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RESEARCH ARTICLE

Effect of TiO_2 Nano-Filler with Jute/Kenaf/Glass in Tensile and Impact Properties on Fiber Stacking Sequence

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Abstract

Objective: The prime goal of this study is to conduct a comprehensive analysis, modelling, and optimization of various independent factors and coming up with a material that suits in structural application in automobile. **Method:** Composite is prepared using hand lay-up technique. The analysis is carried out through the utilization of the Central Composite Design (CCD) approach. Mathematical models are formulated for ultimate tensile strength and impact resistance, employing the RSM. These factors include fiber orientation, fiber sequence, and filler percentage, with a focus on their influence on mechanical properties. **Finding:** These models act as valuable tools for the selection of the most favourable independent variables to maximize the mechanical properties related to tensile strength and impact resistance. In conclusion, the experimental findings emphasize that the inclusion of Nano-filler results in an enhancement of 20% and 36% on tensile strength and impact properties respectively. **Novelty:** TiO2-infused polymers exhibit unparalleled strength and flexibility, promising transformative advancements in this work that can be implemented in aerospace, indoor, automobile, and medical industries.

Keywords: Titanium dioxide; Nanofiller; Hybrid composite; Response surface methodology; Epoxy

1 Introduction

This study delves into the development of a hybrid epoxy Nanocomposite and examines the influence of incorporating Nano graphite for reinforcement. The composite was crafted by means of a mechanical stirring method, and varying amounts of Nano graphite, specifically 1.0, 1.5, and 2.0 weight percent, were added(1). Ultimately, it was determined that the optimal Nanoparticle content significantly impacting the sample properties is 1.5 weight percent(2). This study centred on the examination of the mechanical characteristics of E-glass fibres enhanced with Nanoparticles, intended for application in advanced composite materials. The primary aim was to investigate how the presence of Nanoparticles and different solution concentrations impact these mechanical traits. The results of the research suggest that the E-glass fibres, which have been subject to Nano-particle coating, demonstrate a decreased likelihood of breakdown when compared to their untreated counterparts(3). The aim of this research was to develop hybrid polymer matrix composites that utilized Glass fibres (stranded mat) and Nano-carbon particles in varied weight fractions were used to strengthen these composites. The Response Surface Methodology (RSM) was utilized to measure and compare the impact strength and flexural strength of these composites. The findings revealed that the amount of reinforcement had a substantial effect on overall flexural and impact strength. In particular, the hybrid composite including all glass fibres and carbon Nanoparticles outperformed in terms of flexural and impact strength(4).

Response surface methodology (RSM) is a statistical approach used for designing experiments, assessing the impact of various factors on a process, establishing empirical associations among input and output variables, and identifying the ideal conditions(5,6). Two popular RSM techniques, the Box-Behnken design (BBD) and the CCD, are frequently employed to create models for controlling manufacturing factors in the production of high-quality composite products(7,8). Afterward, optimization tools are utilized to conclude the optimal combination of process parameters that yield the desired results(9).

This study revealed that hybrid composites, incorporating 4% titanium oxide powder, bamboo fibres measuring 15 mm in length, and bamboo fibres with a diameter of 0.24 mm, displayed notably enhanced mechanical strength. As the proportions of fibres and fillers increased, it became progressively more challenging to disrupt the bonds between the matrix and the resin(10). Current research aims to develop an eco-friendly glass/epoxy composite and explore the impact of changing concentrations of Nano silica on the composite mechanical, dynamic mechanical, and optical characteristics. Our results reveal that the properties of the composite improved with increasing Nano particle loading up to 3 wt%, leading to a substantial increase of 45% in tensile strength, 62% in flexural strength, and 9% in impact strength when associated to the pure glass composite.(11)

