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Experimental Investigation of Silicon Carbide filler effect on the Mechanical and Tribological Properties of Woven Carbon Fiber/ polyester Composites material

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ABSTRACT

Owing to their exceptional specific strength, high toughness, and enhanced wear resistance, carbon fiber reinforced polymer composites have become widely employed in structural and tribological engineering. In this study, woven carbon fiber-reinforced polyester composites containing different weight percentages of silicon carbide (SiC) (0, 2, 4, 6, 8, and 10 wt.%) were fabricated using compression molding at 0.5 MPa for 24 hours at room temperature after mechanical mixing of the components. The fabricated composites were tested according to relevant ASTM standards. The experimental results showed that the silicon carbide (SiC) significantly enhanced the mechanical and tribological properties of the developed composites. Density and hardness gradually increased with increasing silicon carbide (SiC) content as in table 1 and figure 7. Mechanical performance was improved significantly as in figure 8., while elongation at fracture gradually decreased due to the increased stiffness of the composite figure 9. Furthermore, wear rate and coefficient of friction decreased considerably, leading to improving surface durability and slip performance figure 10. The composite 8wt.%SiC provided the best overall compromise between mechanical strength and tribological behavior, indicating that this concentration is the most effective reinforced level for the proposed composite. As can be seen from the results especially figure (7) the improvement in the investigated properties was approximately 31% for hardness, 53% for mass loss, about 52% for wear rate and about 24% for coefficient of friction

1. Introduction

Polymer matrix composites (PMCs) are widely recognized as one of the most important categories of engineering materials due to their excellent specific strength, high strength-to-weight ratio, corrosion resistance, and design flexibility. These characteristics have led to their extensive utilization various engineering fields, including aerospace, automotive, marine, biomedical, and structural applications, where lightweight materials with superior mechanical performance are required. [1–3]. Polyester composites reinforced with carbon fibers are considered a key class of advanced engineering applications due to their exceptional tensile strength, high modulus of elasticity, excellent resistance to repeated stresses (fatigue), and low density. The use of woven carbon fiber was preferred due to its ability to carry loads in two perpendicular directions, making it more effective than randomly (chopped) oriented carbon fibers, also resulting in a more uniform stress distribution and improved structural stability [4 -5]. So, woven fibre fabric improves load transfer, dimensional stability and reduce region of high stress. Therefor due to these benefits, woven carbon fiber fabric widely used in automotive structure, aerospace structure, wind turbine blades, and many light weight engineering applications of high specific strength [6]. Furthermore, to these properties silicon carbide SiC is consider the most effective ceramic fillers due to its hardness, high

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modulus of elasticity, superior wear resistance, thermal stability, and chemical resistance. Despite of these features, properties of silicon carbide reinforced composites are strongly influenced by several variables such as particle size, filler content, particles dispersion and bonding interface between particles, polymer matrix and reinforcing fibers [7]. In spite of previous properties, the exceeded value of optimum level, aggregation particles may occur which generate regions of high stresses that negatively affect overall performance of composites Excessive silicon carbide particle addition can lead to particle agglomeration and the formation of stress concentration zones, negatively impacting the overall performance of the composite. [8-9].

Recent studies have demonstrated that hybrid reinforcement using carbon fibers and ceramic particles can significantly improve both the mechanical and tribological properties of polyester composites. However, most existing studies have focused on cut carbon fibers, surface-treated fibers, nan fillers, or alternative fabrication techniques. In contrast, studies investigating polyester sheets reinforced with woven carbon fiber fabrics and different weight percentages of silicon carbide particles, under identical fabrication and testing conditions, and particularly with simultaneous evaluation of tensile and wear resistance properties, remain relatively limited [10-11]. Therefore, this research aims to investigate the effect of silicon carbide particles on the mechanical and tribological properties of polyester composites reinforced with woven carbon fiber. Tensile and dry-slip abrasion tests were conducted to determine the optimal ratio of silicon carbide particles capable of achieving the best balance between tensile and abrasion resistance. The results of this study are expected to contribute to the development of lightweight, high-performance polymer composites suitable for structural and tribological engineering applications. Although several studies have independently examined carbon fiber-reinforced polymer composites with silicon carbide particles, comprehensive studies investigating the combined effect of different weight ratios of silicon carbide on the mechanical and tribological performance of polyester sheets reinforced with woven carbon fiber fabrics remain limited [12-13]. Previous investigations have mainly concentrated on chopped carbon fibers, unidirectional laminates, or nanofiller-reinforced systems. In many cases, the mechanical and tribological characteristics were evaluated separately under different processing conditions, making direct comparisons difficult [14]. Accordingly, the present work examines the combined influence of woven carbon fiber fabrics and silicon carbide (SiC) particles on polyester composites. This combined utilization carbon fiber reinforcement composite and silicon carbide particles improved the understanding of their role in producing lightweight composites with improved mechanical and tribological performance for advance applications

