IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 4, June 2023

Effect of Banana Fibre on Flexural Strength of Reinforced Concrete

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Abstract: *Polymer nanocomposites are one of the important application areas of nanotechnology, as well as naturally derived organic nano phase materials of special interest. Recent years has seen the uses of eco-friendly composites due to its light weight and moderate strength. The potential of nanocomposites in various sections of research and application is promising and attracting increasing investments. The present investigation deals with the synthesis and characterization of banana nanofibers reinforced polymer composites. In this work, nanofibers are extracted from the stem of banana tree and undergoes chemical treatment and mechanical milling process. High energy ball milling is used for preparation of nanofibers to the required dimensions.*
The most important factor in finding good fiber reinforcement in the composites is the strength of adhesion between matrix polymer and fiber. Due to the presence of hydroxyl groups and other polar groups in various constituents of banana, the moisture absorption is high, which leads to poor wettability and weak interfacial bonding between fibers and the more hydrophobic matrices. Therefore, it is necessary to impart a hydrophobic nature of the fibers by suitable chemical treatments in order to develop composites with better properties.

Keywords: Concrete, Banana fibers, Nano silica, Recycled Concrete

I. INTRODUCTION

COMPOSITE MATERIALS - OVERVIEW

The high rate of depletion and the need for better materials have stimulated the search for newer materials compatible technically and with the environment. The waste disposal problems and criteria for cleaner and safer environment, have directed a great part of the scientific research into eco-composite materials that can be easily degraded or bio-assimilated. The natural fibers are abundantly accessible agro-waste is responsible for the new interest in research in sustainable technology. Agricultural related bioresources have received much attention due to their potential key components of bio composites.

NANOTECHNOLOGY IN COMPOSITE MATERIALS

Nanotechnology is the major driving factor for growth at every level of economy. At the 1 nanometer (nm) scales and below, quantum mechanics rules, and at dimension above 100 nm, classical quantum mechanics, physics and chemistry dictate properties of matter. Between 1 and 100 nm a hybrid exists and interesting things can happen such as mechanical, optical, electrical, magnetic, and a variety of other properties can behave quite differently. Polymer nanocomposites contain substantially less filler and thus enable grater retention of the inherent processibility and toughness of the neat resin. Only a percentage of these nanomaterials are normally incorporated into polymer and the improvement is vast due to their large degree of surface area [7-8]. The properties of nanocomposite materials depend not only on the properties of their individual parents but also on their morphology and interfacial characteristics. In the particular case of polymers reinforced with rigid nanofillers, various parameters seem to be of importance in characterizing the fillers. These may be geometrical factors such as the shape, the size aspect ratio, and intrinsic mechanical characteristics such as the modulus or the flexibility, surface properties of specific surface area and surface treatment [9]. The type of polymer matrix used and the possible effects of nanofillers on its microstructure and its intrinsic properties also determine the composite properties.

CHARACTERIZATION OF NANOCOMPOSITE MATERIALS

Characterization of nanocomposites can be performed using different techniques allows a qualitative understanding of the internal structures, spatial distribution of the various phases and direct visualization of defect structure. Scanning electron microscope can be used for structure and morphology determination of nanocomposites.

X-ray diffraction has been widely used for the determination of crystallites and crystallinity index. Thermal properties are very important for nanocomposites. Differential scanning calorimetry to understand the nature of crystallization taking place in the matrix. Thermogravimetric analyzer provides information regarding polymerization reactions and the thermal stability of the nanocomposites. Dynamic mechanical analysis tests can also be used to evaluate nanocomposites performance under various conditions of temperature and relative humidity.

BANANA FIBER REINFORCED POLYMER NANOCOMPOSITE

A nanocomposite material has significantly broadened in the last few years. This term now encompasses a large variety of systems combining one-two and three-dimensional materials with amorphous materials mixed at the nanometer scale. Natural fibers are pervasive throughout the world in plants such as flax, sisal, banana, hemp, banana, wood, grasses etc. Among the all-natural fiber's banana fibers are easily available in fabric and fiber forms with good mechanical and thermal properties. Banana fibers are eco-friendly, low cost and low-density fibers with high specific properties. Therefore, banana based composite materials can be used in industrial, automobile, structural and aerospace applications.

PROBLEM DEFINITION AND SUMMARY

Polymer nanocomposites are an emerging class of new materials which have become an interdisciplinary field and one exciting research area is the isolation of nano cellulose from bio resources using the top-down technique. Polymer nanocomposites comprise a new class of materials where nano scale particles are finely dispersed within the resin. Nano particles take advantage of their dramatically increased surface area to volume ratio. Polymer composites can be reinforced by nano particles, resulting in novel materials which can be used as lightweight replacements for metals. Such nano technologically improved materials enable a weight reduction accompanied by an increase in stability and enhanced function. The direction of using nano fibers from natural fibers as reinforcing materials in plastics may bring changes in the manufacturing scenario since banana fibers are biodegradable and eco- friendly. These are being widely developed to meet the requirements of automotive, aerospace, structural, nonstructural and electrical applications. Nano fibers from natural fibers may evolve as an alternative to conventional nanoparticles in the future. One of the future processing possibilities of composites could be biomimetic processing approaches in view of their great potential in the development of new high-performance materials with low environmental impact, it being environmentally friendly and energy efficient. In the case of development of diverse nanocomposites consisting of different combinations of nano materials (fibers or particles or platelets or tubes), and polymer matrices at various weight fractions or volume fractions, the self-assembly process, a simple approach belonging to biomimetic

process of making nanocomposites, can be adapted. Even wood and other plant based fibers can also be considered as natural, but a complex and highly sophisticated composites, since cellulose microfibrils in these materials are embedded in lignin matrix self-assembly process.

LAYOUT OF THE PROJECT

The present work involves the use of banana natural fibers to be used in different forms for the preparation of composite material. Banana natural fibers are mechanically synthesized and various characterization techniques are used for converting the raw material into a required form.

