Experimental Characterization Of Fibre Metal Laminates For Tensile And Impact Properties With Finite Element Modelling Approach

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Abstract

Fibre Metal Laminates (FMLs) are layered materials based on stacked arrangements of aluminium alloy layers and Fibre Reinforced Plastic (FRP) layers. They have shown great potential in lightweight aerospace applications and the improved mechanical properties have accomplished the new type of laminates which included aramid /silicon / glass / carbon fibre. In this work, aramid/glass fibres with Al 2024, polyester resin laminates were prepared and their impact response, stress-strain behaviour has been investigated with experiments and numerical simulations. The 5-3/2 laminates of size 300x300 mm with thickness 3mm were cut by using Vacuum assisted resin transfer moulding (VARTM) technology in cold compaction, the specimens were prepared by using water jet machining as per standards for impact and tensile test. Impact responses were taken from Charpy testing machine and stress-strain responses were done using 10 ton capacity, servo ball screw mechanism UTM. The tensile and impact specimen fracture surfaces were studied using Scanning Electron Microscope (SEM) and the numerical simulations were studied in a Ansys APDL10 Software. It is shown that aramid have more strength than glass and their impact and tensile values correlated with numerical solutions.

Key Words: FML,VARTM,SEM, Fracture Surface, Numerical Simulatios.

1. Introduction

Fibre Metal Laminates (FMLs) are highly used in aircraft structures like fuselage panels, wing skin and tail skin because of their excellent strength to weight ratio and damage tolerance capability. The unique combination of ductile aluminium layers with high strength FRP layers results in a unique FML having light weight, outstanding fatigue resistance, high specific static properties, excellent impact resistance, good residual and blunt notch strength, flame resistance and ease of manufacture and repair The FMLs with glass fibres (trade name GLARE), and Aramid fibres (trade name ARALL), and carbon fibres (trade name CARALL) are attracting the interest of a number of aircraft manufacturers. For example, ARALL was used in the manufacture of the cargo door of the American C-17 transport aircraft and GLARE laminates were selected as the upper fuselage materials in the ultra-high capacity Airbus 380 and lower wing panels of the Fokker 27 [1-2]. A sandwich structure consists of two basic constituents, the faces and the core. Face sheets typically made from metal sheets or fibrous composite layers, both have some advantages and disadvantages. Searching for new materials with better properties is in progress [3]. Metal sheets are heavy but have better resistance and continuity against transverse loads. On the other hand, although, fibre reinforced plastics have the benefit of being lighter comparing to metal sheets, they are susceptible to the formation of large areas of internal damage when subjected to lateral loads specially impact events and more vulnerable to the environmental effects [4-5].
The variety of fibres of different mechanical properties and orientation and stacking sequences has given a wide range of possibilities. The acronyms ARALL, GLARE or CARALL became the well-known names of the Fibre metal laminates – very efficient structural materials. At present, the most of commercial applications are based on unidirectional glass fibre prepregs which are laid-up between aluminium alloys sheets. However, FMLs as classical laminates can be tailored to any engineering application by choosing different component layers build-up so the new generation is under technological and manufacturing growth [6].At present for design engineers the key property concerning composite structures there is the strength to weight ratio leading to some kind of a strength optimising analysis. It also includes failure criteria application in order to predict loading conditions

under which the composite structure collapses. All specified FML features Make lower thickness or higher stresses in FML structures possible. Thus, thin-walled FML sections are prone to buckling and may undergo different modes of buckling. In a case of thin-walled members buckling load may decide of their capacity not only a strength itself. Various numerical and experimental investigations have been performed to analyse the stability of composite structures their buckling and post-buckling state. Comparative analyses by means of FEM and semi-analytic methods also were carried out in. Nonetheless, there are relatively few papers devoted to buckling strength analysis and load carrying capacity of thin walled FML members [7-8]Fibre metal laminates (FMLs) are hybrid materials; consisting of metal layers and fibre Reinforced polymer which combine the characteristics of metals and composites. These materials have excellent fatigue resistance and damage tolerance. Materials like GLARE, CARALL and ARALL, which are combinations of aluminium with glass, carbon and aramid fibres, respectively, show increasing applications in industries. [7-11]High-cycle fatigue life in aligned glass fibre composites is dominated by fatigue cracking in the matrix, which subsequently propagate and rupture the main load bearing elements, i.e., the fibres. The lower elasticity modulus of glass fibres, when compared to the high-modulus of carbon fibre composites, may impose higher strains in the matrix leading to failure by fatigue. Therefore, the addition of nanoparticles, such as carbon nanotubes (CNTs) or montmorillonite clays (MMTs), is expected to contribute to decrease the scale of damage mechanisms, leading to an increase in the absorption of strain energy through the creation of a multitude of fine nano-scale cracks [9]A review made recently by tensile and impact resistance of FMLs showed that in spite of many articles concerned on the tensile/ impact behaviour of these laminates, the research on this part of FML Performance is still in the early stages. In the present study the performance of glass/carbon/aramid fibre / Al (typically 0.28 mm thick) laminates is investigated by conducting tensile, impact, flexural and hardness test and correlating the values with numerical simulations.

