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# Enhancing Mechanical Properties of Epoxy Resin Composites Through Nano-titanium-coated Hemp Fiber Reinforcement: A Response Surface Methodology Study

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## Abstract

Due to the significant depletion of natural resources, materials collected from the environment are currently prioritized for use. The emphasis of this study is on reinforcing epoxy resin using nano-titanium-coated natural fiber. Polymer composites were created by combining hemp fibers and a suitable quantity of nano $TiO_2$ (Titanium dioxide). Following composite production, standard-sized specimens were prepared for testing of mechanical properties. The tensile strength (TS) test results showed that S8 composites were superior. The flexural strength (FS) test results were best for the S7 composite. The S8 composite was found to be superior in energy absorption. In order to determine the optimal composite composition, the impacts of nano-$TiO_2$ and fiber on mechanical properties were studied using response surface methodology (RSM). The composite characteristics were studied using a central composite design. Predictions of composite strength were made using a polynomial model of the second order. An extremely high $R^2$ score indicates that a quadratic model of regression provides the best fit for the composite. Analysis of variance (ANOVA) was used to look at how hemp fiber and nano-$TiO_2$ affected the experiment. The experiments shown that the quality of the two-layer natural hemp fiber with 4 wt.% of titanium. Manufactured natural fiber reinforced polymer nanocomposites find use in many industries, from transportation and aircraft to sports and construction to consumer goods.

## Keywords

Tensile strength, Polymer composite, Hemp fiber, Response surface methodology, Central composite design

## Introduction

Using natural components makes conservation efforts easier on the environment. Better characteristics can be achieved using the composites produced [1]. Many experts in the field of natural fiber composites have published their findings and discussing the advantages and disadvantages of these materials [2]. Composite materials, say the scientists, have superior mechanical, thermal, and tribological capabilities over those of conventional materials. Epoxy reinforced with natural fibers has superior mechanical qualities [3]. The hemp fiber hybrid composite was manufactured using hardener HY-951 and epoxy resin CY-230. The author created four distinct composites by varying the amount of hemp fiber in the polymer matrix from 0% to 40%. The fabrication of composites involved the use of hand lay-up methods. Used mechanical, thermal, and water absorption tests to decipher material characteristics [4]. Natural fibers like sisal and hemp were employed in a manual lay-up process to create the composites. Provided an update on the material's development in light of the present situation [5]. Synthetic and natural fibers were found to have the same density, and both were found to be nontoxic and nonabrasive [6].

Experiments were conducted on composites made from hemp fibers, and their tensile, impact, and flexural strengths were evaluated [7]. Hemp's flexural strength was measured at 230.09 MPa, tensile strength at 200.5 MPa, and impact strength (IS) at 63.54 kJ/m$^2$. The composites were found to exhibit linear elastic behavior. Scanning electron micrographs show that the natural hemp fiber and the epoxy have bonded perfectly in the shattered specimens of the polymer composite [8]. Researchers have proposed hemp particle reinforced polymer composites as a replacement for wood-based particleboard. Composite composed of hemp and jute fiber was created by the authors [9]. Hemp fiber was discovered to have a higher tensile strength than jute fiber. Jute fiber composite has a superior elastic modulus value. In addition, hemp fiber has a rather high flexural strength. Through thermogravimetric analysis, the authors of this work report that the composite exhibits favorable thermal behavior [10]. Using a toughened epoxy incorporating halloysite nanotubes as the matrix, several hybrid composites with carbon fiber-woven textiles were generated. The hardness, shear strength, and flexural strength of epoxy and carbon fiber composites varied at different rates [11]. In this research, the authors used carbon nano tubes. Composite materials' high value in impact tests has been widely discussed. The acquired value was used to report the material's energy-observing capabilities [12].