The work involves the following steps:

Synthesis of banana fibers by chemical treatment and mechanical milling into nanofibers.

Characterization of treated and untreated banana fibers is carried out by using Fourier transform infrared spectroscopy analysis, X-ray diffraction, and scanning electron microscopy analysis. The chemical composition of the raw material is analyzed using flourier transform infrared spectroscopy and the particle size of the nano powder obtained by synthesis process is found out using X-ray diffraction technique. The structure of the raw material is analyzed using scanning electron microscopy

Fabrication of banana nanoparticles reinforced polymer composites of neat composite composites (70 wt.%/30 wt.%) and with reinforcement of different weight percentage of banana nanofibers in the polymer resin (neat composite, 2, 4, 6 and 8 wt.%) composites. Testing of prepared banana nanocomposites specimens for mechanical, water absorption and thermal properties.

Preparation of nanocomposite specimens for testing mechanical properties like tensile strength, flexural strength, impact Strength, hardness and damping property which is tested as per ASTM standards.

Preparation and testing of banana nanocomposite samples for thermogravimetric analysis, diffraction scanning calorimetric and Dynamic Mechanical Analysis.

Mathematical models formulated using regression and the results from the predicted models are compared with the experimental data and validation of the mechanical and thermal properties

II. LITERATURE REVIEW

Papers Publications in Journals:

P.Surya Nagendra, VVS Prasad, Koona Ramji, Gangadhara Pusty " Synthesis of Bio-Degradable Banana Nano fibers" International Journal of Innovative Technology and Research, Vol. No.2, Dec - Jan 2014, 730-734.

P. Surya Nagendra, VVS Prasad, and Koona Ramji "Fabrication and Mechanical behavior of Banana Nano Fiber Reinforced Epoxy Composite" Journal of Material Science and Mechanical Engineering (JMSME), Vol.2, No.5, April-June, 2015, 483-485.

P. Surya Nagendra, VVS Prasad, and Koona Ramji "Experimental Studies of Nano Banana Fiber Various Mechanical Properties of Laminated Epoxy Composite" Advances in Polymer Science and Technology: An International Journal 2015; 5(4): 44-50.

P. Surya Nagendra, VVS Prasad, and Koona Ramji "Alkali Treated Water Absorption of Banana Nano Filler/E- Glass Fiber Composites" Andhra University Journal of Engineering, Volume 2 - No.1, Jan-2016, pp no: 50-54.

Papers Published in Conferences:

P. Surya Nagendra, VVS Prasad, K, Ramji "Fabrication and Testing of Raw Banana Fiber as Reinforcement Material in Polyester Composites" National Conference on Advances in Materials Engineering (MATERIAUX - 2014)" Metallurgical Engineering, AUCE(A), Andhra University, 06-07 March 2014.

P. Surya Nagendra, VVS Prasad, K, Ramji "Effect on Mechanical Properties of Banana Nano Fiber Reinforced Polymer Composite" Twenty Eighth of Metallurgical and Materials Engineers, National Conference on "Frontiers in Material Processing" JNTU-V, January 23&24, 2015.

P. Surya Nagendra, VVS Prasad, and Koona Ramji "A Study on Dynamic Mechanical Analysis of Natural Nano Banana Fiber Filled Epoxy Composites" International Conference on Advancements in Aeromechanical Materials for Manufacturing (ICAAMM-2016), Elsevier Journal Materials Today Procedia. 7th-9th July 2016

III. REGRESSION ANALYSIS, EFFECT OF PROCESS PARAMETERS MECHANICAL AND THERMAL PROPERTIES ANOCOMPOSITES

INTRODUCTION

These statistical methods for data analysis is used to validate the experimental parameters by using regression analysis. It is used to ensure that the intended constructs can be justified, and to prevent the variables that do not represent the intended to measure are included in the final model. Regression analysis is used to test the established hypotheses. This chapter describes the importance of predicted models of regression results were compared with experimental values. From this, one of the developed equations which are useful for prediction of the trend pattern. In this direction regression analysis is a statistical tool for the investigation of relationships between variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent

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variable and one or more independent variables. An attempt has been made to regression analysis and Analysis of variance (ANOVA) is used to check the validity of the model. The results indicated that the developed models are suitable for prediction of mechanical and thermal properties of banana nanofiber reinforced composite.

DATA ANALYSIS OF EXPERIMENTAL RESULTS

The data analysis is a model which describes the behavior of the system, statistical methods are used to developed model. It will first describe the chosen statistical methods, the variables that are used and then describe the data collection process. Regression analysis can be used to come up with a mathematical expression for the relationship between the two variables. The primary data was collected from respondents that were identified and exported directly Statistical package for the social science and analyzed.

Regression Analysis

A regression describes and evaluates the relationships between a given dependent variable and one or more independent variables. Earlier research focusing on similar subjects has found significant results using regression analysis. During the regression analysis, important assumptions for a valid regression will be elaborated and tested in order to ensure that the final regression models. However, it is also used to understand which, among the independent variables relate to the dependent variable.

The performance of regression analysis methods in practice depends on the form of the data generating process, and how it relates to the regression approach being used. In the present study the results obtained from the experimental data on mechanical properties, water absorption and Thermal properties are developed by using the regression analysis. The data required for regression analysis are generated by experimental data, the data set is used to build model and the other for validation. The data created is subjected testing and regression analysis is done by passing the input and output data as arguments to the program and the polynomial equations are generated. After the analysis is done the required 'R-square' value and coefficients are obtained. The predicted values are then back substituted for finding out error and the error percentage is then calculated.

EXPRESSION FOR POLYNOMIAL REGRESSION MODEL

The general equation for polynomial equation that can be written in the form of

$$axn + bxn\text{-}1 + . . . + rx + s = 0, \qquad (3.1)$$

where a, b, . . ., r and s are constants.