In this work, they ran a total of 20 tests to create a hybrid composite fiber made of glass fiber and coir fiber. We used design expert software to direct the production process, and the finished composite fiber was tested in compliance with ASTM standards. We discovered the ideal parameters for the composite fibre tensile strength and strain using these tests. Our investigation led to the development of two quadratic models that establish connections between process variables and desired results. For instance, we discovered that the inclusion of glass fiber had the greatest influence across both Response variables. Exact parameters resulted in an optimal tensile strength of 49.27 MPa and an optimized strain of 14.43%(12). Researcher constructed a composite material by merging natural fibres with Nano SiC particles in this current research project, and then extensively analysed its mechanical characteristics. Taguchi's Method was used in the experimental design. Researchers used a unique methodology described as the Combined Compromise Solution (CoCoSo) technique, recently discovered in multi-criteria decision making (MCDM), to maximize various response variables. Our ANOVA analysis of our experimental data, which comprised ultimate tensile strength, flexural strength, density revealed that density had the most significant influence on obtaining enhanced mechanical characteristics(13). The principal objective of the ongoing examination is to explore the impact of introducing titanium dioxide (TiO2) particles at the Nano- and micro-scale on the mechanical properties of hybrid composites comprised of kenaf, glass, and epoxy. These composite materials exhibit variations in the concentration of fillers and the arrangement of layers. When compared to unadulterated epoxy resin, the inclusion of 15 wt% micro-sized fillers in a composite structure featuring a sequence of glass-kenaf-kenaf-glass leads to a significant enhancement in both tensile strengths, with a 39.48% rise, and flexural strength, with a 42.88% improvement. Furthermore, the introduction of 5 wt% Nanoscale fillers results in a noteworthy 44.214% increase in tensile strength and an impressive 50.50% boost in flexural strength.(14). The aim of this study is to explore how the addition of lead oxide Nano filler affects the mechanical, thermal, and water absorption properties of epoxy polymer composites reinforced with luffa fibres. It was observed that incorporating 1.25 wt% of the Nano filler led to the most favourable mechanical and thermal characteristics. The study suggests that incorporating Nano filler could potentially enhance the mechanical strength of natural fiber composites.(15).

Based to the scrutiny using glass fibres not only enhances strength however also provides more strength than natural fibres. The incorporation of natural fibres like jute and kenaf in this research is driven by the desire to reduce the reliance on synthetic materials in composites. The authors note that jute fibres find extensive applications across various fields due to their commendable supportive properties, and kenaf also exhibits favourable characteristics when employed in hybrid composites. Furthermore, it's important to note that nanomaterials like Titanium dioxide possess remarkable properties that enhance mechanical strength. In this study, different weight percentages (3wt%, 4wt%, and 5wt %) were selected based on a review of relevant articles. The author noted that increasing the Nano-filler content enhances the strength of the composite material. However, it is crucial to ensure proper dispersion and prevent agglomeration when mixing the epoxy resin with the Nano-filler.

2 Materials and Methods

As shown in Figure 1 **(a, b, c)**, an amalgam of glass fiber mat and natural Jute and kenaf fibre mat was used in this investigation. Epoxy resins were adopted for utilization in advanced composites due to their multiple benefits such as strong adherence to diverse fibres, great performance at high temperatures, and outstanding mechanical and electrical qualities. Furthermore, the epoxy (LY 556), hardener (HY951) and Nano-filler (TiO_2) shown in Figure 1 **(d, e, f)** were chosen for their outstanding properties, such as minimum shrinkage during curing and good chemical resistance, distinguishing them from other thermoset polymers. In preparation for manufacturing the fiber plates, it is essential to conduct a series of designed experiments. Specifically, we have carried out 20 experiments, each involving various fiber compositions, using the Design Expert software. The details of these compositions can be found in Table 1.

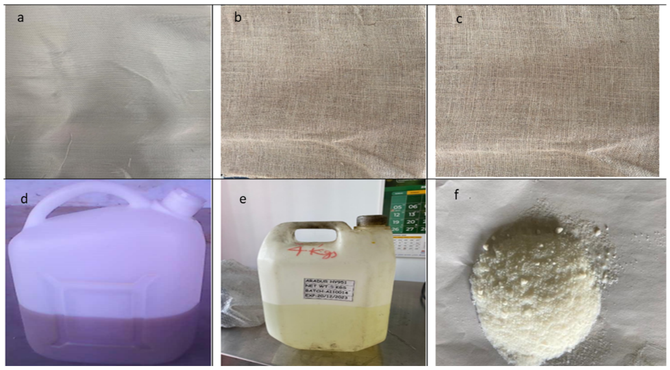

Fig 1. (a) an amalgam of glass fiber mat, (b) Jute and (c) kenaf fibre mat, (d) (LY 556),(e) hardener (HY951), (f) Nano-filler TiO_2

Table 1. Factors and their levels in Central Composite Design of experiment

Name	Units	Low	High
Fibre orientation	Degree	0	90
Fibre sequence		1	3
Filler	Percentage	3	5

2.1 Composite Preparation

Hand-layup was used to create (3wt%, 4wt%, and 5wt %) filled TiO_2 and Jute, Kenaf, Glass hybrid composites is used to create composite laminate. A greasy sort of lubricant (wax) was placed to the bottom of the mould to facilitate the elimination of the cured laminate and to provide a smooth surface. Jute/Kenaf/Glass fibres were cut to the desired size of the mould and placed layer by layer in the inner mould cavity in the specified order. Matrix is a 10:1 blend of epoxy and hardener of 50wt% and fiber remaining wt%, as well as varied filler (3wt%, 4wt%, and 5wt %) of Titanium dioxide filler. The air bubbles and surplus matrix were removed using a roller. The Jute/Kenaf/Glass unidirectional woven mats were stacked in the order specified. Specimens with different sequences were prepared Sequence 1- G/J/J/K/K/K/K/J/J/G, Sequence 2- G/K/K/J/J/J/J/K/K/G, Sequence 3- G/K/K/K/K/J/J/J/J G and also 0°,45°,90° orientation of fiber is used. Mechanical stir method is used to disseminate Nano-fillers applied to an epoxy matrix, in the 300*300 mm mould they were impregnated with epoxy resin. The produced composite was cured for 24 hours at ambient temperature.

