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Experimental Investigation on Mechanical Properties of Epoxy Based Composites

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Abstract:- **Fibre Metal laminates is a sandwich structure having good mechanical and formability when compare to the traditional materials. This paper describes about the manufacturing and testing of FML's having the combination AA/GF-MWCNT-LDH-NC/AA. Multi-walled Carbon Nano Tubes (MWCNT), Layered Double Hydroxides (Mg-Al), Nanoclay (Cloisite 30B) is used as nanofiller which dispersed with the Epoxy resin at 3, 4 and 5wt%. The manufacturing of the material is done with hand layup technique due to it's cost effective. Adding of the filler material in resin improves the mechanical properties, electrical and flame retardant properties of the FML's.**

Macro characterization of sandwich structure is done with the help of mechanical tests like-Tensile, Flexural, Lap shear, Izod impact, Hardness test. Then the mechanical properties can be determined based on the tests performed.

Index Terms— Fibre Metal Laminates, Nanoclay, LDH, MWCNT, Epoxy Resin, Mechanical properties.

1.INTRODUCTION

Fiber-Metal Laminates (FMLs) are hybrid composite materials made of aluminium layer on both the sides laid to fiber reinforced Epoxy layers and it is a lightweight. GLARE (Glass Laminates Aluminium Reinforced Epoxy) FML shows outstanding damage towards tolerance capabilities [1] and have cost effective and having properties like high formability, high strength to low weight ratio and resistance to damping are in high demand for various auto mobile applications. Compare to other sandwich materials (GLARE) is used because of its potential light weight material, high specific strength, impact resistance and sound dampening properties which is used in automotive body panels[2-6]. Aluminum is a metal having good formability, flexural rigidity, dent resistance, corrosion resistance[7]. The intermediate materials in the aluminum sheet based on properties such as density, cost, and recyclability of a material.[8]

When we compare the hand-lay up method with the other methods it is more cost effective method[9-16]. Nanoclay is used to increase the compression and fractural toughness of the materials.[17]

LDH was used to the improve thermal and physical properties and MWCNTs were used to improve the impact resistance[18,19]. Shear support and fiber bridging by glass fibre was found to increase the tensile strength of composites [20].

These investigation is for testing the capability of replacing the sheet metals currently used for the automotive body panels and other applications. The mechanical testing of sheets to determine the properties of composites for applications in automobile and aircraft industries.

2.MATERIALS

2.1 Aluminium Alloy 5052-H32 (AA5052-H32)
Compared to all the other aluminium alloys 5 series(Al-Mg) is more strongest which are non heat treatable and they are more economical, they have good corrosion resistance to others. Aluminium alloy 5052 in H32 temper has better corrosion resistance to marine and industrial atmosphere and it also has good weld ability and formability characteristics.

Si	Fe	Cu	Mn	Mg	Cr	Zn	Other each	Other total
0.25	0.4	0.1	0.1	2.2-2.8	0.15-0.35	0.1	0.05	0.15

Tab.1 Chemical Composition of AA5052-H32

2.2 Nanoclay Cloisite 30 B

Nanoclay Closite 30B is mainly used increase the mechanical properties including tensile strength, young's modulus and flexural modulus.
When we add these nanoclay cloisite 30 B to the composite it becomes lighter and transparent having good heat resistance and increases its heat distortion temperature[21].The composites hence becomes flame retardant and also simultaneously the barrier properties will increases[22].

2.3 Epoxy Resin

Generally Epoxy Resins are well known for their excellent adhesion, heat resistance, good mechanical and chemical properties and also they have good electrical insulating properties. These epoxy based materials are used for

coatings, adhesives etc.The epoxy resin used in this project as resin AV-138 HV-998
Araldite® AV 138M-1 / Hardener HV 998 is a two component, room temperature curing paste adhesive of high strength.

