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Effect of Aluminium Filler in the Impact Behavior of Fiber Metal Laminates

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ABSTRACT

Fiber metal laminates are the hybrid composites that contain both metals and polymeric composites layer by layer in order to combine the effects of both constituents. It has excellent strength to weight ratio, high bearing strength, good impact and fatigue resistance. Due to emerging needs we have to improve the properties of fiber metal laminates and the best idea for this is adding filler materials. These filler materials are added with matrix to increase the homogeneity of the matrix with the metal in order to increase the bonding. In this paper, the effect of filler in the impact behavior of fiber metal laminates through the low velocity impact tests such as Drop weight test, Izod and Charpy tests has been studied. The response of the materials under the impact loading was discussed and found that the addition of filler leads the FML to behave better.

KEYWORDS: Fiber metal laminates, Glass fiber reinforced polymer, Aluminium, Drop weight impact test, Delamination

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INTRODUCTION

Composites are one of the major materials used in the aerospace industry due to its excellence strength to weight ratio, corrosion resistance, stiffness and fatigue properties but lacks in impact and residual strengths. On the other hand metals have good flexural and impact properties but poor fatigue properties. The fiber metal laminates are the combination of metals and composites results low specific mass, good bearing strength, excellent impact and fatigue properties. From the earlier studies the fiber metal laminates are more excellent when compare to the GFRP's because it posses increased damage tolerance. Similarly GLARE (Glass Laminate Aluminum Reinforced Epoxy) has notable mechanical properties when compare to the ARALL (Aramid Fiber Reinforced Aluminum laminate) and CARALL (Carbon Reinforced Aluminum Laminate) such as minimum deformation, higher energy absorption and reduced damage.

Alderliesten R reviewed the various hybrid material concepts[1]. Bernhardt S compared low velocity impact response of the hybrid titanium composite laminate (HTCL) with the carbon/epoxy laminate with the characterization of two modes of failure which differed by failure or non-failure in tension of the bottom titanium ply[2]. Cortes P predicted the fracture properties of magnesium based fiber metal laminates by comparing it with the magnesium for various stacking positions of fiber metal laminates through the tensile specimens[3]. Hariharan E studied the post-crack load capacity of fiber metal laminates made up of aluminium alloy through various static loading tests [4]. Rajkumar G R studied the effect of strain rate and lay up configuration on tensile and flexural behavior of aluminium based fiber metal laminates and shown that these properties are maximum for carbon based FML and minimum for glass based FML[5]. Das R compared the impact properties of fiber metal laminates that are made up of thermoplastic polymers (TPP) and thermoplastic elastomers (TPE) as matrix and shown that impact strength significantly improved for FRTPE through drop weight test[6]. Eslami Farsani R discussed the aspects of modifying the properties of fiber metal laminates by using nano fillers[7]. This work carries out the method to increase the bonding between the adjacent layers by dispersing the filler material in the polymer matrix thus in order to improve the properties of the fiber metal laminates.

MATERIALS & FABRICATION

In this paper the effect of the filler material in the impact behavior of fiber metal laminate was evaluated by comparing it with the fiber metal laminate without addition of filler material. At the same time the performance of the filler contained fiber metal laminate is compared with GFRP and aluminium alloy. For this, four types of specimens are prepared with identical geometry and dimensions. Those are aluminium alloy, GFRP, Fiber metal laminate with and without addition of filler material.

Aluminium Alloy

The aluminium 1100 alloy is used as the specimen for investigation. The geometry and dimensions are maintained same as that of the fiber metal laminate.

Glass Fiber Reinforced Polymer

To fabricate the GFRP plate layers of unidirectional S-Glass fibers (220gsm) is placed in a cross ply configuration and for drop weight test $[45/0/-45/90]_s$ are bonded by Epoxy Ly556 and Hy951. After the layup the specimen is cured in hot air oven as described by the manufacturer.