2.2 Testing methods of composites

Tensile strength of the specimen was equipped according to the ASTM D3039 (ASTM Standard D3039 2008) standard, and the tensile test was performed using the specimen. According to ASTM D3039 requirements, an experiment was conducted. The gauge length and crosshead speed were both adjusted to 50 mm and 2 mm, correspondingly.

2.2.1 ***Impact testing***

The ASTM D 256 standard was used for the impact test, and the strip measurements were 65 * 12.7 mm. The Charpy impact test machine was utilised in accordance with the specifications.

2.3 Experimental design

The study took into account three major factors: Factor A, which represents fiber orientation; Factor B, which represents fiber sequence; and Factor C, which represents the weight % of Nano-filler. The major focus was on determining the tensile strength and impact strength of composite materials shown in Table 2. Given the interconnectedness of these process variables, the researchers used the RSM to develop functional correlations between Factors A, B, and C, as well as the tensile and impact strength of epoxy-based composite materials. Design-Expert version 13 software was used to conduct this research and enhance the results for tensile and impact strength. This program enabled a detailed evaluation and fine-tuning of these aspects in direction to improve the tensile and impact strength of composite materials.

Table 2. Parameters for processing input and their corresponding responses

Std	Run	A:orientation	B:sequence	C:TiO2 filler	Tensile	Impact
		Degree		%	MPA	MPA
7	1	0	3	5	224	57
1	6	0	1	3	222	59
5	7	0	1	5	240	71
9	8	0	2	4	223	62
3	16	0	3	3	205	51
13	2	45	2	3	211	68
20	4	45	2	4	221	70
11	5	45	1	4	238	74
15	9	45	2	4	224	68
18	10	45	2	4	229	69
12	11	45	3	4	228	63
16	13	45	2	4	230	72
14	15	45	2	5	232	75
17	17	45	2	4	226	66
19	18	45	2	4	224	73
8	3	90	3	5	234	67
2	12	90	1	3	223	65
4	14	90	3	3	215	63
6	19	90	1	5	248	82
10	20	90	2	4	236	72

3 Results and Discussion

A sequence of 20 tests were accompanied to extensively explore the mechanical characteristics, especially the tensile strength, of a hybrid composite consisting of natural and synthetic fibres coupled with epoxy resin. Using design expert software, these studies comprised altering the sequence of fibres and mixing different weight percentages of Nano-filler with epoxy resin. The tensile strength of hybrid fibres rises as the amount of Nano-filler rises. Additionally, the weight of the Nano-filler, in conjunction with the varied fibre sequence parameters, has a substantial impact on the tensile strength of the composite material. Tensile strength gradually and consistently improves as the percent of Nano-filler with sequence 1 with better mechanical properties.

3.1 Developing a mathematical model

Tensile Strength = 226.582 + 4.2 * A + -6.5 * B + 10.2 * C + 1.375 * AB + 0.875 * AC + -0.625 * BC + 1.54545 * A^2 + 5.04545 * B^2 + -6.45455 * C^2

Impact Strength = 70.1455 + 4.9 * A + -5 * B + 4.6 * C + 0.625 * AB + 0.375 * AC + -2.375 * BC + -3.86364 * A^2 + -2.36364 * B^2 + 0.636364 * C^2

Let us examine the influence of several aspects in the context of hybrid composite materials. The variables A, B, and C, respectively, reflect fiber orientation, fiber sequence, and the weight of the filler (Epoxy + Hardener) in the material. A, B, and C are variables in these formulas that indicate the square and interaction effects. While looking at the coefficients connected with these concepts, it's vital to remember that increasing coefficients affect both tensile strength and impact strength. In simpler terms, raising the values of A, B, and C, as well as the associated squared and interaction terms, improves the hybrid composite material strength and resilience. Adverse coefficients, on the other hand, have a damaging impact on the material strength. Reduced values of A, B, and C, in addition to their associated squared and interaction terms, degrade the hybrid composite, rendering it prone to tensile strength and impacts. In essence, the coefficients in these equations determine the mechanical characteristics of the hybrid composite, with positive coefficients increasing strength and negative values decreasing it.

