International Journal Of Scientific & Engineering Research, Volume 7 , Issue 5 , May-2016
ISSN 2229-5518

PROCESSING, MECHANICAL CHARACTERIZATION AND TOPSIS RANKING OF GLASS/PARTICULATES REINFORCED EPOXY BASED HYBRID COMPOSITES

Mr. Suresh .J.S [1] Dr. M. Pramila Devi[2] Mr.Raffi Mohammed[3] Dr. C. Naga Bhaskar[4]

Abstract:- In this Research article, the processing and mechanical characterization of hybrid composites which consists of Epoxy resin (E) reinforced with E-glass fiber (G.F) and filled with natural fillers like Arabic gum tree coal powder (A.C.P), Neem tree coal powder (N.C.P) and Jambal tree coal powder (J.C.P) particulates was done. The effect of A.C.P/ J.C.P/N.C.P in modifying the mechanical properties of glass reinforced epoxy composites has been studied. It is found that the mechanical properties like Tensile strength, Flexural strength, ILSS, Impact strength and Hardness of the glass reinforced composites are modified with the incorporation of the fillers. Also The TOPSIS technique is implemented for the ranking of the matrix with respect to the mechanical properties.

Key words: Natural fillers, E-Glass Fiber (G.F), Epoxy (E), Mechanical characterization, TOPSIS

1. INTRODUCTION

Over the past decades, many Glass-fiber reinforced composite materials are used in manufacturing of various parts in automotive and aerospace industries. The major advantage of polymer composites is to offer easy processing, productivity, cost reduction, high strength and modulus-weight ratio etc. over metallic materials. Glass fiber composites have excellent surface finish, higher impact strength and high modulus to weight ratios compared with the other FRP Composite materials, so they are mainly used in industries.

Mr. Sures.J.S[1] Research Scholar, Department of Mechanical Engineering, Andhra University, INDIA-520003,PH-9494578989Email:sampath1026@gmail.com
Dr. M. Pramila Devi[2], Professor&HOD, Department of Mechanical Engineering, Andhra University, INDIA-530003

Mr.Raffi Mohammed[3]Associate Professor, NRI Institute of Technology, Agiripalli, INDIA-521212
Dr. C. Naga Bhaskar[4] Principal, NRI Institute of Technology, Agiripalli, India-521212

To enhance the mechanical properties i.e. tensile, impact and flexural properties of the polymers is the main concept of reinforcing the polymers [1, 3].For thermoset matrices Glass fiber is the typical reinforcing material for various structural applications.

For high ratios of strength and stiffness to weight in orthotropic direction Woven fabric reinforced epoxy composites are well known. In areas where light weight of structures and high performance are essential. These good characteristics of the composites have resulted in numerous applications of the materials [4]. Cho et al. [5] investigated the special effects of particle loading particle medium interface adhesion and particle size, on mechanical properties of polymer matrix composites. Also, the use of epoxy resin for composite manufacture, being one of the most captivating and interesting materials are contemplated, because it is primarily used for preparing high-performance composites with

International Journal Of Scientific & Engineering Research, Volume 7 , Issue 5 , May-2016
ISSN 2229-5518

advancedperfunctory properties, corrosive resistant to liquids and environments, superior electrical properties, high-quality performance at high temperatures, superioradhesion or a combination of above benefits.

It is observed from the literature, the use of fillers in matrix gives rise to improve the mechanical properties, which acts as additional reinforcements and enhances their mechanical properties and also reduces the processing cost significantly.Saroja Devi [6] and Ramakrishna [7] have researched the mechanical properties of composites filled with fly ash for general-purpose with unsaturated polyester resin as matrix. Wong and Truss [8] reported the effect of fly ash addition as filler and the effect of coupling agent i.e. hardener on the tensile and impact properties of polypropylene (PP). Singh et al. [9] studied the selection of material for bicycle chain in Indian scenario using MADM Approach. They concluded that both MADM and TOPSIS methods user friendly for the ranking of the Composites Huang et al. [10] studied the multi-criteria decision making and uncertainty analysis for materials selection in environmentally conscious design. It was reported that TOPSIS method demonstrates a reasonable performance in obtaining a solution; and entropy method. The decision makers' prefer cost or environmental impact and effectively demonstrates the uncertainties of their weights. Khorshid et al. [11] studied that Al-15%Mg2Si composite, the selection of an optimal refinement condition to achieve maximum tensile properties based on TOPSIS method and observed that the TOPSIS method is considered asa suitable way in solving material selection problem when precise performance ratings are available.