The authors shared their hemp and flax research. As an alternative to synthetic fibers and thermosetting plastics, they used thermoforming polymers. Polypropylene biomaterial composites were created from hemp and flax [13]. The material's qualities were tested using tensile, flexural test, and Izod test. Blended polypropylene properties were cited as a strength of the material. Using a hand lay-up method, Kevlar fiber and nano-$TiO_2$ were experimented with as reinforcements in epoxy [14]. After the composite was created, it was subjected to a mechanical evaluation. Up to a specific weight percent of $TiO_2$, material characteristics improve with increasing nano-$TiO_2$ content [15, 16]. The test indicated a rise in tensile strength, hardness, and impact strength of 16 to 42%. Titanium and rice husk ash were used to create composites by the authors [17]. By adjusting the ratio of epoxy and hardener, the composite's titanium content can range from 0% to 6% by weight. The low mechanical qualities are blamed on the material's high titanium content [18]. The sample failed the tensile test because the wrong amount of a component was employed, or because the component was improperly mixed. Banana fiber improves the thermal and mechanical properties of jute/epoxy composites, and reduces the material's moisture absorption, according to studies [19, 20].

In order to compact the composite material, the authors utilized poly(anhydride graphite). According to the author, using it improves the bond's strength and resistance to heat. The characteristics of composites containing bio flour were investigated. They made the composite out of cotton stalk bark and polypropylene wood flour. Bark from cotton stalks was added at concentrations of 2.5%, 10%, 15%, and 30% by weight. Both mechanical and thermal characteristics were tested. Higher quantities of cotton stalk bark in plastic composites were shown to increase their tensile modulus and flexural properties. Increased moisture absorption compared to unmodified polypropylene was shown to be linearly related to the percentage of cotton stalk bark in plastic composites. Cotton stalk bark plastic composites had a greater breakdown temperature than polypropylene, according to the thermodynamic properties. Graphene nanoparticles were combined with carbon fiber and epoxy by the research team. Composites were subjected to field emission-scanning electron microscope testing and mechanical property testing. The A-2 composite was reported to be the most effective (0.5 wt.% of GNP) across all studies.

The environmental friendliness, mechanical qualities, and recycle-readiness of hemp fibers have made them a popular choice among natural fibers reinforced polymer composites. Improving system and process performance without adding extra costs is crucial. Optimization is the technique employed towards this goal.

## Experimentation

### Material

The composite is made from hemp fiber mate, LY-556 epoxy, HY-951 hardener, and nano-$TiO_2$. Nano-$TiO_2$ was purchased from Go green India Pvt. Ltd. in Chennai, and the hemp fiber, epoxy, and hardener were acquired from Kovai Cheenu Enterprises in Coimbatore, India. The mix was 10 parts epoxies (LY-556) to 1 part hardener (HY-951). The mixing was done using white, 50 - 60 nm nano-$TiO_2$. HY951 Hardener is an unmodified aliphatic polyamine with a low viscosity [21]. The epoxy resin LY556 has a medium viscosity and is unmodified because it is based on bisphenol-A. Epoxy LY556 can be used as the basis for a solvent-free curing laminating system by increasing the amount of hardener HY951 from 10 to 12. The reactivity can be modified to meet the needs of any given processing or curing environment [22]. The curing element employed was a hardener. All composites created in this study used a hardener concentration of 10% by weight. Mix LY556 and HY951 in a 10:1 ratio (The resin and hardener need to be thoroughly combined into one consistent material). Epoxy resins can be difficult to work with, but not araldite LY556. As soon as the hardener is added, the curing process begins at ambient temperature and air pressure.

### Composite preparation

To retain the unique properties of each component, composites are made by combining various materials with distinct physical and chemical properties [23, 24]. The composites here were created using a manual lay-up technique and then a compression molding process. Many common kitchen appliances, such as an electric oven, magnetic stirrer, and electronic scale, were put to use here. First, a die shape (15 x 15 cm) was cut from the hemp mat. A beaker containing 150 g (±1 g) of epoxy was heated in an electric oven at 80 °C for 30 min to lower its viscosity. The water in the hemp mat was removed from an electric oven set to 50 °C for 20 min. Epoxy was transferred to a second beaker, and 15 g (±1 g) of hardener was added. Since the addition of the hardener causes an exothermic reaction, heat is released and hardening begins in about 10 to 15 min. This meant that pouring had begun soon after the hardener was mixed.