Table 3. ANOVA for Quadratic model-Response 1: Tensile

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	1802.74	9	200.30	20.07	< 0.0001	significant
A-orientation	176.40	1	176.40	17.67	0.0018	
B-sequence	422.50	1	422.50	42.33	< 0.0001	
C-TiO_2 filler	1040.40	1	1040.40	104.24	< 0.0001	
AB	15.13	1	15.13	1.52	0.2465	
AC	6.13	1	6.13	0.6137	0.4516	
BC	3.12	1	3.12	0.3131	0.5881	
A^2	6.57	1	6.57	0.6581	0.4361	
B^2	70.01	1	70.01	7.01	0.0244	
C^2	114.57	1	114.57	11.48	0.0069	
Residual	99.81	10	9.98			
Lack of Fit	42.47	5	8.49	0.7408	0.6250	not significant
Pure Error	57.33	5	11.47			
Cor Total	1902.55	19				

The Model F-value of 20.07 indicates that the model is statistically substantial in Table 3. It is extremely unlikely, with only a 0.01% probability that such a large F-value could result from random noise. When P-values are less than 0.0500, it suggests that the model terms (in this case, A, B, C, B^2, and C^2) are statistically significant. Conversely, when P-values exceed 0.1000, it implies that these model positions are not statistically substantial. If you have many insignificant model terms (excluding those necessary for model structure), dropping the model complexity might increase its performance. Regarding the Lack of Fit F-value, which is 0.74, it recommends that the Lack of Fit is not statistically substantial compared to the Pure error. There is a 62.50% chance that such a Lack of Fit F-value could arise due to random variations. In this context, having a non-significant Lack of Fit is desirable because it means the model fits the data adequately.

The F-value of 20.58 in Table 4 demonstrates the model importance, with only a 0.01% possibility of such a high F-value happening due to random noise. When p-values are less than 0.0500, it indicates that model terms (in this example, A, B, C, BC, A2) are significant. Standards larger than 0.1000, on the other hand, indicate non-significance. If the model has a large number of unimportant model terms (except those essential for hierarchy), lowering the model may expand its performance. With an F-value of 0.44, the Lack of Fit is not considerably dissimilar from pure error, with an 80.84% likelihood of such an F-value occurring by chance. A non-significant lack of fit is advantageous since it suggests that the model is well-fitting. The ANOVA findings for tensile strength and impact strength in hybrid composite fibers are shown in Tables 3 and 4. Every one of the models produced extremely significant Fisher's F values, showing that they effectively represent the relationship among input process parameters and related responses. The Fisher's F value for tensile strength in hybrid composite fibers was found to have been 20.07, whereas the Fisher's F level for impact strength were found to as 20.58. The P-value for the tensile strength model (P = 0.0001) indicates the fact the models produced have beneficial results. On the contrary, the framework constructed for impact strength has an incredibly tiny chance (0.0001%) of its Fisher's F value being attributed to noise. The residual error value (99.81) for the tensile strength model must be the sum of the lack of fit (42.47) and pure error (57.33). The residual error value (47.86) for the impact strength model should be the sum of the lack of fit (14.53) and pure error (33.33).

3.2 Examination of residual plots for hybrid Nanocomposites

Figure 2(**a**) shows that there is a link among the conventional probability distribution and the externally associated to tensile strength residues. The residual points we found indicate that there is a plausible curve that roughly matches the line that suits the model data. As shown in Figure 2(**a**), there do not appear to be any obvious problems with the residual values normality.

Table 4. ANOVA for Quadratic model-Response 2: Impact

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	886.69	9	98.52	20.58	< 0.0001	significant
A-orientation	240.10	1	240.10	50.17	< 0.0001	
B-sequence	250.00	1	250.00	52.23	< 0.0001	
C-TiO2 filler	211.60	1	211.60	44.21	< 0.0001	
AB	3.12	1	3.12	0.6529	0.4379	
AC	1.13	1	1.13	0.2351	0.6382	
BC	45.12	1	45.12	9.43	0.0118	
A^2	41.05	1	41.05	8.58	0.0151	
B^2	15.36	1	15.36	3.21	0.1034	
C^2	1.11	1	1.11	0.2327	0.6399	
Residual	47.86	10	4.79			
Lack of Fit	14.53	5	2.91	0.4358	0.8084	not significant
Pure Error	33.33	5	6.67			
Cor Total	934.55	19				

Figure 2 **(b)** depicts the relationship between expected and actual tensile strength values. The graph points reflect how much the projected or changed values depart from the actual ones. Those data points are uniformly spread across the axes, showing that the predictions are quite accurate in comparison to the experimental readings. The model is more accurate the closer the data points are to the orientation line. All of the core analyses agree, showing that the proposed empirical model is feasible and suitable for the job.

