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Experimental investigation on the mechanical properties of glass fiber with perforated aluminum sheet reinforced epoxy composite

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ABSTRACT

The importance of composite has been increased for the weight reduction in aerospace, automobile and in other industries need various structures. In recent days, the hybrid and fiber metal laminate composite materials play the vital role due to its ingenious properties like ease of structure, strength to weight ratio and high strength. Instead using the aluminum as sheet, due to the easy availability and less cost, perforated aluminum sheets used of thickness 0.3mm with circular holes of diameter 3mm and pitch distance of 25mm. In this work, the metal/fiber hybrid laminates were tested in four different layer stacking combination of glass fiber and aluminum sheet (A/G/G/A, G/A/A/G, A_p/G/G/A_p, G/A_p/A_p/G). The composite specimens were prepared by hand layup method. As per ASTM standards Tensile, Flexural and Impact specimens were fabricated and its properties were evaluated. The results revealed that fiber metal laminate G/A_p/A_p/G shows better tensile strength 71.01 Mpa and impact energy 5.3 Joules. While in flexural specimen, sample G/A/A/G exhibits better flexural strength of 23.08MPa. From the experimental investigation, it has been concluded that the G/A_p/A_p/G fiber metal laminate have better mechanical properties like tensile and impact strength along with approximately 30% reduction of weight.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Newer Trends and Innovation in Mechanical Engineering: Materials Science.

1. Introduction

The demand on light weight, strong and durable structures have increased [1,3]. Fiber metal laminates (FMLs) are hybrid composite structures based on thin metallic sheets and layers of fiber reinforced plastics(FRPs) [2]. The main advantages of FMLs are their excellent fatigue resistance, damage tolerance, impact resistance compared to monolithic metallic alloys and FRPs [4]. FMLs overcome most of the disadvantages of both materials like poor fatigue strength of the aluminum alloys and the poor impact and residual strength properties of fiber reinforce composites [5]. FML fibers can be basalt fiber, aramid fibers or carbon fibers [6]. Glass laminate aluminum reinforced epoxy exhibit better adhesion with the metallic substrate and between the fibers compared to other reinforcing fibers [79]. The study investigates the applicability of the basalt fibers as strengthening material for structural members through various experimental works for durability, mechanical properties and flexural strengthening [10].

Fiber metal laminates are hybrid composite materials, consisting of alternating metal layers bonded to fiber reinforced prepeglayers [11]. The progressive damage behaviors of FML by considering stress based material failure and shear stress based lamination failure between adjacent layers studied. The scope of this investigation is to find the behavior of aluminum sheets to increase the mechanical properties like tensile strength and impact strength. The FML is fabricated using hand lay-up method followed by compression molding by varying the stacking combinations. In recent years, light weight aircraft and automotive structures not only reduce the fuel consumption and pollution but also improves the service life of key components [1214]. In these, FMLs made through hot pressing and curing has attracted the interest of researchers for its excellent mechanical properties and weight reduction effect [1517], as shown in Fig. 1.

In the 1980s, aramid fiber reinforce aluminum alloy laminates (ARALL) [1819] were implemented in aerospace industries because of its impact resistance, fatigue resistance and anticorrosive nature were stable during service [20]. Late in 1990s the glass reinforced aluminum laminates (GLARE) were used in aerospace industries because of its excellent properties [21].

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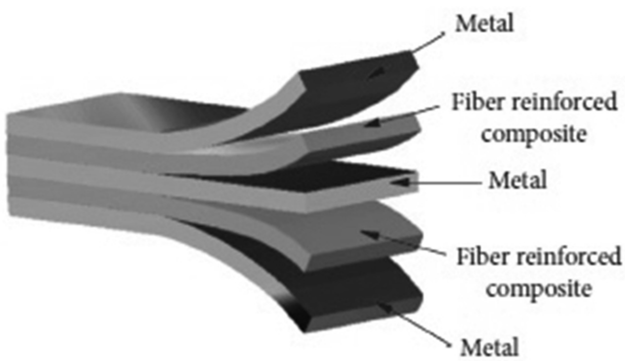

Fig. 1. Stacking arrangement in FML.

Fig. 2. Aluminum sheet with perforation.

