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RESEARCH PAPER

Experimental and Numerical Evaluation of Mechanical and Thermal Properties for Carbon Fibers and Barhee Seeds Nano Powder as a Modified Composites

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ABSTRACT

Natural fibers play an important role in manufacturing of different types of hybrid composite materials due to its unique properties including about zero financial cost, so the fundamental idea of this research paper is using the Barhee palm date seeds as a nano powder and as a natural fibers (Barhee is a Local name, and its scientific name is *Phoenix Dactylifera L.*) in producing hybrid composite structure as an additive material to a standard carbon fiber composite, where the pure carbon fiber composite has been denoted as Original Composite (OC), meanwhile the developed one named Modified Composite (MC) and both of these two specific composites have been produced experimentally by employing the so called Vacuum Assisted Resin Infusion Molding method (VARI), due to the simplicity of this experimental setup in a laboratory testing approach. The modified composite has 60% wt. to 40% wt. mixing ratio and the total quantity was 1000 gm as a net gross weight respectively that gives the modified composite some flexibility and showing deformation ability compared with the original one. Morphology examination showed that a good mutual interfacial bonding with uniform layering profile along with the whole volume of the assigned modified composite, so this style may be named as a homogeneous mixture and exhibiting relatively high level of enhancement of active tensile strength, therefore, final recommendation behind the entire experimentally confirmed results is using this presented modified composite in some industrial applications that are requiring these obtained ranges of the mechanical properties including high strength and associated relatively low specific weight.

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INTRODUCTION

Every year, a tremendous amount of wasteful seafood ends up in landfills. Wastelands are filled with this kind of trash, which mostly includes things like fish scales, crab shells, lobsters, and similar objects. The environmental deterioration caused by these wastes has far-reaching detrimental consequences for society [1,2]. Also, there's a hefty price tag associated with properly disposing of these objects. Alternatively, these resources can be utilized in the creation of biodegradable products through recycling, which will lead to the sustainable expansion of the economy [3]. Roughly seven to ten billion tons of waste residues are produced annually by urbanization processes worldwide, and recycling is in high demand [3-5]. Authors [6] have developed epoxy composites reinforced with goat bone for application in biomedicine. The study of the reinforcing material for goat bones revealed that the main elements found were calcium and phosphorus. Epoxy composites reinforced with 16% goat bone have enhanced tensile, flexural, and hardness properties. Aside from hardness, other mechanical qualities have also been enhanced. Cows are an essential part of daily life in countries like India that depend significantly on agriculture. Consequently, scientists have focused on potential medical, agricultural, and industrial uses for cow manure [6-10]. Authors [11,12] created composites from cocoa bean shell and agricultural waste residue to enhance the mechanical properties of aluminum. Composite materials with enhanced performance characteristics were made by reinforcing palm kernel shell with aluminum alloys, an additional kind of agro-waste residue that was generated globally [13-20]. A composite material that can enhance the hardness and strength of Al2O3 was created by [21] using walnut-shell ash as a reinforcement. In their study, [22,23] investigated the effects of groundnut shell particles on the hardness, yield strength, and ultimate tensile strength of aluminum magnesium silicon composites. The results showed that raising the weight percentage of groundnut shell particles by as much as improved the characteristics. In addition, it has been shown that ceramic particles made of 95% found in eggshell waste may be used as desired reinforcements in composites [24-27]. In this study, experimental and numerical evaluation of mechanical and thermal properties for carbon fibers and Barhee seeds nano powder as modified composites have been employed to investigate accordingly.

MATERIALS AND METHODS

Global climate changes have a dramatic effect on behavior of composite structure component due to the significant rising of ambient temperature, so it is required to produce a specific material that is sustaining such hard circumstances under an assigned direct load, therefore using natural fibers will highly help and gives a more advantage to the modified composite structure. The nominated two major materials are the essential one named carbon fiber and its complementary substances and the second essential natural fiber is so called Phoenix Dactylifera L. locally called "Barhee Variety" see Fig. 1. below, as a grinded seeds nano powder, hence the resultant composite will be

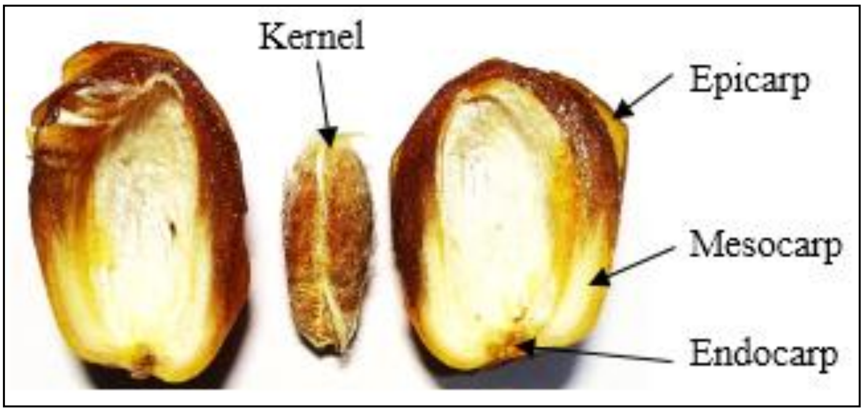

Fig. 1. Sectional Sight for the employed Barhee Fruit.

denoted as Carbon Fibers and Phoenix Dactylifera L. (CFPD). In Iraq, there are millions of such palm trees distributed in the middle and south, so tons of its seeds are produced and totally considered as a waste material with zero financial cost, so the core idea of this research paper is using this amazing material in producing some specific composite material to be investigated under mechanical tests including creep test and morphology test under common boundary conditions.

Table 1. below give principal properties of this type of palm tree dates.

Strategic Materials and Method

The nominated natural fiber is the so called Phoenix Dactylifera L. (its local name is Barhee) seeds nano powder will be added to a carbon fiber for producing modified composite materials as a raw material used for checking mechanical and morphological properties, therefore, the original composite will be pure carbon fiber, epoxy resin, and hardener and denoted as Original composite (OC), meanwhile the modified one will be a mixture of the two mentioned materials and denoted as Modified composite (MC).

Phoenix Dactylifera L. Barhee Nano Powder Preparation

Fig. 2a. below show the nominated samples of the Phoenix Dactylifera L. (Barhee) seeds in its natural size and shape without any processing, meanwhile Fig. 2b. illustrate the nominated seeds

Table 1. Overall properties of Barhee date fruit.