Fiber Metal Laminate without Filler

The fabricated FML consist of 3 layers of Aluminium alloy 1100 grade sheets of 0.35mm thickness and 2 cross-ply layers of unidirectional S-glass fibers (220gsm) with 0.266mm thickness. For drop weight test specimen, instead of cross ply the ply orientation is maintained as $[45/0/-45/90]_{s.}$ To cure the epoxy, Hy951 hardener was added to Ly 556 resin. The surface of the aluminium sheet is roughened before the layup by mixed acid etching by immersing the sheet into the mixture of HF, HCL and H_2O to minimize the possibility of delamination. After the layup the material is vacuum bagged to achieve good fiber volume ratio and to reduce the formation of voids.

Fiber metal laminate with filler

The fabrication of this specimen is same as that of the fiber metal laminate but the aluminium filler is mixed with the matrix to enhance the bonding. The metal powder is added to the matrix after the epoxy and hardener mixing.

Table: 1 Specimen Dimensions

S. No	Test		Standard	Dimension
1	Izod	Notched	ASTM D256	64*12.7*3.2mm^3 & depth of the notch is 10.2mm
		Un-Notched	ASTM D4812	64*12.7*3.2mm^3
2	Charpy		ASTM 7136	55*10*10mm^3 & depth of the notch is 3.3mm
3	Drop weight		ASTM 7136	100mm*150mm*5mm

PROCEDURE OF LOW VELOCITY IMPACT TESTS

Generally low velocity impact tests are carrying out with impact velocity below 10 m/s and also it depends on the properties target and impact object. The well known low velocity impact tests are Izod, Charpy and Drop weight tests. Among which the drop weight test is the widely used one because it enables wide range of real world impact conditions and complex geometry components.

Izod Impact Test

Izod impact test is used to identify the impact toughness of the material. In which the notched specimen is placed as a cantilever beam in the testing machine and the arm attached to the machine is allowed to strike the notched face of the specimen at the tip of the specimen and makes the specimen to break. From the height of the arm movement the absorbed energy is noted after the impact.

Charpy Impact Test

Charpy test is also similar to the izod but the striking position of arm and specimen holding position will differ. The arm drop angle for izod test is 90^0 and for charpy test is 140^0. Also the specimen is attached like a simply supported beam in the bed and the arm is allowed to strike the unnotched face of the specimen at the middle of the sample.

Drop Weight Impact Test

In the drop weight test a mass is allowed to fall from a specific height on the target specimen. Both the physical and geometrical properties of the ball and the height from which it is falling will determine the load on the specimen. The velocity of the falling object at the time of impact could be calculated by

$$V = \frac{d}{(t_2 - t_1)} + g\left(t_i - \frac{(t_1 + t_2)}{2}\right) \quad (1)$$

Where V is the impact velocity in m/sec, d is the distance between upper and lower heads in sec, t_1 is the time when lower head passes the detector in sec, t_2 is the time when upper head passes the detector in sec, $t_1$is the initial time from the force-time curve in sec.

By detecting velocity of the impactor one can calculate the impact energy from the following equation

$$E = \frac{mV^2}{2} \qquad (2)$$

Where E is the measured impact energy in J, m is the mass of impactor in Kg.

The required height to obtain the specified impact energy could be calculated as

$$h = \frac{E}{mg} \qquad (3)$$

Where h is the height required to drop in m, g is the acceleration due to gravity in m/s^2

The velocity or the energy delivered to the target can be controlled by adjusting the height of drop. When the impact happens the falling object either may perforate the target or rebound from it. When the target is perforated by the falling object, it is notable that the absorbed energy is less than the impact energy and while rebound, the impact energy will be the sum of absorbed energy and rebound energy.

RESULTS

Izod Impact Test

Izod test performed on 5 specimens in each category and their results are shown in Figure 1.