2. Materials and methods

2.1. Reinforcement materials

Reinforcement in the composite material is fiber. There are various types of fibers which can be used as reinforcement and they are carbon fiber, glass fiber, E-glass fiber, S-glass fiber etc., Based on the literature survey cited, glass fiber produces good results in mechanical properties. Glass fibers used as a reinforcing agent for many polymer products to form a very strong relatively lightweight fiber reinforced polymer (FRP) composite material called (GRP), also popularly known as fiber glass. This material contains little or no air or gas, is denser and much poor thermal insulator than glass wool.

Aluminum is a commercial wrought alloy of aluminum. Its composition is Cu 4.4%, Mn0.65% and Mg 1.5%. It was first developed by ALCOA in 1931. Some properties of aluminum are high strength to weight ratio, high fatigue resistance, and high fracture toughness. In this research work, glass fibers are used as layers along with the aluminum sheet of thickness 0.3mm thickness. In order to increase the good bonding and adhesion between fiber, metal and epoxy resin circular holes of diameter 3mm are punched in aluminum sheet at a pitch distance of 25mm. The mechanical properties are compared with plain aluminum sheet and perforated aluminum sheet.

Epoxy resin refers to a type of reactive pre-polymer containing epoxies group. These resins react either with themselves in presence of catalysts, or with many co-reactants like amines, phenol, thiols etc. Epoxy resin has many industrial applications for a variety of purposes. It possesses higher mechanical properties and more thermal and chemical resistance than other types of resin. Therefore, it has exclusive use in making aircraft components. Epoxy resin having the outstanding properties like excellent adhesion to different material, great strength, toughness, resistance to chemical attack, resistance to moisture, better electrical insulating property, odorless, nontoxic, negligible shrinkage etc. The properties of the composite materials are shown in Table 1.

Table 1
Properties of composite.

Density of glass fiber	2.54g/cm^3
Density of epoxy resin	1.21g/cm^3
Density of aluminum sheet	2.7g/cm^3
Length of composite plate	30cm
Breadth of composite plate	30cm
Thickness of composite plate	3mm
Volume of composite plate	270cm^3
One square feet of glass fiber	65g
One square feet of aluminum sheet	35g
Total weight of one composite plate	365g

Table 2
Stacking arrangement and designation.

Specimen	Stacking Arrangement
Composite A	A/G/G/A
Composite B	G/A/A/G
Composite C	A_p/G/G/A_p
Composite D	G/A_p/A_p/G

2.2. Preparation of composite specimen

In this FML, composites are prepared using glass fiber and aluminum sheet are reinforced with epoxy resin with hand layup method. Composite plate fabricated to the size of 300mm length, 300mm width and 3mm thickness. The glass fiber(G), aluminum sheet without perforation(A) and aluminum sheet with perforation(A_P) is shown in Fig. 2.

The specimen and stacking arrangements are shown in Table 2

The composite specimens are prepared using hand layup method. The following materials are used,

Epoxy resin LY556
Hardener - HY951
S Glass fiber
Aluminum sheet- 0.3mm thickness

The tools used to make composite plates are silicon rubber, polyester lamination sheet, plywood, roller and weight for setting purpose. The composite plate is allowed to cure for 24h with 50 kg load over it. Then it is post cured in air for another 24h. After removing from the mould the specimens are cut to the suitable dimensions using diamond cutter.

3. Results and discussions

The specimens are prepared as per ASTM standards for testing. Tensile test ASTM D638 is used with a test speed of 2mm/min. Flexural and impact test were performed by ASTM D790 and ASTM D256 respectively.

3.1. Tensile properties of FML composite

Tensile specimen prepared as per ASTM D638, shown in Fig. 3. The specimen tested using universal testing machine and results shown in Table 3.

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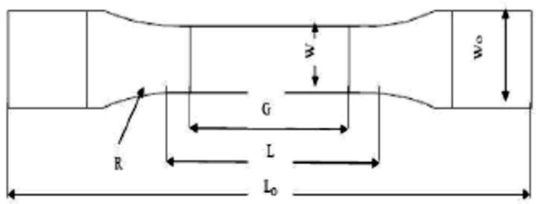

Fig. 3. Tensile test specimen.

Table 3
Tensile test results.