2. Experimental Setup

However, GLARE is expensive to produce and part size is limited due to the required prepreg and use of an autoclave in consolidation. Traditionally, composites have also been fabricated by similar methods. However, infusing liquid resin into dry fabric layers solely by vacuum pressure to produce high quality materials has proven to be a more cost-effective process for preparing composites [2-3]. This process, known as vacuum assisted resin transfer molding (VARTM), utilizes a flow distribution media to allow the resin to proceed rapidly on the surface over the length of the part followed by the slower through the thickness infusion through the part, thereby decreasing infusion times. Aluminium 2024 alloy 0.28 mm thickness plate (composition roughly includes 4.3-4.5% copper, 0.5-0.6% manganese, 1.3-1.5% magnesium and less than a half a percent of silicon, zinc, nickel, chromium, lead and bismuth, data given by the supplier) bi-direction (0° by orientation) Aramid fibre 380 GSM, polyester resin and hardener were selected. The accelerator used for cleaning a 300x300 mm die. Aluminium sheet cleaned by acetone to remove grease, direct and chromate for better adhesion between the layers [12] .The Fig-1 shows stacking arrangement of Al and fibre mat, whereas Fig-2 shows the image drilled sheets of aluminium stacked with fibres placed in the die and Fig-3 explains the way in which resin flows into vacuum bag set up of VARTM.

Fig.1 Stacking of Al and Aramid layer

Resin was introduced by the inlet pipe and distributed by a flow media placed on top of the central zone of the plate. Then resin was forced to impregnate the perform through the drilled aluminium sheets generating a through-thickness flow. In the outer zones of the laminate there was no flow between fibre phases and the resin was forced to advance in the planar dimension, this constrain leaded to two parallel resin infusions. The pulling force was created by applying vacuum at the outlet pipes situated at the end of the plate. Compaction was obtained with a vacuum bag sealed with tapes. [13] Fibre Metal Laminated panel prepared by Vacuum Assisted Resin Transfer Moulding Technique following by pressuring during to 10 bars and followed by pressuring them during curing process.

Fig.2 Stacking of drilled Al/Fibres in Die

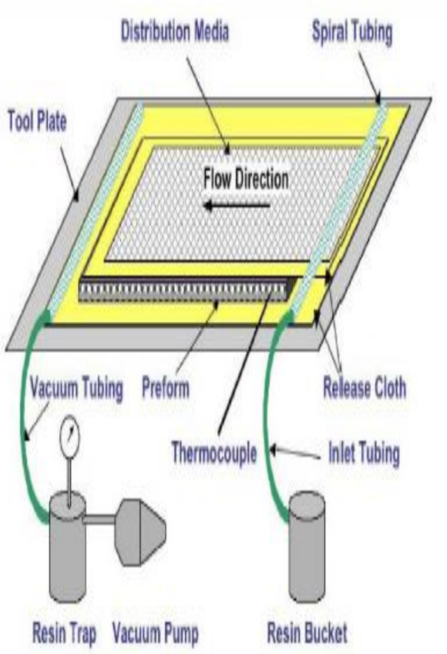

Fig.3 Illustration of VARTM Set-up

Fig.4 VARTM Set-up

3. Material Testing

3.1 Tensile Test

Material strength can be found by testing the material in tension or compression. Standard dog bone shaped specimens were injection molded according to the ASTM D638 specifications for tensile testing. Each specimen having 30 mm width and 280 mm gauge length, as shown in Fig-5. The specimen is loaded in computer controlled Universal Testing Machine (ASE – UTN 10) until the failure of the specimen occurs. Tests are conducted on composites of different combinations of reinforcing materials and ultimate tensile strength and ductility are measured. Simultaneous readings of load and elongation are taken at uniform intervals of a load. A tensile test is carried out at room temperature. Uniaxial tensile test is conducted on the constructed the specimen to obtain information regarding the behavior of a given material under gradually increasing stress-strain conditions. The Tensile stress test results the elasticity limit of the Fibre Metal Laminates.