2.4 Glass Fibre

The glass fibre reinforcement used here was E glass woven type which has density of 610g/m2. E- and S-glass fibers which gives a better corrosion resistance to water and higher surface resistivity. The internal structure of glass fibers is a three-dimensional, long network of silicon, oxygen, and other atoms arranged in a random fashion and they are lightweight, extremely strong material having high strength.[23]

Type	SiO_2	Al_2O_3	CaO	MgO	B_2O_3	Na_2O
E-glass	54.5	14.5	17	4.5	8.5	0.5
S-glass	64	26	—	10	—	—

Tab 2.Chemical CompositonOf E and S glass fibre.

2.5.Layered Double Hydroxides (MgAl)

LDHs have been studied in many aspects like structure, synthesis to know about their use in catalyst, ion-exchange, Adsorption, pharmaceutics and other fields and are used widely. Due to presence of hydrogen bond in it, they have stable strucutre. The composition of LDH is [MII 1–xM 'III x (OH)2](An–)x/n·mH2O (m = 0·33–0·50).It can be reinforced with Mg,AL,Cr etc.[25]

2.6 Multi Wall Carbon NanoTubes (MWCNTs)

CNTs are used mainly because of its thermo-mechanical properties. The addition of MWCNTs into epoxy improved the flexural strength and modulus also.

3.MANFACTURING OF SPECIMEN

The manufacturing was done mainly by hand layup technique. Firstly the sandwich core materials were cut as per given standards. The steps include

3.1Cutting of Aluminum Sheet:

The actual sheet dimension is 1220mm length and 1020mm width. By using of tin cutter the sheet were cut into 9 pieces of dimensions of 406 mm length and 340mm width each.

3.2 Preparation of Sheet Surface:

By using high quality emery paper rub the shine surface side of sheets which provides scratches in order to provide grip to sandwich sheet without causing de-lamination.

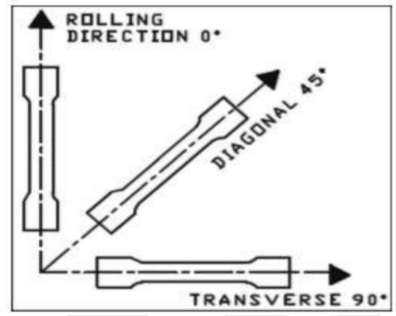

Fig. Different angles used for cutting of sandwich sheet in the direction of rolling.

3.3 Mixing of Resin and Hardner:

The resin was activated by hardener and mixed in a container using a stirrer. Safety precautions were taken.

3.4 Applying of Resin Hardner Mix to Aluminum Sheet Using Hand layup Technique:

The mixture was applied purely by hand and gloves were used for this purpose .The load was applied to spill out extra filler .

3.5 Application of Load on Sheets:

After the application of filler and epoxies, load was applied on the material for better joining. About 40kg of load was applied and the material was left for curing for about three to four days.

4. MACROSCOPIC TESTING OF SPECIMEN

Various kinds of macroscopic tests were performed on the specimen to check various mechanical characteristics including tensile strength, shear strength, flexural modulus etc. The various tests performed include Tensile test, Flexural test.
Tensile test specimens with gauge width of 12.5 mm and length of 50 mm were prepared as per ASTM standard. FIE Universal Testing Machine (UTM) was used to perform the tensile tests on the sandwich specimens. The specimens were fixed at both ends and pulled at a constant rate using a 400-kN UTM. A standard extensometer having the length of 25 mm was used to measure the strain accurately.

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To measure an isotropy, tensile specimens were cut with different angles using water jet technique like 0°, 45°, and 90°, to the sheet rolling direction. The stress was found with the equation.

$\sigma = k\varepsilon n$ (1)

Where σ is the true stress, k is the strength coefficient, n is the strain hardening exponent, and ε is the true strain of the specimen respectively.