In order to release the sample from the die after curing, the die is heated and then coated with mold relief agent. The hemp mate was coated with an epoxy hardener mixture, rolled, and the excess epoxy hardener mixture was applied to the die [25, 26]. After closing the die, the compression molding machine was run for a whole day. This method was utilized until the nano-$TiO_2$ was well blended. After the epoxy has been heated, nano-$TiO_2$ is added, and the mixture is then dried in an electric oven at 4 or 8 wt.%. After waiting 30 min, a coupling agent of 10 ml acetone was added to the epoxy mixture. Epoxy and nano-$TiO_2$ were mixed in a magnetic stirrer apparatus at 80 °C for 45 min with a magnetic bit rotating at 500 rpm. After that, nano-$TiO_2$ in epoxy was mixed in the ultrasonic bath for 10 min. After this was done, the mixture was let to remain at room temperature for a while before the hardener (15 g (± 1 g)) was added and it was thoroughly mixed; the rest of the technique utilized to finish fabricating the composites was the same as described before (Table 1).

In general, materials can be found in a wide variety of forms, and these forms can be altered by means of a wide range of tools and machines. Compression molding machines, magnetic stirrers, electric ovens, ultrasonic baths, etc., are some of the most common composites manufacturing equipment. Compression molding is placing material on a heated metal mold, letting it soften, and then closing the mold so that the material is pressed into the mold and takes on the exact shape of the mold. Machines used for compression molding often have a vertical opening. Epoxy was mixed with nanoparticles using a magnetic stirrer. In order to decrease the viscosity of the epoxy and dry out the nanoparticles and hemp mats used in the composite; an electric oven is an essential piece of machinery in the creation of polymer matrix composite. To eliminate contaminants and ensure that the nanoparticles are well mixed with the epoxy matrix, an ultrasonic bath is used.

### Mechanical testing

Because of their low weight and high strength, composites are finding widespread use in manufacturing. To evaluate the composites' strength and durability, mechanical testing is necessary. Their properties will inform the determination of their potential uses once testing has been completed. For widespread use of composites, mechanical testing is a common and fundamental component. Mechanical testing is performed to verify a product's quality and to characterize a material's qualities before it is put to use [27, 28]. Composites are distinguished by their combined light weight, strength, and stiffness. The universal testing machine was used to assess tensile strength, Young's modulus, and elongation in accordance with ASTM D638 [29, 30]. Flexural strength and modulus were evaluated using a three-point bending test machine using the ASTM D790 standard. The impact test and shear strength were measured using the Izod testing machine and the ASTM D256 standard. Measurements of hardness were made using the ASTM D 2583 standard.

## Results and Discussion

### Results of mechanical properties

The mechanical qualities of a substance are those that affect how it reacts to applied forces. Mechanical properties are helpful in determining a material's performance in each application during the selection of materials and loading specification phases. Table 2 displays the values of mechanical characteristics. Figure 1 graphically displays the data for your convenience. It was determined through testing that going above a specific amount of titanium weakens the composites. S8 and S9, both made of a 3-layer mat of natural hemp fiber reinforced with nano-$TiO_2$ at 4 wt.%, reach tensile test values of 33.52 and 31.42 MPa, respectively. When the titanium content is increased above a certain point, the strength decreases. Titanium's strong cohesion between its atoms is largely re-

**Table 2:** Results of testing.

| S. No. | Samples | TS (MPa) | FS (MPa) | IS (Izod test) (KJ/m²) | Hardness |
|---|---|---|---|---|---|
| 1 | S1 | 10.12 | 34.56 | 41.46 | 13 |
| 2 | S2 | 14.56 | 34.62 | 43.52 | 15 |
| 3 | S3 | 16.15 | 34.75 | 45.10 | 21 |
| 4 | S4 | 23.86 | 37.52 | 41.26 | 22 |
| 5 | S5 | 24.52 | 40.12 | 43.88 | 23 |
| 6 | S6 | 28.13 | 41.63 | 45.18 | 24 |
| 7 | S7 | 29.60 | 43.65 | 34.62 | 21 |
| 8 | S8 | 33.52 | 43.72 | 45.91 | 19 |
| 9 | S9 | 31.42 | 37.52 | 41.16 | 15 |