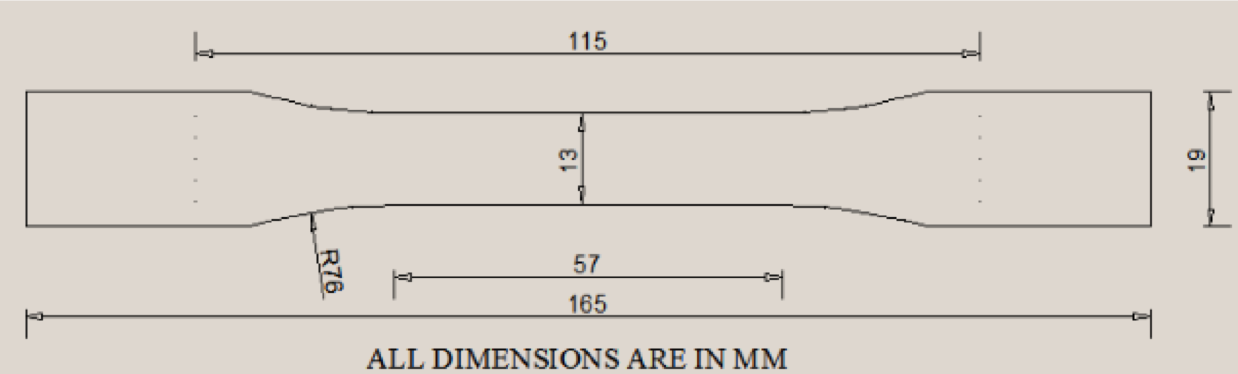

Fig.5 Tensile test specimen

3.2 *Impact Test*

The impact test is performed to study the behaviour of specimen under suddenly applied load. Specimens are prepared according to the ASTM (D256) standard shown in Fig-6. Impact Test tests the condition for absorbing the energy.

Case (i) - When the striker impacts the composite specimen, the specimen absorbs energy until the yield point, then the specimen begins to undergo plastic deformation by absorbing energy and work hardening occurs at the plastic zone.

Case (ii) - When the composite can absorb no more energy, eventually failure occurs. [14].The Izod impact test is a standardized high strain- rate test which determines the amount of energy takes up by a material during fracture. This test is carried out on the samples are made as per the ASTM D256 standard. The absorbed energy by the specimen is noted until fracture takes place during testing. The average impact value of each six test specimens of Aramid,Carbon and Glass FMLs are shown in the graphical representation of Fig-10.

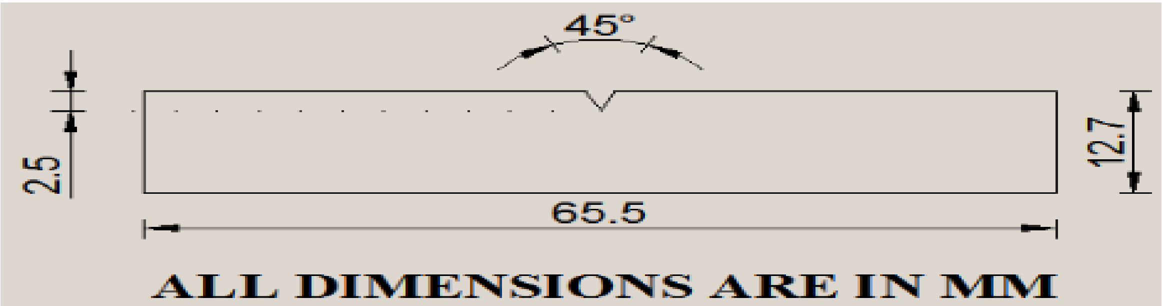

Fig.6 Impact test specimen

3.3 *Flexural Test*

The Flexural stress is the quantitative measure that defines the variations of Load with respect to the displacement. The Flexural stress test results the rigidness of the Polymer composite fiber. The Flexural specimens are equipped as per the ASTM D790 standard shown in Fig-7. The 3-point flexure test is the most common Flexural test for composite materials. Specimen Deflection is considered by the crosshead position. Test results take account of Flexural strength and displacement. The testing process involves placing the test specimen in the universal testing machine and applying force to it until it fractures and breaks. The specimen used for carrying out the Flexural test. The tests are regulating at a condition of an average relative humidity of 50%. A graph is drawn for each sample between the force and the displacement in the Flexural test.

