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Research Article

Optimization of Hybrid CFRP Composites with AHP-Topsis Method in Mechanical charecteriztion

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Abstract

The purpose of the present study is to investigate the direct relationship between mechanical properties such as tensile strength, tensile modulus, flexural strength, hardness, Impact strength and flexural modulus. The impact of graphite powder combined with epoxy LY556 and HY-951 hardeners, as well as the performance of hybrid composites, were determined. In the same way, CFRP and basalt composites with varying stacking sequences are investigated in the same way. Using AHP-TOPSIS, it was possible to optimise the mechanical characterization of a composite hybrid. The results of this study offer an analytical model for composite materials that may be used to categorise materials

Keywords: Hybrid composites, Hand-Lay Up, CFRP, Mechanical characterization, AHP-TOPSIS Method. Ranking.

1 Introduction

In the current research, the direct links between mechanical characteristics such as tensile strength, tensile module, flexural strength ,flexural module, Impact strength and hardness are investigated.Graphite powder strength coupled with epoxy hardener LY556 and HY-951 was measured as well as the performanc of hybrid composites. CFRPs and basalt composites are also studied in the same manner with different stacking sequences. The mechanical characterisation of a composite hybrid has been optimised using AHP-TOPSIS. The findings of this research provide a composite material analysis model which may be utilised for the categorisation of materials.

2. LITERATURE REVIEW

Hybrid composites combine the effect strength, tensile module, and compressive strength characteristics not obtainable from composite materials[1]. The constructions are very weight-resistant and have excellent plastic enhanced fibre corrosion (FRP). A numerical computation is carried out in Taylor and Nayfeh for simple composition layered, thick plates

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that support free vibration[2]. They examine the impact on vibration by change the inherent frequencies of microstructures and bonding agents[3-6].AHP-TOPSIS method was utilised by Mansor et al. to rank the composites hybrid natural fibre materials used for the car parking brake lifting component. The electronic copper cathode procurement has identified eight factors, i.e. quality, availability, origin, costs, transportation costs, delivery requirements, quality certifications and supplier dependability[7-11].The ranking analysis was conducted using the measured data to identify the most meaningful material for better performance.

3 Methodologies

The materials and techniques utilised in the production of studied composites are explained in this chapter. It shows mechanical characterisation in tensile, flexural, hardness and impact testing of hybrid composites. Experimental technique based on specimen 3.1 Mixed manufacturing: In order to produce fiber-enhanced epoxy composites CFRP and basaltic fibre composites were independently strengthened in epoxy resin.. Conventional hand lay-up processes have produced these composite panels. The specifics and identification of the prepared composites are provided in the manufacturing procedure Table 3.1.

Table 3.1 Detailed designation and composition of composites

Composites	Composition
CCCC	Epoxy (42%) + CCCC (58%)
BBBB	Epoxy (36%) +BBBB (64%)
CBCB	Epoxy (39%) + CBCB (61%)
BCCB	Epoxy (39%) + BCCB (61%)
CBBC	Epoxy (39%) + CBBC (61%)
CCCC + 1% graphite	Epoxy (41%) + CCCC (58%) + Graphite (1%)
BBBB + 1% graphite	Epoxy (35%) + BBBB (64%) + Graphite (1%)
CBCB + 1% graphite	Epoxy (38%) + CBCB (61%) + Graphite (1%)
BCCB + 1% graphite	Epoxy (38%) + BCCB (61%) + Graphite (1%)
CBBC + 1% graphite	Epoxy (38%) + CBBC (61%) + Graphite (1%)
CCCC + 2% graphite	Epoxy (40%) + CCCC (58%) + Graphite (2%)
BBBB + 2% graphite	Epoxy (34%) + BBBB (64%) + Graphite (2%)
CBCB + 2% graphite	Epoxy (37%) + CBCB (61%) + Graphite (2%)
BCCB + 2% graphite	Epoxy (37%) + BCCB (61%) + Graphite (2%)
CBBC + 2% graphite	Epoxy (37%) + CBBC (61%) + Graphite (2%)
CCCC + 3% graphite	Epoxy (39%) + CCCC (58%) + Graphite (3%)
BBBB + 3% graphite	Epoxy (33%) + BBBB (64%) + Graphite (3%)
CBCB + 3% graphite	Epoxy (36%) + CBCB (61%) + Graphite (3%)
BCCB + 3% graphite	Epoxy (36%) + BCCB (61%) + Graphite (3%)
CBBC + 3% graphite	Epoxy (36%) + CBBC (61%) + Graphite (3%)

The two-way composites CFRP and Basalt together with epoxy resin and hardener are independently produced by hand-laying in composites. A high quality surface initially applies to cover to the mould. When the gel coat is adequately dried, glass fibre reinforcement of the rolling stock is put manually on the mould.

