January - February 2020
ISSN: 0193 - 4120 Page No. 2854 - 2862

Effect of Al2O3 Nano filler on Mechanical Behaviour of Hybrid Polymer Composite-A Taguchi Approach

Mr. Dilip Kumar K, Research Scholar,Dept of Mechanical Engineering, UVCE, Bangalore University.NMAM Institute of Technology,Nitte, Karkala Tq, Udupi District,Karnataka, India.
Dr. Shantharaja M,Associate Professor,Dept of Mechanical EngineeringUVCE, Bangalore UniversityBangalore-01,Karnataka, India.
Dr. Ravindra,Assistant Professor,Dept of Mechanical EngineeringNMAM Institute of Technology,Nitte, Karkala Tq, Udupi District,Karnataka, India

Article Info
Volume 82
Page Number: 2854 - 2862
Publication Issue:
January-February 2020

Article History
Article Received*: 14 March 2019*
Revised*: 27 May 2019*
Accepted*: 16 October 2019*
Publication*: 18 January 2020*

Abstract:
In structural applications such as automotive parts, aerospace structures, physical exercise equipment's and civil structures. The reinforced polymer composites are extensively used for their characteristics such as high specific strengths and specific modulus. The Composite material of hybrid nature is made from Glass fiber, Nylon fiber and aluminium oxide along with epoxy resin to prepare the test model. The factors, levels of factors and number of test model which are been considered for the experiments as well as for the analysis is decided based on Design of Experiment method by Taguchi. Test models are subjected to tensile test by extracting results for experimental and optimal evaluation of mechanical behaviour of test models. Experimental values obtained from the tests used as input information for the Taguchi analysis utilizing orthogonal array method. Analysis will give the optimized combination of factors and hence from the inputs data signal to noise ratio and mean value we can expect. The aim of this paper is to showcase the analysis which has been carried out to predict the best combination of factors level, predict the most influencing factors for the test models and to get an optimized mechanical properties.

Keywords:*Taguchi Technique, Mechanical behavior, aluminium oxide, Orthogonal array, nano polymer composite.*

I. INTRODUCTION

In variety of application of structures, such as automotive, aircraft, robotics and automation machines the Fiber Reinforced polymer composites have been widely used. The machining operation efficiency is mainly dependent on material properties. The applications of materials use in machining require high quality surface finish, including dimensional accuracy and surface integrity. The properties of a polymer composite material can be improved by reinforcing the low and high aspect ratio fillers into the epoxy. The inclusion of lower dimension fillers in brittle polymer composite materials is found to be the better method to improve the toughness, since the micro-structural perfection of composites increases by reducing the potential defects to a large extent.

The presence of polymer matrix in fiber reinforced polymer (FRP) composites is the main draw back for their low mechanical properties. Composite consists of matrix, which is a continuous medium into which a different reinforcement material is properly mixed and processed to form the composite. The matrix acts as binding agent and transfers load to reinforcement. Polymer matrix composites are simple in processing, and relatively cheaper when compared to metal matrix and ceramic matrix composites. The FRP composites can be processed using various combination of

January - February 2020
ISSN: 0193 - 4120 Page No. 2854 - 2862

matrix to get optimized mechanical and other desired properties.

The Design of experiment technique is the design of particular outcome of experiments by validating the available information's and optimizing the information which will bring major impact on the output results.

Design of experiment technique has different methods for validation and optimization of outcome results that are,

a. Randomized complete block design method
b. Latin square method
c. Full factorial method
d. Fractional factorial method
e. Central composite method
f. Box Behnken method
g. Plackett Burman method
h. Taguchi method

In these methods of Design of experiment most commonly and widely used method is Taguchi method of design of experiment because it is simple and easier to analyze and understand. The Taguchi method of analysis is a quality control tool for an engineering that promotes the product design and development in the field of material science by reducing the probability of occurrence of defects and breakdown of products or models. The Taguchi method of analysis is used to examine how the variables will affect the process performance characteristics.