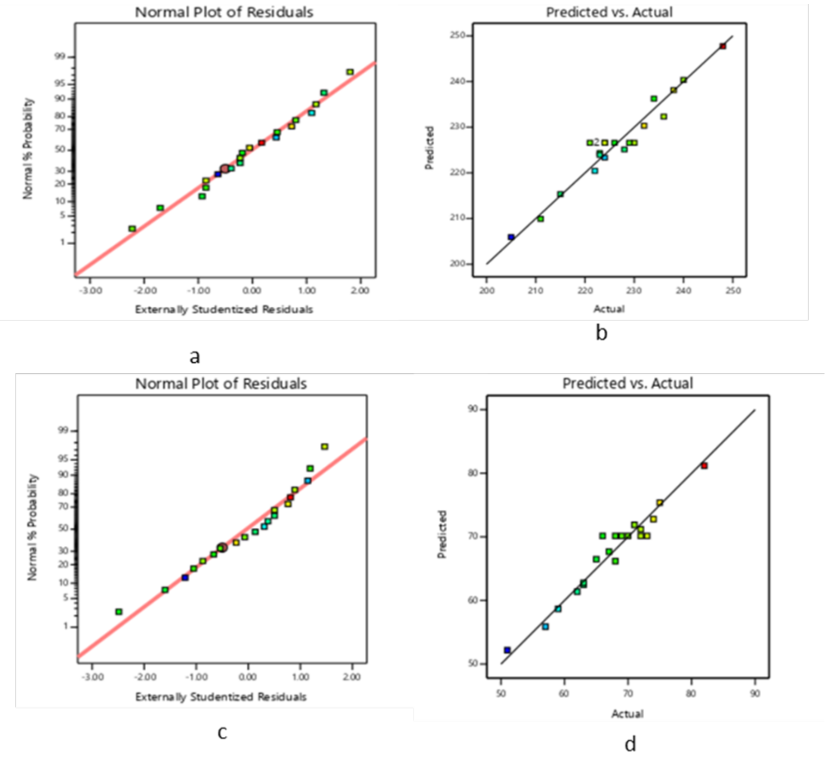

Fig 2. a) assessing the contrast between normal probability and residuals, b) Comparison of anticipated versus observed values after considering tensile strength, c) Comparison between normal probability and residuals, d) Comparison of predicted values with actual values in relation to impact strength

Figure 2(**c**) depicts a relationship between the conventional probability distribution and the Impact strength-related externally linked residues. The residual data points we found indicate the presence of a credible curve that roughly corresponds with the model data. As shown in Figure 2(**c**), there do not appear to be any significant concerns with the residual values normality. The connection between predicted and actual impact strength values is depicted in Figure 2 (**d**). The graph points show how much the anticipated or adjusted values differ from the actual measurements. These data points are spaced equally along the axes, showing that the predictions nearly reflect the outcomes of the experiment. As the data points approach closer to the orientation line, the model accuracy improves.

3.3 Surface response contour plots of hybrid Nanocomposite tensile strength

Figure 3 depicts the effect of input parameters on tensile strength behaviour. Figure 4 shows a 3D surface map as well as a 2D contour plot highlighting the effect of various settings. The 3D surface map in Figure 3 **a, b** demonstrates how the proportion of TiO_2 influences with respect to sequence and orientation of tensile strength. We can see the outline view of this map that increasing the Nano-filler content increases the tensile strength of the hybrid Nanocomposite. Additionally, the orientation of the materials influences strength; particularly, when the orientation is at a 90-degree angle and there is a 5wt% Nano-filler of Tio_2, the material attributes increase.