Fig 3.1 Cutting of fibers

Fig 3.2 Weighing of fibers

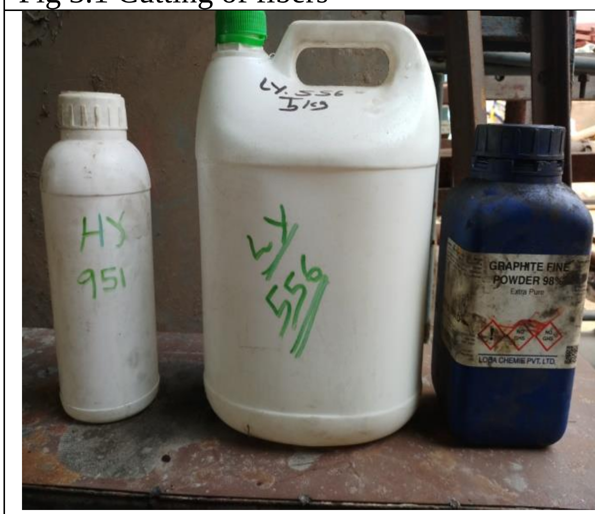

Fig 3.3 Hardner, epoxy and Graphite powder

Fig 3.4 CFRP and Basalt fibers after cutting

For the ranking of materials, the following method, AHP-TOPSIS, is utilised. In designing any products or components, material selection plays a very significant role. AHP may be implemented in three easy steps: weight of the option scoring criterion vector matrix, and option ranking. The standard specimen with end-tabs are the most frequently utilised specimen geometries. The ASTM D 3039-76 standard test technique was utilised.the following steps are followed for AHP-TOPSIS method

Step 1:-For weighing purposes, a three-level hierarchical structure is constructed. At the first level, the objective of the research is to classify the composites for usage-proof applications. The study criteria are displayed at the second level. Tensile strength, tensile modulus, flexural strength and flexural modulus, impact strength and hardness. The third hierarchy includes the alternatives, i.e. a range of materials, which are classified as the best option.

Step 2:-In order to compute the weighing of various criteria, the AHP begins with the establishment of a pair-wise comparison matrix, A (m alternatively), where m is the number of alternative evaluations taken into account and n is the number of criteria. The significance of the i th criteria relative to the jth criterion is represented by each A $_{ij}$ member of matrix A. If the i^{th} criteria are greater than the j^{th} criterion, then the ith criterion is less significant than the j^{th} criterion, whereas a_j is less important than the j^{th} criterion.

Intensity	Definition
1	Equal importance
3	Moderate importance
5	High importance
7	Very importance
9	Extreme importance
2, 4,6,8	Intermediate values
Reciprocals	Reciprocal for comparison

$$A = \begin{bmatrix} 1 & a_{12} & a_{13} & \cdots & a_{1j} \\ a_{21} & 1 & a_{23} & \cdots & a_{2j} \\ a_{31} & a_{32} & \ddots & \cdots & a_{3j} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{i1} & a_{i2} & a_{i3} & \cdots & a_{ij} \end{bmatrix}$$

If the significance of two criteria is the same, the entry is 1. The Aij and Aji entries meet the following limitations: * aji = 1 Aij*

Step 4:-Each cell will use Xij = Cij / TOCIJ standardised

Phase 5:- Calculation is performed on the row value ri = alleviation Xij of the standardised matrix for pairs.

Step 6:-If you are using Wi = To dxij /n, whereby n is the number of criteria, you calculate the weight of the conditions.

Step 7:- Vi = Ai * Wi for i= 1, 2, 3,., n is used for the vector priorities

Step 8:- Calculates the μi vector and determines the main own value of the whole value (by averaging the own vector values).

Step 9: - The Equation is used as the consistency index (CI).