2. Methodology Frame Work

The materials used in this study were plain woven carbon fiber fabric (300g/m^2), unsaturated polyester as matrix resin KSA made, methyl ethyl ketone peroxide (MEKP) and silicon carbide SiC micro particles. The SiC particles were incorporated into the resin at different weight fractions (0,2,4,6,8,10) % to investigate their influence on the mechanical & tribological behaviour of the fabricated composite. The characteristics and properties of above materials are listed in following tables.

2.1Samples Preparation

The composite laminates were manufactured using a manual-lay-up process followed by compression moulding figure1. To ensure consistent manufacturing conditions, all processing conditions were maintained unchanged throughout the process, with the weight percentage of silicon carbide (SiC) particles being the sole investigated parameter. Prior to fabrication, the mould surfaces were thoroughly cleaned and coated with an anti-stick agent to facilitate sheet removal after curing and to ensure defect-free surfaces. Silicon carbide particles were incorporated progressively to the unsaturated polyester resin at selected weight fractions percentages (0, 2, 4, 6, 8, and 10% by weight). The mixture was then stirred mechanically for 5 minutes to ensure homogeneous dispersion SiC particles within the Polyester matrix and to reduce particle clustering. The hardener according to the manufacturer's recommended mixing ratio was added. Next, 18 layers of woven carbon fiber fabric with a surface density of 300 g/m² were impregnated with a polyester/Sic mixture using a manual layer - by –layer- lay-up. To ensure that the resin fully impregnation within the carbon fiber, to minimize air voids and increase fiber-matrix adhesion a manual roller was applied. Each ply was laminated using the same procedure till the stack completed which were 250x250x20 mm, then the stack compressed under 0.5 MPa and left to cure at ambient temperature for seven days. The test specimens were obtained by precision cutting of the fabricated laminates with CNC milling machine to meet the specified testing requirement following ASTM -D638, ASTM- D695 and ASTM- G99 for tensile, compression and wear test respectively [15-16].

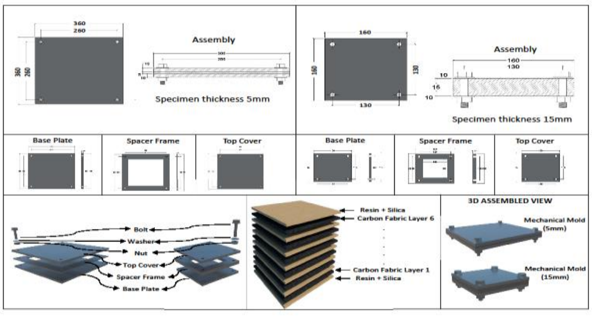


Figure.1 Mould for Tribological specimen’s fabrication

3.Mechanical and Tribological Characterization.

The mechanical and tribological characteristics of the manufactured composites were examined to evaluate the effect of silicon carbide content on these characteristics and to study the performance of dry sliding wear behaviour under controlled laboratory conditions using standardized testing method

3.1Tensile and compression characterization

An Instron universal testing machine was used to determine the tensile properties. The conditions were the same for all specimens tested i.e. maximum loading capacity was 1000 kg and constant crosshead speed of 2 mm/min was kept constant throughout the tests to ensure consistent testing conditions and ensuring reliable, reproducible results. While the compression tests carried out at the same device with applied load of 1000 kg with loading rate was fixed at 2 mm/min [17].

3.2.Dry Sliding Wear Test

By using pin-on-disc machine as shown in figure 3 the prepared composite specimen was tested to investigate the tribological performance using the requirements of ASTM- G99.Mass prior to testing weighing by precision balance with an accuracy of 0.0001 g. The specimens and steel disc were cleaned after each experiment to remove wear debris and ensure controlled testing conditions. Then mass loss was found by subtracting the final specimen mass from the initial specimen mass providing a measure of the material removed during sliding wear test The experimental variables included normal loads ranging from 5 to 31.392 N, sliding speeds between 2.67 and 5.34 m/s, and sliding distances from 1920 to 3850 m. Each testing condition was repeated three times to improve the reliability of the measurements, and the reported results represent the average value of the three independent experiments. The wear rate calculated according to [21]:

$$\mathbf{W_r = (m_1 - m_2) / (\rho F_n . S_d)} \quad (1)$$

Where:

Wr is the wear rate $mm^3/N.m$, m_1 & m_2 the mass before and after test g, **ρ** the density of the sample, $\mathbf{F_n}$ the normal load applied on the sample during slid while $\mathbf{S_d}$ the sliding distance m

While the coefficient of friction has calculated according to [17].

$$\boldsymbol{\mu} = F_f / F_n \quad (2)$$

Where **μ** is the coefficient of friction, F_f average friction force N, and F_n the normal load N.