Taguchi method of design of experiment uses orthogonal array method to arrange the process parameters and levels of parameters, so we can also get best factors combination[1], [2]. From this we can get minimum necessary data for a smaller number of experiments and optimized factors for the experiments as well as analysis, thus by saving time and number of resources. The fiber reinforced polymer nano composite made from polymer matrix and reinforced fibers are validated by using Taguchi analysis.

The number of nano composite specimens are opted for experiments from Design of experiment method is examined for Tensile strength by tensile load application method using fatigue testing machine[3]. Similarly opted set of nano composite specimens are undergone bending test using 3-point bending test method. The outcomes of the tensile Experiments are analyzed and validated using Taguchi Orthogonal array type of analysis using Minitab software.

II. LITERATUREREVIEW

The FRP composite limitations are the low mechanical properties because of the presence of polymer inclusion with it. Extensive research has been carried out on increasing the tensile strength, Young's modulus of the FRP and Taguchi technique used for design of experiments.

The experiments on the effect of short Glass fibre on polyamide 66/ polypropylene polymer blend matrix composites revealed that an increase in tensile strength and bending strength, whereas the impact strength showed a decreasing trend. The fibre material and the ploughing action of fibers because of the negative bonding between fibre and matrix, inclined fibre breakage and cohesive matrix fracture are the reason by which might be attributed to the flexure and impact behaviour decrease of the material[4].

The epoxy matrix modified by Al_2O_3, SiO_2 and TiO_2 micro particles in glass fiber/epoxy composite to improve the mechanical properties. Compare to SiO_2 and TiO_2 modifiers Al_2O_3 modified epoxy composite increases the hardness and impact energy. SEM analysis indicated the mode of failure was the combination of crack in matrix; matrix/fiber debonding and fiber pull out. The mechanical properties increase with decrease in ceramic particle size for the glass fiber/epoxy composite [5], [6].

The varying concentration of silicon carbide, Alumina and magnesium hydroxide on E-glass fiber reinforced epoxy composites showed that silicon

Published by: The Mattingley Publishing Co., Inc.

January - February 2020
ISSN: 0193 - 4120 Page No. 2854 - 2862

carbide filled composites exhibited high hardness, impact strength and bending strength whereas maximum ultimate tensile strength is observed during magnesium hydroxide filler addition on E-glass fiber reinforced epoxy composites. The experimental results showed the addition of filler materials above 10% by volume leads to decrease in ultimate strength because of more filler distribution and filler materials dominated in the materials. The silicon carbide filled composites having high impact strength when compared with other filled composites this due to that good bonding strength between filler, matrix and fiber and flexibility of the interface molecular chain resulting in absorbs and disperses the more energy, and prevents the cracks initiator effectively [7], [8].

The study on Carbon nanotube (CNT) as reinforcement and Polystyrene as matrix material are selected to improve mechanical properties of material[9]. The factors like type of CNT, type of solvent, type of Polystyrene, temperature for drying a nano composite percentage of fibers, and duration of mixing after adding CNT at different levels are studied. Using Taguchi Orthogonal array method for analyzing the best tensile strength value outcome obtained is matches with outcome of the analysis.

The tensile and bending properties study for hybrid nano composite material is done using carbon fiber, Nano clay and Nano silica using Taguchi Orthogonal array type. The results showed that the component interactions between Nano clay and Nano silica are required to both tensile and bending strength properties. The interaction between other Nano silica and Nano clay has no observable effect on the responses. The evaluation of specimens at different factor levels showed that all input parameters have an opposite effect on the corresponding response[10]. S Navaneetha Krishnan et al, done optimization of fabrication factors along with mechanical properties by using Taguchi method and found the best combination of mechanical properties in composite[11]. Fabrication factors selected are roselle fiber, coconut shell powder and reinforced Vinyl esters are used to produce a composite material following Taguchi L27 Orthogonal array method and material fabricated at room temperature using hand- layup technique. The Optimized fiber length, fiber content and fiber diameter levels are analyzed and the result showed the fiber content is the most significant parameter which are affected mechanical properties of prepared specimen, comparing with fiber length and fiber diameter.

