RESEARCH PAPER

Impact and Shore Hardness Experimental Investigation for Carbon Fiber Composite Supported with Silicon Carbide as a Nano Material Additive

*Haider Kadhum Khashan [1], Modher Zidi [1], Emad Kamil Hussein [2]**

[1] Mechanical Engineering Department. National Engineers School of Monastir, Monastir, Tunis

[2] Mechanical Power Techniques Department, Mussaib Technical College, Al Furat Al Awsat Technical University, 51006, Babil, Iraq

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ABSTRACT

Today industrial sector is deeply seeking for materials that are having relatively high strength and low specific weight, so composite material is fairly exhibiting such desired properties but not much enough, hence, adding nano material as an additive is play an important role in highly enhancing some specific mechanical properties including impact and shore hardness, so based on this fact the core idea of this research paper has been built, where carbon fiber, epoxy resin, hardener has been chosen as an elementary components for producing the assigned composite material by using the so-called vacuum bagging method (VBM), and supported with three weight based mixing style of (2, 4, and 6)%wt. of silicon carbide as a nano material, in addition, both of impact test ASTM D256, shore hardness tests ASTM D2240, and morphology imaging have been nominated to be conducted on both the traditional composite (T) and the hybrid three composites (H_1, H_2, and H_3) under exactly the same boundary conditions. Final experimental results showed that impact test average percentage results were -3.01 % Min., +27.13% Max., and +9.21% Ave., meanwhile for shore hardness they were +3.99 % Min., +7.98% Max., and +6.21% Ave. for H_1, H_2, and H_3 respectively, so that means that the H_2 (4%wt. SiC) composites is the best composite and having a significant enhancement in its mechanical properties, so this improvement has been confirmed via the morphology test where it shows a homogeneous mixture without any flaw or segregation for the above and last mentioned one.

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INTRODUCTION

Optimum design is depending on two main factors, they are geometry and material selection, and it is required to make a successful mutual engagement between these two essential factors for getting a reliable product and sustain hard working conditions, so the sole idea behind this experimental investigation is shedding light on the second factor, material selection, where the modern life has been built on manufacturing, modifying new materials especially composites, so one of the most important and common is the

* *Corresponding Author Email: emad_kamil72@atu.edu.iq*

so called carbon fibers where this specific material has an excellent mechanical, physical, and thermal properties [1] and has good compatibility with epoxy resin and hardener [2], on the other hand, enhancement of mechanical properties requires adding some especially characteristic nano

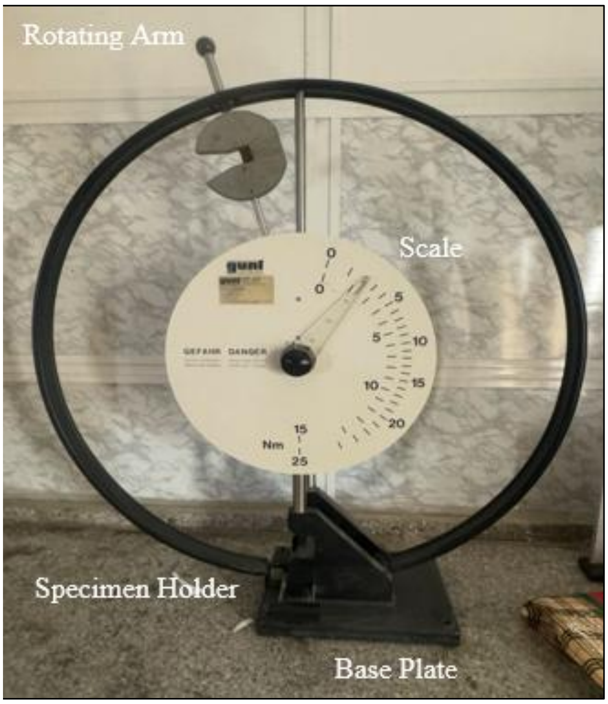


Fig. 1. The employed impact test machine [4].