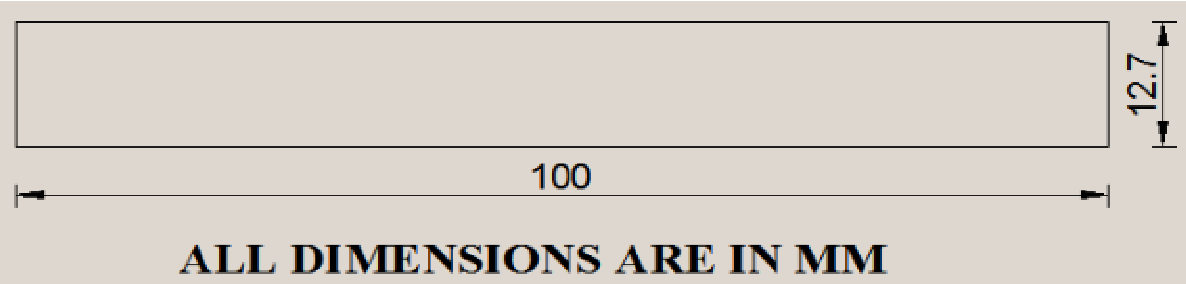

Fig.7 Flexural test specimen

3.4 Hardness Test

To check for pierce resistance which serves the best objective of tyres hardness test using Barcoll hardness machine is done. The results shows that the Aramid ,Carbon and Glass based FMLs can withstand up to 42 HRL for maximum. Barcol in Scale for Major Load-60Kgf and Minor Load-10 Kgf with Indenter - ¼" Ball the hardness value at three regions were found to be shown in table .The Fig-11 shows the variations harness value for arall/carall/glare.

4. Result And Discussion

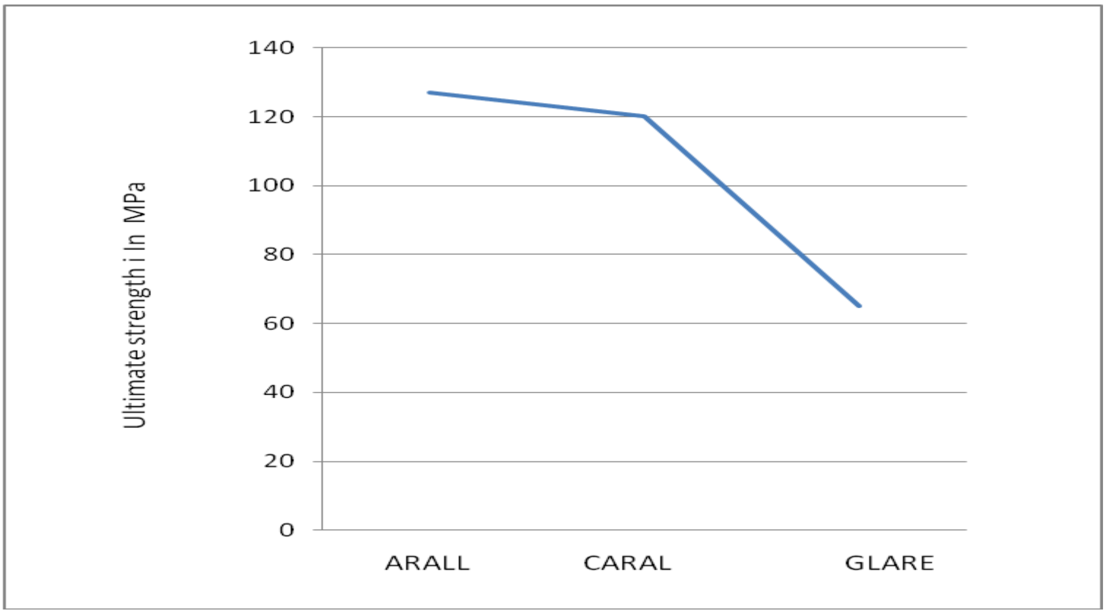

Fig. 8 Tensile Test on Aramid/Carbon/Glass Fibre Metal Laminates

The Fig-8 shows average ultimate strength value of six specimens for Aluminium FML,Carbon FML and Glass FML, from this it is clear that Arall have high ultimate strength followed by carbon and Glass.