Local Name	Barhee
Scientific Name	Phoenix Dactylifera L.
Total Weight (gm)	7.9
Total Length (cm)	3.2 – 3.5
Outside Diameter (cm)	2.3
Wall Thickness (cm)	0.5 – 0.6
Seed to Fruit Mass Ratio	10.9%
Total Number of Samples	50
Crude Fibers (gm/100gm) DW	≈20 ± 0.32
Production Country - City	Iraq - Babil
Production Date	September 2025

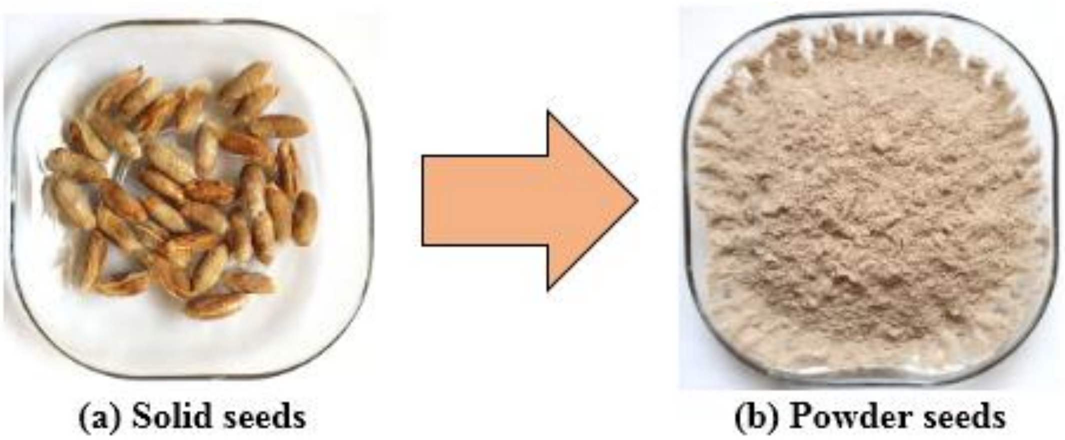

Fig. 2. Two phases of Phoenix Dactylifera L. (Barhee) seeds, (a) solid, and (b) nano powder.

nano powder for the Barhee type for completing the practical procedure.

Producing seeds nano powder is passing through four stages, starting with washing the available seeds (one kilogram of Barhee seeds) according to specific procedure under 20 °C, average room laboratory humidity of 40% under ordinary atmospheric pressure, where the adopted standard procedure is isolating wisely and washed with deionized water (H_2O) and by using soft plastic brushes the peripheral tissues have been detached then followed by soaking within one half liter, 500 cubic centimeters of 30-40% chemical concentration of aqueous solution of Phosphoric acid (H_3PO_4) for a about two sunny days, then washing the whole quantity with a homogeneous mixture of deionized water (H_2O) and Sodium Hydroxide (NaOH) and finally washing with purified water, so the final step is drying route inside a fully controlled chamber under 70°C for about six hours so the total moisture content has been fully released. After that, grinding the seeds by using special grinding machines of type Gdrasuya - 10 followed by sieving the produced powder for removing the undesired granules until reaching a fine nano powder of size 0.2 micrometers corpuscular shape nano powder as shown in Fig. 3.

Carbon Fibers, Epoxy Resin, and Hardener Prime Properties

Using carbon fibers as a principal element is very common in many previous research investigations due to its unique mechanical and physical properties, so in the research paper the employed type is (TC33-6K – 2025) and will be assigned as an Original Composite (OC) and it would be a reference for comparing with other developed Modified Composite (MC), therefore, Table 2. below summarize its principal properties.

The employed epoxy resin was manufactured by a Turkish company named Kompozitshop, where the epoxy resin was PROPOX Resin LR160. Table 3. review the reliable properties of this resin.

The second complementary element is the hardener of type PROPOX Hardener LH1287, made by Turkish company, so Table 4. reveal chief characteristics of this hardener. [7,8].

Original (OC) and Modified (MC) Composites

Two different composites have been nominated within this experimental research paper for conducting the adopted practical part and then comparing the obtained final results for reaching

Fig. 3. Producing phases of Phoenix Dactylifera L. (Barhee) nano powder.

Table 2. Principal properties of the hired TC33-6K Carbon Fibers.

Maximum Tensile Strength (GPa)	Young's Modulus (GPa)	Yield Strength (MPa)	Elongation to Failure (%)	Sizing (wt. %)	Density (Kg/m³)
3.55	224	410	1.6	1.60	1800

Table 3. Key properties of the employed LR160 epoxy resin [5,6].

Average Tensile Strength (MPa)	Modulus of Elasticity (MPa)	Density (Kg/m³)	Maximum Weight Based Ratio @25°C
75	3.1	1120	100: 30

logical conclusions, they are:

1) Carbon fibers, epoxy resin, and hardener composite and denoted by original composite (OC) and will be as a reference one.

2) Carbon fibers supported with Phoenix Dactylifera L. (Barhee) seeds nano powder and called as modified composite (MC) with specific weight mixing ratio as follows.

As a first primary step, the measure mass density for the modified composite was about 1200 Kg/m^3 and the adopted practical procedure for producing both of the nominated composites is so called vacuum assisted resin infusion molding (VARI).

Vacuum Assisted Resin Infusion Molding (VARI)

Simply this vacuum assisted resin infusion method is very effective in the field of composite materials production due to its simple structure and procedure for such research purpose, so the assembled rig is shown in Fig. 4. below where it consists of specific one directional flow vacuum pump, suitable trap box with pressure gauge, glass mold with already stated dimensions, control valves, flexible houses, electronic accurate scale, and other complementary accessories. It is important to indicate that the volumetric mixing ratio of the nominated resin to the employed hardener is (2:1) respectively.

Table 4. Foremost properties of the PROPOX Hardener LH1287 [7,8].