**Table 1:** Different composite samples and their compositions.

| S. No. | Samples | Hemp fiber layer | Hemp fiber weight (g) | Epoxy (g) | Hardener (g) | $TiO_2$ (g) |
|---|---|---|---|---|---|---|
| 1 | S1 | 1 | 6.3 | 145.5 | 14.5 | 0 |
| 2 | S2 | 1 | 6.1 | 145.6 | 14.3 | 4 |
| 3 | S3 | 1 | 6.2 | 145.7 | 14.6 | 8 |
| 4 | S4 | 2 | 12.6 | 145.7 | 14.2 | 0 |
| 5 | S5 | 2 | 12.2 | 145.2 | 14.4 | 4 |
| 6 | S6 | 2 | 12.4 | 145.8 | 14.7 | 8 |
| 7 | S7 | 3 | 18.9 | 145.3 | 14.4 | 0 |
| 8 | S8 | 3 | 18.3 | 145.1 | 14.5 | 4 |
| 9 | S9 | 3 | 18.6 | 144.8 | 14.6 | 8 |

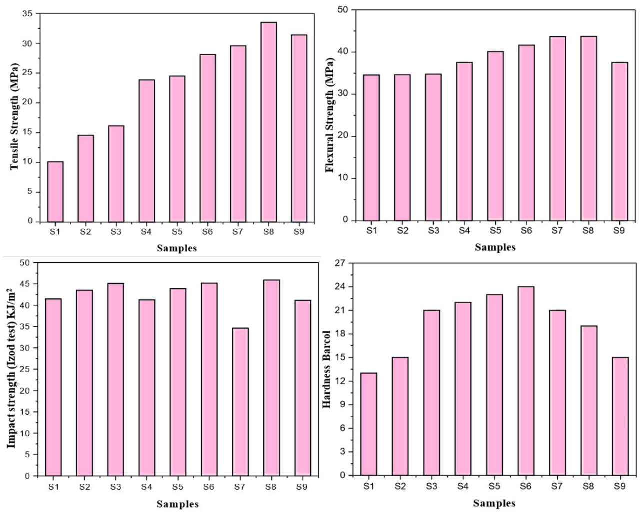


**Figure 1:** Strength properties vs samples.

sponsible for this property. Because of their tendency to form clusters, the nano-$TiO_2$ particles accessible for strengthening are diminished. Both the S8 and S9 composites have comparable flexural strengths of 43.72 and 37.52 MPa, respectively.

An increase in the consistency of the resin phase and a subsequent decrease in its flexural strength will be discussed as a result of an excess of $TiO_2$ particle loading in the organic compound portion. Impact strength can be increased by including titanium nanoparticles in an epoxy in a uniform distribution. However, values dropped to S9 following S8. The aggregation of titanium nanoparticles is the root cause of this decrease due to their mutual affinity. In light of the preceding, the importance of the hardness test relied on the precision with which it was conducted at a given location inside the sample. In the case where the material's hardness corresponds to a fixed value, examining the composite at different points on its plane will produce a varying hardness value (Table 3).

## Optimization

### RSM

Many fields besides design and manufacturing can benefit from RSM's suite of statistical and mathematical tools for modelling, optimizing, and analyzing engineering problems. It's a helpful resource for building and fine-tuning the models. In this investigation: Hemp fiber layer and nano titanium weight percent was focused.

The composites were sampled for nine times, each time with a different composition, and compared the samples over a range of response characteristics. The Design Expert program was used to do statistical analysis on the values acquired from the data after testing according to the ASTM standard. The effect of changing the processing variables on the features of the response was studied using ANOVA. Using analysis of variance, one may determine which process parameters have the most impact on the mechanical properties of composites [30]. Mechanical properties such as tensile strength, flexural strength, impact strength, and hardness have been studied for hemp fiber, nano-$TiO_2$, hardener and epoxy.