2. EXPERIMENTAL DETAILS

2.1 Materials

In our study, coal powders are prepared from Arabic gum tree, Neem tree and Jambal tree which acts as natural fillers to modify the Epoxy matrix. The commercially available E-glass fiber (Woven Roving fabric type) with 360 grams weight per m^2 area is used as reinforcement. Araldite (LY-556) chemically belongs to epoxide family is used as resin and (HY-556) is used as hardener, these materials (E-glass fiber, Araldite and Hardener) are supplied by Kotsan Engineering corporation, Guntur.

2.2. Fabrication of composites

Ten types of composites are prepared with different natural fillers are processed/ prepared using hand layup technique. The weight percentage of Epoxy, E-glass fiber, hardener and natural fillers Arabic gum tree coal powder (A.C.P), Neem tree coal powder (N.C.P) and Jambal tree coal powder (J.C.P) are fixed and their designations are written in Table-1.

Table-1: Designation and Composition of Composites

Designation of composite	Composition
C1	57.5 wt%E+40 wt%G.F+2.5 wt% A.C.P
C2	55 wt% E + 40 wt% G.F+ 5 wt% A.C.P
C3	52.5 wt%E+40 wt%G.F+7.5 wt% A.C.P
C4	57.5 wt%E+40 wt%G.F+2.5 wt% J.C.P
C5	55 wt %E + 40 wt% G.F+5 wt% J.C.P
C6	52.5 wt%E+40 wt%G.F+7.5 wt% J.C.P
C7	57.5 wt%E+40 wt%G.F+2.5 wt% N.C.P
C8	55 wt% E + 40 wt% G.F+ 5 wt% N.C.P
C9	52.5 wt%E+40 wt%G.F+7.5 wt% N.C.P
C0	60 wt% E+ 40 wt %G.F

Where C_1, C_2, C0 indicates the composites with different compositions. Initially the natural filler materials in powder form are dried at 105^0C for 2 hours before mixing with the epoxy resin for the

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ISSN 2229-5518

removal of moisture, before the addition of hardener the fillers are mixed with epoxy resin and it is stirred manually using a mechanical stirrer. This mixer is coated on the work side of the mold with a brush. A layer of E-glass fiber cloth is placed on it and then resin and filler mixture is coated on that E-glass fiber. To remove entrapped air and to get uniform thickness a mild steel roller is rolled on each layer of the glass sheet. This procedure is continued until the eight layer of glass fiber is placed and then laminates are cured for at least 72 hours at room temperature. The same procedure is followed to fabricate the composite without filler materials.

2.3 Specimen Preparation

The fabricated sheets are removed from the molds and as per ASTM standards of mechanical characterization (i.e. Tensile strength, Flexural strength, Impact strength, Hardness and ILSS) sheets are cut into specimens.

2.4 Material Test Details

2.4.1 Tensile Strength and Tensile Modulus

As per ASTM –D-638-III the dog bone type specimen with end tabs is used for tensile test. On MCS 60 UTE-60 machine tensile test was performed. From tensile strength we have to find out the tensile modulus

Using the formula $E = \sigma * l/\delta l$

Where, σ = tensile strength

δl = Elongation

l= length of the specimen

2.4.2 Flexural and Inter Laminar Shear Strength

By using three point bend test on universal testing machine UTE-60T for the specimen of size as per ASTM D-790-2003, we can determine the flexural strength and ILSS.

The ILSS equation is

ILSS = 3P/4bd

And the flexural strength equation is

Flexural strength= $3PL/2bd^2$

Where,

P= maximum load applied on the specimen

b = width of the specimen

d=thickness of the specimen

L=span of the specimen

2.4.3 Impact strength

On Impact testing machine (Krystal Elmec) mode: K1 300 of range -168 Joules for I-20D as per ASTM D-256 impact test was done. The values of different specimens are recorded from the dial indicator of IZOD impact testing machine.