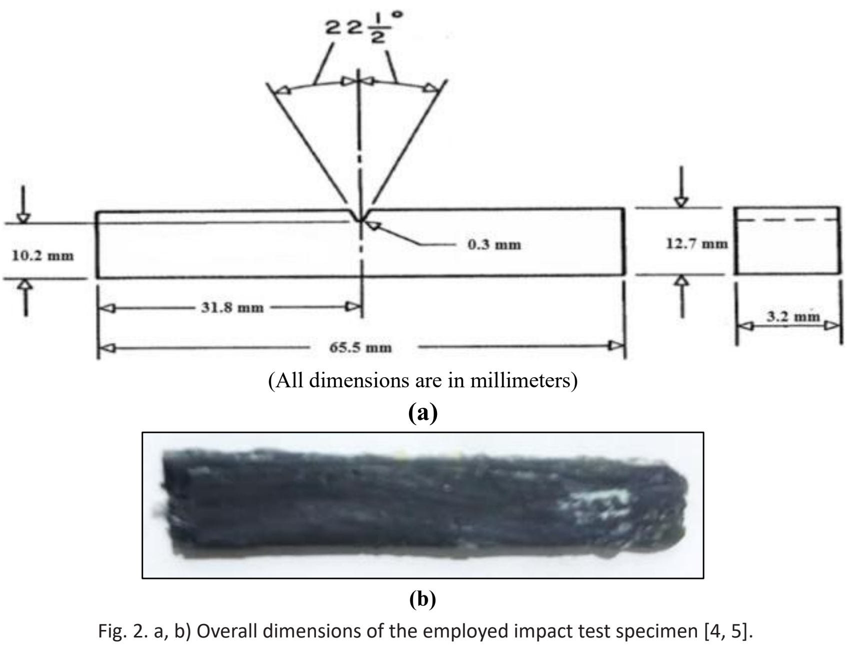


Fig. 2. a, b) Overall dimensions of the employed impact test specimen [4, 5].

material where due to its very tiny volume size, in terms of nano meters, such a nano material fills in the whole microscopic structure but under carefully assigned mixing and boundary conditions for producing a modified composite with a wide range of weight based mixing ratio and for checking the best or optimum amount of the additive material and avoid over dosing, and it is so important to mentioned that the adopted practical procedure for producing composites is named vacuum bagging method [3], where this method is allowing using different sizes of the attached glass mold so that offering producing different shape and size of composites. Based on the previous explanation, the adopted carbon fibers supported by silicon carbide with different weight based mixing ratio has been nominated for performing this experimental investigation.

MATERIALS AND METHODS

Impact test

The adopted impact test within this experimental investigation is under license of American Standard Test and Materials ASTM D256 [4, 5], so the employed rig for conducting this test is shown in Fig. 1.

In addition, the associated standard specimen dimensions are illustrated in Fig. 2.

Shore Hardness Test

Shore Hardness test is so essential test in mechanical engineering, so the considered hardness investigation in this experimental study was done under recommendation of the American Standard Test and Materials ASTM D2240 [6,7] as indicated in Fig. 3.

Where the nominated mechanical rig is exactly as appear in Fig. 4 with the following specifications: Shore A, Durometer with working range of (0-100) millimeter under 12.5 N direct applied force.

For conducting and completing this specific examination it is required to preparing a test specimen, where Fig. 5 shows a full circular specimen detail.

Silicon Carbide (SiC) at a Glance

Silicon Carbide is considered as a very common and available nano materials in academia, plus it has a unique property that is nominating it as an additive material to the employed carbon fiber composites, so Table 1 gives a full property of this specific nano particles [7-9].

Fig. 6 shows two photographs for the employed Silicon Carbide nano particles and the manufacturing company [9, 10].

Carbon Fibers Properties

The nominated principal fibers used in this practical investigation is Carbon Fibers, where this specific material has a unique properties including relatively low specific weight associated with high tensile strength, plus it is available with moderate financial cost, so Table 2 summarizes main properties of carbon fibers, plus Fig. 7 shows a photograph for the used carbon fiber within this research paper [11].

