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A Review on Industrial Fibre Hybrid Composites for Automotive Safety Application

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ABSTRACT

The FML is newest classification of metal and it is having more demand due to it higher mechanical and metallurgical property. Few materials can be produced by the diversity of behaviours which depends on the shape, cost etc. However, the fibre metal laminate is subject to imperfections, which are directed by various factors namely, skin type, core, treatment process, load and preparation method. The conceivable faults can be overwhelmed by the next care though the preparation of the materials as per the requirement. The fibre metal laminate is used to various demands less weight to more strength ratio like automobile sector, aeronautical, structure and marine applications etc.

Keywords: Treatment, FML, Aluminium, Fracture toughness, Composite materials, Corrosion, Laminate material.

I. INTRODUCTION

The developments in the field of resources and industrial field it is brought further development of new kind of materials. The laminate material is kind of new class of composite material in which have been industrialized newly. In that, few materials are fit made to use for some special case applications. The FML was introduced in the year of 1967. It was noted that the comparison with laminate of similar thickness fibre made and aluminium has double the fracture toughness. Similar the composite materials, laminate materials are shaped to improve the complete property like less density and corrosion resistance. However, the property of few materials are got collective to provide assistances as well as disadvantage like less fatigue resistance and more moisture concentration. The immeasurable mixture of ingredients that can be mixed to make composite materials, produce it open ended to the R&D department. Few materials are used widely in an aeronautical, structural and automobiles industries. In this paper, the sandwich material, which is a kind of composite material is noted and discussed. The sandwich materials are contains of various layers of compositions prescribed to imitate the sandwich, like plywood. The skin in which act as the matrix form, while as interlayer performances as the reinforcement.

The composition of composite material, the sandwich material is chosen based on requirements as the property looked-for the produced composites. There are various layers between the outer skins in sandwich material.

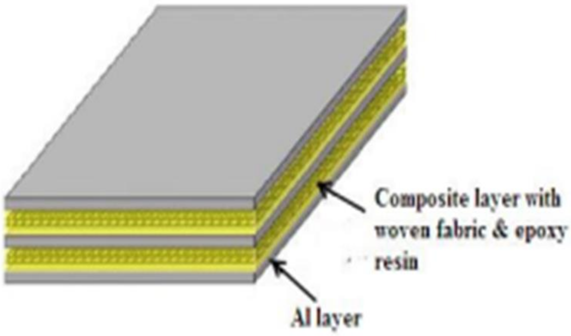

Fig.1 Laminate material

1.1 Laminate Material

The initial study about the usage of bonded laminate structure in the year of 1950. It was exposed that to stop emergence of fatigue crashes by the laminated material. It was noted that the performances were good than the monolithic structure made of few materials. The Research and development on FML is invented by an Aerospace Engineering in Netherland country. They industrialized a FML containing of Aramid fibres in Aluminium laminates and it was commercialized in the period of 1982. The more number of research is going in FML which bring forward to Carbon reinforced Aluminium laminate. They developed a fibre metal laminates comprising of Aramid fibres in Aluminium laminates (ARALL). It was commercialised during 1982 with two variations: ARALL 1 with AA7075 as the laminate and ARALL 2 with AA2024 as the laminates. Later two more types of ARALL came into existence and commercialised respectively. More research on FML brought forward Carbon reinforced Aluminium laminates (CARALL). During 1989 Glass Laminate Aluminium Reinforced Epoxy (GLARE) was developed and patented. It was later commercialised during 1991. Generally E-glass fibres are used to make GLARE.

1.2 Types of FML structures

There are various FML Structures are used widely in the industries. In that, the following things are widely used. These are Krzysztof Dragan, Lukasz Kornas, Michał Kosmatka and Jarosław Bienias. The Fibres metal laminate (FML) is kind of a class of metallic materials it consisting of a laminate of various thin metal layers mixed with composite material layers. It permits the material to perform more as a simple metal structure, but with large specific merits with respect to various properties.