Step 10:- Ratio of coherence (RC) is achieved through. The Random Incoherence Index (RI) is determined by n. RI values between 1-10 matching to n

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.149

TOPSIS method is used for ranking purpose and the steps are mentioned below;

Step 1:- Determination of the decision matrix: The decision matrix, X, can be represented as follows

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} B_1 & B_2 & B_3 \cdots & & B_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & x_{13} & \dots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \dots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \dots & x_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \dots & x_{mn} \end{bmatrix} \end{array}$$

where A_i represent alternative maintenance i, i = 1,....,m and Bj denotes decision criteria j, j = 1,...,n of which alternatives are judged. x_{ij} represent j^{th} criteria with respect to i^{th} alternative maintenance.

Step 2:- Determination of normalised decision matrix

$$f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \; i = 1, \cdots, m; \; j = 1, \cdots, n$$

Step 3:- Weighted standard decision matrix selection. The weighted standard decision matrix may be calculated and expressed by multiplying the normalised decision matrix by the weight of decision criteria:

$$v_{ij} = w_j f_{ij}, \; i = 1, \cdots, m; \; j = 1, \cdots, n$$

where w_j is the weight of the j^{th} criterion. There are several technique available in the literature for the evaluation of criteria weights. The approach chosen in this paper is the AHP method because of its ability to utilised both qualitative and quantitative information in determining weights of decision criteria.

Step 4:- Determination of the positive-ideal and negative-ideal solutions The positive ideal solution and the negative ideal solution are evaluated respectively as follows:

$$Z^+ = \left\{v_1^+, v_2^+, \cdots, v_j^+\right\} = \left\{\left(\max_i v_{ij} \mid j \in I\right), \left(\min_i v_{ij} \mid j \in I'\right)\right\}$$

$$Z^- = \left\{v_1^-, v_2^-, \cdots, v_j^-\right\} = \left\{\left(\min_i v_{ij} \mid j \in I\right), \left(\max_i v_{ij} \mid j \in I'\right)\right\}$$

where I is associated with the benefit criteria and I′ is associated with cost criteria.

Step 5:- Calculation of the separation measure The separation of each alternative from the positive-ideal solution and from the negative-ideal solution, are evaluated, respectively as:

$$S_i^+ = \left\{\sum_{j=1}^{n}\left(v_{ij} - v_j^+\right)^2\right\}^{\frac{1}{2}} \quad i = 1, 2, \cdots, m; \; j = 1, 2, \cdots, n$$

$$S_i^- = \left\{\sum_{j=1}^{n}\left(v_{ij} - v_j^-\right)^2\right\}^{\frac{1}{2}} \quad i = 1, 2, \cdots, m; \; j = 1, 2, \cdots, n$$

Step 6:- Calculation of the relative closeness to the positive ideal solution. The relative closeness Pi of the alternatives to the positive ideal solution is evaluated as follows:

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-}, \quad i = 1, \cdots, m$$

The alternative with the maximum Pi value is the optimum solution.

4. Results and Discussions

4.1 AHP-TOPSIS Analysis on Mechanical Characterization of Materials

The mechanical features of CFRP and basalt fibre composites are studied and the impact of material sequencing on different circumstances is established. The mechanical characteristics of the CFP are examined. Foe raking of materials is employed as the following method in the following tables: AHP-TOPSIS technology.

Table 4.1 Experimental design

S.No	Composite material	Tensile Strength	Tensile Modulus	Flexural Strength (MPa)	Flexural Modulus	Impact Strength	Hardness (BHN)
1	Epoxy + CCCC	432.93	25930	181.12	30040	4.61	31.4
2	Epoxy + BBBB	238.88	11130	104.8	10280	6.15	26.53
3	Epoxy + CBCB	384.82	23700	100	56830	6.15	36.2
4	Epoxy + BCCB	368.61	24380	104.4	57280	4.61	26.53
5	Epoxy + CBBC	284.9	20840	104.8	39020	3.84	31.4
6	Epoxy + CCCC +	433.44	25690	187.32	30250	10.38	37.4
7	Epoxy + BBBB +	267.36	12880	108.8	47460	6.46	26.53
8	Epoxy + CBCB +	192.43	17700	98	46820	3.84	31.4
9	Epoxy + BCCB +	347.26	20840	98.8	40450	3.38	31.4
10	Epoxy + CBBC +	292.96	21470	101.6	63640	7.38	31.4
11	Epoxy + CCCC +	387.91	21940	102	52850	5.84	36.2
12	Epoxy + BBBB +	325.62	11110	112.4	94780	5.53	26.53
13	Epoxy + CBCB +	349.83	19920	130.74	22180	4.61	36.2