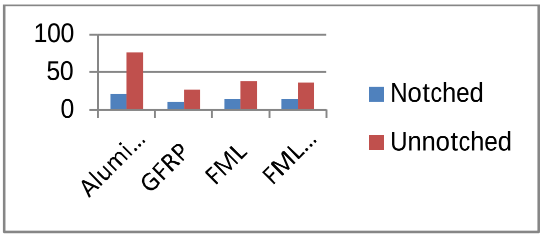

Figure 1. Energy absorption of various specimens in J during Izod impact test

The energy absorption of Fiber metal laminates falls in between the aluminum and GFRP due to the outer metal layer of aluminium. Although, the toughness of FML with filler and without filler specimens are identical.

Charpy Impact Test

Charpy impact test performed on 5 specimens and their results are summarized in Figure 2.

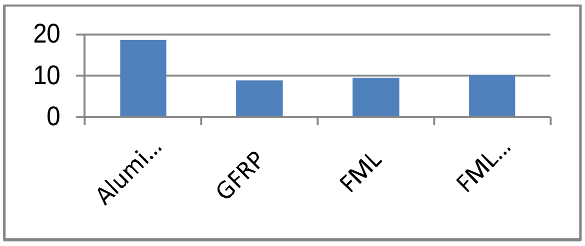

Figure 2. Energy absorption of various specimens in J during Charpy impact test

Similar to the Izod test, the chapy test also results the energy absorption of the FML with and without filler are identical and falls between the metal and composite specimens.

Drop Weight Impact Test

For the low velocity impact testing, 2 values of impact velocity were selected. Impact test was done for velocities of 2.5m/s and 3m/s on monolithic aluminium, glass fiber reinforced composite, fiber metal laminate (FML) and FML with filler material. The data obtained from the instron ceast 9340 drop weight impact tester, was processed for further analysis.

Figure 3. (a) Monolithic aluminium (b) Glass fiber reinforced composite (c) Fiber metal laminate (d) Fiber metal laminate with filler specimens at velocity 2.5m/s

Fig 4. (a) Monolithic aluminium (b) Glass fiber reinforced composite (c) Fiber metal laminate (d) Fiber metal laminate with filler at velocity 3m/s

The specimens after the impact test are visually inspected and deformation is found to be higher in the case of aluminium and lower in the case of GFRP. In FML specimen, there was an intermediate dent and the failure was found in the form of delamination between the metal and composite layers. The FML added with filler was not undergone delamination but the indentation depth is found to be fall in between the aluminum and GFRP specimen at impact velocity of 2.5m/s. At 3m/s, the delamination was also found in the FML with filler specimens, but the delaminated area is less when compared to the FML specimen.

The peak of the time-force curve represents the maximum force withstands by the material during low velocity impact loading. Maximum force is defined as the maximum amount of force that the specimen was subjected in the duration of test. It could also represent the load at which the specimen fails. When velocity of the tub reaches zero and the specimen was not perforated, hence the maximum deformation will be achieved. From Figure 5, it is observed that the minimum force was experienced by aluminium and maximum force was experienced by GFRP.

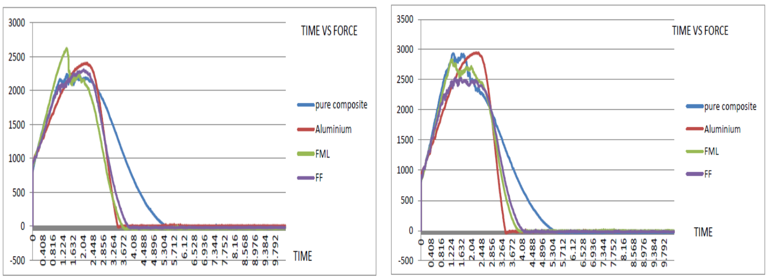

Figure 5. Time-force curves for different materials at velocity (a) 2.5m/s (b) 3m/s

The maximum deformation in the time-deformation curve represents the impact damage depth and also maximum elastic deformation before failure. From Figure 6, the deformation of FML and FML with filler specimens is found to be identical also falls in between the GFRP and aluminium specimens. The aluminium specimen experiences maximum deformation and of GFRP is found to be minimum. Even though the deformation of the FML and FML with filler specimens is same, the FML with filler results lesser delamination.