Through the past decades, raising the demand in aerospace industry for more-performance, less weight structure have stimulated a heavy-duty trend to the development of refined prototypes for FML. The FML are hybrid composite material, which built up from linking layers of thin metals, and fibre reinforced adhesives. The greatest well-known FMLs are ARALL (aramid reinforced aluminium laminate), GLARE (glass reinforced aluminium laminate), CARALL (carbon reinforced aluminium laminate) etc.

Based on the types of reinforcements used FML are of the following types: Kevlar reinforced laminate, CARALL and GLARE. Kevlar has the benefit of extremely light weight however being costly makes its applications restricted to scientific research and government aided projects. Glass and carbon fibre has the advantages of low cost yet reliable hence highly preferred for commercial applications.

Based on the layup of the laminates and reinforcements in FML can be of the following types: 2/1 laminate in which there will be one layer of reinforcement sandwiched between two metal laminates and 3/2 laminate in which there will be three layers of metal laminates separated by two layers of reinforcements. The fibre may be oriented in different directions between the laminates. Fig. shows a 3/2 laminate.

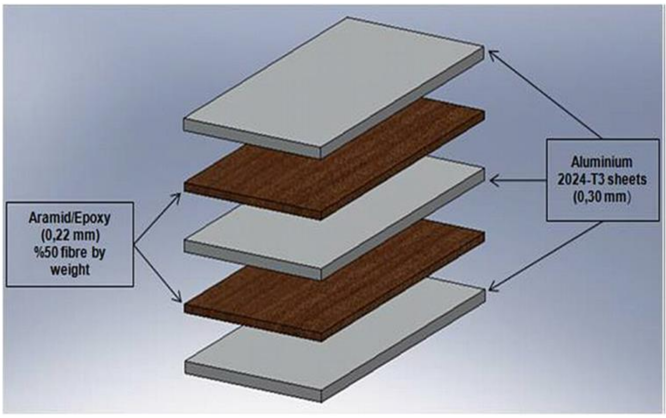

Fig.1. 3/2 laminate material

II. CONSTRUCTION OF FML

The fibres metal laminate are equipped with a purpose of minimizing the overall weight without affect the advantageous properties on an explicit application. There are the four main steps are involved in FML namely pre-treatment, preparation of prepreg, FML production and post treatment.

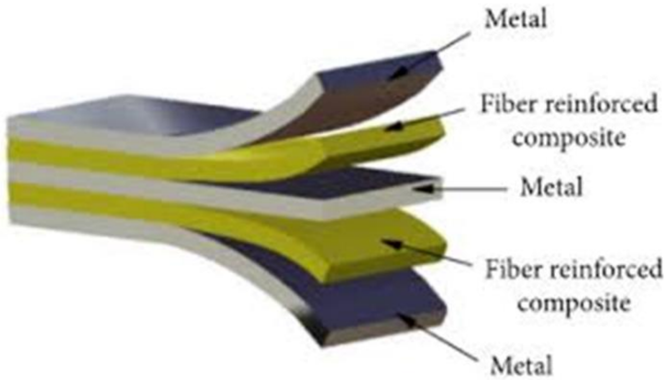

Fig.2 Construction of FML

2.1. Production of the FML

There are many methods are available to produce a FML. In that, the following things are playing the major role. These are namely hand layup, autoclave, Resin Transfer Moulding (RTM) and stamp forming. In further the various types of RTM available like, Structural Resin Injection Moulding (SRIM), Vacuum Assisted Resin Transfer Moulding (VARTM), Vacuum Assisted Resin Injection (VARI)s and Resin Film Infusion (RFI).

2.2. Hand layup

In case of the hand layup technique as shown in Fig.3 the reinforcement will be prepared just before it is to be used. The reinforcement material mostly in the form of fabric, fibres or powders will be mixed with a suitable resin to enhance its bonding with the skin. As soon as the reinforcements is mixed with the resin. It will be placed between the skins. Then light to moderate pressure is applied to the skins in the form of pressing by hand or a roller. The applied pressure compresses the prepreg and enables proper bonding between the skin and the reinforcements. Enough time is allowed to enable proper bonding. The hand layup technique is used for creating large laminates which are to be used for low cost and light load applications.