The investigation of tensile performance and fracture behaviour of aluminium matrix, composite reinforced with titanium di-boride Nano particles by considering volume fractions of Nano titanium boride powders was separately mixed with molten A356 aluminium by mechanical stirrer showed increase in toughness value with increase in strength and stiffness with increase in reinforcement content. The porosity present in the material is increased with increase in volume fraction and reducing ceramic reinforcements. The material is subjected for different tensile tests and elongation of nano composite led Nano particle to reduction in strength[12]. An attempt is made to study the mechanical properties of glass and Vinyl ester composite material using with fiber and without fiber [13]. The composites are subjected to tensile test and analyzed the behaviour and variation of mechanical properties of composition. As an outcome the residual tension from tensile test was reduced the mechanical properties of composite. Means the residual tensile strengths of specimen has relation between load levels and delamination area.

An evaluation of force levels of two sizes of fiber reinforced composites are compared with stainless steel wires [14]. For experimentation purpose divided the samples into 12 groups, and each group contains 10 specimens. Specimens are subjected for 3-point bending test. Outcome of this test and

January - February 2020
ISSN: 0193 - 4120 Page No. 2854 - 2862

analysis showed that 1.2mm composite material has higher load than stainless steel. It gives high load values in composite material can be used for joining dental segments to form active tooth movement.

III. EXPERIMENTAL WORK

Two or more chemically different materials combined to obtain a new material with enhancement in mechanical and other properties than the raw material is known as composite material. The hybrid composite material fabricated by making use of Nylon fiber and Glass fiber as reinforcing material, Aluminium oxide or Alumina as matrix material along with curable epoxy resin. For experimental purpose we divided the raw material into input factors with different levels of percentages. This division of factors and factors level gives the total number of Experiments to be conducted on the specimen. The decision of minimum total number of specimens to be fabricated or minimum total number of Experiments to be conduct on specimen will decided by applying Design of experiments techniques to the specimen fabrication. Here the used technique is to design the experiment is Taguchi technique. Here we used L16 method of design of experiment. The percentage levels of factors are as follows,

Table 1: List of factors and factors levels

Factor A (Glass Fiber)		Factor B (Nylon Fiber)		Factor C (Nano Aluminium oxide)	
LEVEL	Value in %	LEVEL	Value in %	LEVEL	Value in %
A1	5	B1	5	C1	0.25
A2	10	B2	10	C2	0.5
A3	15	B3	15	C3	1.0
A4	20	B4	20	C4	2.0

The composite material is fabricated using conventional type Hand-layup technique. For testing 48 specimens of different factors levels are fabricated with three specimens for each combination.

TENSION TEST:

The fabricated composite materials are of different factors levels are subjected to Tension test. For the tension test experiment tensile type composite specimens are made use. The tension test specimen specifications are,

Table 2: List of Tensile specimen dimensions

Tensile Specimen	
Total length	250 mm
Gauge length	190 mm
Cross sectional area	100 mm^2
Width	25 mm
Thickness	4 mm

The Tension test is carried out in tensile testing machine, and specimen is holds between the two jaws, which is upper jaw and another one is lower jaw. The load is applied on the specimen at the rate of 0.033mm/Sec.

Figure 1: Tensile testing machine

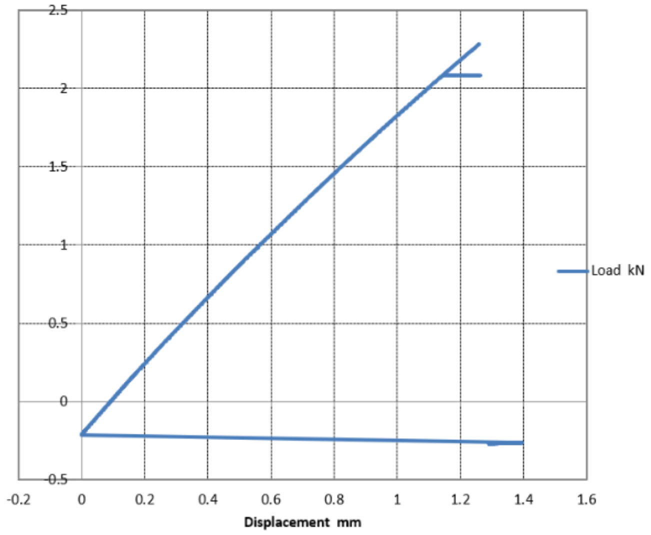

Figure 2: Tensile test result plot

Tension test results:

The tensile test was carried out for 48 tensile test specimens using 16 sets of an experimental specimens. Each set had 3 test specimens and the average value from out of 3 for 16 experimental test specimens is considered.