Specific Gravity	Viscosity @ Lab. Temp. (MPa.sec)	Density (Kg/m^3)	Color	Gel Time @ 25°C (hour)	Pot Life @ 25°C (min)	Production Year
1.02 ±0.1	620	1000	Clear	24 - 36	30 ±10	Feb. 2025

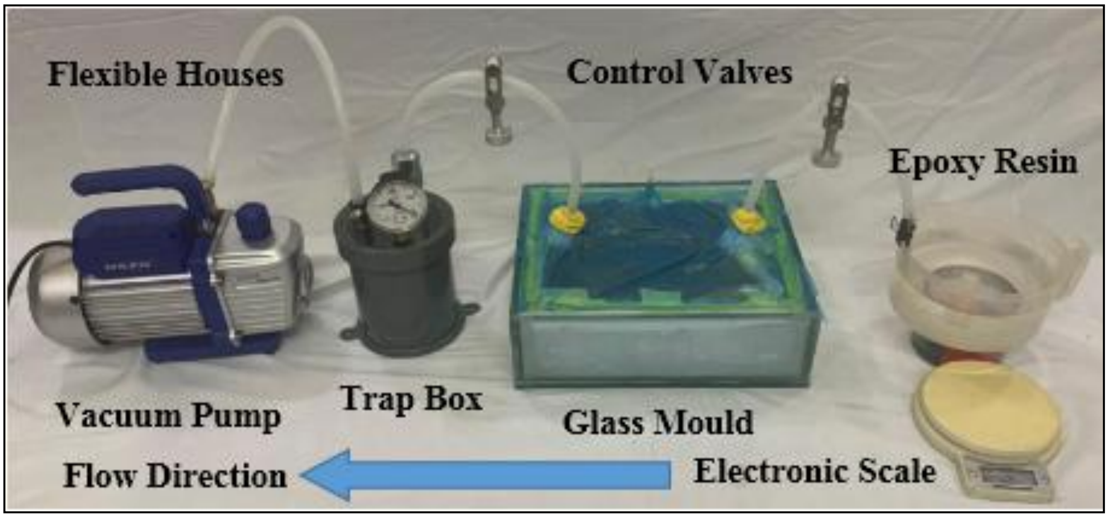

Fig. 4. Vacuum assisted resin infusion constructed practical rig.

Fig. 5. Standard tensile test specimens according to ASTM D3039.

Composite Name	Composition	Additive Weight (% wt.)
Original (OC)	(Carbon Fiber + Epoxy Resin + Hardener)	0
Modified (MC)	(Carbon Fiber + Epoxy Resin + Hardener) + (Barhee Date Seeds nano Powder)	40

Percentage Weight Mixing Ratio (%wt.)

The suggested practical weight base mixing ratio and the associated masses for the two submitted composites are shown in Tables 5. and 6. respectively.

The suggested two composites (OC and MC) are explained in the following list with percentage ratios of mixing process.

a) Carbon fiber composite - Original (OC) = 100% wt. of carbon fibers, epoxy resin, and hardener + 0% wt. Additive

b) Modified composite (MC) = 60% wt. of carbon fibers, epoxy resin, and hardener + 40% wt. Additive.

All of the above two mentioned composite structures were facing multiple repetitions of both

Table 6. Weights and masses for the three presented composites.

Composite Name	Carbon Fiber (%wt.)	Date Seed Nano Powder (%wt.)	Mass of Carbon Fiber (Kg)	Mass of Nano Powder (Kg)	Gross Mass of the Composite (Kg)
Original (OC)	100	0	1	0	1
Modified (MC)	60	40	0.6	0.4	1

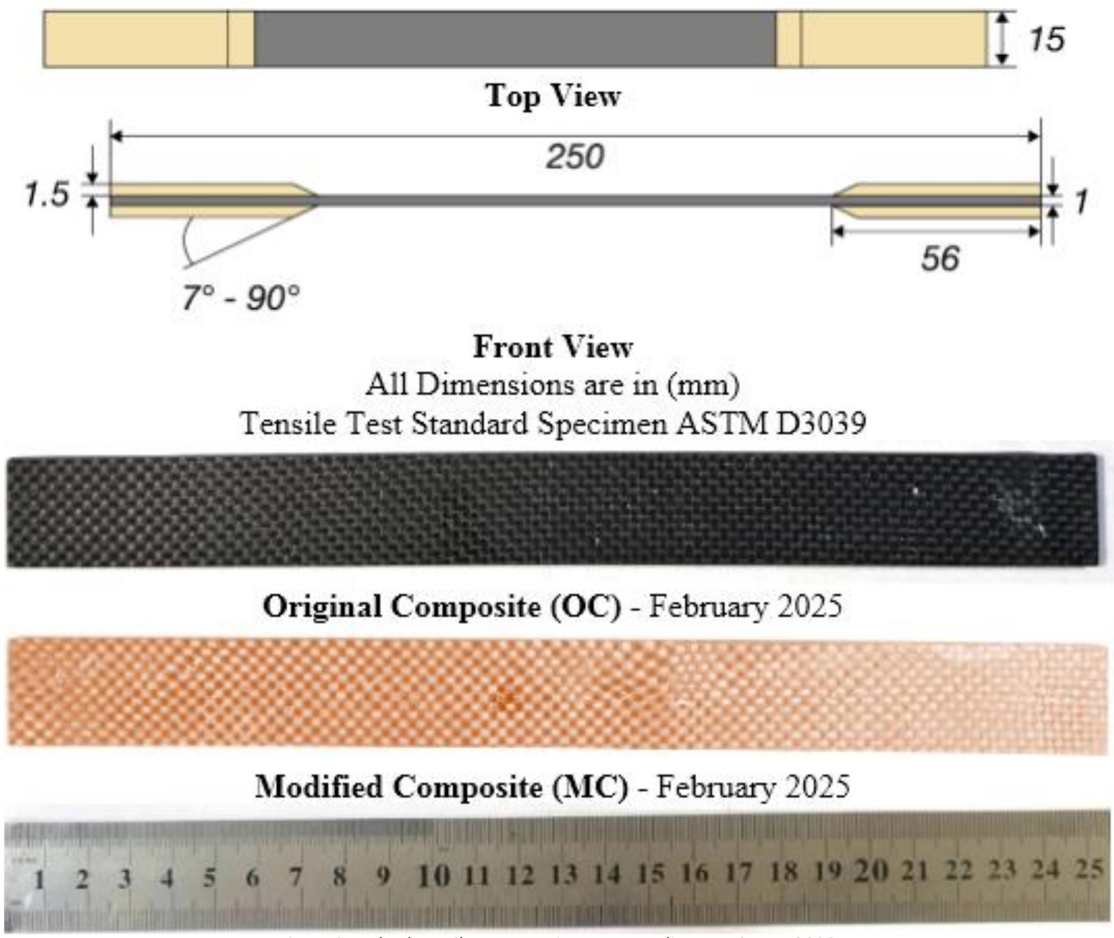

Fig. 5. Standard tensile test specimens according to ASTM D3039.

tensile strengths, bending, and morphological tests for getting more precise mean investigational practical results as follows.