The density of the fabricated composites was determined using the water displacement technique before calculating the wear-related parameters[17]. Figures 2 to 5 illustrate the experimental setup together with representative tensile and tribological specimens prepared for the present investigation.

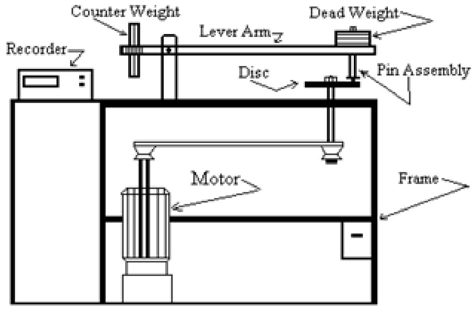


Figure 2. Pin- on- disc arrangement

Figure3. Specimens for tribological test

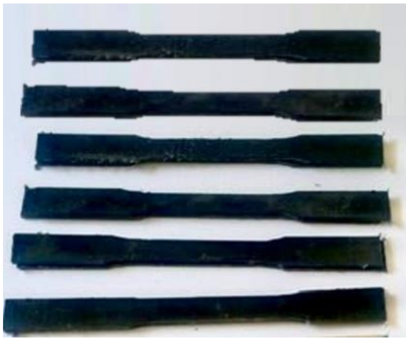


Figure 4. Specimens for Tensile test

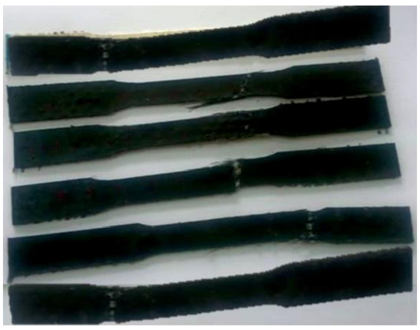


Figure.5. Specimens after test

Table-1 Sample details

No	Matrix	Reinforcement	Filler	Weight %	Density Composite g/cm^3
1	Unsaturated Polyester Resin	Carbon Fibre CF	None	0	1.5
2	Unsaturated Polyester Resin	Carbon Fibre CF	Sic	2	1.6
3	Unsaturated Polyester Resin	Carbon Fibre CF	Sic	4	1.63
4	Unsaturated Polyester Resin	Carbon Fibre CF	Sic	6	1.67
5	Unsaturated Polyester Resin	Carbon Fibre CF	Sic	8	1.69
6	Unsaturated Polyester Resin	Carbon Fibre CF	Sic	10	1.72

Table-2: Physical & Mechanical properties of Woven carbon fiber fabric adopted in this study.

D micron	Density g/cm^3	Shear Strength MPa	Tensile Strength MPa	Young Modulus GPa	Elongation e %	Compression Stress Mpa	Poisson ratio	Yield strength MPa
7	1.8	120	4887	240	2.1	3880	0.28	200

Table-3: Physical & Mechanical properties of silicon Carbide filler incorporated into the composite [12].

Prop. \ Sic%	0%	2%	4%	6%	8%	10%
Elongation %	2.6	2.47	2.32	2.16	2.04	1.92
Young modulus GPa	31.8	33	34.6	36.4	38.1	37.6
Tensile strength MPa	431	452	471	487	499	489
Compression strength(MPa)	382	400	419	437	451	442
Yield Strength MPa	368	387	403	418	429	422
Flexural strength MPa	583	614	634	656	672	663
Hardness (Hv)	27.7	29.4	31.8	34.6	36.8	36.2
Weight loss (mg)	16.1	13.8	11	9.4	7.5	7.9
wear rate (10^{-6} x mm^3/N.m)	5.2	4	3	2.3	2.5	2.9
Coefficient of friction	0.46	0.43	0.4	0.38	0.35	0.36

Table- 4: Composite's tensile and compression test results

Density g/cm^3	Young Modulus GPa	Poisson ratio	Hardness Kg/mm^2	Compression Strength Mpa	Flexural Strength MPa	Hardness Kg/mm^2	Maximum temperature	Fracture toughness
2.6	410	0.142	2800	4900	550	2800	1650	4.61

Table- 5: Improvement table at 8% Sic

Property	Improvement %
Elongation	7.6
Young modulus	19.81
tensile strength	15.77
Compression strength	18.06
Yield Strength	16.57
Flexural strength	15.26
Hardness (Hv)	30.68
Weight loss (mg)	53.41
Wear rate	51.9
Coefficient of friction	23.9

Table-6: Factors and their levels

Factors & units	Symbols	Level 1	Level 2	Level 3
Sic %	A	6%	8%	10%
Load N	B	11.772	21.582	31.392
Speed m/sec	C	3.2	4.5	5.34

Table-7: Experimental result presents the effect of factors on the tribological behaviour.