The largest exponent of 'x' appearing in a non-zero term of a polynomial is considered as the degree of that polynomial.

Considerations in fitting of polynomial equation for mechanical properties

The polynomial models of second order can be used where the relationship between study and explanatory variables is curvilinear. It is always possible for a polynomial of order n-1 to pass through n points so that a polynomial of sufficiently high degree can always be found that provides a "good" fit to the data. Such models do not enhance the understanding of the unknown function. From the experimental data of the banana nanofibers composite of different weight percentage and their mechanical properties were formulated in polynomial equation by the regression model.

The equations obtained from the regression analysis for the mechanical properties are represented below.

Tensile Strength,	$yt = -6.113x2 + 49.89x + 78.66$	(3.2)
Impact Strength,	$yi = -0.04321x2 + 0.4017x + 2.684$	(3.3)
Flexural Strength,	$yf = -3.22x2 + 26.74x + 114.1$	(3.4)
Hardness,	$yh = -0.2214x2 + 2.551x + 79.87$	(3.5)
Damping ratio,	$yd = -0.02839x2 + 0.1906x + 2.467$	(3.6)

Considerations in fitting of polynomial equation for thermal properties

This function fits a polynomial regression model to the powers of a single predictor by the method. Interpolation and calculation under the curve are also given. The thermal properties are analyzed by using thermogravimetric analysis, differential scanning calorimetry and dynamic mechanical analysis have been formulated in polynomial equation by regression models.

Thermogravimetric Analysis

Thermal degradation temperature (Tg) can be expressed as

$$y = -0.7068x^2 + 6.123x + 332.3 \quad (3.7)$$

Decomposition temperature (Tdecomp) can be expressed as

$$y = -0.4248x^2 + 4.032x + 533.2 \quad (3.8)$$

Differential Scanning Calorimetry

Crystallization temperature (Tc) can be expressed as

$$y = -0.2666x^2 + 2.242x + 83.36 \quad (3.9)$$

Melting temperature (Tm) can be expressed as

$$y = -0.5891x^2 + 5.289x + 131.6 \quad (3.10)$$

Dynamics Mechanical Analysis

Storage modulus (E') can be expressed as

$$y = -45.77x^2 + 419.7x + 569.9 \quad (3.11)$$

Loss modulus (E") can be expressed as

$$y = -37.71x^2 + 374.6x + 785.3$$

Tan delta (δ) can be expressed as

$$y = 0.000071x^2 - 0.01117x + 0.3138 \quad (3.13)$$

The mechanical properties such as tensile strength, impact strength, flexural strength, hardness and damping ratio has been predicted using the above equations and compared with the values obtained from the experiment test data. Thermal Properties like thermal degradation temperature and decomposition temperature from TGA, crystallization temperature, melting point temperature from DSC, and the dynamic behaviours like storage modulus, loss modulus and tan delta values has been predicted using the above equations and compared with the results obtained from the experiment test data. It is observed that the banana nanofibers reinforced composites with different weight percentages show good agreement with regression models, the remarks are found to be capable of predicting the percentage of error.

R, R2, ADJUSTED R2

'R' is a measure of the correlation between the experimental value and the predicted value of the response (criterion) variable. R2 is called the coefficient of determination indicates the explanatory power of any regression model. Its value lies in between '0' and '+1'. It can be shown that R2 is the correlation between experimental and predicted value. It will reach a maximum value when the dependent variable is perfectly predicted by the regression. R2 is the square of this measure of correlation and indicates the proportion of the variance in the response variable, which is accounted for by the model. In essence, this is a measure of how good a prediction of the criterion variable can be made by knowing the predictor variables. However, R2 tends to somewhat overestimate the success of the model when applied to the real world and so an adjusted R2 value is calculated which takes into account the number of variables in the model and the number of observations the model is based on. This adjusted R2 value gives the most useful measure of the success of the model.

EXPRESSIONS FOR THE OUTPUT VARIABLES - ANALYSIS OF VARIANCE (ANOVA)

Analysis of variance is a powerful statistical technique used to confirm the effect of several simultaneously applied factors on the response variable. A null hypothesis, postulating no dependence of the applied factors and response variables are considered and is checked for its validity. degrees of freedom (df) and the sum of the squares (ss) are computed from the consideration data. f-statistic (variance ratio) is computed as the ratio of sums of squares denoting influence of factors and their interdependence. The computed value of variance ratio (f) is compared with the standard ANOVA table and the hypothesis is significant or not significant. The significance of the parameters on the responses could be found using ANOVA. Analysis of Variance (ANOVA) consists of calculations that provide information about levels of variability within a regression model and form a basis for tests of significance. In this work, a commercially available mathematical software package Statistical Package in Social Science was used for the computation of regression constants and parameters.

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SIGNIFICANCE OF REGRESSION

The significance of a regression coefficient in a regression model is determined by dividing the estimated coefficient over the standard deviation of this estimate. To determine the regression analysis, there is a relationship between response variable 'y' and a subset of regression. The hierarchical model of ANOVA response as shown in Table 6.1, the coefficient of determination R-square is proportion of variability. In this definition, the term "variability" is defined as the sum of squares. There are equivalent expressions for R-square based on analysis of variance decomposition. Adjusted R- square is a modification of R-square that adjusts for the number of terms in a model

Table 3.1 ANOVA response

Source	Hierarchical Method				
Model	Degrees of freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Significant
Regression	k	SSR	MSR	MSR MSE	-
Error	n-k-1	SSE	MSE	-	-
Total	n-1	SSy = SSR + SSE	-	-	-

ANOVA response on mechanical properties

Analysis of variance is similar to regression in that it is used to investigate and model the relationship between a response variable and one or more independent variables. The main purpose of this work is to use a new technique that combines functional data analysis and design of experiments, functional ANOVA for a one- way treatment to measure the influence of adding banana fiber nanocomposites. The functional ANOVA uses all the information of each test or functional data. The results obtained using this methodology with the mechanical properties indicates that the percentage weight of nanofibers significantly affects the banana fiber nanocomposites.