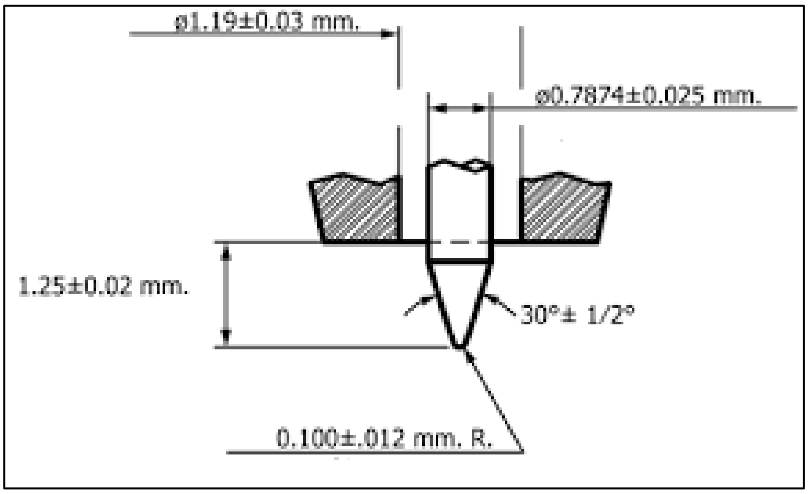


Fig. 3. Hardness test schematic rig according to ASTM D2240 [6, 7].

Vacuum Bagging Method VBM

The adopted effective and experimental method for producing composites is called Vacuum Bagging Method, where the rig of this procedure is consists of the following main component: main vacuum pump, glass mold, trap can, houses, digital scale, flask, and complementary parts exactly as designated in Fig. 8 [12-15].

Scanning Electron Microscopy SEM

One of the most important mechanical engineering tests is the so-called morphology test which is carried out by using an electronic device named Scanning Electron Microscopy SEM, where its general view is illustrated in Fig. 9, where via this professional test it is so accurate to get image for the micro structure of the material

Fig. 4. Hardness test experimental rig according to ASTM D2240 [5].

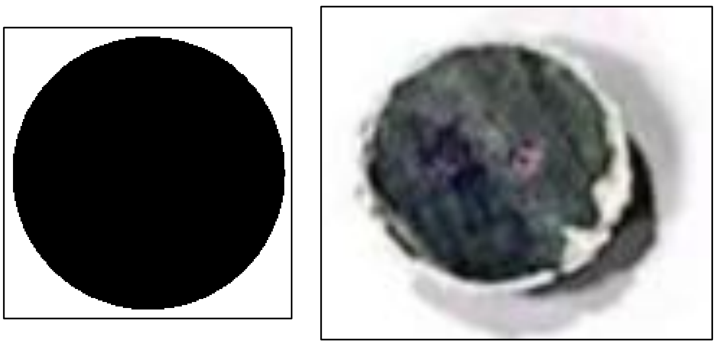


Fig. 5. Shore hardness test specimen.

Fig. 6. The employed Silicon Carbide nano particles [9, 10].

Fig. 7. The hired carbon fibers.

Table 1. Main mechanical and physical properties of employed Silicon Carbide [7].

Mechanical Properties				
Max. Tensile Strength (MPa)	Modulus of Elasticity (GPa)	Poisson Ratio	Fracture Toughness K_{Ic} MPa. $m^{0.5}$	Hardness (Kg/m^2)
240	410	0.15	4.6	2750
Physical Properties				
Mass Density (Kg/m^3)	Color	Particles Size (nm)	Max. Service Temperature under zero load (°C)	Purity (%)
3100	Dark Black	40	1650	99.0

under investigation which displaying a mutual entanglement of the layers and specifying the formed defects including dislocations. [16-22].

Experimental Considerations

Fig. 10 shows a logical flow chart for the main frame work of this research paper, where it summarizes the adopted steps for nominating traditional and nano materials and their mixing ratios and the associated experimental results from conducting impact test, hardness checking, and morphological analysis.

Proposed Four Composites

In order to conduct the proposed experimental part of this investigation, a set of four suggested composites has been stated as indicated in Table 3, where the first sole composite consists of carbon fibers, epoxy resin, and hardener without any other additive materials and this composite has

Fig. 8. The employed VBM rig components.