### ANOVA

Design-of-experiment software were used and the RSM to analyze the experimental data we collected. After performing ANOVA on all of the response variables and a regression analysis to fit the model and able to assess the importance of the coefficient. Table 4 displays the outcomes of an ANOVA conducted on tensile strength. The model is statistically significant with a F value of 1.50. A chance (tensile strength) p (0.3932) of an F-value this high occurring

**Table 3:** Input variables and their outputs.

| Exp. run | A: Hemp | B: $TiO_2$% | TS (MPa) | FS (MPa) | Impact strength | Hardness |
|---|---|---|---|---|---|---|
| 1 | 3 | 0 | 28.2 | 42.4 | 46.5 | 25 |
| 2 | 2 | 9.65 | 17.4 | 35.8 | 45.8 | 22 |
| 3 | 1 | 0 | 23.6 | 38.9 | 41.3 | 21 |
| 4 | 0.58 | 4 | 30.1 | 39.1 | 41.3 | 14 |
| 5 | 1 | 8 | 15.3 | 36.3 | 45.4 | 18 |
| 6 | 2 | 4 | 11.6 | 36.2 | 42.8 | 14 |
| 7 | 3.41 | 4 | 25.2 | 42.4 | 44.8 | 24 |
| 8 | 2 | -1.65 | 33.7 | 45.8 | 47.8 | 19 |
| 9 | 3 | 8 | 30.1 | 45.3 | 35.6 | 21 |

**Table 4:** ANOVA for the tensile strength.

| Source | Sum of squares | DF | Mean square | F-value | p value | Status |
|---|---|---|---|---|---|---|
| Model | 328.79 | 5 | 65.76 | 1.50 | 0.3932 | Significant |
| A - Hemplayer | 19.44 | 1 | 19.44 | 0.4421 | 0.5536 | |
| B - $TiO_2$% | 108.43 | 1 | 108.43 | 2.47 | 0.2143 | |
| AB | 26.01 | 1 | 26.01 | 0.5916 | 0.4978 | |
| $A^2$ | 161.46 | 1 | 161.46 | 3.67 | 0.1512 | |
| $B^2$ | 119.16 | 1 | 119.16 | 2.71 | 0.1983 | |
| Residual | 131.90 | 3 | 43.97 | | | |
| Cor. total | 460.69 | 8 | | | | |
| Standard deviation = 6.63 $R^2$ = 0.7137 and adeq. precision = 3.4213 | | | | | | |

due to noise is exceedingly low in the derived model. Table 5 displays the outcomes of flexural strengths. The F value of 1.54 indicates the importance of the model. There is a one in 38.3 probability that such a high F value is the result of pure chance. An ANOVA was performed on a quadratic model of response 3 impact strength (Izod test), and the outcomes are displayed in table 6. The model F value of 1.75 indicates statistical significance in this table. An F-value of this magnitude is extremely unlikely to be the result of chance. Table 7 displays the ANOVA findings for the quadratic model's response to the four different hardness transformations (square roots). The model F-value of 2.18 in this table indicates statistical significance. An F-value this high can only be the result of chance events (27.71%). When the value of p is less than 5% and $R^2$ is greater than 90%, it is clear that there is a relationship between the variables, and that the model accurately represents them. The S/N ratio is a proxy for adeq. precision. It's preferable to have a ratio higher than 4. In order to further explore the design space, that model can be used.

Figure 2 displays residual normal probability maps for tensile, flexural, impact, and hardness tests. Their results demonstrate that the residual follows a normal distribution, with the mean and standard deviation located on the least-squares line with just a small number of improbable outliers. In addition, there was no unusual data structure in the model, and all the data fit comfortably inside the bounds.