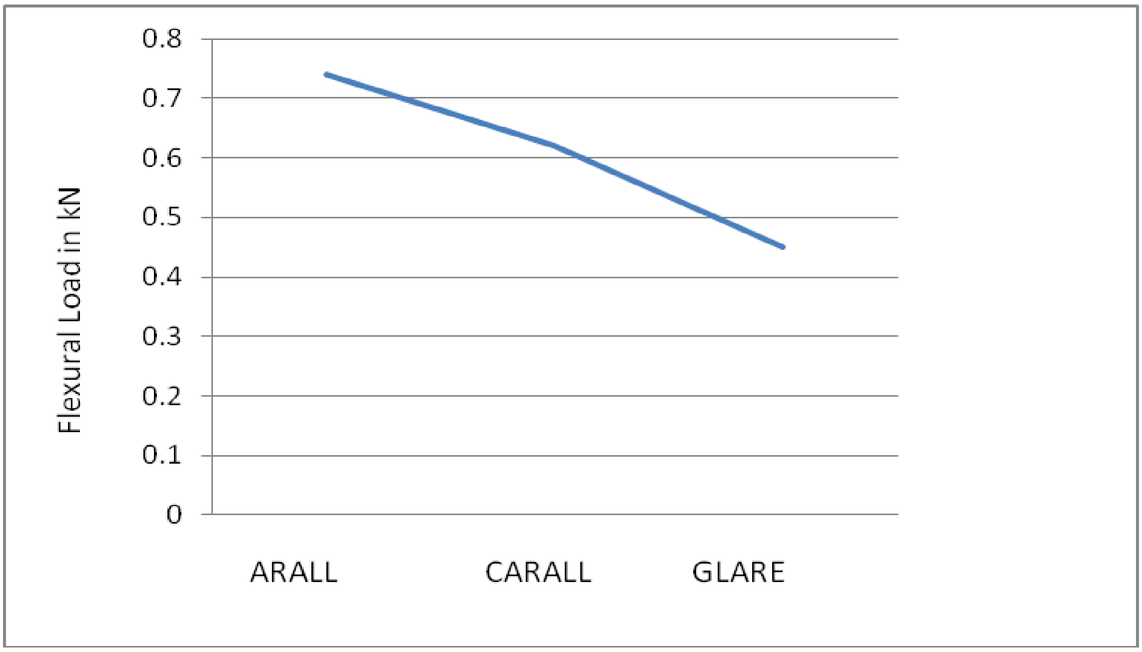

Fig.9 Flexural Test on Aramid/Carbon/Glass Fibre Metal Laminates

In Fig-9 the graphical representaion is obtained from the set of six test specimens of each. Similarly from the graph it is clear that Aramid have more Flexural strength followed by Carbon and Glass FMLs.