Tensile Test Specifications

Tensile test is considered as an informative test that gives a clear indication about the material under direct applied loads and provide many essential parameters that are describing behavior of the assigned material, so the adopted tensile test was under license of American Standard Tests and Materials ASTM D3039 where it is designated specifically for polymeric composites, where the selected normal applied force was 100 KN and two millimeters per minute as a controlled continuous displacement, hence, Fig. 5. Show samples for the prepared specimens.

Bending Test Description

The chosen bending test was three points bending test procedure in accordance with the ASTM D790, hence Fig. 6. show the employed standard specimen for both original (OC) and modified (MC) composites, where the provided ambient boundary conditions were 25°C, average humidity 40% available for 48 days before conducting these tests.

Meshing and modeling

For the purpose of this investigation, the software AutoCAD was used to model the geometry. Through the utilization of the steady state thermal tool, the mesh was produced within the ANSYS program. For the present model, which has elements of the square type, the uniform structure has been successfully implemented. The rate of growth of the components that were included in the model was acceptable. in addition, the smoothness has reached the level that is considered acceptable. It has been getting closer and closer to the number of components hitting 2000. Fig. 7 illustrates the model with meshes.

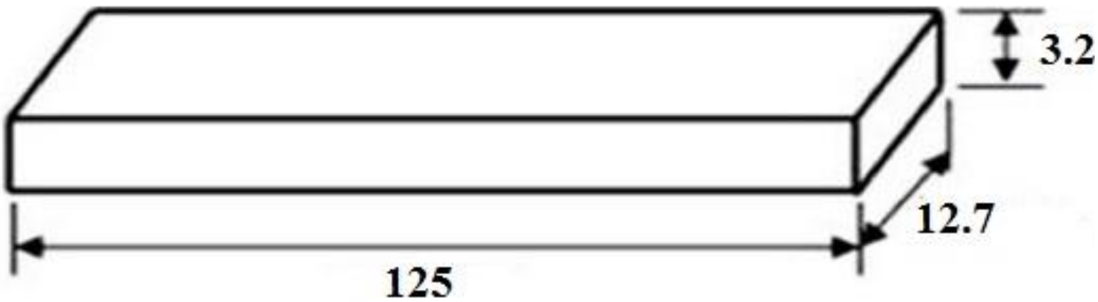

Fig. 6. Bending test specimens according to ASTM D790. All dimensions are in (mm).

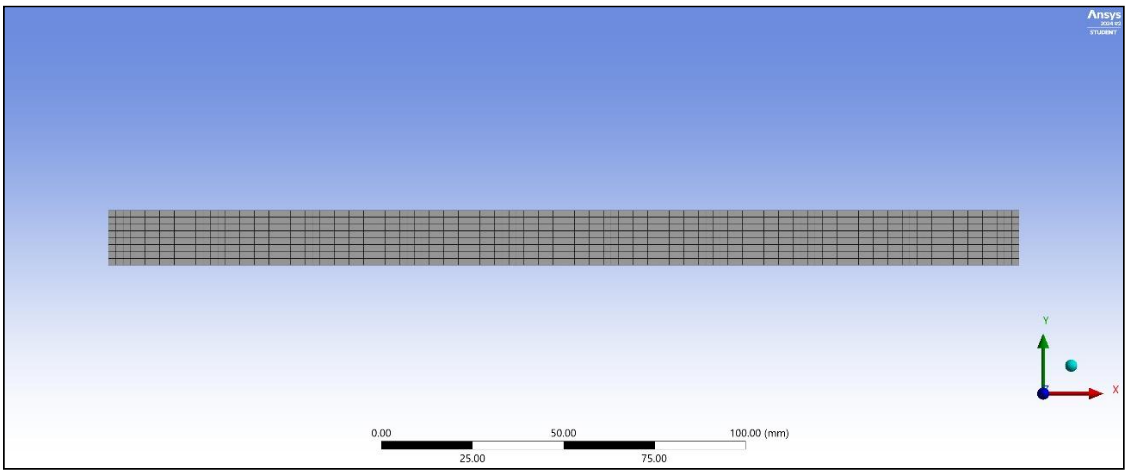

Fig. 7. Illustrates the model with meshes.

RESULTS AND DISCUSSION

Tensile Test Results

In return to Fig. 5. Above where it indicates the adopted stress strain test specimens for both the OC and MC types under license of ASTM D3039, where these tests have been done under 25°C laboratory temperature with moderate ambient humidity at 32 meter over sea level location. Fig. 8. below show the obtained tensile strength test results where the maximum tensile strength value was about 215 MPa and the associated Young's modulus of elasticity and maximum mechanical breaking force are 1.80 GPa and 45 KN respectively.

On the other hand, regarding the second

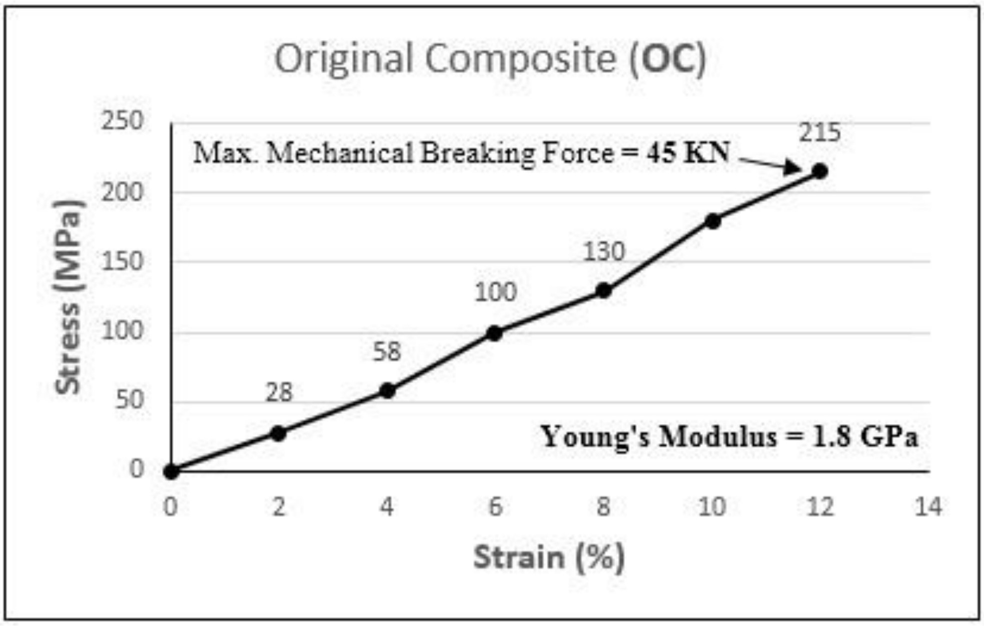

Fig. 8. Practical tensile strength test result for the original composite (OC).