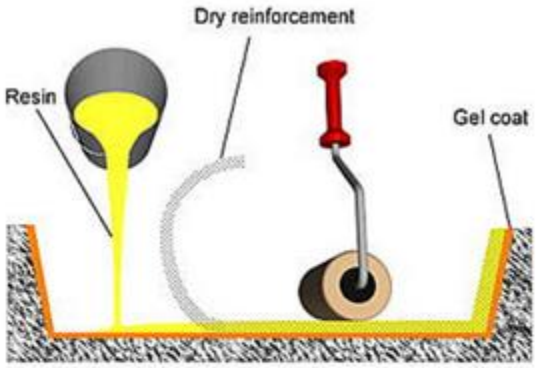

Fig.3 Hand layup technique

2.3. Stamp forming

Stamp forming is similar to the above method except that heavy force is applied to bond the laminate and prepreg as shown in Fig.4. In this method layers of laminate and the prepeg are arranged as desired over the cavity of a blank. The cavity resembles the final desired shape of the finished laminate. It is then pressed using a round tipped tool into the blank. The applied pressure forces the prepreg to get bonded to the laminate. The layers are held in a die, blank holder and punch setup. The shape of the produced part is determined by the design of the die and punch. Pressure is applied from both sides of the mould.

Hence this method is also called as press forming or stamp forming depending upon the direction of the applied force.

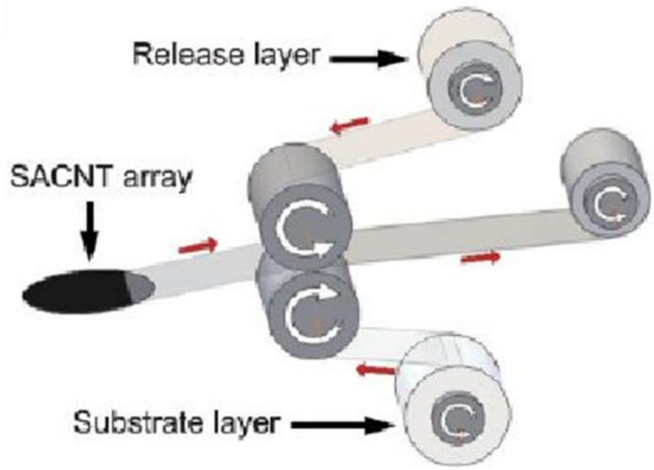

Fig.4. Stamp forming technique

2.4. Autoclave

Autoclave method as shown in Fig.5 is a traditional method used for production of FML. The stored prepregs are taken out of the deep freezer and its temperature is allowed to get to room temperature. Then it is separated from the polythene sheets and stacked with the pre treated metal laminates. Since the layers are stacked by hands, the autoclave method is otherwise names as hand forming technique. The number of layers depends upon the end requirements as desired such as 2/1 laminate, 3/2 laminate or 4/3 laminates. It is then placed in autoclave chamber and vacuumed. Pressure is then applied along with heat to enhance the bonding between the laminate and the prepreg. This method is simple in design and do not require a power feed during manufacturing and parts can be fabricated quickly. However it has some drawbacks such as: not suitable for preparing larger parts, high operating costs, prior knowledge in curing and properties of the resin, fibre and metal laminate.