Table 3.2 ANOVA response on tensile strength

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distributions (P)	
Model	2	8408.65	4204.33	44.81	0.022	Significant
Error	2	187.64	93.82	-	-	
Total	4	8596.29	-	-	-	

From the table 3.2. analysis of variance, a complete realization of the tensile strength of the nanocomposites and their effects were achieved. The variation of percentage weight nanofibers and tensile strength was mathematically modeled using

response surface methodology. Finally, the developed model is validated with the set of experiments. The Model F-value of 44.81 implies the model is significant and the R- squared value is obtained as 97.8% and the adjusted R-squared 95.6%. It is observed that developed model is in close agreement with the experimental results

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Table 3.3 ANOVA response on impact strength

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distrubution (P)	
Model	2	0.543754	0.271877	34.06	0.029	Significant
Error	2	0.015966	0.007983	-	-	
Total	4	0.559720	-	-	-	

Impact strength of the banana fibers nanocomposites and their effects were achieved by ANOVA. The predicted data from the regression analysis is used for surface roughness with impact properties of different weight percentage of nanofibers. The developed model is validated with the set of experiments. The variance ratio is 34.06 which implies the predicted model is significant as given in the Table.5.3 and the R-squared value is obtained as 97.1% and the adjusted R-squared 94.3%.

Table 3.4 ANOVA response on flexural strength

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distributions (P)	
Model	2	2362.37	1181.19	35.60	0.027	Significant
Error	2	66.36	33.18	-	-	
Total	4	2428.73	-	-	-	

Flexural strength of the banana fiber nanocomposites and their effects were achieved by ANOVA. The predicted data from the regression analysis is used for surface roughness with flexural properties of different weight percentage of nanofibers. The developed model is validated with the set of experiments. The variance ratio is 35.60 which implies the predicted model is significant as given in the table. 5.4 and the R- squared value is obtained as 97.3% and the adjusted R-squared 94.5%.

Table 3.5 ANOVA response on hardness

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distrubution (P)	
Model	2	35.3189	17.6594	34.19	0.028	Significant
Error	2	1.0331	0.5166	-	-	
Total	4	36.3520	-	-	-	

From the ANOVA response Table 3.5 the model f-value of 34.19 implies the model is significant and the R- squared value is obtained as 97.2% and the adjusted R- Squared 94.3%. The hardness of the nanofibers composites and their effects were achieved by analysis of variance. The developed model is validated with the set of experiments and the model is suitable.

Table 3.6 ANOVA response on damping ratio

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F Distributions (P)	

DOI: 10.48175/IJARSCT-11521

Model	2	0.233869	0.116934	38.90	0.025	Significant
Error	2	0.006011	0.003006	-	-	
Total	4	0.239880	-	-	-	

The stiffness of the nanofiber composites with different weight percentage and their effects werw predicted by regression analysis as given in Table. 3.6 The predicted model is validated with the set of experimental values. These results influence the overall damping effect of the nanofiber composites. The variance ratio 38.90 is significant and the R-squared value is 97.5% and the adjusted R-squared 95.0% is satisfied with the experimental results.

ANOVA response on thermal properties

The thermal properties like thermal degradation temperature and decomposition temperature by TGA. The crystallization temperature, and melting point temperature by DSC, and the dynamic behaviours like storage modulus, loss modulus and tan delta values by DMA are used for ANOVA response.

Table 3.7 ANOVA response on thermal degradation temperature (Td)

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F Distributions (P)	
Model	2	120.697	60.3484	32.97	0.029	Significant
Error	2	3.661	1.8305	-		
Total	4	124.358	-	-		

The variation of percentage weight nanofibers and surface roughness with thermal degradation was mathematically modeled using response surface methodology. The model variance ratio is 32.97 is significant as shown in Table 5.7, R-squared value is 97.1% and the adjusted R- squared is 94.1%. The prediction provides valuable information that can be used to select banana nanofiber composite for certain end-used application.

Table 3.8 ANOVA response on thermal decomposition (Tdecomp)

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distrubution (P)	
Model	2	56.4789	28.2394	34.76	0.028	Significant
Error	2	1.6250	0.8125	-	-	
Total	4	58.1039	-	-	-	

The thermal decomposition of banana fiber nanocomposites was predicted by using analysis of variance as shown in table 3.8. The ANOVA response predicts decomposition information of nanofiber composites and composite life time. The variance ratio is 34.76 and R-squared value is obtained as 97.2% and the adjusted R- squared 94.4%. which is suitable for experimental values.

Table 3.9 ANOVA response on crystallization temperature (Tc)

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distrubution (P)	
Model	2	16.4014	8.20069	33.82	0.029	
Error	2	0.4849	0.24245	-		Significant
Total	4	16.8863	-	-		

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The variation of percentage weight of banana nanofibers and surface roughness with crystallization temperature was mathematically modeled using response surface methodology is shown in Table 3.9. The developed model is validated with the set of experimental data of crystallization temperature. The model f- value of 33.82 implies the model is significant and the R-squared value is obtained as 97.1% and the adjusted R-squared 94.3%. It is observed that developed model is in close agreement with the experimental results.