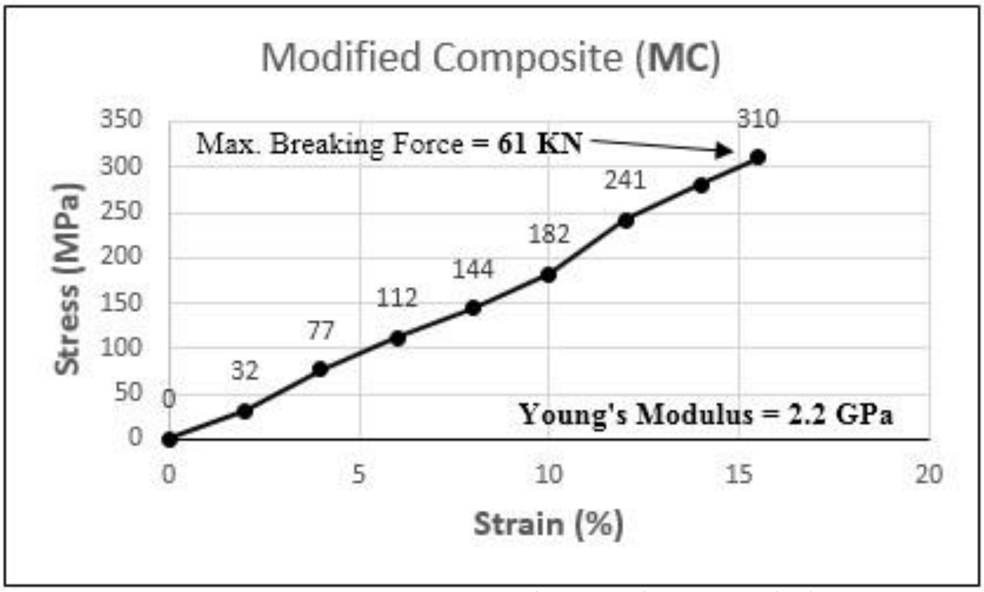

Fig. 9. Practical tensile strength test result for the modified composite (MC).

presented composite named as modified composite (MC), the above-mentioned test has been also done for this composite, and final results were completely different from those for the original composite, where maximum tensile strength, Young's modulus, and maximum mechanical breaking force were about 310 MPa, 2.25 GPa, and 61 KN respectively, see Fig. 9.

Table 7. below shows a summary for the maximum tensile strength, Young's modulus, and maximum mechanical breaking forces and the associated percentage variations for both the adopted original and modified composites as follows.

The gained percentage increment in maximum tensile strength, Young's modulus, and maximum mechanical breaking forces were +44.1%, +22.2%, and +35.5% respectively, so the expected main reason behind these three success positive is that adding Barhee seeds nano powder is filling all of the already existence cavities and longitudinal grooves within the matrix composite structure so this issue has transformed the modified composite into a completely solid structure with relatively high sustainable strength. See Fig. 10. below.

Bending Test Results

Three points bending test is so important because it gives indication about the ability of a material under investigation to sustain lateral applied loads and the associated induced bending stress, so three specimens have been prepared for each composite, means 6 specimens. Three flexural parameters have been investigated, they are flexural strength (MPa), flexural modulus (GPa), and maximum bending force (N) as shown in Figs. 11, 12. and 13. respectively. Fig. 11. below give the gained results the flexural strength from the three points bending tests where they were 270 MPa and 230 MPa for both the OC and MC respectively with negative decrement of about 14.8% due to the dramatic change in flexural properties as a result of adding the Barhee seeds nano powder to the original composite and it has been transformed into soft material and un able to resist bending.

Table 7. Maximum tensile strength, Young's modulus, and maximum mechanical breaking forces comparisons for both original and modified composites.

Test Type	Original Composite (OC)	Modified Composite (MC)	Percentage Variation (%)
Max. Tensile Strength (MPa)	215	310	+44.1
Young's Modulus (GPa)	1.8	2.2	+22.2
Max. Breaking Force (KN)	45	61	+35.5

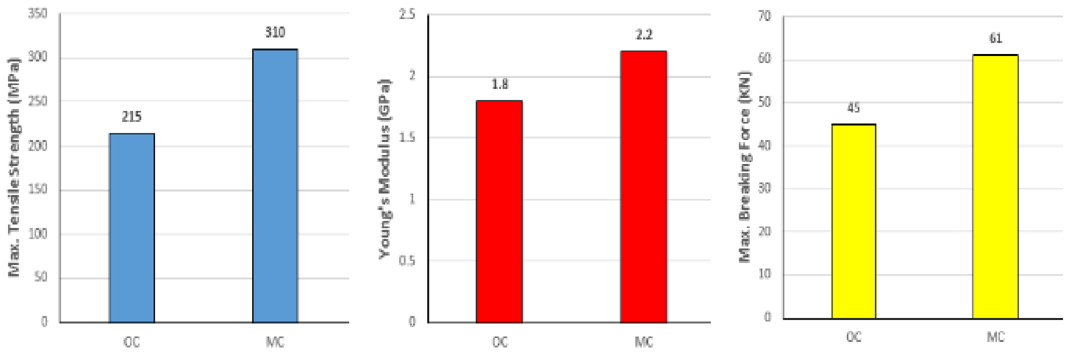

Fig. 10. Overall comparisons between the three parameters for both OC and MC.

The situation regarding flexural modulus for the same two composites is slightly different, where the obtained flexural modulus values were 4.75 and 4.15 GPa for the employed OC and MC respectively with negative reduction percentage ratio of approximately 12.6% as shown in Fig. 12. below, and also in retune to the structural transformation from relatively tough to soft composite that is showing highly deformation level comparing with the original carbon fiber composite as expected.