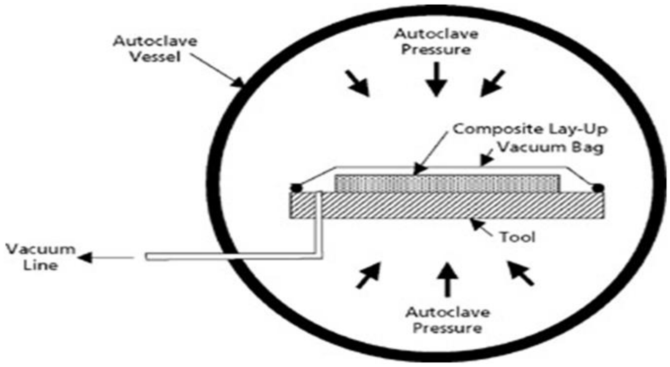

Fig.5 Autoclave method

2.5. Vacuum Assisted Resin Injection (VARI)

VARI has the benefit of low cost production of FML and also the ability to manufacture large sized parts. In the VARI, the layers of perforated reinforcements and metal skins are arranged as desired. It is then placed inside a one sided mould and covered by flexible film resembling a mould cavity. Peel plies are provided to enable easy removal of the finished laminate materials as shown in Fig.8. The process is carried out by removing the air from inside the cavity by using a vacuum pump attached at one of the longer ends of the arrangement. It is then followed by pumping of hot resin from the other end. The resin flows inside the cavity because of the pressure difference and gets infused with the reinforcement. After curing for some hours a FML with the desired properties will be obtained.

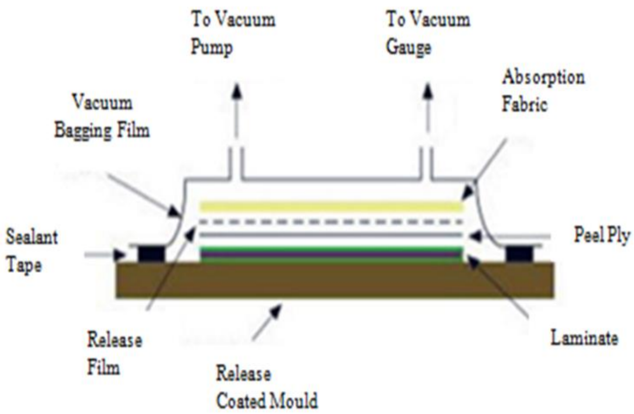

Fig. 6. Vacuum Assisted Resin Injection

2.6. Vacuum Assisted Resin Transfer Moulding (VARTM)

VARTM technique has a similar construction of the VARI. Fig. shows the construction of VARTM and the important parts. In VARTM the vacuum pump creates a much greater negative pressure than the VARI. Resin is sucked into the mould cavity because of pressure difference between the cavity and the resin holder. The quality of the FML depends upon the fluidity of the resin. After the transfer of the resin into the mould chamber, the composition is allowed to cure and set.

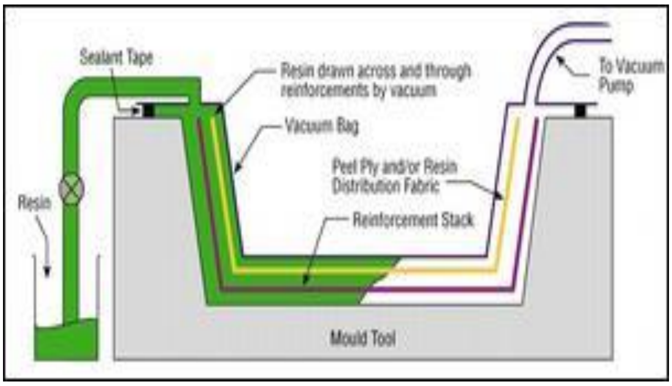

Fig.7. Illustration of VARTM

Post treatment

Post treatment is referred to the curing of the FML after the resin is introduced into the reinforcements. The curing time differs, depending upon various factors mentioned below.

- Pre-treatment employed
- Type of the resin used i.e., semisolid or liquid during the time of infusion into the reinforcements.
- Whether prepreg is used or not i.e., if the preparation method uses prepregs then the resin had been already infused into the reinforcement. Hence the post treatment employs higher heat required to enable resign flow into the pre-treated skin material.
- Type of the reinforcements and the skin materials used.