Figure 3: Tensile test specimen after testing

Table 3: List of Maximum Tensile stress values

Specimen No	**Max. Tensile Stress in MPa**
1	16.64
2	18.50
3	18.82
4	17.50
5	23.51
6	25.79
7	26.52
8	25.10
9	25.01
10	28.10
11	28.20
12	26.02
13	27.10
14	26.50
15	27.06
16	24.04

The table 3 gives the maximum tensile stress value for different combinations of factors level for input parameters. The tensile stress value is minimum for first level of factors combination and reaches maximum value when factors level of the Nylon fiber and Aluminium oxide at its peak level of percentage and Glass fiber at its lowest possible percentage level. The lowest possible tensile stress value is reached when Glass fiber and Nylon fibers are high in percentage and Aluminium Oxide is at lowest percentage level. Hence higher the matrix percentage level higher the Tensile stress value.

Table 4: List of Young's modulus value

Specimen No	Young's modulus **in GPa**
1	3.62
2	3.75
3	3.94
4	3.98
5	4.05
6	4.05
7	4.21
8	4.12
9	4.32
10	4.36
11	4.10
12	4.14
13	4.35
14	4.42
15	4.30
16	4.00

January - February 2020
ISSN: 0193 - 4120 Page No. 2854 - 2862

The above table is for the different percentage levels of factors to corresponding value of Young's modulus. The table starts from first level of factors percentage and Youngs modulus from its least value. As the analysis proceeds the Youngs modulus changes along with factors percentage level also changes. The maximum value of Young's modulus value 4.36 GPa noted when Nylon fiber at its peak percentage of 20% and Aluminium oxide at moderate value of 1% and Glass fiber at 10%. So for maximum Modulus of elasticity value the Nylon fiber percentage and Aluminium oxide nano particle shows the larger impact.

IV. RESULTS & DISCUSSIONS

Tensile Test Results: Taguchi Analysis

Figure 4: Means value plot of Maximum Tensile stress

The figure 4 shows the response of the different factor levels of the factors for the mean values of tensile stress. As the percentage level increases main effect for mean value remains almost same for nylon fiber except at peak value, decreases for glass fiber after initial increment up to third level but for the Aluminium oxide increases almost linearly and showing saturation behaviour after the third level compounding. Hence Aluminium oxide has main effect on tensile property and glass fiber also shows a clear increment in the property, but the nylon fiber addition not having much impact on the property at the lower level inclusion.

Table 5: ANOVA table for tensile stress value.

Source	DF	Adj. SS	Adj. MS	F-Value	P-Value
GF	3	13.653	4.5511	5.81	0.033
NF	3	3.312	1.1040	1.41	0.329
AO	3	207.609	69.2029	88.39	0.000
Error	6	4.698	0.7829		
Total	15	229.272			

Model Summary: R-sq = 97.95%, R-sq (adj) = 94.88%,
R-sq (pred) = 85.43%.

The experimental results were analyzed by using Analysis of Variance (ANOVA) which is used to understand and interpret the influence of different factors on tensile stress. ANOVA interpretation can be used to decide the independent factor domination over the other factors and the percentage contribution of that particular independent variable. In this study the analysis was carried out for a level of 5% significance that is up to a confidence level of 95%. Sources with a P value less than 0.05 were considered to have a statistically significant contribution to the performance measures. Tables 5 show the result of ANOVA analysis for Hybrid nano composite of tensile stress value. It can be noticed from the table 5 all the GF and AO has moderately significant influence on tensile stress value of hybrid composite.