Concerning maximum bending force, there

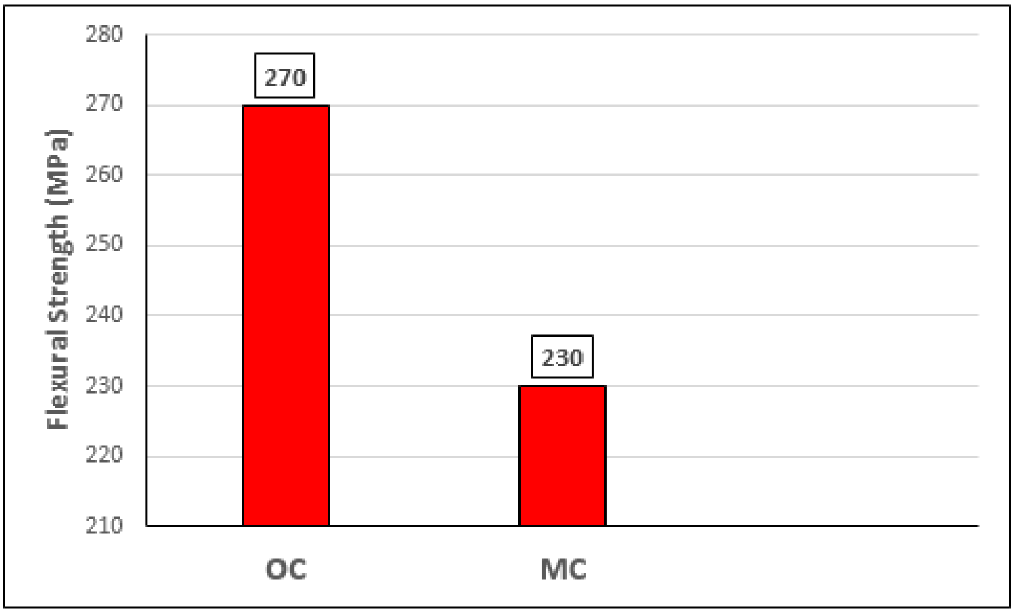

Fig. 11. Flexural Strength from 3Ps bending tests for both OC and MC.

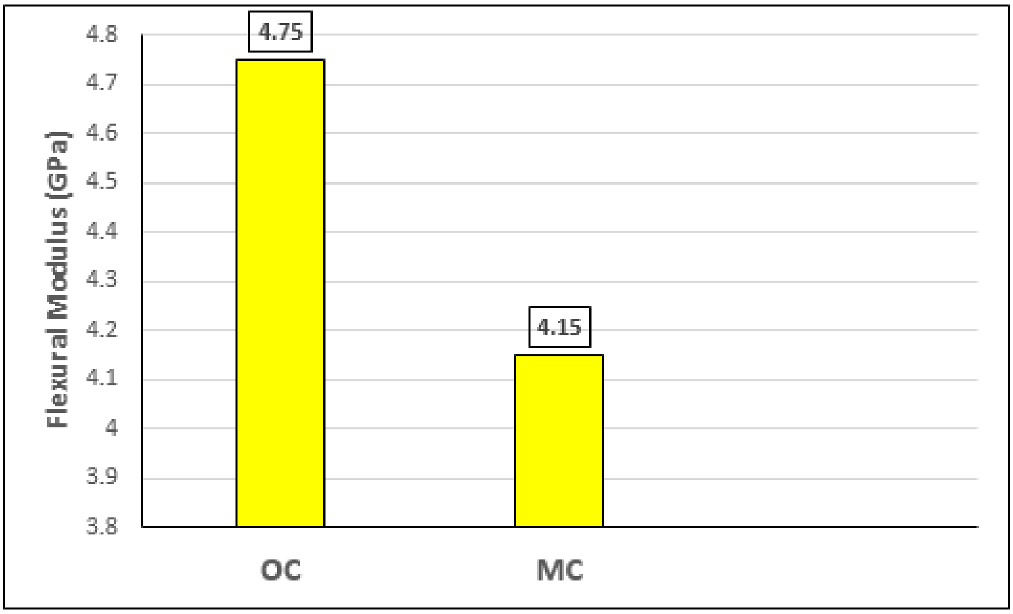

Fig. 12. Flexural Modulus from 3Ps bending tests for both OC and MC.

were analogy in the obtained results as shown in the two previous tests, see Fig. 13. The practically recorded maximum flexural or bending force were 1 and 0.7 KN for both OC and MC compsites with upto -30% reduction in the mean value of the maximum bending forces, so that such reduction state means the developed composite has become more mealable against the applied load.

Table 8. below show the total gained results from the adopted three points bending test for both the original and modified composites and the associated percentage variations.

Thermal analysis of the both materials

All of the materials have been investigated using the steady state thermal tool that is available in ANSYS. It has been accomplished by utilizing a rectangular plate for the composite plates. A simulation of the total heat flow was performed on the materials in less than one second. As can be seen in Fig. 14, the results of the simulation indicate that the maximum heat flow has reached 1.4244 e-12 w/mm.

Through the use of the steady state thermal tool that is accessible inside ANSYS, both of the materials have been extensively examined. The utilization of a rectangular plate for the composite plates has allowed for the successful completion of this task. In less than one second, a simulation of the total heat flow was carried out on the materials for the directional heat flux for the Y axis. This simulation was done on the materials.

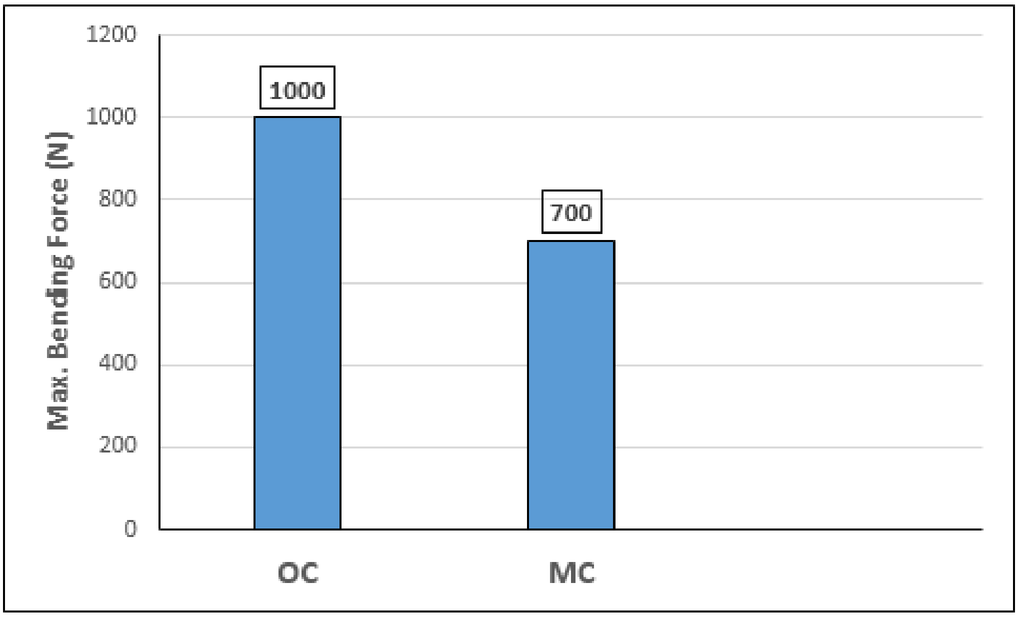

Fig. 13. Max. Bending Force from 3Ps bending tests for both OC and MC.