Exp. No.	Sic		Load		Speed		Wear rate Nm/m^3	Coefficient of friction
	Level	%	level	N	level	m/sec		
1	1	6	1	11.772	1	3.2	2.82	0.332
2	1	6	2	21.582	2	4.5	3.36	0.358
3	1	6	3	31.392	3	5.34	3.42	0.389
4	2	8	1	11.772	2	4.5	3.31	0.251
5	2	8	2	21.582	3	5.34	3.2	0.273
6	2	8	3	31.392	1	3.2	2.5	0.298
7	3	10	1	11.772	3	5.34	2.24	0.279
8	3	10	2	21.582	1	3.2	2.61	0.309
9	3	10	3	31.392	2	4.5	3.18	0.337

Table-8. Experiment Test Results and its S/N.

Exp. No.	Wear rate		Coefficient of friction	
	Nm/m^3	S/N	value	S/N
1	2.82	-9.005	0.332	9.577
2	3.36	-10.527	0.358	8.922
3	3.42	-10.681	0.389	8.201
4	3.31	-10.397	0.251	12.007
5	3.2	-10.103	0.273	11.277
6	2.5	-7.959	0.298	10.516
7	2.24	-7.005	0.279	11.088
8	2.61	-8.333	0.309	10.201
9	3.18	-10.049	0.337	9.447

Table-9. Average Value of Signal to Noise Ratio at Different Parameter Levels.

Parameter	Symbol	Parameter level			max-min	Optimal level
		1	2	3		
Wear rate (Nm/m^3)						
Sic%	A	-10.0708	-10.4861	-8.4621	1.6087	A2B2C1
Load (N)	B	-8.8022	-9.6542	-9.5626	0.8520	
Speed (m/sec)	C	-9.4322	-9.3240	-9.2628	1.8918	
Coefficient of friction						
Sic%	A	8.9002	11.2663	10.2454	2.3661	A1B1C1
Load (N)	B	9.2980	10.1333	9.3880	1.5025	
Speed (m/sec)	C	10.0979	10.1254	10.1886	0.0906	

Table-10: The results of the ANOVA

Parameters	Sum of Squares	Degree of Freedom	Mean Squares	Contribution (%)
Wear rate (Nm/m^3)				
Sic%	3.9782	2	1.9891	28.64
Load (N)	1.3126	2	0.6563	9.45
Speed (m/sec)	5.3947	2	2.6974	38.83
Error	3.2072	2	1.6036	23.09
Coefficient of friction				
Sic%	8.4504	2	4.2252	71.26
Load (N)	3.3865	2	1.6932	28.56
Speed (m/sec)	0.0130	2	0.0065	0.11
Error	0.0084	2	0.0042	0.07

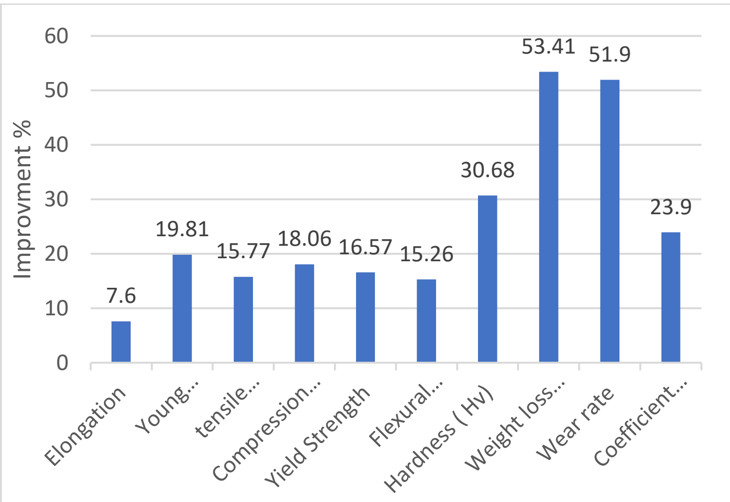


Figure 7: Mechanical and tribological properties improvement due to SiC filler content