Fig. 9. The employed SEM apparatus [21].

Table 2. Principal properties of carbon fibers [11].

Max. Tensile Strength (GPa)	Modulus of Elasticity (GPa)	Mass Density (Kg/m^3)	Elongation to Failure (%)	Strain (%)	Poisson Ratio	Fiber Diameter (μm)
3.80	232	1850	1.5	2.2	0.25	6

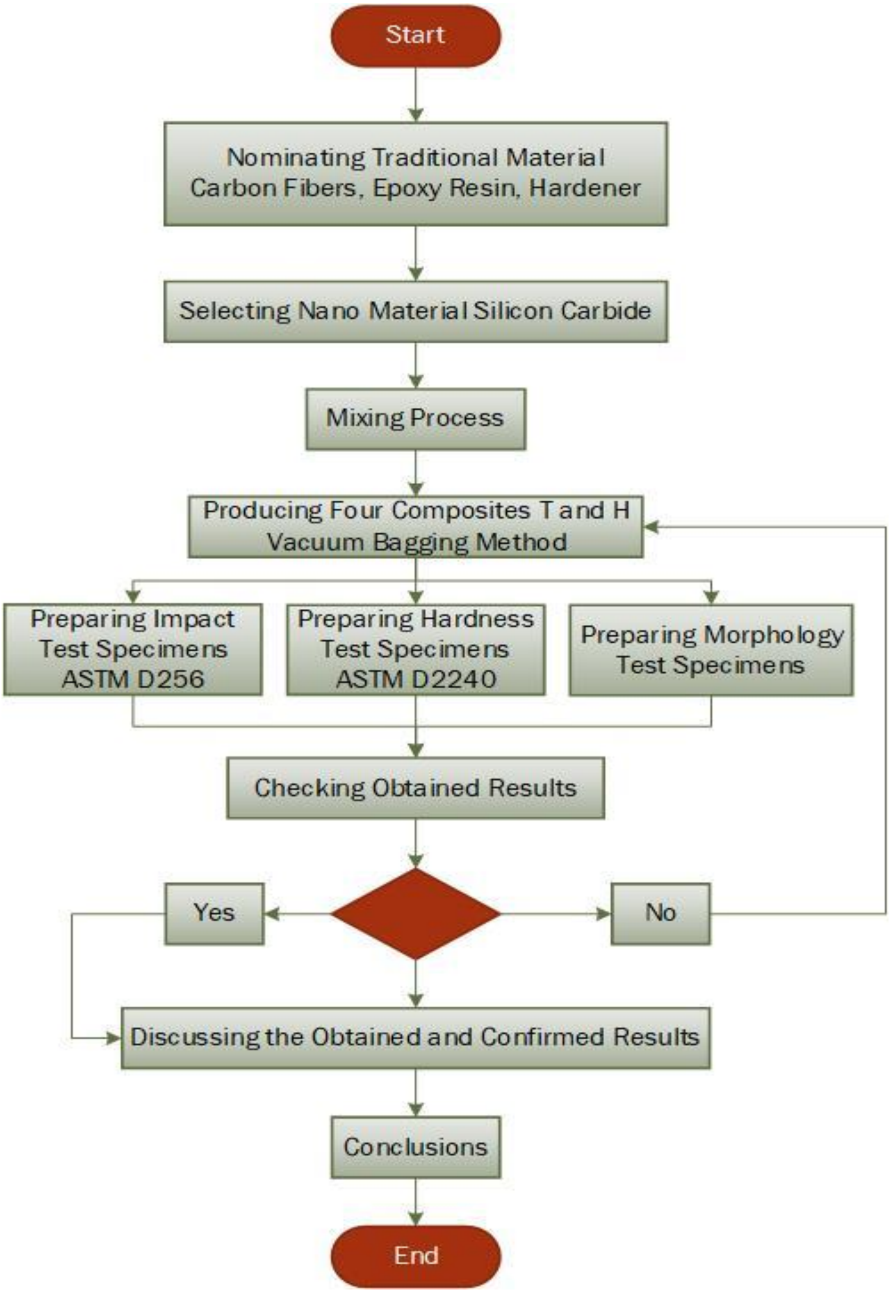
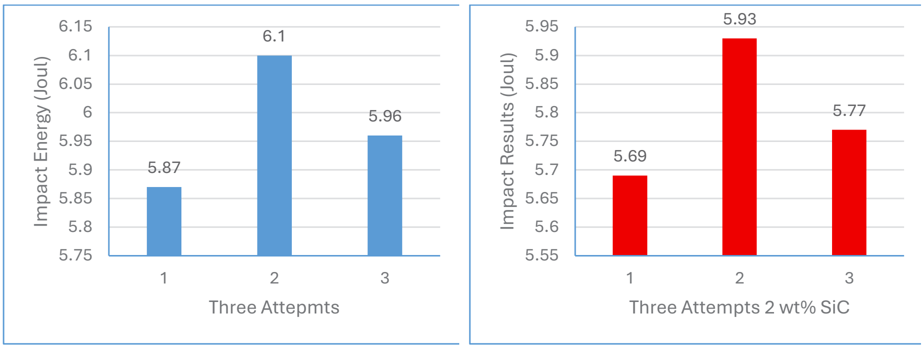
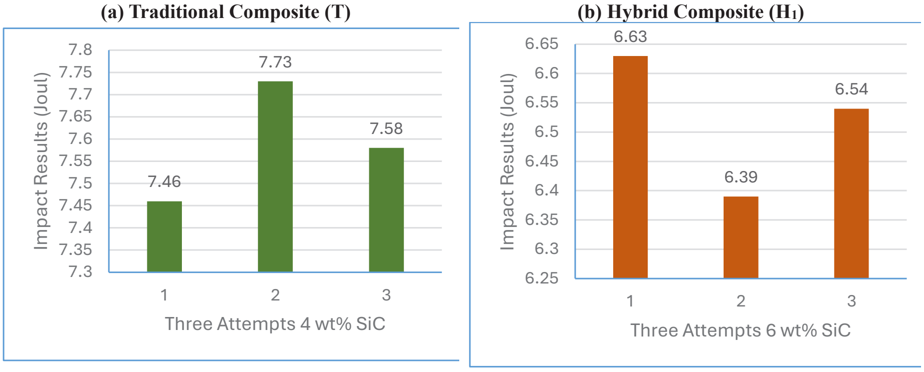