Table 3.10 ANOVA response on melting temperature (Tm)

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distrubution (P)	
Model	2	91.0327	45.5163	33.18	0.029	Significant
Error	2	2.7432	1.3716	-		
Total	4	93.7759	-	-		

The thermal behaviors heat flow with temperature variation and thermal stability of the nanofiber composites were predicted by regression analysis. The melting point temperature of the banana fiber nanocomposites and their effects were achieved by ANOVA. The different weight percentage of nanofibers and surface roughness with experimental data was modeled by using response surface methodology, as shown in Table 3.10. The predicted model is validated with the set of experimental values and the model f-value of
33.18 implies the model is significant the R- squared value is obtained as 97.1% and the adjusted R- squared 94.1%. These analyses useful for composite applications and different temperature conditions

Table 3.11 ANOVA response on storage modulus

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distrubution (P)	
Model	2	583905	291952	36.52	0.027	Significant
Error	2	15986	7993	-	-	
Total	4	599891	-	-	-	

Table 3.11 describes the storage modulus of the banana fiber nanocomposites and their effects by ANOVA. The developed model is validated with the set of experiments and model of variance ratio value is 36.52. This analysis provides glass transition temperature secondary transition temperatures and yield information about the morphology of the nanofiber composites. It is observed that the model is in close agreement with the experimental results. The R-squared value is obtained as 97.3% and the adjusted R-squared 94.7%.

Table 3.12 ANOVA response on loss modulus

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distrubution (P)	
Model	2	530872	265436	34.05	0.029	Significant
Error	2	15589	7795	-		
Total	4	546461	-	-		

The complete realization of the loss modulus of the nanofibers composites and their effects were achieved by analysis of variance. The variation of percentage weight nanofibers and surface roughness with loss modulus was mathematically modeled using response surface methodology. The predicted model f-value of 34.05 implies the model is significant. and the R-squared value is obtained as 97.1% and the adjusted R-squared 94.3% it is observed that developed model is satisfied with experimental results as shown in table 3.12

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Table 3.13 ANOVA response on tan delta

Source	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Square (MS)	Variance ratio (F)	F-Distrubution (P)	
Model	2	0.0044955	0.0022478	35.89	0.027	Significant
Error	2	0.0001253	0.0000626	-	-	
Total	4	0.0046208	-	-	-	

The tan delta of the banana fiber nanocomposites and their response was tabulated by ANOVA. The different weight percentage of nanofibers and surface roughness with tan delta was modeled by using response surface methodology. The above table is validated with the set of experimental values and the Model f-value of 35.89 is significant and the R-squared value is obtained as 97.3% and the adjusted R-squared is 94.6% satisfied the experimental results as shown Table 5.13. This result provides the phase lag the displacement composite to the applied force which implies the damping property of banana nanofiber composites.

COMPARISION OF MECHANICAL PROPERTIES WITH REGRESSION ANALYSIS

The values obtained using the regression equations is represented in Table 5.14 (Appendix - II). The experimental values of mechanical properties are compared with the predicted values. The error percentage is tabulated in Table 5.16 (Appendix - II)

Tensile strength results predicted by regression analysis

The tensile strength values of the predicted by regression model are compared with experimental results with the different weight percentages of nanofiber reinforcement in epoxy resin as shown in Fig.5.1. It is observed that the maximum error

2.67 for regression model when compared to experimental results Which shows better agreement with experimental results for 4wt. % of BNFC.

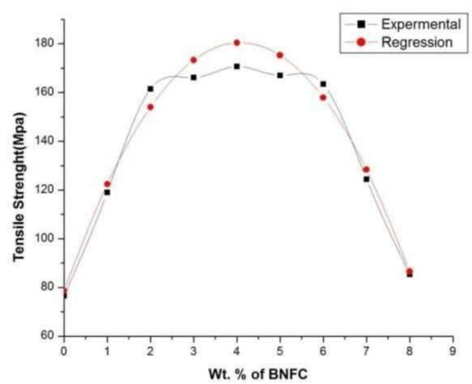

Fig.3.1 Regression with experimental values for tensile strength

Impact strength results predicted by regression analysis

The percentage error observed maximum for regression model is 2.82, regression analysis are presented in Fig.5.2. It is observed that maximum error 2.82 for regression model at 6wt. % of BNFC Composite. These errors are due to the precence of voids in the nanofibr composites.

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.301

Volume 3, Issue 4, June 2023

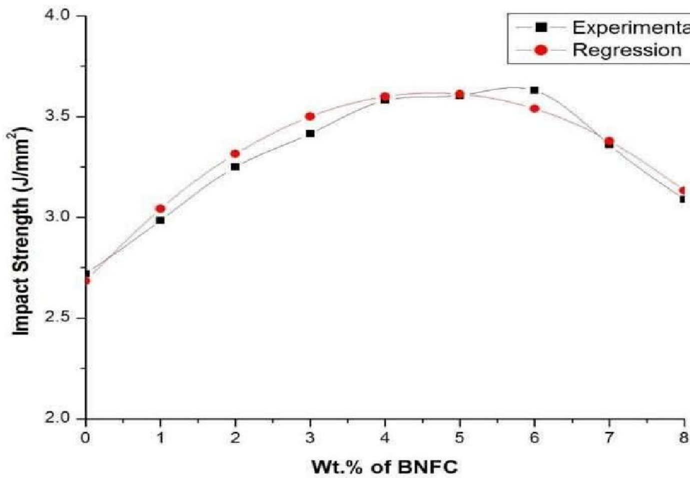

Fig.3.2 Regression with experimental values for impact strength

Flexural strength results predicted by regression analysis

The percentage error observed in regression model is 2.82, regression analysis is presented in Fig.5.3. It is observed that maximum error 2.82 for regression model at 3 wt. % of BNFC Composite. These errors ar due to the presence of voids in the nanofiber composites.