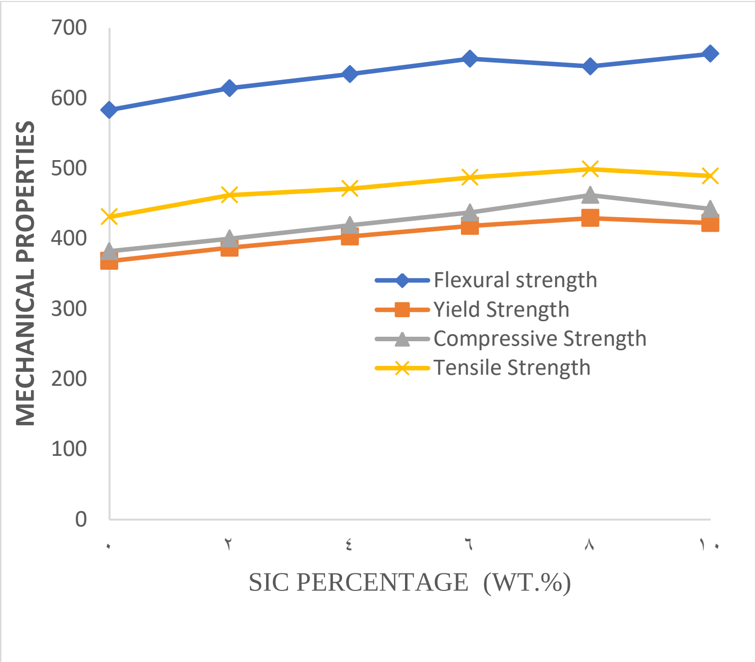


Figure 8: The effect of Sic filler percentage on mechanical properties of composite