Table 8. Overall comparison for the 3Ps bending tests for both OC and MC.

Test Type	Original Composite (OC)	Modified Composite (MC)	Percentage Variation (%)
Flexural Strength (MPa)	270	230	-14.8
Flexural Modulus (GPa)	4.75	4.15	-12.6
Max. Bending Force (N)	1000	700	-30

Fig. 15 illustrates the findings of the simulation, which show that the maximum heat flow has reached 9.3e-12 w/mm. This is the greatest value that may be seen.

Morphology Inspection Results (ASTM D3849-22)

Regarding this unique examination method, the two presented composites have been under direct inspection of the scanning electronic microscopy for getting a clear understanding of effect of adding the Barhee seeds as a nano powder on the microstructure of the original and modified composites, so Fig. 16. Sample No. OC-1 below shows a microscopic image for the pure carbon fiber composite and it is so easy to specify the formation of longitudinal linear grooves between each successive fibers, and it is thought that such tiny channels are considered as a points of weakness in the matrix and local failure starts from there towards the whole structure, so it is

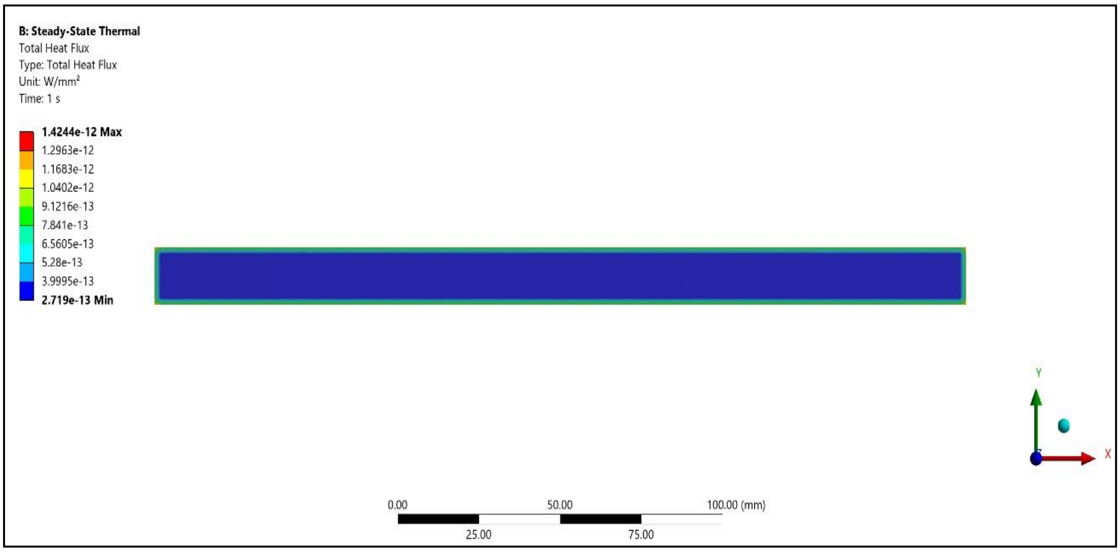

Fig. 14. Numerical results of Heat flux.

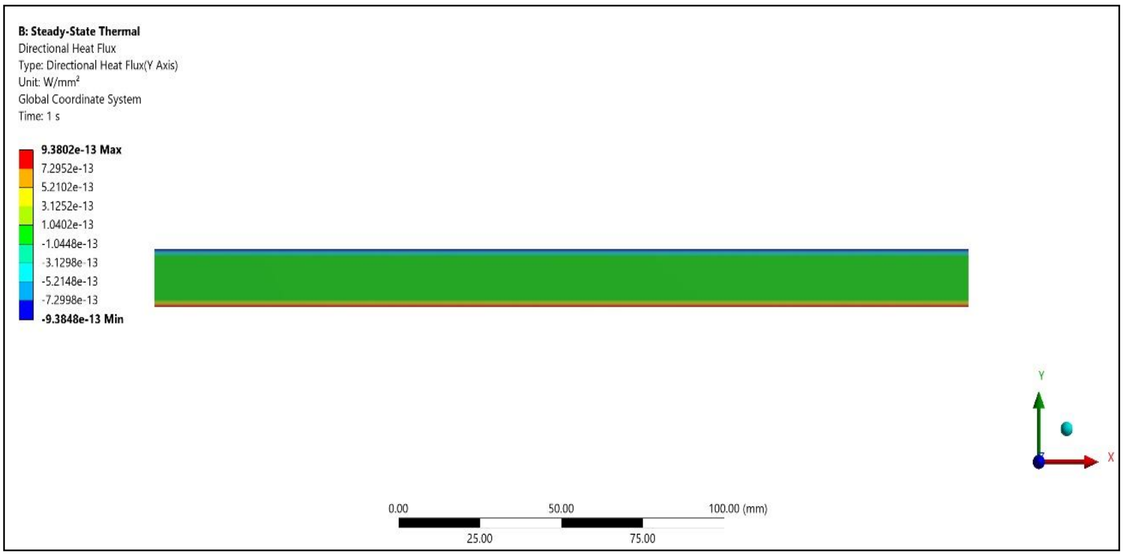

Fig. 15. Directional heat flux.