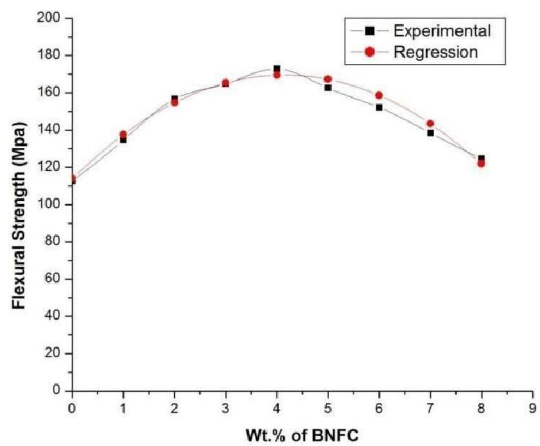

Fig.3.3 Regression with experimental values for flexural strength

Hardness results predicted by regression analysis

Fig.5.4. The maximum error 1.35 for the regression model.The error is observed in 6wt.% nanofiber composites with regression values.The results provide the homogenity of the nanofiber composites.

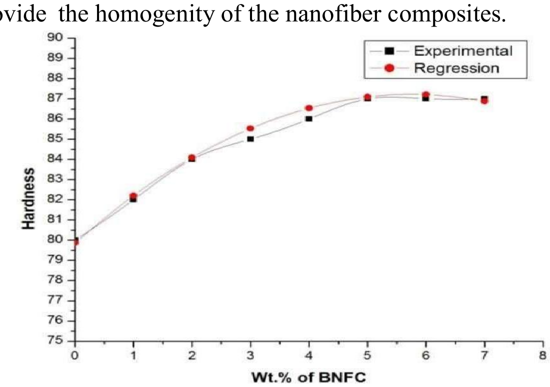

Fig.3.4 Regression with experimental values for hardness

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Damping property results predicted by regression analysis

The damping ratio error percentage predicted by regression model is compared with experimental results with the weight percentages of nanofiber reinforcement in epoxy resin as shown in Fig.5.5. It is observed that the maximum error 2.44 for regression model for the 2wt. % of BNFC.

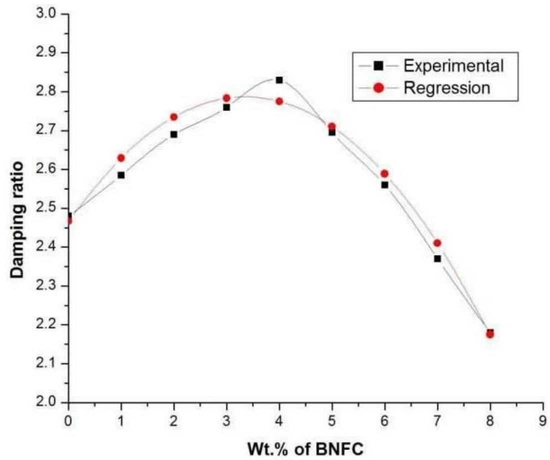

Fig.3.5 Regression with experimental values for damping ratio

COMPARISION OF THERMAL PROPERTIES WITH REGRESSION ANALYSIS

The thermal properties results obtained by the predicted models of regression were compared with experimental results of BNFC composite with different wt.% of nanofiber reinforcement.The values obtained from the regression equations are tabulated in Table 5.15 (Appendix -II). The error percentage between experimental values and the values obtained experimentally for both mechanical and thermal properties are represented in Table 5.17 shown in Appendix - II.

Thermal degradation temperature

The error percentage provides the thermal stability of nanofibers composites with change in temperature. It is also useful to determine the weight loss of the composites at specified temperature. The maximum error of regression models is 0.35 for 3wt. % nanofiber composites as shown in Fig.5.6.

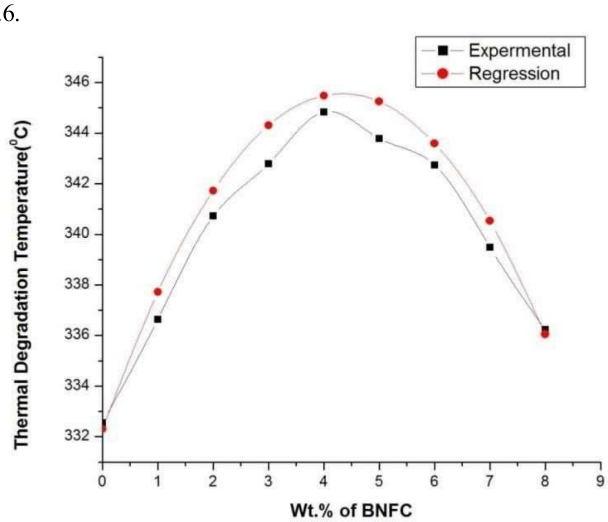

Fig.3.6 Regression with experimental values for thermal degradation temperature

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Decomposition temperature

The decomposition temperature values of the predicted by regression model are compared with experimental results with the different weight percentages of nanofiber reinforcement in epoxy resin as shown in Fig.5.7. It is observed that the maximum error 2.07 for regression were observed in 3wt. % nanofibers composites. These error values are useful to predict the composite life.

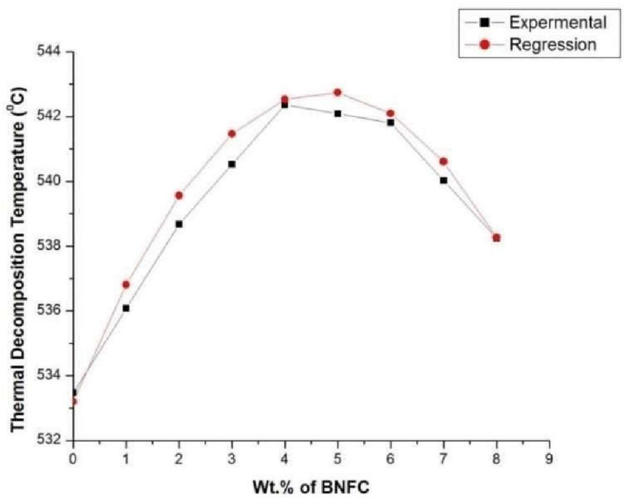

Fig.3.7 Regression with experimental values for decomposition temprature

Crystallization temperature

The effect of banana nanofiber reinforcement alters the crystallization temperature of nanofiber composites. The values predicted by regression model, compared with experimental results with the nanofiber reinforcement in epoxy resin as shown in Fig.6.8. The percentage error is less. These error percentage results are useful to adjust the processing parameters of reinforced polymer nanofibers composites.The maximum error in a regression analysis is 0.9, for 5wt. % banana fiber nanocomposites.