14	Epoxy + BCCB +	415.45	27750	97.2	29430	5.53	31.4
15	Epoxy + CBBC +	247.67	15900	104	84610	3.38	31.4
16	Epoxy + CCCC +	338.37	24080	100	52110	6	36.2
17	Epoxy + BBBB +	246.47	11390	157.6	22550	6.46	31.4
18	Epoxy + CBCB +	388.05	21640	98.8	52680	6.15	31.4
19	Epoxy + BCCB +	377.63	24330	101.6	96850	3.38	31.4
20	Epoxy + CBBC +	313.18	19140	104	93560	9.23	31.4

Table 4.2 Pair-wise comparison matrix

Alternatives	**Tensile Strength**	**Tensile Modulus**	**Flexural**	**Flexural Modulu**	**Impact Strengt**	**Hardness**
Tensile Strength	1	1/3	3	0.2	5	5
Tensile Modulus	3	1	7	0.2	5	5
Flexural Strength	1/3	1/7	1	1/9	3	1
Flexural Modulus	5	5	9	1	7	7
Impact Strength	1/5	0.2	1/3	1/7	1	1/3
Hardness	0.2	0.2	1	1/7	3	1

Table 4.3 Determine Weighted matrix

Material	**ΣX_{ij}**
Tensile Strength	0.87010
Tensile Modulus	1.36003
Flexural	0.34046
Flexural	2.87299
Impact Strength	0.20367
Hardness	0.35274
Sum	6

Material Property	**Weights**
Tensile Strength	0.14502
Tensile Modulus	0.22667
Flexural Strength	0.05674
Flexural Modulus	0.47883
Impact Strength	0.03395
Hardness	0.05879
Sum	1

Coherence index mum (CI) of CR: 0.121, Coherence of Coherence (CR):0.098, and CR <0.1 for approval. Until the step above, AHP's method is finished with a weight calculation and a weight coherence check. From here the TOPSIS technique begins.

Table 4.4 Determine Normalized matrix

S.No	**Composite material**	**Tensile Strength (MPa)**	**Tensile Modulus (MPa)**	**Flexural Strength (MPa)**	**Flexural Modulus (MPa)**	**Impact Strength (MPa)**	**Hardness (BHN)**
1	Epoxy +	0.99882	0.93441	0.96690	0.31017	0.44412	0.83957
2	Epoxy +	0.55113	0.40108	0.55947	0.10614	0.59249	0.70936
3	Epoxy +	0.88783	0.85405	0.53385	0.58678	0.59249	0.96791
4	Epoxy +	0.85043	0.87856	0.55734	0.59143	0.44412	0.70936
5	Epoxy +	0.65730	0.75099	0.55947	0.40289	0.36994	0.83957
6	Epoxy +	1.00000	0.92577	1.00000	0.31234	1.00000	1.00000
7	Epoxy +	0.61683	0.46414	0.58082	0.49004	0.62235	0.70936

8	Epoxy +	0.44396	0.63784	0.52317	0.48343	0.36994	0.83957
9	Epoxy +	0.80117	0.75099	0.52744	0.41766	0.32563	0.83957
10	Epoxy +	0.67590	0.77369	0.54239	0.65710	0.71098	0.83957
11	Epoxy +	0.89496	0.79063	0.54452	0.54569	0.56262	0.96791
12	Epoxy +	0.75125	0.40036	0.60004	0.97863	0.53276	0.70936
13	Epoxy +	0.80710	0.71784	0.69795	0.22901	0.44412	0.96791
14	Epoxy +	0.95849	1.00000	0.51890	0.30387	0.53276	0.83957
15	Epoxy +	0.57141	0.57297	0.55520	0.87362	0.32563	0.83957
16	Epoxy +	0.78066	0.86775	0.53385	0.53805	0.57803	0.96791
17	Epoxy +	0.56864	0.41045	0.84134	0.23283	0.62235	0.83957
18	Epoxy +	0.89528	0.77982	0.52744	0.54393	0.59249	0.83957
19	Epoxy +	0.87124	0.87676	0.54239	1.00000	0.32563	0.83957
20	Epoxy +	0.72255	0.68973	0.55520	0.96603	0.88921	0.83957