Fig. 10. A logical frame work flow chart of this research paper.

been named as traditional composite and denoted by (T), meanwhile the other three composites are having a 2%, 4%, 6% **wt.** (SiC) and named hybrid composites H_1, H_2, and H_3 respectively, hence it is required to conduct both impact and hardness tests on all of the four mentioned composites followed by comparing the practically obtained results.



(a) Traditional Composite (T) (b) Hybrid Composite (H_1)



(c) Hybrid Composite (H_2) (d) Hybrid Composite (H_3)

Fig. 11. Four obtained results from impact test.

Table 3. The considered weight mixing ratio.

Entry	Sample Name	Four Samples Main Compositions	Additive Weight (%wt.)
1st.	Traditional (T)	(Carbon Fiber + Resin + Hardener)	0 (Pure)
2nd.	Hybrid (H_1)	(Carbon Fiber + Resin + Hardener) + 2%wt. (SiC)	2%wt. (SiC)
3rd.	Hybrid (H_2)	(Carbon Fiber + Resin + Hardener) + 4%wt. (SiC)	4%wt. (SiC)
4th.	Hybrid (H_3)	(Carbon Fiber + Resin + Hardener) + 6%wt. (SiC_	6%wt. (SiC)

Table 4. Mixing weights for both cases.

Entry	T CF (%)	H (SiC) (%)	Weight of CF (gm)	Weight of (SiC) (gm)	Total weight of composite (gm)
1st.	100	0	160	0	160
2nd.	98	2	156.4	3.6	160
3rd.	96	4	153.6	6.4	160
4th.	94	6	150.4	9.6	160

Preparing Samples

The adopted protocol for preparing samples is mixing 100 milliliters of epoxy resin plus 50 milliliters of the nominated hardener, i.e. according to (2:1) mixing ratio and after taking into account the already stated mixture density, three cases

Table 6. Shore hardness practical results summary.