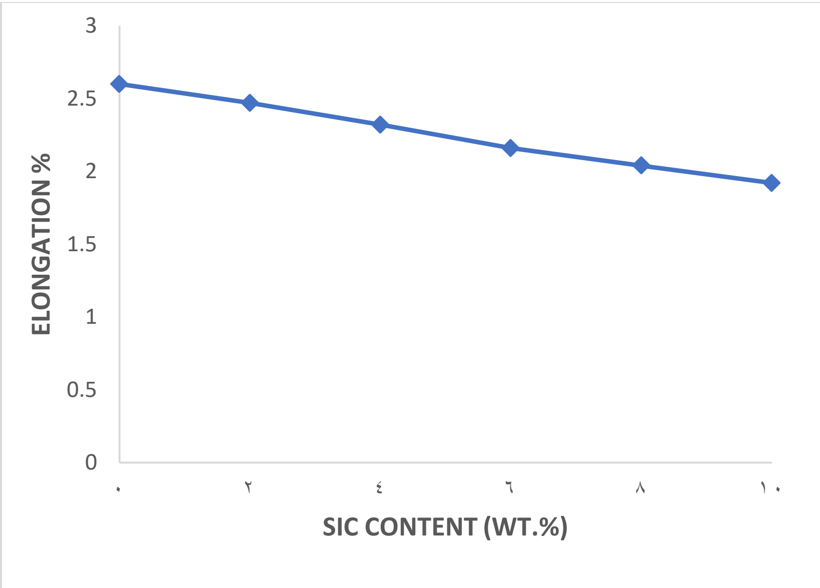


Figure 9: The effect of SiC content on the elongation at fracture point

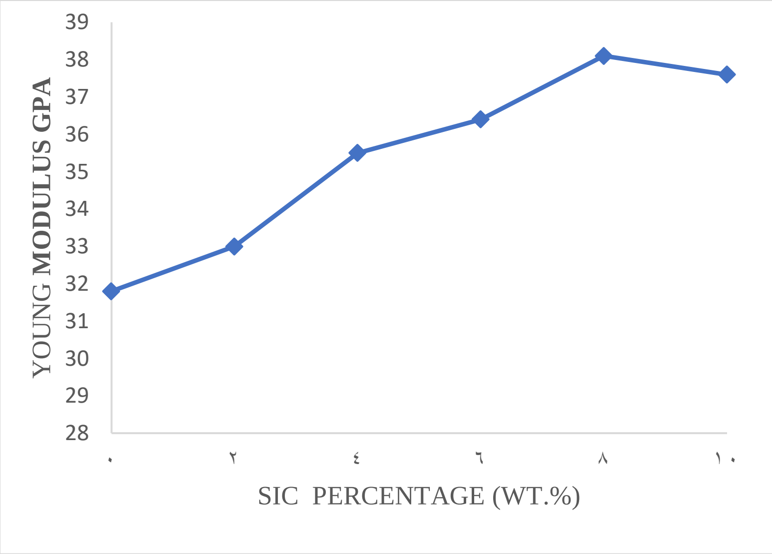
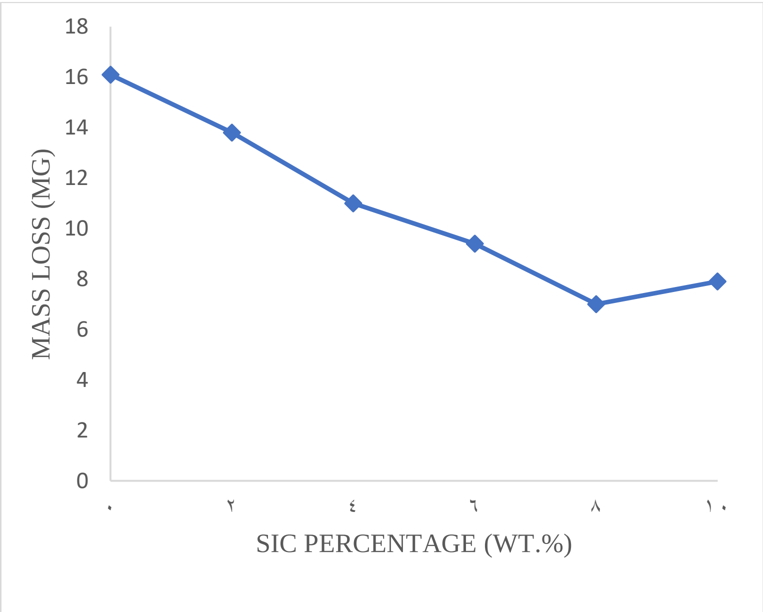


Figure 10: The effect of Sic filler percentage on young modulus of elasticity of composite



Figue 11: The effect of SiC filler percentage on mass loss of composite

3. Results and Discussion

The aim of the experimental plan is to find an important and combination factors influencing the mechanical and tribological properties of SiC carbide filler on woven carbon fiber/polyester reinforced composite material The experimental tests were done on the specimens using tensile test machine and pin on disc machine. The value of results is shown in table 4 represent the average results of three tests. The results show that the mechanical and tribological properties improved with using 8% (SiC) filler weight fraction compared to other weight fractions as shown in tables (4) and (5). From figure 7 the behaviour of composite properties against the silicon carbide(SiC) filler content increase is illustrated. The figure shows that the behaviour of the tensile strength, compression strength, yield strength, and flexural strength exhibited non-linear behaviour with increasing silicon carbide SiC weight fraction. The increase in compressive strength associated with high stifneess of SiC particles provided by the ceramic particles, thereby improving the load bearing capability of the composite. The specified properties improve gradually up to 8wt.% at which the maximum values, beyond this best concentration, no further improvement is observed, since the certain property either still near the peak values or begin to decline, the excessive SiC addition no longer provides additional benefits and may negative affect the composite performance

Figure (8) shows as the silicon carbide filler content increase, the young modulus will increase by the explaining above. When silicon carbide filler content increase the composite density was increased see table (1) due to silicon carbide possesses higher density than both polyester matrix and carbon fiber reinforced, so when replacing any part from polyester matrix by Sic filler content leads the all density of the composite increase. Hardness displayed behaviour table (4) similar to the density i.e. the improvement in hardness due to high hardness and elastic modulus of silicon carbide particles. When SiC particles uniform distribution with polyester matrix they prevent regional plastic deformation and restrict the penetration depth in locally surface [20]. So, the composite hardness progressively increases as the SiC content increase but when SiC content excessive addition may aggregation will occur at many regional creating stress concentration sites that negatively influence tensile strength and ductility. Therefore, hardness property should be associated together with mechanical and tribological properties to get the optimum carbide silicon filler content.

To demonstrate the combination of factors on the tribological behavior, the experiments were introduced depend on design of orthogonal array as shown in table (7), according to the aim of relating the effecting of additives weight fraction, load and speed. Taguchi presents analyzing the S/N ratio by using conceptual approach. The sensitivity of the quality investigated be measured using Signal to noise ratio to the goal of "lower is better" using following equation to perform S/N ratio analysis.

$$\frac{S}{N} = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n} y_i^2\right] \qquad (3)$$

Where: n is the number of observations. yi is the observed data.

The results of nine experiments shown in table 7, while the S/N ratios had been estimated and presented in table 8. The experiments number (3 and 9) has the minimum values of wear rate and friction coefficient S/N ratio, respectively. The parameters combinations with their level in these experiments are A1B3C3 and A3B3C2 respectively. According to the combinations results generated from the selected orthogonal array.