2.4.4 Micro Hardness By using shore hardness tester, hardness of the specimen were found for the specimens as per ASTM D 2240 -2003

2.5 Topsis: The basic principle of the TOPSIS method is that the chosen alternative should have the ''shortest distance'' from the positive ideal solution and the ''farthest distance'' from the negative ideal solution. The TOPSIS method introduces two ''reference'' points, but it does not consider the relative importance of the distances from these points.

Step 1: Create an evaluation matrix consisting of m alternatives and n criteria, with the intersection of each alternative and criteria given as x_{ij}, we therefore have a matrix $(x_{ij})_{m\times n}$. This matrix is called as a decision matrix (D)

Step 2: The matrix $(x_{ij})_{m\times n}$ is then normalized to form the matrix

$R = (r_{ij})_{m\times n}$, using the normalization method

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ISSN 2229-5518

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, i = 1, 2, ..., m, j = 1$$

Step 3:Calculate the weighted normalized decision matrix

$$T = (t_{ij})_{m \times n} = (w_j r_{ij})_{m \times n}, i = 1, 2, ..$$

Where

$$w_j = W_j / \sum_{j=1}^{n} W_j, j = 1, 2, ..., n$$

So that

$\sum_{j=1}^{n} w_j = 1$, and W_j is the original weight

given to the indicator $v_j, j = 1, 2, ..., n.$

Step 4: Determine the ideal (best) and negative ideal (worst) solutions in this step. The ideal and negative ideal solution can be expressed as:

$$A_w = \{\langle max(t_{ij}|i = 1, 2, ..., m)|j \in J_-\rangle, \langle min(t_{ij}|i = 1, 2, ..., m)$$

$$A_b = \{\langle min(t_{ij}|i = 1, 2, ..., m)|j \in J_-\rangle, \langle max(t_{ij}|i = 1, 2, ..., m)|j \in J_+\rangle\} \equiv \{t_{bj}|j = 1, 2, ..., n\},$$

Where

$J_+ = \{j = 1, 2, ..., n|j$ associated with the criteria having a positive impact, and

$J_- = \{j = 1, 2, ..., n|j$ associated with the criteria having a negative impact

Step 5: Determine the distance measures. The separation of each alternative from the ideal solution is given by n- dimensional Euclidean distance from the following equations:

Calculate the L2-distance between the target alternative i and the worst condition A_w

$$d_{iw} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})^2}, i = 1, 2, ..., m$$

,

and the distance between the alternative i and the best condition A_b

$$d_{ib} = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{bj})^2}, i = 1, 2, ..., m$$

Where, d_{iw} and d_{ib} are L2-norm distances from the target alternative i to the worst and best conditions, respectively.

Step 6: Calculate the relative closeness (closeness coefficient, CC) to the ideal solution:

$$s_{iw} = d_{iw}/(d_{iw} + d_{ib}), 0 \le s_{iw} \le 1, i = 1, 2, ..., m$$

$s_{iw} = 1$ if and only if the alternative solution has the best condition; and

$s_{iw} = 0$ if and only if the alternative solution has the worst condition

Step 7: Rank the alternatives according to $s_{iw} (i = 1, 2, ..., m)$

3. RESULTS&DISCUSSIONS

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Table-2: shows the mechanical properties of fabricated composites

Designation of composites	Mechanical properties					
	Tensile strength(MPa)	Tensile modulus(GPa)	Flexural strength(MPa)	Impact strength(Joule)	Micro hardness	ILSS(MPa)
C1	119.5	3.7	214	9	86.5	7
C2	90.4	2.1	166.5	7	80	7.4
C3	96.3	2.1	186.7	8	83	6.3
C4	141.1	3.9	187.4	8	80.5	6.4
C5	152.4	3.2	214.8	8	86.5	5.7
C6	138.7	2.8	188.5	6	80	7
C7	155.7	3.8	190.2	9	82.5	5.2
C8	126.5	3.5	195.8	7	86	6.5
C9	130.6	2.7	205	9	81	7.7
C0	221.4	6.4	216.1	8	80.5	7.9