Entry	Experimental Attempts	Average Shore Hardness	Variation Percentage Ratios (%)
Traditional Composite 1st. Case	1st. Trial	76.5	--
	2nd. Trial	77.2	--
	3rd. Trial	76.9	--
Average Value		76.86	Reference
Hybrid Composite 2nd. Case	1st. Trial	79.7	--
	2nd. Trial	80.2	--
	3rd. Trial	79.9	--
Average Values		79.93	+3.99 % Min.
Hybrid Composite 3rd. Case	1st. Trial	82.8	--
	2nd. Trial	83.2	--
	3rd. Trial	83	--
Average Values		83	+7.98% Max.
Hybrid Composite 4th. Case	1st. Trial	81.6	--
	2nd. Trial	82	--
	3rd. Trial	81.3	--
Average Values		81.63	+6.21% Ave.

Table 5. Impact experimental results summary.

Entry	Experimental Attempts	Average Impact Test Results (Joul)	Variation Percentage Ratios (%)
Traditional Composite 1st. Case	1st. Trial	5.87	--
	2nd. Trial	6.10	--
	3rd. Trial	5.96	--
Average Value		5.97	Reference
Hybrid Composite 2nd. Case	1st. Trial	5.69	--
	2nd. Trial	5.93	--
	3rd. Trial	5.77	--
Average Values		5.79	-3.01 % Min.
Hybrid Composite 3rd. Case	1st. Trial	7.46	--
	2nd. Trial	7.73	--
	3rd. Trial	7.58	--
Average Values		7.59	+27.13% Max.
Hybrid Composite 4th. Case	1st. Trial	6.63	--
	2nd. Trial	6.39	--
	3rd. Trial	6.54	--
Average Values		6.52	+9.21% Ave.

of adding silicon carbide to the prepared mixture depending on weight based style, where the selected additive percentage weights are 2%wt., 4%wt., and 6%wt. SiC where the total gained weight is 160 gm as indicated in Table 4. It is so crucial to mention that mixing process has been done by using hot plate stirrer under moderate temperature, room temperature about 25°C, and ambient humidity of 30% in an isolated laboratory.

RESULTS AND DISCUSSION

Impact Test

Impact test has been repeated three times for each composite, where the already four prepared specimens are facing a separate test under the same boundary conditions and ASTM D256, so the obtained results have been shown as indicated in Fig. 11, in other words, impact test has been repeated twelve times as a total number.

So, in order to get a summarized numerical view for the impact test only on both the traditional composite and the other three hybrid three ones, Table 5 will help.

Impact test gives indication about ability of a material to absorb energy and then resisting fracture as a result of sudden impact due to