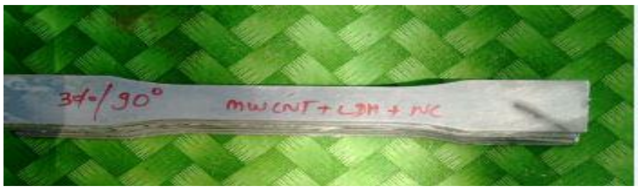

Fig .Tensile Test Specimen

The strain hardening exponent (n), planar anisotropy ΔR and the plastic strain ratio (R) are the parameters of formability of sheet metal. The tensile strength depends on planar anisotropy.

$R = \varepsilon w/\varepsilon t$(2)

$\varepsilon w = \ln(w/w0)$ (3)

$\varepsilon t = \ln(t/t0)$ (4)

where R is the state of anisotropy, which is the ratio of true width strain to true thickness strain. The value of R is evaluated and εw is the width strain, εt is the thickness strain, w is the change in width, w0 is the original width, “t” the change in thickness, and t0 is the original thickness was found using the above-mentioned formula.

4.2FLEXURAL TEST

The flexural test was performed as per ASTM D790 standard with the help of FIE Universal Testing Machine (UTM). For the specimen with a 150 mm length, 30mm wide, and 4mmthick, the load was applied at the center points of the span and a loading rate of 3 mm/min was used to carry out the flexural test. Loading pins and the supports were used to prevent local indentation failure on the test specimen. Strain gauges were placed on both sides of the specimen to analyze strain till failure.

$\sigma f = 3PL/2bd2$ (5)

$\varepsilon f = 6Dd/L2$(6)

The above equations (5) and (6) show the flexural stress on the midpoint and over the span respectively.

Fig.Flexural Test specimen

4.7 FLAME TEST:

Flamability test is conducted to check the fire retardant properties of the matetial when it is subjected to horizontal and vertical burning test.

5. RESULT AND DISCUSSION – MACRO CHARACTERIZATION

Macro characterization is a technique which helps to determine the formability parameters and mechanical properties by simple performing numerous Mechanical tests (tensile test, flexural test) over the Fabricated Sandwich structure. In this the formability parameters and mechanical properties are determined by calculating from the given data obtained from testing. This helps to know the differences between the experimental-observed and calculated values.

5.1. Tensile Test

5.1.1.AA/GF+NC+MWCNT+LDH-Epoxy-3%/AA: 00,450,900.

The table represented below has the values of sandwich material of combination AA/GF+NC+MWCNT+LDH-Epoxy-3%/AA. The stacking sequence is 00, 450, 900.

The observed results of tensile test at 3% at 00, 450, 900 is shown in tab 5.1

Tab 5.1

Degrees	0^0	0^0		45^0	45^0		90^0	90^0	
Specimens	1	2	Average	1	2	Average	1	2	Average
Breaking load	2850N	2850N	2850N	2800N	2700N	2750N	2900N	2800N	2850N
Ultimate load	3410N	2960N	3185N	3020N	3050N	3035N	3050N	3250N	3150N
Displacement at Max	mm	mm	mm	mm	mm	mm	mm	mm	mm
Area (mm^2)	44.088	44.088	44.088	44.789	44.789	44.789	37.979	37.979	37.979
Ultimate stress (N/mm^2)	77.345	67.138	72.24	67.427	68.097	67.762	80.308	85.575	82.9415

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Elongation %	10.5%	12.14%	11.32%	6.38%	6.07%	6.22%	8.36%	8.21%	8.25%
Yield stress (N/mm^2)	74.615	65.9	70.257	61.84	59.487	60.645	75.126	66.140	70.633
YS/UTS ratio	0.964	0.981	0.9725	0.9166	0.8735	0.8949	0.9354	0.7760	0.8557
Max displacement (mm)	7.43	6.92	7.71	3.64	3.46	3.55	4.77	4.68	4.72

