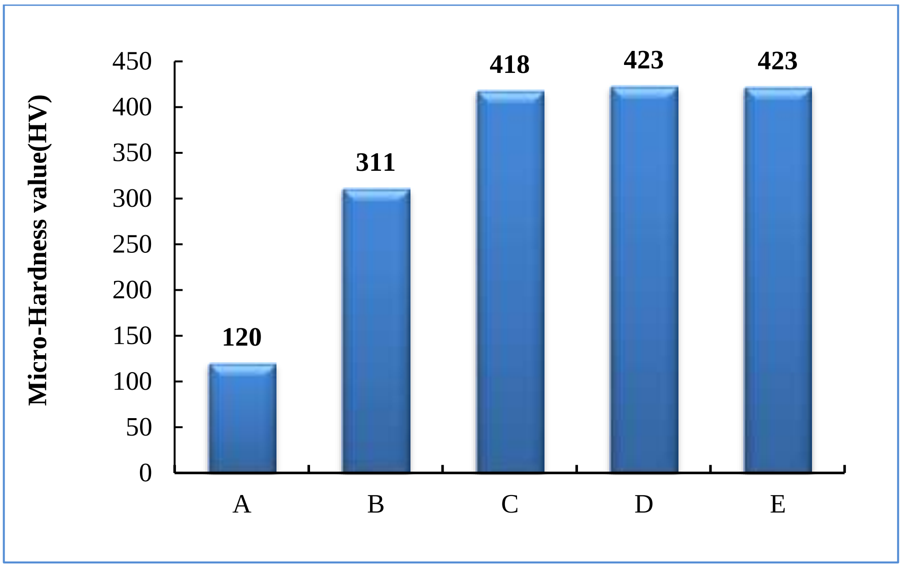

Figure 7: Mean value of micro-hardness (HV)

Table 3: Vickers micro hardness percentage improvement

Sample Code	Vickers Hardness Improvement %
A	0%
B	61%
C	71%
D	72%
E	72%

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Conclusions

In summary, the mechanical properties such as tensile and impact strength were improved significantly after reinforcing neat polyester with E-glass fibers and NCSP. Best results were observed with the hybrid sample (C) that consists of 3% (NCSP)/ E glass fiber. E-glass fibers are approved to enhance the tested property for the entire composite prepared. Additionally, Nano chestnut shell powder (NCSP) played a marked role in property improvement as it showed better mechanical performance in both tensile and impact strength values although the increase was not progressive. Yet, this was completely different in the case of hardness evaluation, as the highest value was found for hybrid sample (D and E) the 6 and 9% (NCSP). More than 70% was the determined enhancement compared to the neat polymer. Hence, the mechanical behavior of polyester composites was studied in order to improve an engineering material for industrial applications such as car seats, dash boards, gear cams, and interior parts of automobiles**.**

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