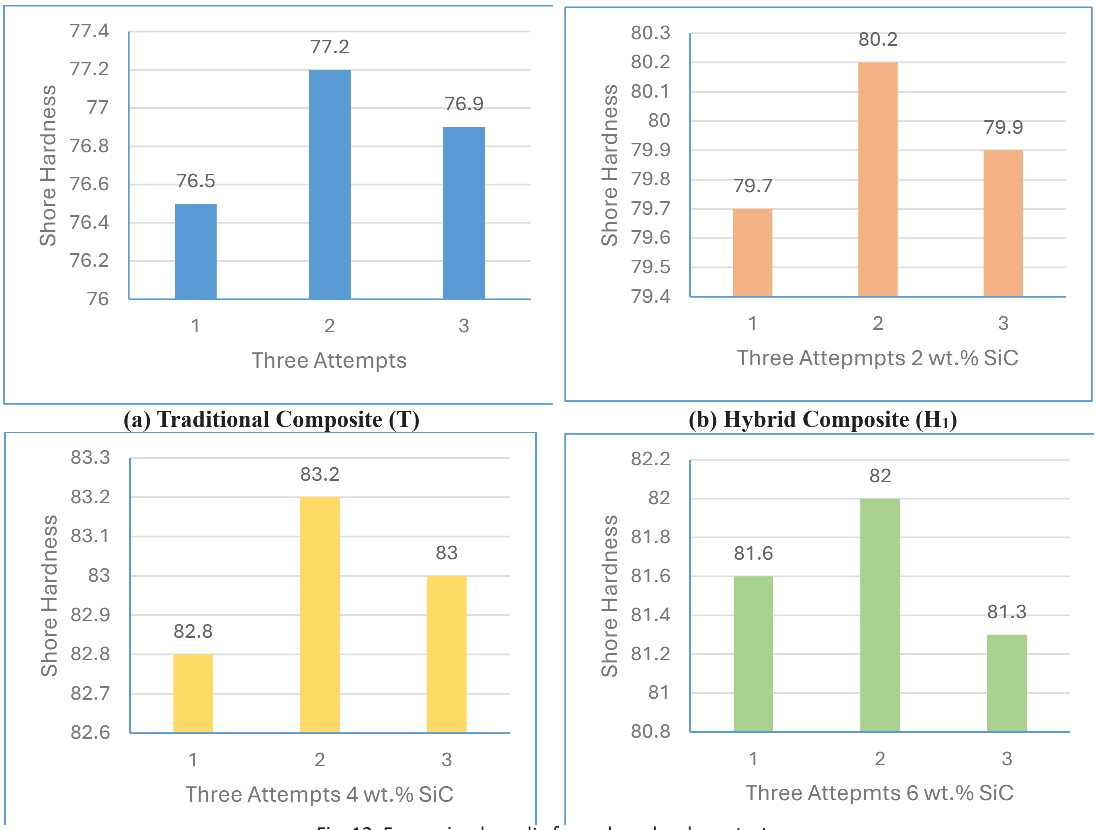


Fig. 12. Four gained results from shore hardness test.

Table 7. The employed initial and boundary conditions for SEM test.

Pressure (Pa)	WD (mm)	Magnification	H Voltage
4.66^{-3}	7.9	40000	30
Spot	size	Det.	Date and time
3.5	2 micrometers	ETD	82/7/2025 10:24 AM

external affecting force, so in return to the above experimental results, it is so clear that for a traditional composite its average impact result is about 5.97 Joul, but in case of adding 2%wt. SiC, 4%wt. SiC, and 6%wt. SiC the associated impact results were 5.79, 7.59, and 6.52 and as a variation percentage ratios as -3.01% as a minimum value, +27.13% as a maximum value at all, and +9.21% as an average value respectively, so in the second case there was a significant sole increment in impact results, and this is attributed to formation of a homogenous mixture that allow absorption of external applied force but in the third gained case there is a decrement in the impact result because the composite has become relatively saturated with the additive silicon carbide to tends to be brittle and un able to absorb impact energy, hence final dependable result is surely the second case Hybrid (H_2) with 4%wt. SiC additive, so this case will be a reference for the other experimental morphological test.

Shore Hardness Test

It is usually measuring shore hardness for a soft material including polymers group as a default case, where this test gives practically a hint about resisting the material under investigation to indentation, so this test has been conducted on the above four mentioned composites and the accompanying resulted are shown in Fig. 12.

Table 6 clearly presents a numerical result of the assigned shore hardness results for the adopted four composites.

Shore hardness test shows an exactly similar results as in the previous impact test, where the 4%wt. (SiC) additive case shows a maximum value comparing with the other two cases, so that means adding additive material is controlled by the suitable amount of this silicon carbide, in other words, resisting of indentation will significantly increase starting from no additive followed by the first considered amount with increment of hardness result but as the amount doubles gives more indentation resistance but not in a linear proportional manner, because in the third case the measured value has been decreased, hence this phenomenon is attributed to formation of hard enough surface that resist traces as a result of interference of the silicon carbide with this employed epoxy resin in a fair style, but as the silicon carbide quantity increased this will a local plastic zones embedded in an elastic foundation, which makes irregular hardness properties within the whole adopted material, therefore, final nomination for the optimal hybrid structure is the second one Hybrid (H_2) with 4%wt. (SiC) additive for performing the third test named morphology test.