III. EXPLORATION OF FML CHARACTERIZATION

Generally, the fibres metal laminate is exposed to the following types of testing namely impact test, flexural test, tensile test, fire retardant characteristic etc. During the test on FML, attention should be taken on the scaling effect also. The detailed Literature review state that the scaled model and full sized model provided severely various deviations in the result due to of change in parameters like fibre laminate thickness, material removal rate, mass and overall thickness etc.

3.1 Impact test

The study of force-time on the laminate revealed three notable occurrences. First is the materials resistance against impact damage. Second is the fluctuation in force which indicates decrease in local bending stiffness. Third is the maximum bearing load before the material cracked to the impactor. The major cause of failure is delamination. It was observed that the load and the ply direction influenced the failure of the laminates. Lower load to cross ply and 90O orientation of fibre gave better resistance to damage.

3.2 Tensile Strength

Generally the tensile test is carried out in various FMLs exposed that the failure in FML happened due to various factors like metal used as laminate, fibre type, laminate prepeg stacking sequence, impact geometry, post stretching percentage etc. The various properties like yield stress, Young's modulus, strain hardening coefficient, stress vs strain curve and anisotropic parameters are the important constraint need for the pre-processing of the deep drawing process and henceforth essential to be obtained from the tensile test. The analysis of pre stress on GLARE, ARALL and CARALL exposed that the GLARE could with stand higher stresses. The failure mode is due to fibre and laminate materials. The increasing in stiffness and laminate strength of material showed to have a disadvantage. The metal showed brittleness and the failure initiated less energy absorption and less impact on resistance characteristics. Fig. gives the relation between the different reinforcement in failure on associating with the base metals. It is noticed that the GLARE showed higher resistance to failure that other materials.

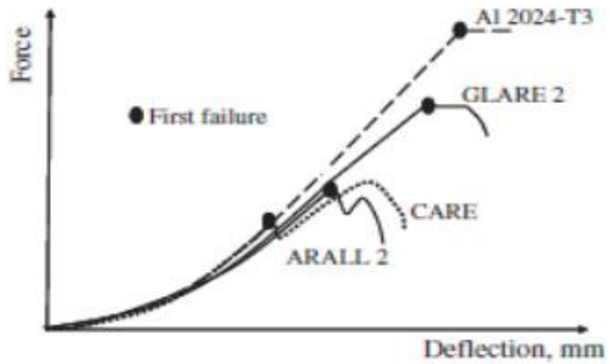

Fig.8. Force vs deflection

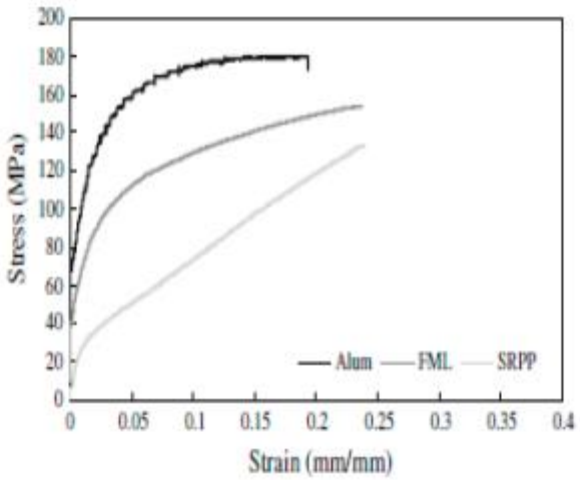

Fig.9 Stress strain curve

The tensile test is conducted by the help of universal testing machine on a rectangular sample in contrast with the old-fashioned style by using ASTM standards. The test exposed that the strain to failure on fibres metal laminate is similar which comparison with the composite material. However, the same is higher than in comparison of fibres metal laminate with base metal. It is necessary by the bonding strength in which added to the tensile strength of fibres metal laminate.

3.3 Flexural test

Logesh et.al conducted analysis on flexural characteristics on FML AA8011/Polypropylene/AA1100. There are different standards to perform flexural tests. One such standard is ASTM D790 in which the specimen of length 150 mm, 30 mm width and 4 mm thick is subjected to a load at its centre. The applied load, displacements were recorded and obtained using the formulas shown in equation (2) and (3) respectively.