## Optimization of input parameter

Using the validated model and the optimized process parameters, a 3D RSM graph and contour plots are generated. Figure 3 depicts the results of a hardness test on a hybrid composite fiber by indenting the material at various depths to illustrate the fiber's tensile, flexural, impact strength, and overall hardness. The mechanical properties of the composite were improved by including nano-$TiO_2$ and up to two layers of hemp fiber. It is clear from the 3D and contour plots that the strength dropped as the percentage of nano-$TiO_2$ was raised. RSM and the Design Expert software was used to determine that a two-layer hemp/4% nano-$TiO_2$ composite yielded the best results.

**Table 5:** ANOVA for the flexural strength.

| Source | Sum of squares | DF | Mean square | F-value | p value | Status |
|---|---|---|---|---|---|---|
| Model | 86.76 | 5 | 17.35 | 1.54 | 0.3830 | Significant |
| A - Hemplayer | 36.84 | 1 | 36.84 | 3.27 | 0.1681 | |
| B - $TiO_2$% | 23.95 | 1 | 23.95 | 2.13 | 0.2406 | |
| AB | 7.56 | 1 | 7.56 | 0.6723 | 0.4723 | |
| $A^2$ | 14.89 | 1 | 14.89 | 1.32 | 0.3333 | |
| $B^2$ | 15.22 | 1 | 15.22 | 1.35 | 0.3288 | |
| Residual | 33.75 | 3 | 11.25 | | | |
| Cor. total | 120.50 | 8 | | | | |
| Standard deviation = 3.35 $R^2$ = 0.7200 and adeq. precision = 3.0166 | | | | | | |

**Table 6:** ANOVA for the impact strength.

| Source | Sum of squares | DF | Mean square | F-value | p value | Status |
|---|---|---|---|---|---|---|
| Model | 82.43 | 5 | 16.49 | 1.75 | 0.3417 | Significant |
| A - Hemplayer | 0.0153 | 1 | 0.0153 | 0.0016 | 0.9704 | |
| B - $TiO_2$% | 11.59 | 1 | 11.59 | 1.23 | 0.3480 | |
| AB | 56.25 | 1 | 56.25 | 5.98 | 0.0921 | |
| $A^2$ | 0.9001 | 1 | 0.9001 | 0.0957 | 0.7773 | |
| $B^2$ | 5.06 | 1 | 5.06 | 0.5378 | 0.5165 | |
| Residual | 28.22 | 3 | 9.41 | | | |
| Cor. total | 110.66 | 8 | | | | |
| Standard deviation = 3.07 $R^2$ = 0.7450 and adeq. precision = 3.9560 | | | | | | |

**Table 7:** ANOVA for the hardness.

| Source | Sum of squares | DF | Mean square | F-value | p value | Status |
|---|---|---|---|---|---|---|
| Model | 96.88 | 5 | 19.38 | 2.18 | 0.2771 | Significant |
| A - Hemplayer | 55.87 | 1 | 55.87 | 6.28 | 0.0872 | |
| B - $TiO_2$% | 0.9504 | 1 | 0.9504 | 0.1069 | 0.7652 | |
| AB | 0.2500 | 1 | 0.2500 | 0.0281 | 0.8775 | |
| $A^2$ | 24.05 | 1 | 24.05 | 2.70 | 0.1986 | |
| $B^2$ | 38.23 | 1 | 38.23 | 4.30 | 0.1298 | |
| Residual | 26.68 | 3 | 8.89 | | | |
| Cor. total | 123.56 | 8 | | | | |
| Standard deviation = 2.98 $R^2$ = 0.7841 and adeq. precision = 3.9994 | | | | | | |

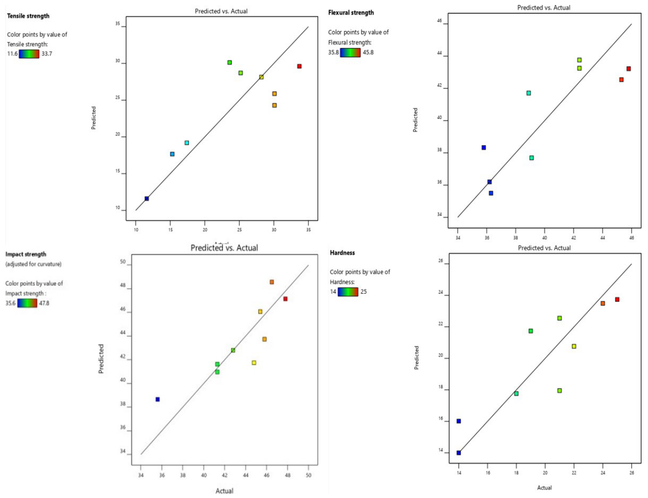
**Figure 2:** Predicted value vs actual value.