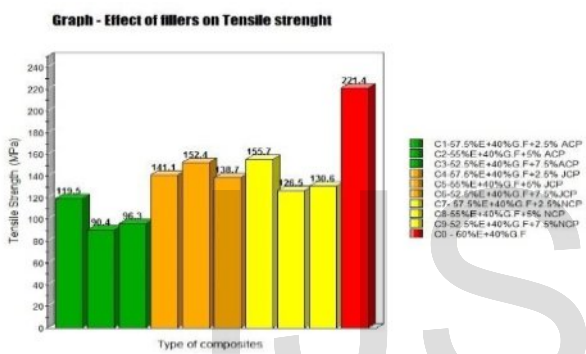

Figure-1: Graph for composites VS Tensile strength

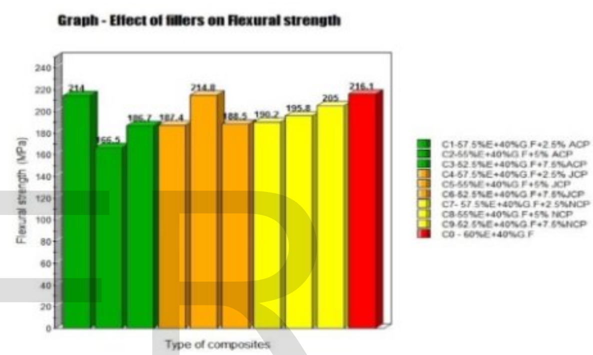

Figure-3: Graph for composites VS Flexural strength

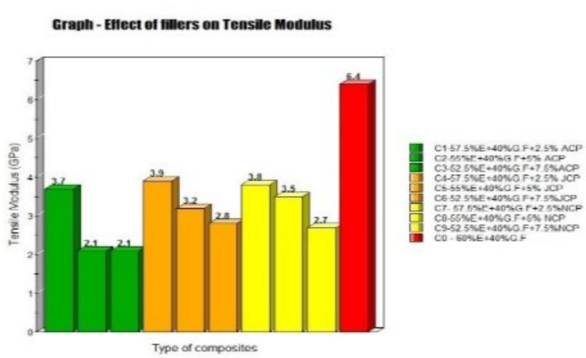

Figure-2: Graph for composites VS TensileModulus

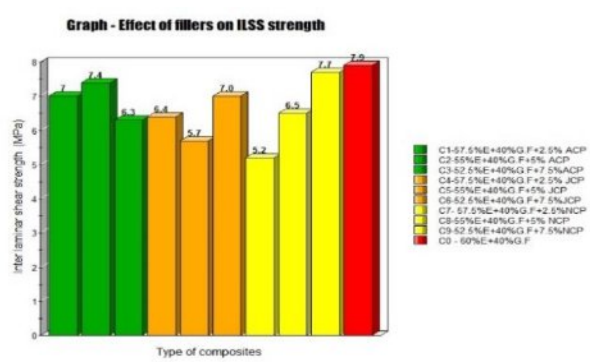

Figure-4: Graph for composites VS ILSS

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ISSN 2229-5518

Figure-5: Graph for composites

VS Impact strength

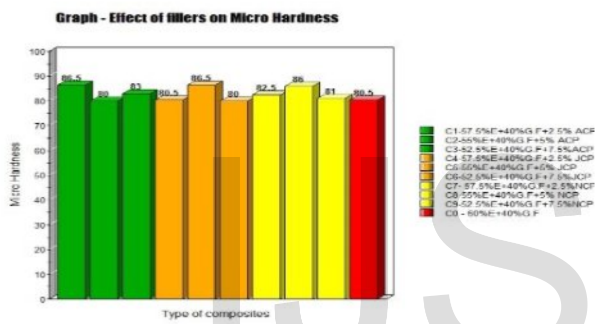

Figure-6: Graph for composites

VS Micro hardness

From the figure-1, graph of composite VS Tensile strength, it is observed that C7 composite filled with 2.5 wt % N.C.P exhibited maximum tensile strength of 155.7 MPa when compared to other filler composites and lower than the unfilled composites due to the strong interface adhesion between epoxy resin and filler and excellent particle dispersion in matrix. The tensile strength of unfilled composite is more compared to other particulate filled composites. The decrease in tensile strength in particulate filled composites is due to the irregular shape of the filler which leads to the stress concentration in matrix base. The presence of pores at the interface between the matrix and filler particles, the interfacial adhesion may be too weak to transfer the tensile stress.

From the figure-2, graph for composites VS tensile modulus, the tensile modulus of unfilled composite is more when compared with the filler composites.

In particulate filled composites, the composite (C4) filled with 2.5 wt% J.C.P exhibited maximum tensile modulus compared to other filler composites. From the figures-3&4, graph for composites VS flexural strength and graph for composites VS ILSS. It is observed that the unfilled composites exhibited maximum flexural and ILSS compared to other filler composites due to good adhesive strength of matrix and glass fiber reinforcement.

The composite C5 filled with 5 wt% J.C.P exhibited more flexural strength compared to other filler composites because of finer particle size of J.C.P than other fillers.