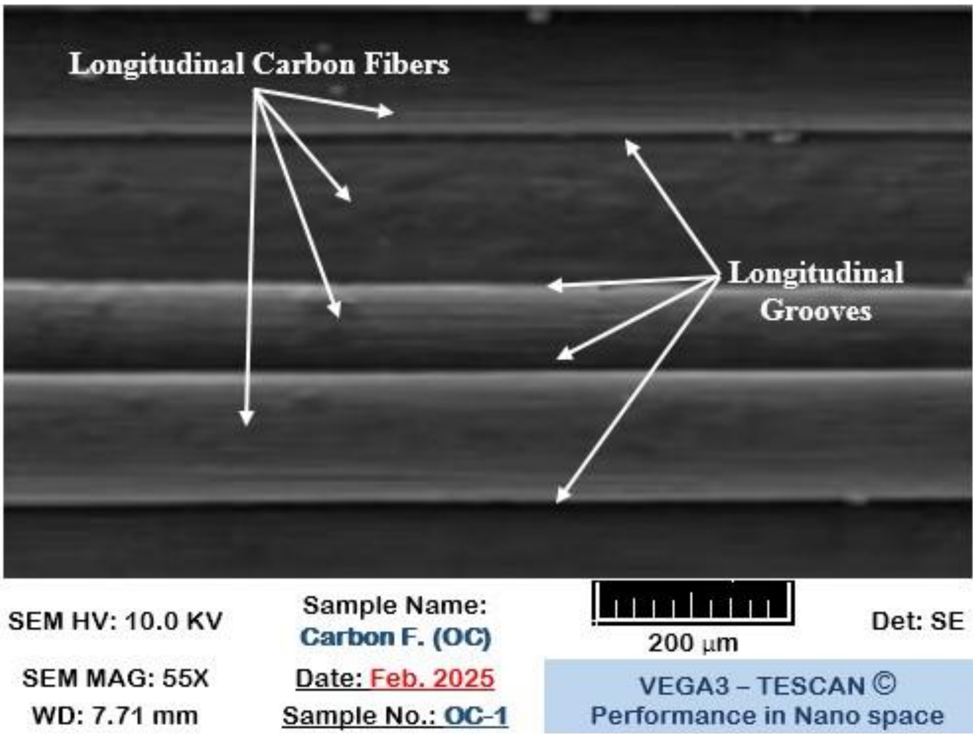

Fig. 16. Carbon fibers composite (OC) SEM image (ASTM D3849-22).

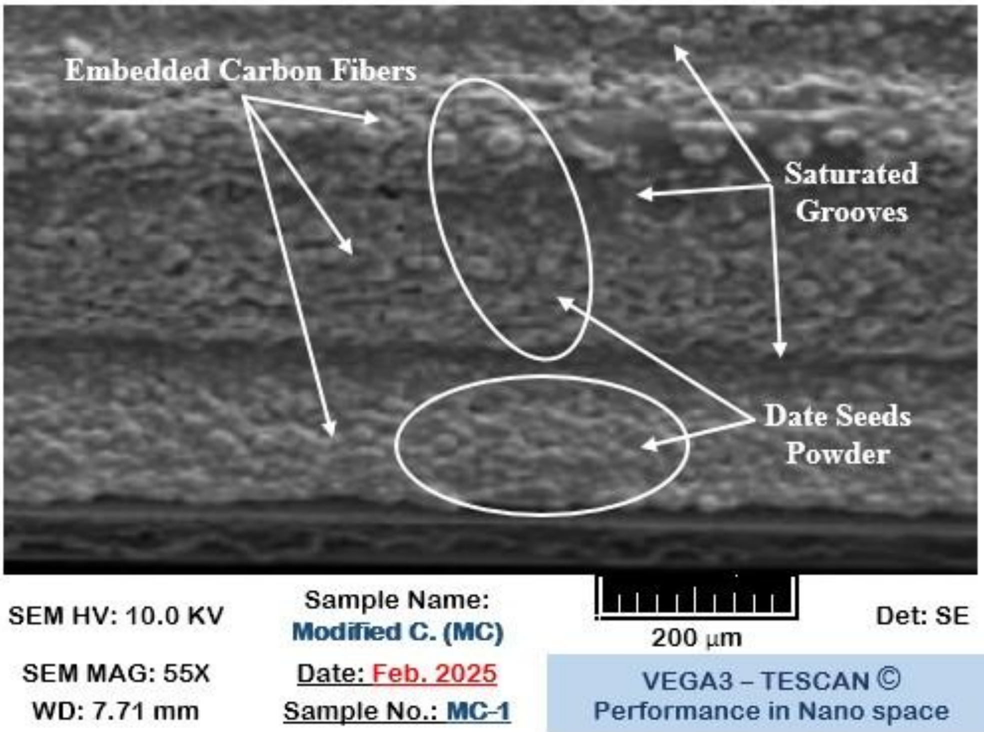

Fig. 17. Modified composite (MC) SEM image (ASTM D3849-22).

required to filling up such undesired grooves via adding some specific either natural fibers as done here within this research paper for improving some of the induced mechanical properties.

And in return to the core idea of this experimental investigation, microscopic image for the developed composite MC shows a homogeneous diffusion of the Barhee seeds nano powder with the whole structure of the original composite as shown clearly in Fig. 17. below Sample No. MC-1, where the original grooves have been embedded and totally covered and filled with the assigned powder and transform the composite into solid state structure, but inappropriately some of the mechanical properties have facing reduction in their values but does not considered as a shortage in mechanical properties at all, and logically there is no gain in all of the mechanical properties without setback in other ones exactly as shown within this research paper.

CONCLUSION

Final results including mechanical tensile tests, three points bending inspection, and morphological examination may lead to conclude the following main points. Adding Phoenix Dactylifera L. (Barhee local name) seeds as a nano powder is exhibiting a satisfactory interaction with the employed carbon fiber composite, therefore final results are confidentially showing noteworthy augmentation in some specific studied mechanical properties with relatively accepted percentage ratios but surly not to all of them. Positive variation results have proved that diffusion of the suggested Phoenix Dactylifera L. (Barhee) seeds as a nano powder in all directions of the modified composite without any un desired chemical interactions as a side effect. Phoenix Dactylifera L. (Barhee) seeds as a nano powder has in some unique specific natural fabric properties, so as it has been added to the original composite (OC), the measured rheological properties of the presented modified composite (MC) have been showing a propensity to be more flexural and exhibiting elasticity to the applied external loads especially in the three points bending tests , in other words, adding natural fibers makes the modified composite is having limited level of rheological behavior but of course with some limited elastic levels. Phoenix Dactylifera L. (Barhee) seeds as a nano powder are totally inert (Chemical inert material) so that makes it fully compatible in mixing process with the employed carbon fiber composite supported epoxy resin, and hardener. Morphological images showed that there is uniform diffusion of the additive material Phoenix Dactylifera L. (Barhee) seeds as a nano powder, well trapped with the whole structure especially within the already existed grooves, and very good mutual interfacial bonding. Final essential conclusion and recommendation is that adding this specific natural fiber as a powder is safe and improving mechanical properties, it is recommended to safely depend on this modified composite in manufacturing some specific component that require the stated mechanical results within this research paper.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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