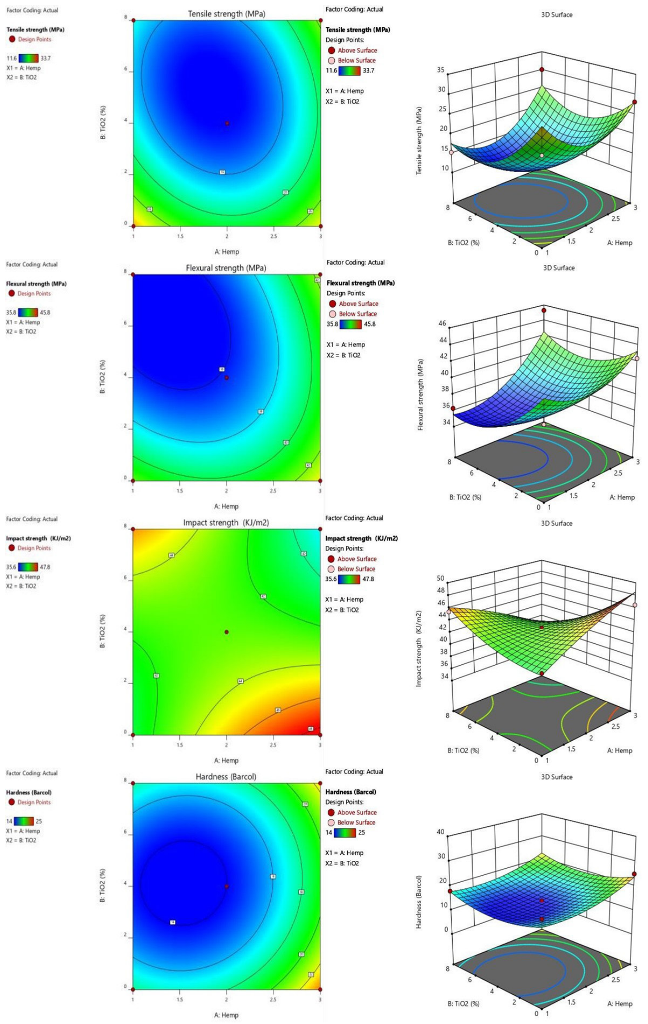
**Figure 3:** Contour plot and 3D RSM plot.

## Perturbation graph

Correct explanations can be found in the perturbation graph. Figure 4 of the perturbation plot depicts the contour plot for hemp and $TiO_2$. In the central composite design, it is recommended that you use only valid factorial combinations.

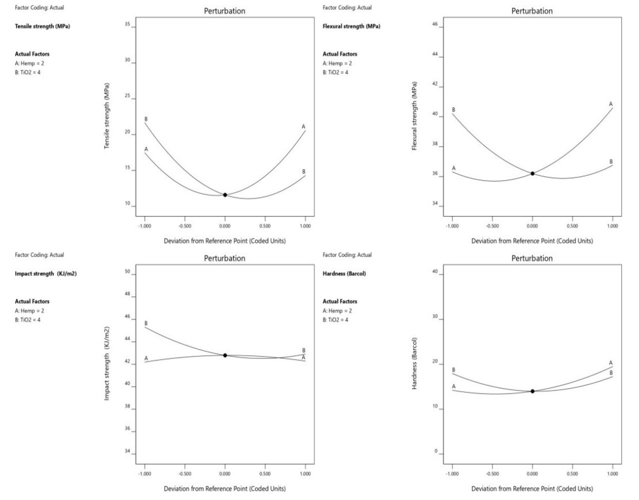
**Figure 4:** Perturbation graph displaying the result of variables on the properties.