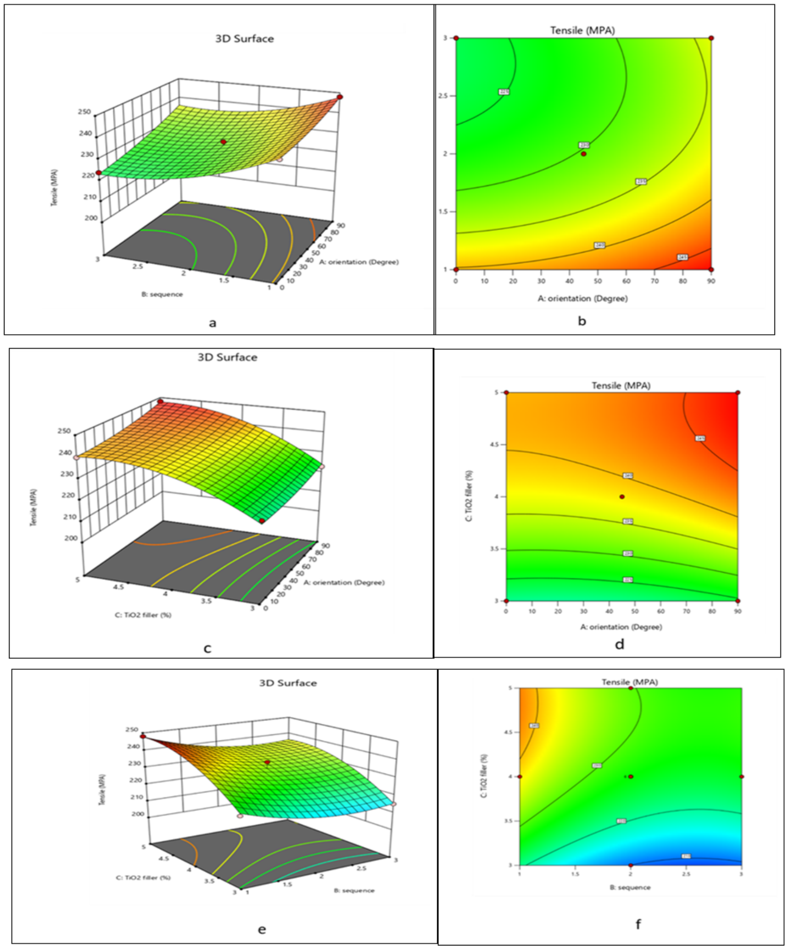

Fig 3. a, b- Surface representation of the relationship between fiber sequence and fibre orientation with respect to tensile strength, in both three-dimensional (3D) and two-dimensional (2D) formats. c, d- Comparative surface plot depicting the relationship between TiO_2 Nano-filler orientation and its impact on tensile strength (3D and 2D). e, f- Surface representation of TiO_2 Nano-filler effects on tensile strength across different sequences (3D and 2D)

The 3D surface map in Figure 3**(c)** and **(d)** shows how the fraction of TiO_2 impacts the tensile strength in relation to the Nano-filler content and material orientation. Examining the outline view of this map demonstrates that the tensile strength of the hybrid Nanocomposite rises as the Nano-filler content improves. Furthermore, the orientation of the materials influences strength, particularly when the orientation is at a 90-degree angle, and arise in TiO_2 Nano-filler improves the mechanical characteristics even further.

Figure 3 depicts a 3D surface depiction as well as a 2D contour plot, emphasizing the influence of various configurations. The 3D surface map in Figure 3, notably in Figure 3**e** and **f**, shows how the fraction of TiO_2 influences the tensile strength in terms of Nano-filler content and material sequencing. When we look at this map from the side, we can see that increasing the Nano-filler content increases the tensile strength of the hybrid Nanocomposite. Furthermore, material sequencing has a substantial influence on strength, particularly when using sequence 1 with 5 wt % TiO_2 Nano-filler, which leads to an increase in mechanical characteristics.

3.4 Surface response contour plots of hybrid Nanocomposite Impact strength

Figure 4 demonstrates the effect of input factors on impact strength behaviour. It includes a 3D surface map as well as a 2D contour plot to highlight the impact of various setups. The 3D surface map in Figure 4**(a)** and **(b)** demonstrates how the quantity of TiO_2 influences the sequence and orientation of impact strength. A deeper look at this map demonstrates that increasing the content of Nano-filler improves the hybrid Nanocomposite's impact strength. Furthermore, material orientation influences strength, particularly when the orientation is at a 90-degree angle and there is a 5 wt % Nano-filler of TiO_2, resulting in better material characteristics. The figure comprises both a three-dimensional surface map and a two-dimensional contour plot, aimed at emphasizing the effects of different configurations. In Figure 4 **(c)** and **(d)**, the three-dimensional surface map illustrates how the sequence impacts both the Nano-filler and the orientation concerning impact strength. A more detailed examination of this map reveals that when it comes to enhancing the impact strength of the hybrid Nanocomposite, sequence 1 outperforms sequence 2 and 3. Additionally, the orientation of the material plays a substantial role in determining strength, especially when the orientation is at a 90-degree angle and when using a 5% TiO_2 Nano-filler, resulting in superior material characteristics.

A more detailed examination of this map reveals that when the orientation is set at a 90-degree angle, the impact strength of the hybrid Nanocomposite improves. Additionally, the material orientation has a significant impact on its strength, particularly when considering sequence 1 and a 5 wt % Nano-filler of TiO_2, resulting in enhanced material properties due to the favourable characteristics of the glass fiber outer layer and the strong adhesion between the fiber and epoxy.