Specimen	Tensile strength, MPa	Max. strain	Tensile modulus, MPa
Composite A	36.91	0.1045	353.21
Composite B	47.89	0.0997	480.34
Composite C	36.38	0.1018	357.37
Composite D	71.01	0.0872	814.33

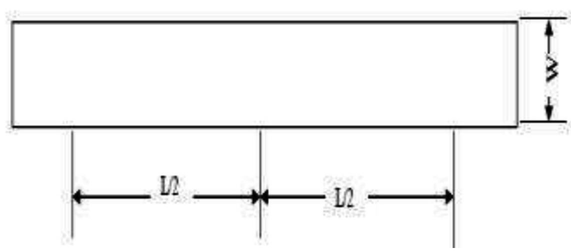

Fig. 4. Flexural test specimen.

Table 4
Flexural strength test results.

Specimen	Flexural strength, MPa	Flexural modulus, MPa
Composite A	23.08	157
Composite B	20.19	137
Composite C	20.19	132
Composite D	20.19	137

Based on the testing results obtained, Composite D has higher tensile strength than Composite B as glass fibers restricts the perforated sheet contains holes which act as crack initiators.

3.2. Flexural properties of FML composite

Flexural test specimen prepared as per ASTM D790 standard as shown in Fig. 4

The planned combinations are tested for flexural strength has been obtained and results are shown in Table 4.

The specimen Composite A having plain aluminum sheet layer outermost has higher flexural strength than perforated aluminum FML (Composite C & D). The difference in the values is due to the presence of perforations that might be the reason for reduction in flexural strength. At the same time Composite B also indicates no change in the flexural strength as the glass fibers are in inner layers.

3.3. Impact properties of FML composite

The composite specimen prepared as per ASTM D256 standard is shown in Fig. 5.

The impact result tests for the combinations are shown in Table 5.

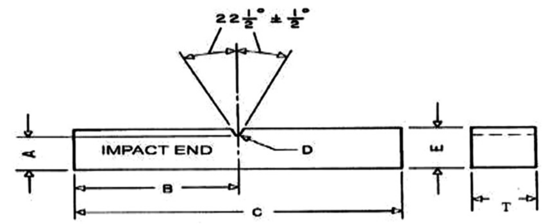

Fig. 5. Impact test specimen.

Table 5
Impact test results.

Specimen	Impact energy, Joules
Composite A	2.4
Composite B	5
Composite C	2.8
Composite D	5.3

Due to the presence of glass fibers in the outermost layer (Composite B & D) results in good impact strength because of the absorption of energy by the fibers. In Composite A and Composite C, the chances for delaminate and aluminum layer metal surface reduces the absorption of energy in outermost layer.

4. Conclusions

The effect of stacking arrangement to various combinations of glass fiber, aluminum plain sheet and perforated aluminum sheet are investigated. From the above results it was concluded that,

- Based on the perforated circular hole diameter 3mm and pitch distance 25mm, the weight is reduced approximately 30% in perforated aluminum sheet.
- When comparing flexural strength 20.19MPa of Perforated Aluminum sheet/Glass fiber/Glass fiber/Perforated Aluminum sheet (Composite D) with flexural strength of 23.08MPa of Aluminum plain sheet/Glass fiber/Glass fiber/Aluminum plain sheet (Composite A) has less value due to perforation, but significant reduction in the weight of the aluminum sheet as mentioned earlier.
- By Comparing the impact energy 5 Joules of Glass fiber/Aluminum plain sheet/Aluminum plain sheet/Glass fiber (Composite B) with impact energy 5.3 Joules of Glass fiber/Perforated Aluminum sheet/Perforated Aluminum sheet/Glass fiber (Composite D) has more impact strength with significant reduction in the weight of the aluminum sheet as mentioned earlier.
- In converse to above results, perforated aluminum sheet Composite A and Composite C having almost same tensile strength and impact strength, but significant increase in flexural strength in Composite A.
- Composite D, Glass fiber/Perforated Aluminum sheet/ Perforated Aluminum sheet/Glass fiber exhibits better mechanical properties when compare to the other combinations like Composite A,B & C having tensile strength 71.01MPa, impact energy 5.3 Joules, flexural strength 20.19MPa due to perforation in Composite D makes strong interface bond between aluminum and composite layer.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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