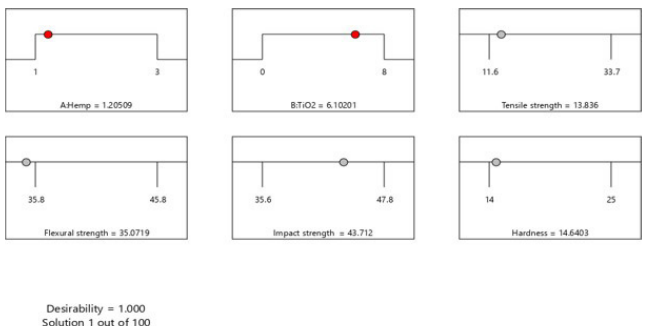

**Figure 5:** Optimal input and output values for the composite fiber response.

To extrapolate to higher axial levels, we use the coded unit of measure of 1 to + 1.

## Solution

For clarification, figure 5 displays the optimized contour plot and ramp report with separate reaction graphs. Mechanical properties including tensile strength (13.836 MPa), flexural strength, impact strength, and Barcole hardness were calculated using the optimal input process variables of 2 phases of hemp fiber with 4 wt.% of nano-$TiO_2$. The model's desirability is 1. RSM has resulted in these optimal values.

Table 7 shows the input and response parameters that were utilized to generate the design-of-experiments for RSM-based optimization. Version 13 of the expert system software was developed using the Box-Behnken method. In addition, the model was determined to be significant for all four answers prior to optimization using an ANOVA test, as shown in table 4, table 5, table 6, and table 7. In ANOVA, it is crucial to consider the model's significance. The p value determines the model's statistical significance. In all cases (tensile, flexural, impact, and hardness tests), the p value is less than 0.05 (5%), showing that the model is accurate. Using the RSM tool, it was determined that, of the nine composites prepared for this investigation, the S5 composite performed the best. In figure 5, nine distinct locations were shown both above and below the slant line. Testing each composite yielded consistent results between 6.4 and +6.4 using a second order equation, as displayed in figure 5. Essentially, the quadratic model can be compared to a straight line. Normal distributions hold for both the predicted and residual sets. Figure 5 demonstrates the reliability of the value by showing that points that are on the line, or even just a little bit closer to it, are preferable. The central dot on the 3D RSM plot and contour plot represents the proper composite, which consists of two layers of natural hemp composite including 4 wt.% of nano-$TiO_2$ (S5). This is because of the powerful intermolecular connections between the crystalline titanium and the natural hemp fiber. Figure 5 shows that the S5 composite has a greater desire factor than 0.65, expanding its potential applications. The proposed model works and is satisfactory.

## Conclusion

The experimental technique we used to create and examine the impact of the processing parameters was a central composite design. 3D RSM plots were used to zero in on the sweet spot for a given set of process parameters. To determine the relationship between the process variable and the results, four quadratic models were developed. The optimal input parameters were two layers of hemp fiber doped with 4 wt.% nano-$TiO_2$. Mechanical properties were evaluated in accordance with ASTM standards for a total of nine newly designed composites. The design expert software applied the RSM to optimize the final result. When there are multiple goals that need to be satisfied, the RSM is used. This study aimed to determine the best processing conditions for transforming hemp fiber into a natural fiber reinforced polymer composite with the desired characteristics. According to previous research, natural fiber keeps the environment in check. Titanium is used to reinforce the all-natural hemp fiber. The mechanical properties of a composite can be enhanced by adding filler material. Due to the fact that high-quality hemp layer 2 wt.% titanium was experimentally determined. Which demonstrated that S5 was a good choice of material. Results from this research suggest that this material has potential for usage in the automobile industry. The engine cover, a section of the door, the gas tank, and so on are all examples.

## Acknowledgements

None.

## Conflict of Interest

None.

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