Table 5. Comparative analysis of other work with result

Author	Fiber Used	Tensile Strength (Mpa)	Impact Strength (Mpa)
1. Ariff Farhan Mohd Nor (16)	PP/Glass/graphene	125	65
2. Abeer Adel Salih (17)	Bamboo fiber	200	72
3. Faramarz (18)	PP/Glass/graphene	204	71
4. Asma Benkhelladi (19)	Jute/sisal/flax	100	75
5. Iti Dikshit, Gian Bhushan (20)	Carbon, Jute	197	94
6. My work	**Jute/kenaf/glass**	**248**	**82**

Table 5 underscores the remarkable strength of our materials, showcasing their superiority in both tensile and impact strength compared to existing optimization approaches. Our innovative materials approach stands out, exhibiting an impressive strength increase of over 30% when compared to traditional fibres like sisal, glass, jute, and bamboo. This comparison analysis serves as compelling evidence that our material optimization strategy outperforms established alternatives. Notably, our research highlights a peak value in tensile strength, affirming that the synergistic combination of specific materials and advanced optimization techniques results in a product that excels beyond the capabilities of other materials in the market. This substantiates the claim that our approach not only surpasses existing methods but also produces a more robust and suitable product, marking a significant advancement in the field.

3.5 Confirmation and optimization test of hybrid Nanocomposites

Subsequently, an extensive analysis of the variable parameters influencing both tensile and impact strength in the hybrid Nanocomposite, we identified the optimal parameter range for optimizing these strengths. Specifically, for tensile strength, the ideal range fell between 205 and 248 MPa, while for impact strength, it was between 51 and 82 MPa, as obtained from Table 2. The optimization process is visualized in Figure 4. In Figure 5 we can observe the optimal operational conditions for achieving