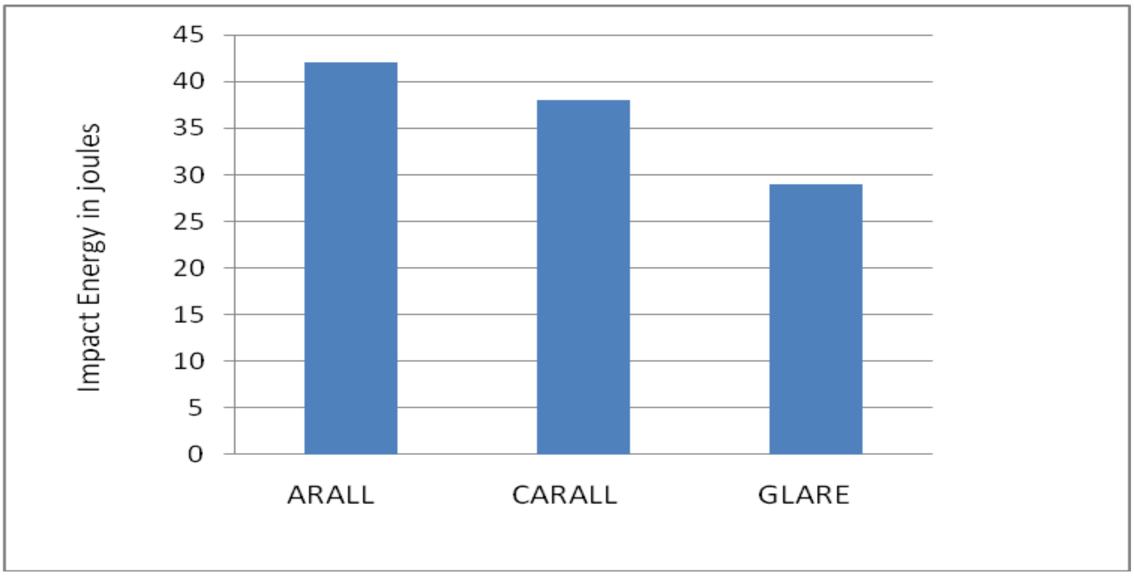

Fig.10 Impact Test on Aramid/Carbon/Glass Fibre Metal Laminates

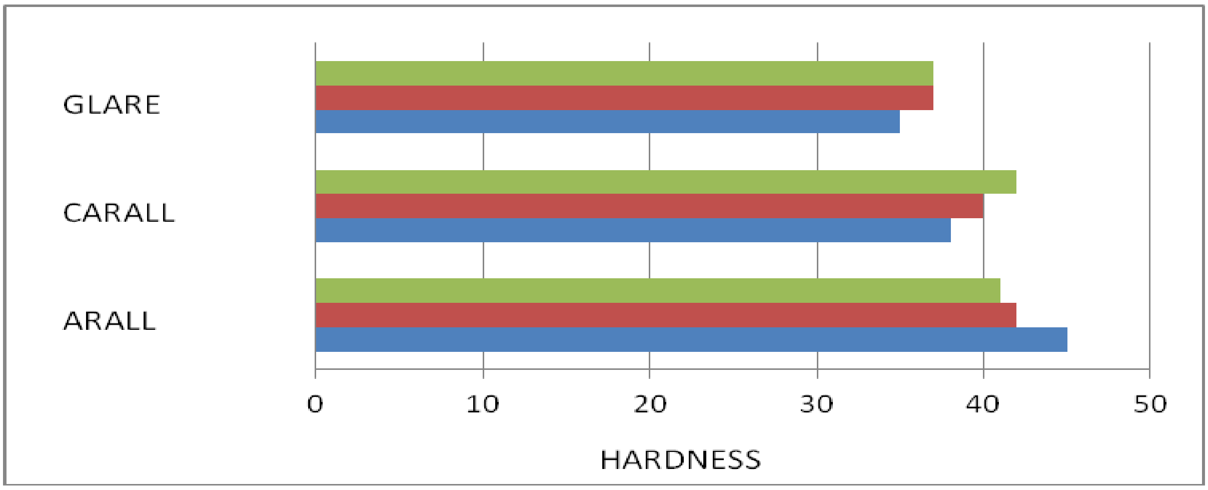

Fig.11 Hardness Test on Aramid/Carbon/Glass Fibre Metal Laminates

Table 1-Details of the FMLs

FML	Lay-Up	Al Thickness (mm)	Total Thickness (mm)
GLARE	3/2	0.27	3
ARALL	3/2	0.27	3
CARALL	3/2	0.27	3

Table 2-Summary of FML from Experiment and Simulation

Description	ARALL	CARALL	GLARE
Maximum stress from Experiment (MPa)	50.4	45.6	34.4
Strain at maximum stress from Experiment	0.146	0.124	0.106
Maximum Stress from FEA (MPa)	49.5	42.4	34
Stress at initiation of delamination from FEA(MPa)	48	42	33

4.1. *Fracture Surface Using SEM*

A scanning electron microscope (SEM) is one of the most useful instrument available to study the micro structure morphology of fractures surfaces. In order to explain the mechanism of fracture occurs in the surfaces of test specimens of tensile, flexural and impact the Zeiss SEM instrument was used and the corresponding images with notification of salient observations are marked in the Fig.11-13.