The peak value in the time-energy curve represents the maximum energy absorbability of the material. This parameter is an indication of the efficiency in the specimen in energy absorbability. The curve was found to be smooth and indicates that the energy was attenuated by the plastic deformation of the specimen. From Figure 7, the energy absorption is identical for aluminum, FML and FML with filler specimens, which indicates the energy absorption rate of FML is identical to that of metals as well as separated greatly with the GFRP specimens after impact.

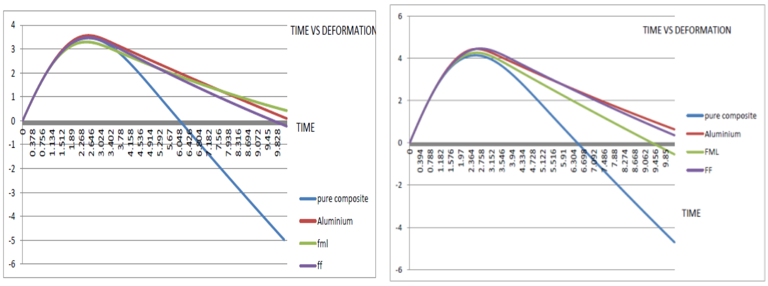

Figure 6. Time-deformation curves for different materials at velocity (a) 2.5m/s (b) 3 m/s

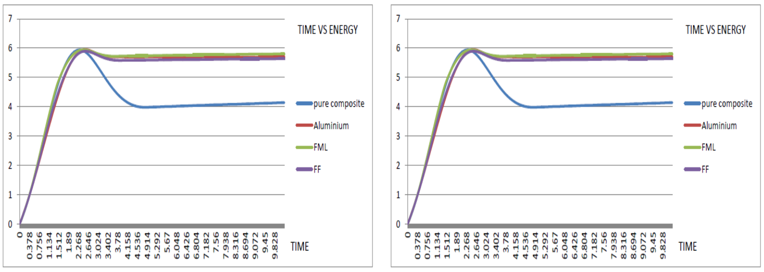

Figure 7. Time-energy curve for different material at velocity (a) 2.5m/s (b) 3m/s

Deformation-force curve represent the force required for unit deflection typically the stiffness of the specimen. There was two sharp drops found in the curve, represents the first material damage and first lamina failure respectively.

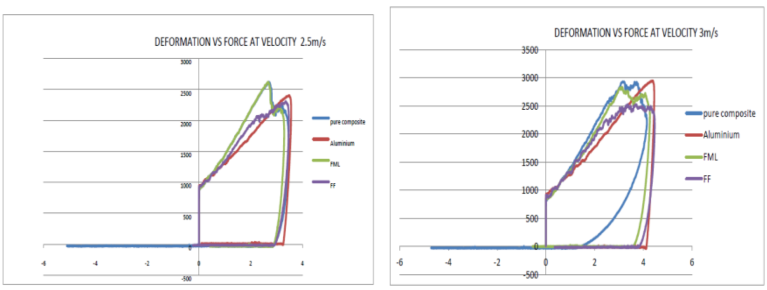

Figure 8. Force-deformation curve for different material at velocity (a) 2.5m/s (b) 3m/s

From Figure 8, the aluminium is found to have less stiffness and GFRP is stiffer. It was observed that there were two sharp drops on the force-deformation curves of FML and GFRP, which represents the initial damage and first ply failure. There was no such type of drops are found in the FML with filler and metal specimens, thus shows that there was difference between the initial damage and initial ply failure.

CONCLUSION

This work demonstrates the effect of filler material in the impact response of the fiber metal laminates. Aluminium filler was added into the matrix to improve the bonding between composite and metal layers. From the results, it is observed that the FML specimens with filler has significant increase in the impact response, when compared to ordinary FML specimens but produces higher deformation than the GFRP. From the visual inspection of the tested samples, it is evident that the delamination of the FML reduced with the usage of the filler contents and the first ply failure was postponed, when compare to GFRP and FML specimens.

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