From Table 9 it can be seen that the combination of the optimal parameters and the wear rate levels is A2B2C1, equivalent to (8% Sic, 21.582 N and 3.2 m/sec). While the optimal combination of friction coefficient is A1B1C1equivelant to (6% SiC, 11.772 N and 3.2 m/sec). To investigate the experimental results ANOVA analysis is used, where the effect of parameters (filler weight fraction, load and speed) on the wear rate and coefficient of friction of the prepared samples has been studied. The analysis to determine the dominant independent parameter with its percentage contribution. Table 10 indicates that filler weight fraction has the most significant effect compared to the other parameters on the tribological properties. Figure 9 show the behavior of the mass loss against silicon carbide (SiC) filler content percentage which shows that mass loss decreased as increased of hardness since the hardness of the composite had been increases as the Sic filler content increase as the explanation stated above. Figure (10) indicate the improvement of mechanical and tribological properties of composite materials at 8wt.% SiC filler content, this figure shows the percentage amount of the properties which show the best improving was the wear rate 51.9%. while mass loss was improved about 53% i.e. the amount of mass loss is the less at 0.8wt.%SiC at the same condition operations.

4. Conclusion

The following important points can be summarized the present investigation

1. The addition of silicon carbide filler enhanced the mechanical and tribological properties of carbon fiber-reinforced polyester composites relative to the unreinforced material.
2. The composite density progressive rise as the silicon carbide content increase. This can be explained by the higher density of Sic particles and the lower amount of void formation during manufacturing process
3. As the concentration of silicon carbide content increased in the composite, surface hardness composites improved because SiC particles possesses an exceptional hardness and high stiffness, resulting in contributing to greater resistance to surface damage at discrete location.
4. The incorporation of silicon carbide significantly affected the tensile behaviour. Moderate filler additions improved tensile strength through more efficient stress transfer and stronger fiber-matrix adhesion, whereas excessive Sic loading caused particle agglomeration that reduced tensile performance.
5. Increasing the Sic content resulted in a higher elastic modulus accompanied by a reduction in elongation at break, demonstrating that the composites became progressively stiffer while their ductility decreased.
6. Compressive strength increased with the addition of Sic and reached its maximum value at 8 wt.% SiC, indicating that this filler concentration provides the most effective reinforcement and load-bearing capability for the developed composite.
7. The tribological characteristics were significantly improved after Sic incorporation. Both the wear rate and coefficient of friction decreased because the ceramic particles enhanced surface hardness and protected the matrix from severe material removal. However, a slight decline in performance was observed at the highest filler loading due to particle agglomeration.
8. The Taguchi optimization and ANOVA results confirmed that the Sic weight fraction was the dominant factor affecting the tribological responses of the fabricated composites, whereas the effects of applied load and sliding speed were comparatively smaller within the investigated experimental range.

References

[1] Silvina Siddika Shifa**1** ,Ning Zhang **”** Progress and perspectives on plant-based natural fiber- reinforced polymer composites: Structure–property relationships and emerging design strategies” Journal of Polymer Research (2026) 33:254, https://doi.org/10.1007/s10965-026-04954-y

[2] Jenish Iyyadurai, Felix Sahayaraj Arockiasamy, Gokulkumar Sivanantham, Yuvaraj Gopal, Sasi Kumar Mani, Makeshkumar Mani & Rajkumar Sivanraju” Enhancing friction and wear performance of epoxy composites with sustainable cistus quadrangular is stem fiber and Nano silica fillers” Sic Rep (2026). https://doi.org/10.1038/s41598-026-51053-5

[3] Sajjad Hossain, Md Shariful Islam, Md AshrafulIslam*, Md Abdul Hasib, Md Seam Shaikh “Effect of silicon carbide on enhancing interfacial adhesion and mechanical properties of Kevlar- glass fiber hybrid composites” Journal of hybrid advance. https:// doi.org/10.1016/ j. hybadv.11(2025). 100534

[4] D. Singh**,** R. R. Kumar, P. K. Karsh, M. Karthik Kumar, G. S. Mandal & H. M. Sulfikhar Ali**”** Investigation on tribological and mechanical behaviour of GFRP composites with varying weight percentages of nano-graphite powders” Scientific Reports | (2025) 15:34924.