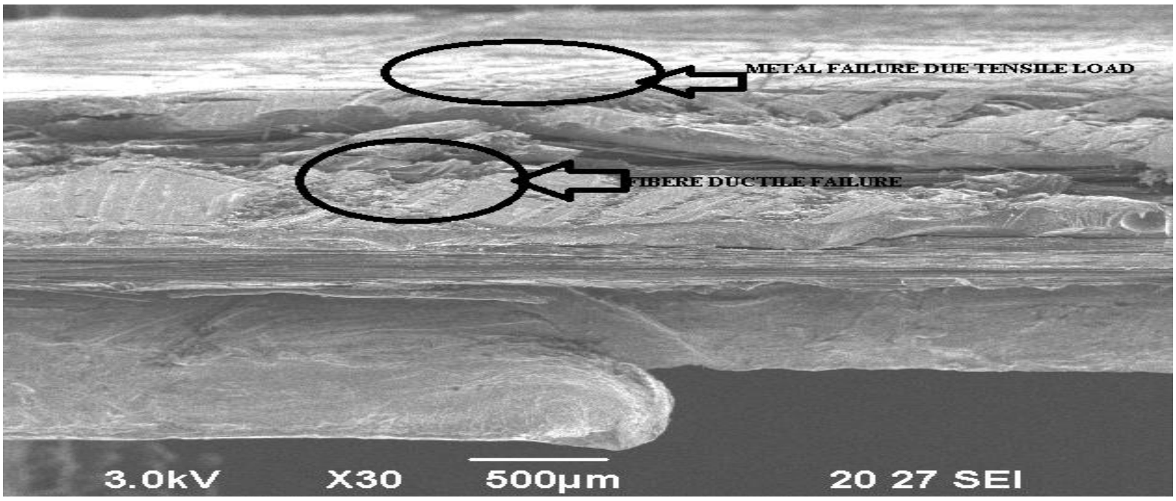

Fig.11 Tensile Failure

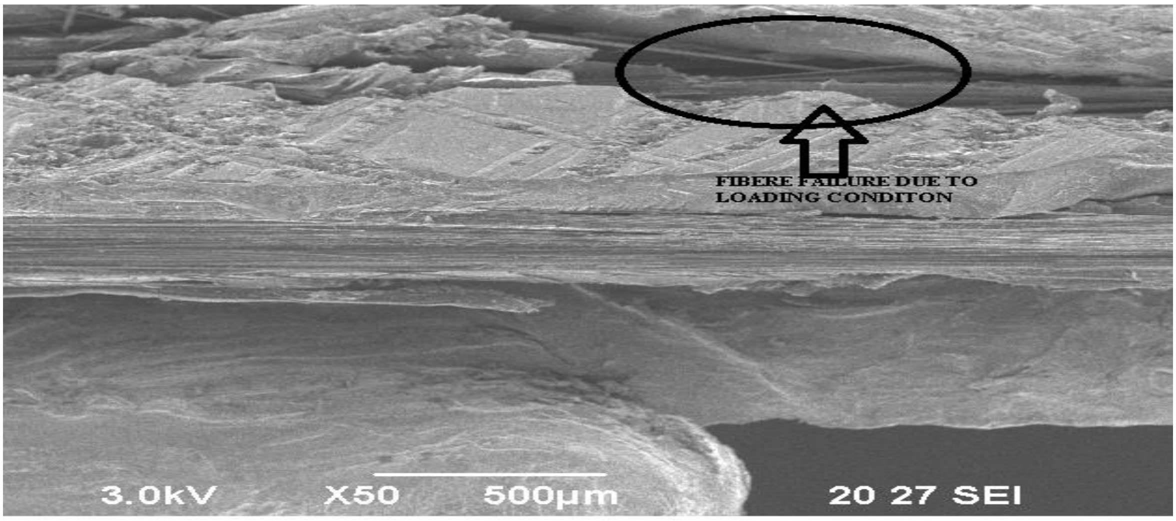

Fig.12 Flextual Failure

Fig.13 Impact Failure

5.Conculusion

The paper has to be concluded the Fibre Metal Laminates (FMLs) are layered materials based on stacked arrangements of aluminium alloy layers and Fibre Reinforced Plastic (FRP) layers. They have shown great potential in lightweight aerospace applications and the improved mechanical properties have accomplished the new type of laminates which included aramid / glass / carbon fibre. In this work, above mentioned fibres with Al 2024, epoxy resin laminates were prepared by VARTM method and their stress-strain behaviour, impact, flexural behaviour and hardness level, has been investigated with experiments and numerical simulations and the fracture morphology of them were observed using SEM.

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