Table 6: Response Table for Means of Tensile stress

Level	GF	NF	AO
1	23.07	23.67	17.87
2	24.72	23.77	25.23
3	25.15	23.86	26.83
4	23.16	24.81	26.17
Delta	2.08	1.14	8.97
Rank	2	3	1

The table 6 shows the response of tensile stress values against means. The rank based on delta values clearly shows that the aluminium oxide nano particles have major impact on the tensile property where as Glass fiber is the second factor in the rank which is influencing the tensile values. The Nylon fiber is having the least influence on tensile values and the variation is very less with reference to the mean value.

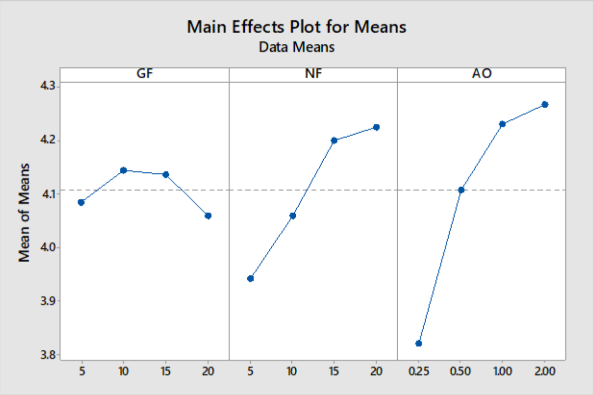

Figure 5: Main effect plots of Young's modulus

The figure 5 shows the response of the different factor levels of the compositions for the Means values of Young's modulus. As the percentage level increases Main effect for means value for young's modulus increases for Nylon fiber and Aluminium oxide nano particles, but Aluminium oxide shows a larger trend than nylon fiber. For Glass fiber the variation observed is less and the trend decreases as the percentage increases above 10. Hence aluminium oxide nano particle has the main effect on modulus of hybrid composite and Nylon fiber shows a clear increase in the property, but the Glass fiber addition not having much impact on the property at the higher level of addition.

Table 7: ANOVA Table for Young's Modulus value

Source	DF	Adj. SS	Adj. MS	F-Value	P-Value
GF	3	0.02027	0.006756	1.49	0.309
NF	3	0.20737	0.69123	15.25	0.003
AO	3	0.48732	0.162440	35.85	0.00
Error	6	0.02719	0.004531		
Total	15	0.74214			

Model Summary: R-sq = 96.34%, R-sq (adj.) = 90.84%,
R-sq (pred.) = 73.95%.

The results from experiments were analyzed by using ANOVA which is used to understand and interpret the influence of different factors on young's modulus. The analysis was carried out for a level of 5% significance that is up to a confidence level of 95%. Sources with a P value less than 0.05 were considered to have a statistically significant contribution to the performance measures. Tables 7 show the results of ANOVA analysis of Hybrid composite for Young's Modulus values. It is noticed from the table 7 all the NF and AO has moderately significant influence on modulus value of hybrid composite, whereas the GF has less impact on modulus of the hybrid composite.

Table 8: Response Table for Means of Young's Modulus

Level	GF	NF	AO
1	4.085	3.942	3.823
2	4.145	4.060	4.107
3	4.138	4.200	4.230
4	4.060	4.225	4.268
Delta	0.085	0.282	0.445
Rank	3	2	1

The table 8 shows the response of Young's modulus values against means. The rank based on delta values clearly shows that the aluminium oxide nano particles have major impact on the tensile property where as Nylon fiber is the second factor in the rank which is influencing the tensile values. The Glass fiber is having the least influence on tensile values and the variation is very less with reference to the mean value.

V. CONCLUSION

In the study of Taguchi method, the influence of the three factors which are dependent on tensile and Young's modulus of hybrid nano composite material was evaluated.

The Taguchi orthogonal array method was chosen for designing the experiments and 16 specimens with different factor levels tested for the response.

January - February 2020
ISSN: 0193 - 4120 Page No. 2854 - 2862

From the Analysis of variance method results the means and main effect plot gives the most influencing or effecting factor for Tensile stress and Young's modulus. The nylon fiber contributing more for Young's modulus whereas glass fiber having larger effect on tensile stress value. The glass fiber increases the Young's modulus value up to 15% by volume fraction and shows decreasing trend by increasing the fraction above 15% by volume. The nylon fiber will show increasing trend upon increasing the fraction by volume of nylon but reduces the trend above 15% by volume fraction addition. The experiments showed the alumina filler materials addition above 1.0% by volume leads to decrease in tensile stress value due to more filler distribution and filler materials dominated in the materials whereas the Young's modulus shows increasing trend upon increasing the nano aluminium oxide percentage but the trend decreases after 1.0% by volume fraction of nano aluminium oxide.