[5] Mays A. Abbas & Ali S. Al-Turaihi” A review of particulate fillers in unsaturated polyester composites: property enhancement and applications” The Iraqi Journal for Mechanical and Material Engineering, Vol.24, No.3, October 2025

[6] Nadhir Abd. Rashid, Hamid M. Mahan, Omran A. Shabeeb” The effect of cilicon- carbide additions on the mechanical and thermal conductivity properties of fiber-reinforced epoxy composites” Materiali in tehnologije / Materials and technology 58 (2024) 6, 793–799

[7] Talal Alsaeed , Ayedh Eid Alajmi, Jasem Ghanem Alotaibi , Voravich Ganthavee and Belal F. Yousif “Mechanical and Tribological Performance of Epoxy CompositesReinforced with YSZ Waste Ceramics for Sustainable Green Engineering Applications” Processes 2024, 12, 260 https://doi.org/10.3390/pr12112609//

[8] Paleti Pavan, Thota Veera Durga Prasad,Gautam Kumar, Matta Daniel Raju, PMMS Sarma, Tankeshwar Prasad” The Mechanical Properties of Carbon Fiber Reinforced Epoxy Polymer Composites” 2024 IJCRT | Volume 12, Issue 3 March 2024 | ISSN: 2320-2882

[9] Haixia and Sinan Zhang “Mechanical and tribological properties of silicon carbide/carbon fiber/epoxy resin based composite “journal of engineered fibers and fabrics V19:1-13, 2024

[10] S.O. Amiebenomo, B.O. Ozigi, and V. O. Edeawe” Finite Element Analysis and Mechanical Properties of Carbon Fiber Reinforced Polymer” European

Journal of Mechanical Engineering Research, 10 (1),82-118, 2023 Print ISSN: 2055-6551

[11] Muna Noori Ismael1, Hazim F. Hassan" Mechanical Behaviour of Polymer Matrix Composite Reinforced by Silicon Carbide Particles" Journal of Techniques, ISSN: 2708-8383, Vol. 5, No. 2, 2023, Pages 108-113

[12] Thamer Albahkali, Ahmed Fouly , Ibrahim A. Alnaser, Mahmoud B. Elsheniti , Ahmed Rezk and Hany S.Abdo "Investigation of the Mechanical and Tribological Behavior of Epoxy-Based Hybrid Composite" Polymers 2023,15,3880https ://doi.org/ 10.3390/ polym15193880

[13] Yasser S. Mohamed a, Ahmed Abdelbary" Theoretical and experimental study on the influence of fiber orientation on the tensile properties of unidirectional carbon fiber/epoxy composite" Alexandria Engineering Journal (2023) 67, 693–705

[14] Ekpechi Daniel , Osita Obiukwu "Mechanical and Physical Properties of Silicon Carbide, Aluminium Oxide and Epoxy Hybrid Composite: AOverview" GSJ: Volume 9, Issue 11, November 2021, Online: ISSN 2320-9186

[15] Ramesh Ganugapenta, S Madhusudan,K Balaji, P Prathyusha" Study on Mechanical and Tribological Properties of Glass Fiber Reinforcedepoxy Composites with Sic & Flyash as Fillers" International Journal of Engineering Science Invention (IJESI) ||Volume 7 Issue 7 Ver II || July 2018 || PP 25-38

[16] S Vigneshkumar and T Rajasekaran" Experimental analysis on tribological behavior of fiber reinforced composites" 2nd International conference on Advances in Mechanical Engineering (ICAME 2018) IOP Publishing//IOP Conf. Series: Materials Science and Engineering 402 (2018) 012198 doi:10.1088/1757-899X/402/1/012198

[17] Drai Ahmed Smait, Farag M. Mohammed, Hussam Lefta Alwan, "Study the effect of the additive type on the composite panel behavior under impact load using optimization method" 3rd int science conference of Babylon university 20-21 May 2015

[18] Ritesh Hooda, Nishant Kumar, Yogesh Sharma"Study and Analysis on Mechanical and Wear Behaviour of Sic Filled Epoxy Composite" International Journal of Recent Research in Civil and Mechanical Engineering (IJRRCME) Vol. 2, Issue 1, pp: [19] Farag M. Mohammed, Drai A. Smait '' Mechanicaland tribological behavior of glass-polyester composite system under graphite filler content". Eng. & Tech Journal, V30, No.4, 2012 pp. 672-683

[20] S. Basavarajappa, K.V. Arun, J. Paulo Davim" Effect of Filler Materials on Dry Sliding Wear Behavior of Polymer Matrix Composites – A Taguchi Approach" Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.5, pp 379-391, 2009

[21] Lihe Mao, Yanan Jiao, Haohe Geng, Youhong Tang "Understanding friction and wear properties of carbon fiber/epoxy stitched composites" Composites: Part A169 (2023)107501.Journalhomepage:www.elsevier.com/locate/composites. https://doi.org/10.1016/j.compositesa