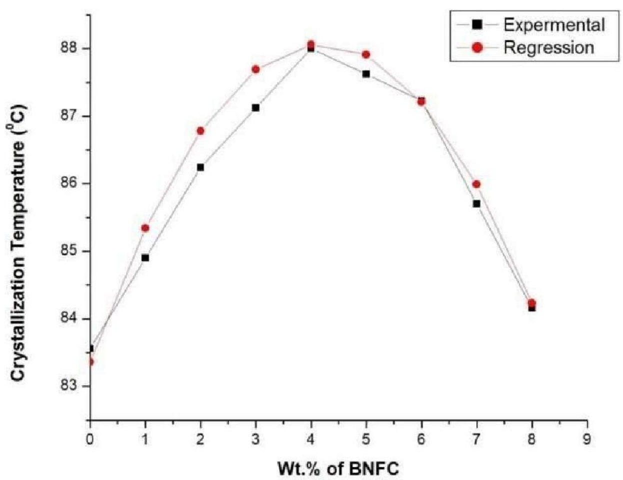

Fig.3.8 Regression with experimental values for crystallization temperature

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Melting point temperature

The melting point temperature values of the predicted by regression model and compared with experimental results with the different weight percentages of nanofiber reinforcement in epoxy resin as shown in Fig.5.9. It is observed that the maximum error

0.08 for regression model for 3wt. % nanofibers composites.

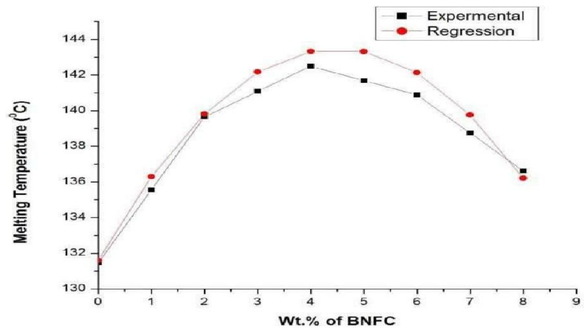

Fig.3.9 Regression with experimental values for melting point temperature

Dynamic Mechanical Analysis

The predicted results obtained by regression are compared with experimental values and the comparison graphs are plotted for storage modulus, loss modulus and tanδ.

Storage Modulus

The storage modulus values obtained by DMA were predicted by regression model are compared with experimental results with the different weight percentages of nanofiber reinforcement in epoxy resin as shown in Fig.5.10. It is observed that the maximum error 3.42 for regression model for 2wt. % banana nanofiber composites.

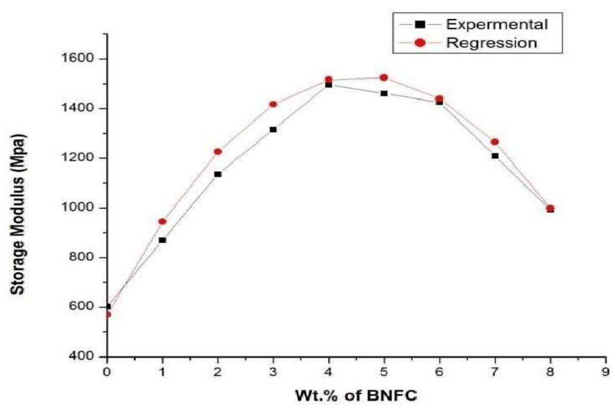

Fig.3.10 Regression with experimental values for storage modulus

Loss Modulus

The Loss Modulus values of the predicted by regression model compared with experimental results with the different weight percentages of nanofiber reinforcement in epoxy resin as shown in Fig.5.11. The maximum error 2.75 for Regression model and

3.05 for 2wt. % nanofibers composites.

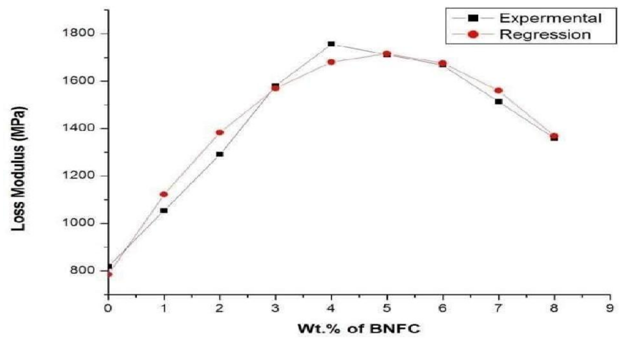

Fig.3.11 Regression and experimental values for loss modulus

Tan δ

The Tan δ error percentage values are predicted by regression model compared with experimental results with the different weight percentages of nanofiber reinforcement in epoxy resin as shown in Fig.6.12. It is observed that the tan delta decreased with the increased nanofibers reinforcement, at 3wt. % maximum error 3.85 for Regression model.