Table 4.5 Determine S_i^+ matrix

S.No.	**Composite material**	**S_i^+ Values**
1	Epoxy + CCCC	0.12627
2	Epoxy + BBBB	0.16960
3	Epoxy + CBCB	0.07700
4	Epoxy + BCCB	0.07633
5	Epoxy + CBBC	0.11193
6	Epoxy + CCCC + 1% graphite	0.12566
7	Epoxy + BBBB + 1% graphite	0.10180
8	Epoxy + CBCB + 1% graphite	0.10100
9	Epoxy + BCCB + 1% graphite	0.10879
10	Epoxy + CBBC + 1% graphite	0.06665
11	Epoxy + CCCC + 2% graphite	0.08497
12	Epoxy + BBBB + 2% graphite	0.04363
13	Epoxy + CBCB + 2% graphite	0.14261
14	Epoxy + BCCB + 2% graphite	0.12766
15	Epoxy + CBBC + 2% graphite	0.04309
16	Epoxy + CCCC + 3% graphite	0.08601
17	Epoxy + BBBB + 3% graphite	0.14692
18	Epoxy + CBCB + 3% graphite	0.08545
19	Epoxy + BCCB + 3% graphite	0.01643
20	Epoxy + CBBC + 3% graphite	0.02653

Table 4.6 Determine S_i^- matrix

S.No.	**Composite material**	**S_i^- Values**
1	Epoxy + CCCC	0.05763
2	Epoxy + BBBB	0.00575
3	Epoxy + CBCB	0.09497
4	Epoxy + BCCB	0.09588
5	Epoxy + CBBC	0.05988
6	Epoxy + CCCC + 1% graphite	0.05846
7	Epoxy + BBBB + 1% graphite	0.07071

8	Epoxy + CBCB + 1% graphite	0.07078
9	Epoxy + BCCB + 1% graphite	0.06345
10	Epoxy + CBBC + 1% graphite	0.10433
11	Epoxy + CCCC + 2% graphite	0.08672
12	Epoxy + BBBB + 2% graphite	0.15984
13	Epoxy + CBCB + 2% graphite	0.03502
14	Epoxy + BCCB + 2% graphite	0.05856
15	Epoxy + CBBC + 2% graphite	0.14073
16	Epoxy + CCCC + 3% graphite	0.08630
17	Epoxy + BBBB + 3% graphite	0.02498
18	Epoxy + CBCB + 3% graphite	0.08614
19	Epoxy + BCCB + 3% graphite	0.16733
20	Epoxy + CBBC + 3% graphite	0.15884

Table 4.7 Finding Relative Closeness P_i

S.No.	Composite material	P_i Values	Ranking
1	Epoxy + CCCC	0.31338	17
2	Epoxy + BBBB	0.03278	20
3	Epoxy + CBCB	0.55222	7
4	Epoxy + BCCB	0.55678	6
5	Epoxy + CBBC	0.34853	14
6	Epoxy + CCCC + 1% graphite	0.31751	15
7	Epoxy + BBBB + 1% graphite	0.40990	12
8	Epoxy + CBCB + 1% graphite	0.41202	11
9	Epoxy + BCCB + 1% graphite	0.36837	13
10	Epoxy + CBBC + 1% graphite	0.61018	5
11	Epoxy + CCCC + 2% graphite	0.50508	8
12	Epoxy + BBBB + 2% graphite	0.78559	3
13	Epoxy + CBCB + 2% graphite	0.19717	18
14	Epoxy + BCCB + 2% graphite	0.31447	16
15	Epoxy + CBBC + 2% graphite	0.76560	4
16	Epoxy + CCCC + 3% graphite	0.50086	10
17	Epoxy + BBBB + 3% graphite	0.14533	19
18	Epoxy + CBCB + 3% graphite	0.50201	9
19	Epoxy + BCCB + 3% graphite	0.91058	1
20	Epoxy + CBBC + 3% graphite	0.85690	2

From TOPSIS method the best suitable material is Alternative 19 ie; Epoxy + BCCB + 3% graphite.

Conclusions

The characterization and ranking of mechanical hybrid composites was shown using AHP-TOPSIS method by the addition of graphite powder to composites to enhance the mechanical properties of epoxy composites. The following findings were reached via study of the composite structure of the CFRP hybrid: In line with the stacking sequence, the change in graphite % has been efficiently generated using CFRP and Basalt composites and also ranking of the hybrid composite.Future researchers may further analyze many more aspects of composites, including the effect of other production technology on the performance of composites.

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