Calculations:-

Given data for specimen/degree of cut
Gauge length, l0 = 57 mm
Final gauge length, l = [(Avg % of Elongation × l0) = [(0.1132 ×57)] + 57=63.4532mm
Original gauge width, w0 = 13.20 mm
Thickness, t = 2.96mm
Avg. of % elongation = 11.32 %
Yield stress, σy=70.257N/ mm2
Final gauge width,w =13.2 mm
Initial area, A0 (w0×t) = (13.42×2.96) =39.072mm2
UTS (avg) = 72.241 N/mm2
Average area, A = 38.676 mm2

Formability Parameters

1) Engineering stress, σeng= load/original length = (p/A0)= (3250/39.072)=87.274N/mm2
2) Engineering strain, εeng= change in length /original length = (Δl/l0)=(l-l0/l0)= (63.452 - 57/57) =0.0461
3) % of elongation, (Avg. strain ×100) = 11.32 %
4) UTS, P/ A = (3250/38.676) =8 4.031 N/mm2
5) Poisson ratio, = 1/m= lateral strain/longitudinal strain = (w0-w/l-l0) = (13.42 – 13.20 / 63.425- 57)= 0.157N/mm
6) Anisotropy, R = ln(w/w0)/ ln(w0l0/wl)=(ln 0.979/ln 51.070)=0.0303
7) Yield load, Ry= (yield stress*area) = (σy×A0)=(74.61x39.072)=2745.08N
8) Breaking stress, (Load at fracture / Avg. Area) = (2850/38.676)=90.62
9) Strain hardening (co-efficent and exponent):
True stress, σt= σ(1+εe) =0.8151(1+0.112)=0.90637
True strain, εt = ln(1+εe)=ln(1+0.112)=0.1062
logσt= -0.0427
logεt= - 0.9746
Strain hardening, n = Δy/Δx=0.0438
Strain hardening, k = σt/ εtn =999N/mm2
nR = 0.0438*4.407 = 0.19302

Graphical Representation

Now the graph is plotted using origin and plotter software (as shown in fig. 5.2) for the results that is obtained from the test lab. This graph provides us a clear cut representation of the best result over 3 stacking sequences (00, 450, 900) for the same percentage weight composition – 3%.

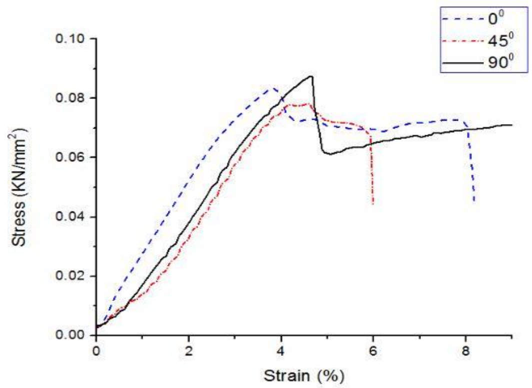

Fig.5.2. Represents the collective graphical image of different stacking sequence for 3%.

Planar Anisotropy, ΔR = ((R0+R90-2R45)/2) = 0.1707

Plastic Anisotropy Ratio, = ((R0+2R45+R90)/4) = 0.4213

CONCLUSION

Tensile test performed on sandwich of structure AA/GF+NC+MWCNT+LDH-Epoxy-3%/AA reveals that the cut along 00 rolling direction simply has better mechanical and formability characteristics because of it's ductile behavior.
Flexural test results show that among all different materials fabricated MWCNT of 3% weight is best outcome. It is because the stiffness as well as the max deflection of the material is comparatively higher than other.
This proves that this particular material has the stiffness as well as the max deflection of the material is comparatively higher than others. This proves that this particular material has the ability to absorb maximum load forced to it and further has the capacity to transmit the load uniformly without any failure.

For horizontal flame test the result depicts that specimen was self extinguished type & for vertical flame test the result obtained was V-0. Both the results of flames test signify that the samples posses a very high fire resistant nature.

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