VI. REFERENCES

[1] S. Fraley, M. Oom, B. Terrien, and J. Z. Date, "Design of experiments via Taguchi methods: orthogonal arrays," The Michigan chemical process dynamic and controls open text book, USA, 2006.
[2] S. Fraley, M. Oom, B. Terrien, and J. Zalewski, Design of experiments via taguchi methods: orthogonal arrays., Retrieved November 4, 2009. 2007.
[3] M. H. Wichmann, J. Sumfleth, F. H. Gojny, M. Quaresimin, B. Fiedler, and K. Schulte, "Glass-fibre-reinforced composites with enhanced mechanical and electrical properties–benefits and limitations of a nanoparticle modified matrix," Engineering Fracture Mechanics, vol. 73, no. 16, pp. 2346–2359, 2006.
[4] B. V. Lingesh, B. M. Rudresh, and B. N. Ravikumar, "Effect of Short Glass Fibers on Mechanical Properties of Polyamide66 and Polypropylene (PA66/PP) Thermoplastic Blend Composites," Procedia Materials Science, vol. 5, pp. 1231–1240, Jan. 2014.
[5] R. K. Nayak, A. Dash, and B. C. Ray, "Effect of epoxy modifiers (Al2O3/SiO2/TiO2) on mechanical performance of epoxy/glass fiber hybrid composites," Procedia materials science, vol. 6, pp. 1359–1364, 2014.
[6] K. Padmanabhan, "Role of alumina in flexure of glass/epoxy composites," Bulletin of Materials Science, vol. 13, no. 4, pp. 245–253, 1990.
[7] K. Devendra and T. Rangaswamy, "Determination of mechanical properties of Al2O3, Mg (OH) 2 and SiC filled E-glass/epoxy composites," Int J Eng Res Appl, vol. 2, no. 5, pp. 2028–2033, 2012.
[8] B. Rajeswari, K. S. Amirthagadeswaran, and K. G. Anbarasu, "Investigation on mechanical properties of aluminium 7075-silicon carbide-alumina hybrid composite using Taguchi method," Australian Journal of Mechanical Engineering, vol. 13, no. 2, pp. 127–135, 2015.
[9] M. Farbodi, "Application of taguchi method for optimizing of mechanical properties of polystyrene-carbon nanotube nanocomposite," Polymers and Polymer Composites, vol. 25, no. 2, pp. 177–184, 2017.
[10]Y. Rostamiyan, "Modeling and analysis of the tensile and flexural properties of a fiber-orientated hybrid nanocomposite using Taguchi methodology," Strength of Materials, vol. 47, no. 6, pp. 820–834, 2015.
[11]S.Navaneethakrishnan & A.Athijayamani -" Taguchi method for optimization of fabrication parameters with mechanical properties in fiber and particulate reinforced composites", Research Article, Dec 2015.
[12]M. K. Akbari, H. R. Baharvandi, and K. Shirvanimoghaddam, "Tensile and fracture behavior of nano/micro TiB2 particle reinforced casting A356 aluminum alloy composites," Materials & Design (1980-2015), vol. 66, pp. 150–161, 2015.
[13]V. G. Kamble and N. Kumar, "Fabrication and tensile property analysis of polymer matrix composites of graphite and silicon carbide as fillers," Am. J. Eng. Applied Sci, vol. 9, pp. 17–30, 2016.

[14]V. Cacciafesta, M. F. Sfondrini, A. Lena, A. Scribante, P. K. Vallittu, and L. V. Lassila, “Force levels of fiber-reinforced composites and orthodontic stainless steel wires: a 3-point bending test,” American Journal of Orthodontics and Dentofacial Orthopedics, vol. 133, no. 3, pp. 410–413, 2008.