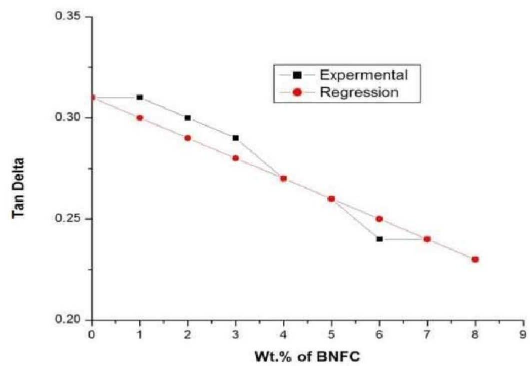

Fig.5.12 Regression and experimental values for tan δ

IV. SUMMARY

The mechanical properties of the nanofiber's composites such as tensile strength, impact strength, flexural strength, hardness, damping and thermal properties like thermal degradation temperature, decomposition temperature, crystallization temperature, melting temperature and the dynamic behaviors like storage modulus, loss modulus and tan delta prediction models are developed using regression. The experimental data have been used to develop these models. Then models are used to predict the mechanical, thermal properties at different weight percentage of banana fiber nanocomposite. The comparison of predicted values with experimental values in all tested cases indicates that the error is less, than 5% in the regression model when compare to experimental results. From this it is observed that this model is found to be capable of predicting the above parameters with accuracy

V. CONCLUSIONS AND FUTURE SCOPE

CONCLUSION

The present work investigates the performance of banana fiber polymer nanocomposites. Different parameters which affect the mechanical, thermal and water absorption properties are studied. Most of the investigations include experiments and analytical modelling. From all these investigations, it is observed that there are several common conclusions besides those remarks at the end of each chapter for the banana fiber nanocomposites.

Physical and Tensile Properties of the banana fiber nanocompoaites exhibit superior advantages over the synthetic fibers especially in cost, environmental aspects and high specific modulus compared to synthetic fibers. The physical and mechanical properties of the banana fiber nanocompoaites are observed. The results found good agreement within the range in the literature. The tensile strength of nanocomposites was increased from 50% to 96% with an increasing

Banana nanofiber neat composite, 2, 4, 6 and 8wt. % contained. The maximum tensile strength improvement was noticed as 96% for the 4wt. % banana fiber nanocomposites, and then decreased when the content of fibers is 6wt. % and 8wt. %. The increase in tensile strength is attributed to strong interaction between the polymer and banana nanofibers. The interaction has a large impact in nanocomposites due to the large interfacial area between the nanofibers and the resin.The improvement in tensile strength appears to be promising in structural applications irrespective of the direction of the applied load. However, the drawbacks of natural fibers include wear, low shear strength and compression limiting the potential of natural fiber composites in structural use. The drawbacks can be partially overcome by introducing chemical treatment.

The mechanical properties of fiber reinforced composites are dependent upon the stability of the interfacial region. Thus, the characterization of the interface is of great importance. Alkali treatment increases the impurities of fiber surface and increased the interface between fiber and matrix, and also decreases the fiber pullout which enhanced tensile, flexural, impact and hardness properties. Different parameters affected the mechanical properties of natural fiber composites in this investigation, namely curing process, nanofiber weight fraction and fiber treatment. SEM analysis showed that the interaction between the hybrid fibers and polymer matrix is poor such that fiber debonding, fiber pull-out, matrix fracture and fibers fracture occurred. The experimental data of mechanical properties results was compared with mathematical predictions and found to be in good agreement with some of these models.

Effects of Water Absorption, The results of this part discussed the water absorption characteristics and environmental affects of alkali treated banana fiber nanocomposites at immersion times, and fiber weight fraction and temperature surrounding played a role in the rate of moisture uptake. The natural fiber nanocomposites were found to be dependent on the fiber length and fiber weight fraction. Thermal properties of composites and thermal stability of banana fiber reinforced polymer nanocomposites are considerably dependent on nanofiber weight fraction. The results exposed that incorporation of the nanofibers gave rise to a considerable increase of the E', Tg and a decrease in the tan delta values.

All the nanocomposites had a higher melting temperature compared to neat composites. The TGA curves indicate that the thermal degradation of pure epoxy composite started at 344°C and 100% degradation was noticed at 559°C. However, with the incorporation of banana nanofibers, there was a substantial enhancement in the thermal stability of the nanocomposites with an initial degradation temperature at 370°C and final decomposition at 584°C. This indicates that a significant increase in the Banana nanofibers content of fiber reinforced composites plays an important role in controlling its rate of thermal degradation. DSC curves show that the addition of banana nanofibers increased the crystallization temperature Tc by up to 1-4°C compared to the Neat composites. This result indicates that the nucleating effect of Banana nanofibers composites was strengthened. The banana nanofibers played the role of a nucleating agent and facilitated crystallization due to the strong interaction between banana nanofibers and polymer resin. The nucleating effect of banana nanofibers could also explain the increase of crystalline. The nano dispersion of the filler and its orientation in the matrix is among these factors. DMA results banana nanofiber composites indicates the storage modulus E' decreases with increasing temperature, while the loss modulus E" increases. This indicates that the increased modulus, together with a positive shift in the tan delta peak position.

FUTURE SCOPE

In this research work, the mechanical and Thermal behavior of a nanocomposite was evaluated.

- The Potential applicability of nanofiber composites is widely extended by studying its electrical and magnetic properties like dielectric strength and permeability that investigated to know the electrical strength of the material as an insulator.
- To investigate the rheological behavior of the nanocomposites, which provides an insight into the processability of the materials, polymer molecular architecture, morphology, chain branching in polymer micro-structural development, temperature dependent of properties and degradation and stability.
- The dynamic mechanical analysis in shear and tension, fatigue failure and creep failure with oscillating frequencies. Since these materials are suitable for automotive, aerospace, marine, military, structural and other applications. The nanocomposites can be fabricated by using other natural fibers and investigate the mechanical and thermal properties for suitable applications.

- The tribological behavior of the composite will be of immense importance because when components are made from natural fibers, their wear behavior is crucial, when subjected to working environments.
- The application of banana nanofiber composites can be used for further review so as to make it compatible to be used in various fields.
- The experimental values of the static and dynamic analysis can be further validated by using various other empirical rules and techniques.
- Testings can be carried out in the component level which are manufactured using nanocomposite material in order to satisfy wide applications.
- Static and dynamic structural analysis can be extended to consolidate the experimental results.

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