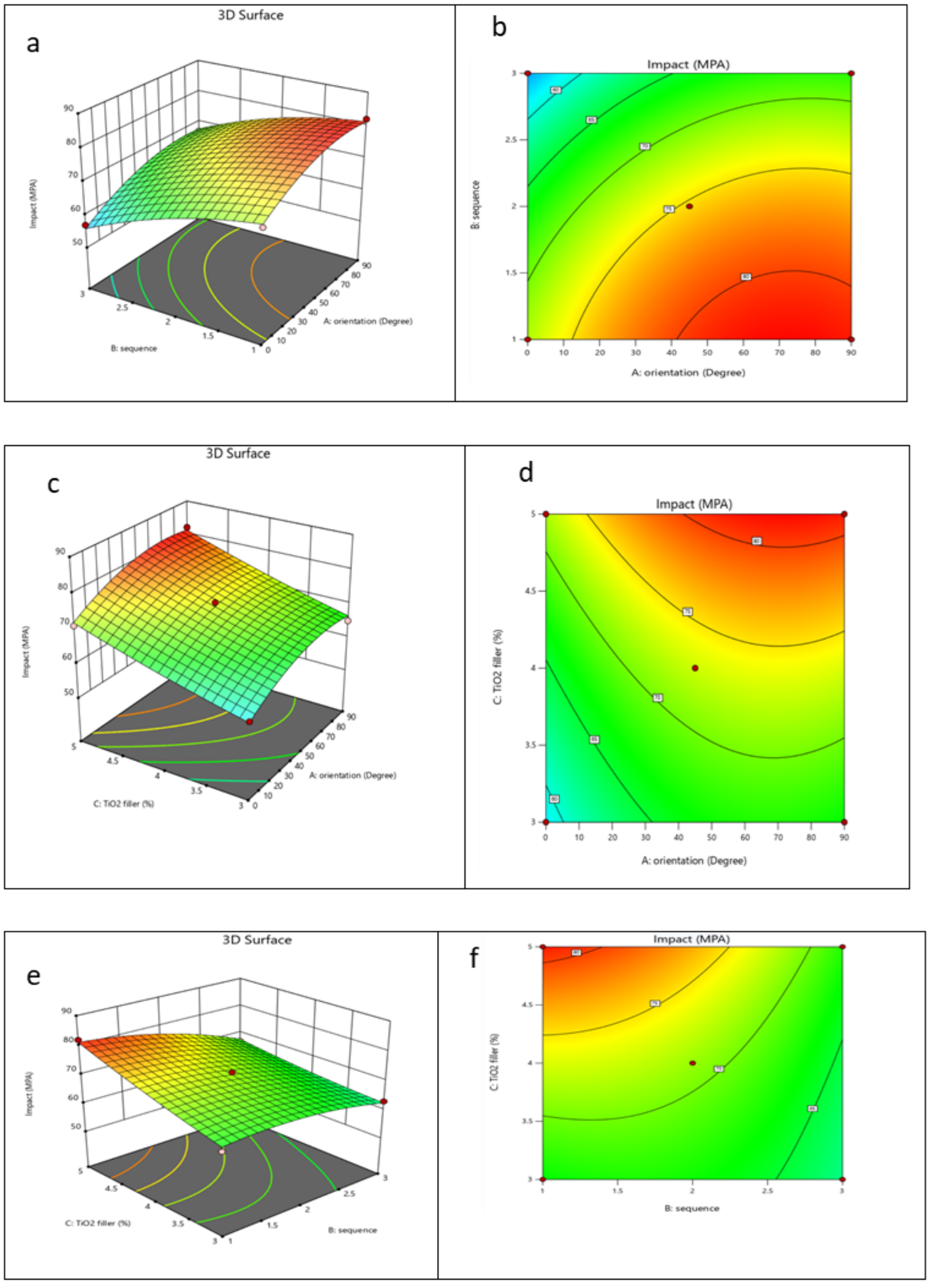

Fig 4. a, b- Surface representation of the relationship between fiber sequence and fibre orientation with respect to impact strength, in both three-dimensional (3D) and two-dimensional (2D) formats. c, d- Comparative surface plot depicting the relationship between TiO_2 Nano-filler orientation and its impact strength (3D and 2D). e, f- Surface representation of TiO_2 Nano-filler effects on Impact strength across different sequences (3D and 2D).

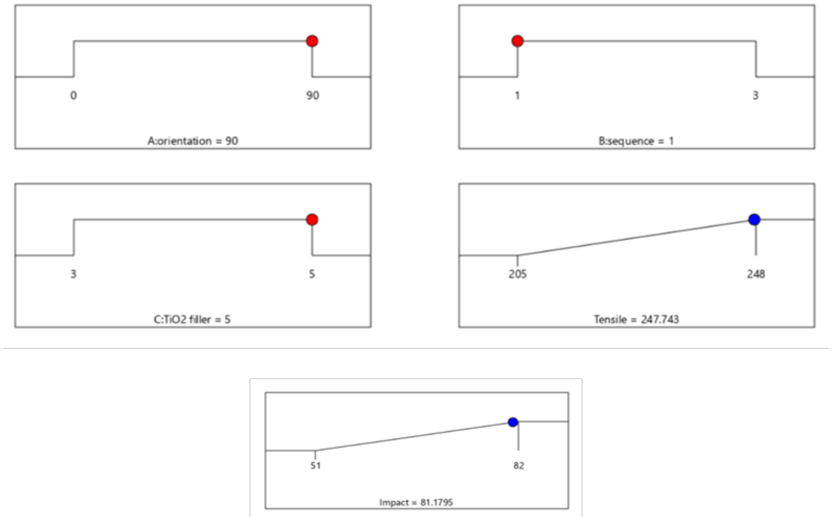

Fig 5. Plot of ramp numerical optimization for TiO_2 (%), fibre orientation and fibre sequence

the highest tensile and impact strength in the hybrid Nanocomposite. These conditions include a 5 wt % concentration of TiO_2 Nano-filler, a fiber orientation of 90 degrees, and the sequence 1 of G/J/J/K/K/K/K/J/J/G. To validate the scientific rigor of our findings, we conducted impact studies under these optimal conditions indicating that the model competence was suitable for approximately 98.4% of the predictable values. These findings suggest a substantial agreement among the predicted outcomes and the actual experimental results, providing strong justification and affirming the effectiveness of the optimal conditions.

4 Conclusion

This study conducted 20 experiments to create composite fibres by combining glass fiber, jute fiber, and kenaf fiber using design expert software. The resulting composite fibres were then tested according to ASTM standards to determine their optimal tensile and impact strengths. The study effectively utilized RSM to investigate the impact of hybrid composite composition and filler weight on the outcomes. Two quadratic models were developed to create the relationship among the process variables and the responses. Notably, glass fiber was identified as the most significant factor influencing both tensile and impact strengths. Tensile strength values ranged from 205 to 248 MPa, demonstrating a notable improvement of 20% from the lowest to the highest values. This improvement was observed under specific conditions, namely sequence 1 and a 90-degree angle of fiber and filler with 5 wt %. Similarly, impact strength values ranged from 51 to 82 MPa, showing a substantial 36% improvement from the lowest to the highest values. This improvement also occurred under specific conditions, including sequence 1 and a 90-degree angle of fiber and filler with 5 wt %. The optimized values for tensile and impact strengths were determined to be 247 MPa and 81 MPa, respectively. In summary, this study successfully employed Response surface methodology to examine the effects of composite composition and filler weight on tensile and impact strengths that can be implemented where mechanical properties are very much important. The research highlighted the ultimately identified optimized values for both tensile and impact strengths that can be used in marine, automobile, spacecraft application. In this work we made mechanical properties as the main goal in the next study we will do thermal properties that suits in structural application like aerospace and marine application.

Data Availability Statement

All the authors mentioned in the manuscript have agreed for authorship, read, and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.

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