Morphology Test

This test is representing a back bone of the mechanical engineering media, because it gives a real and precise microscopic image for the internal structure of the composite under consideration,

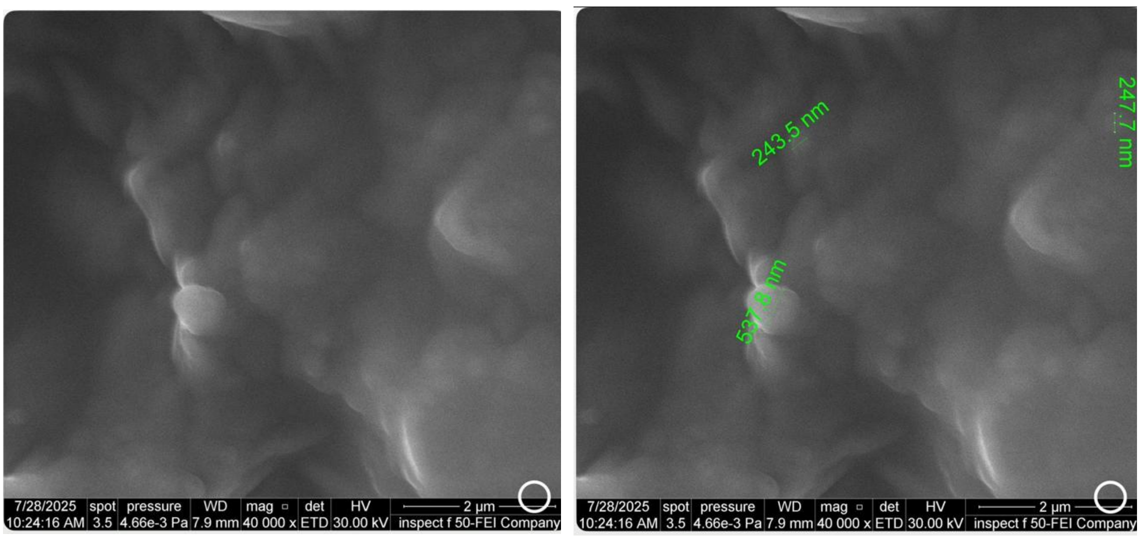


Fig. 13. Morphology imaging for the Hybrid (H_2) 4%wt. (SiC) additive.

therefore Table 7 shows the employed initial and boundary conditions for conducting this specific micrography tests:

so based on the two previous mentioned tests the nominated composite is the second one maned Hybrid (H_2) with 4%wt. (SiC) additive, therefore, Fig. 13 shows a microscopic image for this composite and it is so clear the adding silicon carbide to the employed resin gives a homogeneous mixture without any segregation or any other undesired masses or defects with a local dimensions ranging from 243.5 to 537.8 nanometers, so the produced hybrid composite is exhibiting a fair behavior under both impact and shore hardness tests.

CONCLUSION

Based on the previous illustrated experimental work and its associated confirmed results, some specific conclusions may be drawn as listed:

1) Adding nano materials as an additive material to composites is surely enhancing mechanical properties including both impact and shore hardness tests but with limited amount of this additive.

2) Silicon Carbide shows an excellent dissolve property with the employed epoxy resin and forming a homogeneous structure under room temperature and humidity and producing flaw free mixture under examinations of morphology tests.

3) Adding 4%wt. SiC gives a better experimental results (optimum one) comparing with the other two cases (2% and 6%) wt. in both impact and shore hardness tests.

4) For some specific industrial applications which are requiring relatively tough material resisting ambient conditions, hybrid (H2) composites show an accepted ability to absorb external sudden applied impact (load) of about 7.59 Joul comparing with the other two cases.

5) In case of required a composite material for sustain indentation resistance, the hybrid (H2) composites tend to be tough where the standard scale for shore hardness is (0 very soft, 100 very hard), where if the H2 case the hardness average value was 83 more close to hard material.

6) Adding silicon carbide as an additive material to the nominated composite is slightly increase its specific weight due to the relatively low specific weight of this carbide, means there is no weight over dose.

CONFLICT OF INTEREST

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

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