From the figure-5, graph for composites VS Impact strength; it is observed that the impact strength of the composite is more compared to other composites. It may be due to the more hardness of the filler materials for the composite C1

From the figure-6, graph for composites VS Micro Hardness; it is observed that the hardness of the composite C1 and C5 are more when compared to othercomposites

TOPSIS:

In this methodology, all the composite materials such as C1 to C0 are compared based on the TIOPSIS method and ranking has been done. The decision matrix, normalization matrix, weight normalized matrix, ideal positive and ideal negative solution,

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ISSN 2229-5518

separation measure, relative closeness value and ranking are tabulated in Tables as follows.

STEP-1

Table-3: Decision Matrix (D) Of Fabricated Composites

composites	DECISION MATRIX(D)					
	T.S(MPa)	T.M(GPa)	F.S(MPa)	I.S(Joule)	M.H	ILSS(MPa)
C1	119.5	3.7	214	9	86.5	7
C2	90.4	2.1	166.5	7	80	7.4
C3	96.3	2.05	186.7	8	83	6.3
C4	141.1	3.85	187.4	8	80.5	6.4
C5	152.4	3.2	214.8	8	86.5	5.7
C6	138.7	2.75	188.5	6	80	7
C7	155.7	3.75	190.2	9	82.5	5.2
C8	126.5	3.45	195.8	7	86	6.5
C9	130.6	2.65	205	9	81	7.7
C0	221.4	6.35	216.1	8	80.5	7.9

STEP-2:

Table-4: Normalized Matrix

composites	NORMALIZED MATRIX (R)					
	Tensile strength(MPa)	Tensile modulus(GPa)	Flexural strength(MPa)	Impact strength(Joule)	Micro hardness	ILSS(MPa)
C1	0.266931	0.326734	0.343378	0.357718	0.330796	0.327486
C2	0.20193	0.185444	0.267161	0.278225	0.305939	0.346199
C3	0.215109	0.181028	0.299573	0.317971	0.317411	0.294737
C4	0.31518	0.33998	0.300696	0.317971	0.307851	0.299415
C5	0.340421	0.282581	0.344662	0.317971	0.330796	0.266667
C6	0.309819	0.242843	0.302461	0.238479	0.305939	0.327486
C7	0.347793	0.331149	0.305189	0.357718	0.315499	0.243275
C8	0.282568	0.304657	0.314175	0.278225	0.328884	0.304094
C9	0.291726	0.234012	0.328937	0.357718	0.309763	0.360234
C0	0.494549	0.560746	0.346748	0.317971	0.307851	0.369591

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STEP-3:

Table-5: Weight Normalized Matrix

composites	WEIGHT NORMALIZED MATRIX					
	T.S	T.M	F.S	IS	H	ILSS
C1	0.044489	0.054456	0.05723	0.05962	0.055133	0.054581
C2	0.033655	0.030907	0.044527	0.046371	0.05099	0.0577
C3	0.035851	0.030171	0.049929	0.052995	0.052902	0.049123
C4	0.05253	0.056663	0.050116	0.052995	0.051308	0.049903
C5	0.056737	0.047097	0.057444	0.052995	0.055133	0.044444
C6	0.051637	0.040474	0.05041	0.039746	0.05099	0.054581
C7	0.057965	0.055192	0.050865	0.05962	0.052583	0.040546
C8	0.047095	0.050776	0.052362	0.046371	0.054814	0.050682
C9	0.048621	0.039002	0.054823	0.05962	0.051627	0.060039
C0	0.082425	0.093458	0.057791	0.052995	0.051308	0.061598

STEP-4:

Table-6: Best & Worst Solutions

SOLUTION	BEST & WORST SOLUTIONS					
	T.S	T.M	F.S	IS	H	ILSS
Positive Ideal Solution (A_b)	0.082425	0.093458	0.057791	0.05962	0.055133	0.061598
Negative Ideal Solution (A_w)	0.033655	0.030171	0.044527	0.039746	0.05099	0.040546

STEP-5:

Table-7: Separation Measures of Attributes

composites	SEPARATION MEASURES OF ATTRIBUTES	
	S*	S-
C1	0.054862646	0.038439189
C2	0.07952278	0.018403394
C3	0.079704609	0.016934123
C4	0.049132333	0.036776841
C5	0.055314721	0.034554258
C6	0.059001513	0.025711376
C7	0.050598995	0.040677929
C8	0.055164798	0.02877235
C9	0.064278276	0.034399378
C0	0.0076495	0.084725988

STEP-6&7:

Table-8: Relative Closeness and Composite Ranking

composites	RELATIVE CLOSENESS	COMPOSITE RANKING
	C1*	R
C1	0.588012512	7TH
C2	0.812068688	2ND
C3	0.824768783	1ST
C4	0.571910204	8TH
C5	0.615504054	6TH
C6	0.696488027	3RD
C7	0.55434597	9TH
C8	0.657215545	4TH
C9	0.651396475	5TH
C0	0.082808647	10TH

International Journal Of Scientific & Engineering Research, Volume 7 , Issue 5 , May-2016
ISSN 2229-5518

All the mechanical characterization of fabricated hybrid composites are compared based on the TOPSIS method and ranking has been done. The decision matrix, normalization matrix, weight normalized matrix, ideal positive and ideal negative solution, separation measure, relative closeness value and ranking are tabulated in Tables 3, 4 , 5, 6, 7 , 8 respectively. It has been observed that ranking of composite materials are as follows: Rank 1(C3), Rank 2 (C2), Rank 3 (C6), Rank 4 (C8), Rank 5 (C9), Rank 6 (C5), Rank 7 (C1), Rank 8 (C4), Rank 9(7) and Rank 10(C0).

4. CONCLUSIONS

The experimental investigation on mechanical characterization of glass fiber reinforced epoxy based hybrid composites lead to the following conclusions:

1. Fabrication of epoxy based glass reinforced particulate filled composites has been done successfully by hand layup technique.

2.Mechanical properties like tensile strength, tensile modulus, flexural strength, impact strength, ILSS and Hardness were determined as per ASTM standards.

3. Topsis technique was employed to determine the ranking of the composite successfully.

5. SCOPE FOR FURTHER WORK

1. We can fabricate the composites by varying the composites from 10 wt% to 15 wt% and the mechanical characterization can be done.
2. We can extend this work to find the erosive wear response of various compositions of fabricated hybrid composites
3. We can apply various optimization techniques to find the more results without experimentation.

6. ACKNOWLEDGEMENT

Corresponding Author:
J.S.SURESH
Associate Professor,
Department of Mechanical Engineering
NRI Institute Of Technology.AP-521212.
Email Id:sampath1026@gmail.com

The authors thank the management of NRI Institute of Technology, Agiripalli and management of JYOTHI SPECTRO Analysis Pvt Ltd, Hyderabad-INDIA for their support.

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