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

$\varepsilon f = 6Dd/L2$ (3)

where

'L' is the span length,

'b' is the width of the sandwich sheet,

'd' depth of the sandwich sheet

Specifically, mechanical properties and failure modes of AA8011/Polypropylene/AA1100 sandwich sheets were characterized. Flexural strength of three specimens cut from the sandwich sheets are summarized and the optimum value of load (P), maximum deflection (D), flexural stiffness (Sf), flexural stress (□y) and flexural modulus (E) of sandwich sheets were found to be 140 kN, 28 mm, 8.23 MPa, 81.56 MPa and 323.81 MPa respectively.

Fig.10. shows load-mid span deflection under three-point bending of sandwich sheet by flexural test. It was revealed that the deflection of sandwich specimen increased almost linearly with load up to final failure. Hence it was determined that specimen could withstand flexural load. Much of the force was absorbed by the thick layer of epoxy resin and the reinforcement than the skin material. The flexural tests reveals that the sandwich sheet can be applied as outer shell of automobiles and aeroplanes.

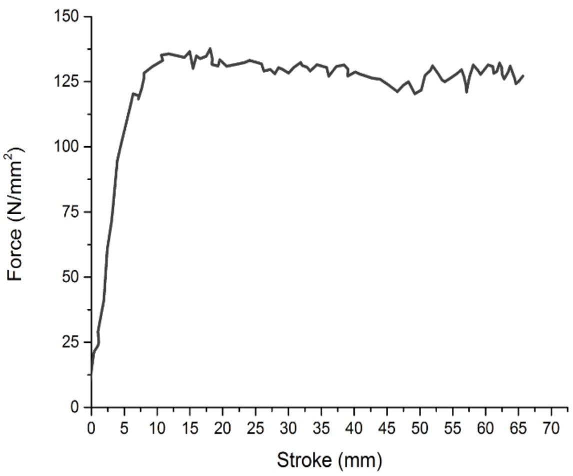

Fig.10. Load-mid span deflection of sandwich sheet in flexural test

3.4 Fire Retardant Characteristic

Fire retardant characteristic is an important property for a FML. Logesh et.al, conducted extensive research on the fire retardant characteristics on FML. A typical FML material should have the following characteristics while subjected to flame:

- Should not be toxic to human, animals and plants,
- Should not release any harmful evaporating gases,
- Should not release any additional toxic, harmful or corrosive smoke gases in case of fire,
- Should not negatively affect the flame retardancy.

3.4.1. Cone Calorimeter Investigation

The cone calorimeter investigation is a very popular and standard method for ranking and comparing the flammability properties of polymeric materials. During the entire combustion process of the sample in a cone calorimeter, a constant external heat flux is maintained to sustain the combustion of the test sample i.e. the test method creates a forced flaming combustion scenario. Therefore, the test results from cone calorimeter are very important in flammability evaluation of any polymeric materials [80].

3.4.2. Flammability Study by UL 94

- UL94 testing was carried out following two standards: one is the vertical burn test (UL94 V) and the other is the horizontal burn test (UL94 HB). The LDPE/LDH nano-composites containing up to 16.2 wt% LDH did not pass any of the UL94 V specification. All the samples start burning spontaneously after first 10 seconds flame application, which continues until the test specimen is completely burnt up to the sample holding clamp. This means that the nano-composites are not self-extinguishing

IV. CONCLUSION

- The fibres metal laminate having more benefits like less density, higher strength, and hardness over the composite material and base metal. Therefore, the fibres metal laminate is noted that the applications in various applications like aeronautical field, structural, marine, automobile industry and more.
- There are various approaches of preparing fibres metal laminate, which can choose, established on the various parameters like cost and finish from the progression.
- Explicit properties can be convinced on the fibres metal laminate by appropriately choosing the reinforcements, fibre orientation and MVF.
- The Pre-treatment on the metal and post treatment of the fibres metal laminate can improve the property of the fibres metal laminate.

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