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Characterization of Fiber Metal Laminates, Bonding and Manufacturing Methods

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Abstract:*Materials having low density combined with superior strength are gaining demand in the field of automobiles, aeronautical and military appliances. Fiber Metal Laminates (FML) is becoming the material of choice for the above mentioned applications because of the ability to tailor it to meet the demands of the end applications. This paper throws light on the commercially available for of FMLs, its production methods, property enhancement and diverse applications. As such Carbon fibre reinforced composite are preferred for making automobile bonnets and fuselage in military aircraft due to the superior strength to weight ratio. On the other hand glass fiber reinforced composite materials are used to manufacture railway locomotive body panels due to the high tensile strength and impact strength. This paper can be used as reference for budding engineers who want to gain first-hand knowledge on FMLs.*

Keywords:*Fiber Metal Laminates, Carbon fibre reinforced composite, glass fiber reinforced composite*

I. INTRODUCTION

In many industrial and structural application low weight, high strength and cost is the significant constraint in material selection. Fiber metal laminate (FML) is a good selection of the above applications that is one of the mixture of composite laminates created the total of metal layers sandwich a fiber-strengthened plastic layer [1-2]. It comprises of, on the other hand organized layers of polymer and thin layer– fiber composite for all time reinforced together. Because of importance of design requirement in the extent of aircraft technology and improved protection from corrosion. The concentrated works are proceeded so as to present the new sort of FML sandwich materials, for example the endeavors to present the new aluminum combinations magnesium and titanium alloy. The FMLs gives super mechanical residences like excessive corrosion resistance, unique electricity to weight percent compared to conventional composite lamina. The main objective of composite material has permissible a significant weight reduction in structural design, which is much useful in aircraft and automobile industry [4]. It gives more advantages than metal, particularly where high quality, stiffness and great weakness protection. Their superfluity of employments in aircraft and space part additionally stretches out to applications that are progressively outlandish.

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Generally FML is made with thin sheet thickness 0.2 to 0.4 mm which gives light weight,for example aluminium or titanium, bonded to thin layers of prepreg composite with external surfaces being metal. Presently titanium and its compounds appear to be the best application. Their developing utilities have emerged from a drive inside the aeronautic trade to deliver lightweight flying machine, as the expense of fuel increments and natural mindfulness turns into a significant thought [5-6].

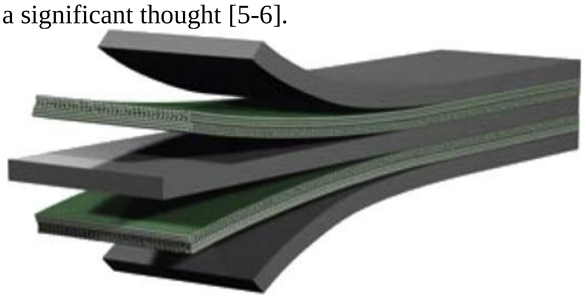

Fig. 1. A typical Fiber Metal Laminate [7]

These skin material plays because the matrix, while the interlude play because the reinforcements. based on the desired material properties in various material combinations of sandwich composite material can be selected [8-9]. There is a consensus among social scientists that fibre metal laminates integrates the optimal fatigue and fracture properties of fiber reinforced composite and superior durability characteristics of metal while at the same time eliminates their individual drawbacks [10].

II. ADHESIVE BONDING TECHNIQUE

This type of bonding technique is utilized in assembling of aircraft industries from the past 50 years. The bonding process is utilized in a consistently developing the uses of aviation, aircraft industries, ship industries and automotive industries. Commonly Fibre metal laminate composite provides fatigue and high impact strength when compared to fiber reinforced composites. However, the manufacturing of an FML have a crucial issues with the holding of the fiber metal laminate can be insufficient. Adhesive bonding structural components provide a lower manufacturing cost, low weight and better harm resilience over ordinary mechanical method. Structural bonded joints and sandwich material construction extent of present day aircraft [20]. In commercial aircraft were introduced with modern metal joined structures utilizing longitudinal lap joints in Airbus A300 [21]. Adhesive bonding is mostly utilized for connecting stringers to the fuselage and wing skins,to solidify the structures against clasping. It is likewise connected to skin-to-centre bonding in metallic structures,for example spoilers, lifts, ailerons, etc.

The most significant part of planning airplane body is to consider skin breaks coming about because of weariness that the splits will be found inside a specific review interim preceding their achieving a basic break length that can prompt disastrous disappointment. The weakness break improvement rates in cement fortified sheet materials can be diminished [22]. The layer of adhesives performing as break splitters, Hence cracks begin at one of the laminate sheets only. The decrease in the split development rates perseveres until a split is started in the neighboring sheet too. The crack development is reduced, when the crack is started in the neighboring sheet. Adhesive joints exhibit lower stress when compared to mechanical joints, so that increase the static strength. Bonded joints, reduce the weight 10 to 25% in primary and secondary structures. The main advantages of this joint over mechanical high corrosion resistance and easy repairable.

III. MECHANICAL BONDING

The main advantage of this method there is not required for any particular surface treatments. In current technology, mechanical fastening is used for joining the composite segments. There are numerous Bolted and riveted joints are utilized in several manufacturing industries. Hybrid bolted bonded joining technology consistently reduces the weight and cost of manufacturing. Most of the time high load and stress affect the composite joints when the utilization of laminate high strength and composite layers increase the load withstanding capabilities[23]. By this reinforcement technique ingrain the layers into bonded joining area. The advantages of mechanically fastened composite joints have easy disassemble, can be repaired, any thickness can join with this method. At the same time few disadvantages are relative weaker than adhesive joint, fatigue prone and stress concentration.

IV. SURFACE TREATMENT PROCESS

The surface treatment process will change the substrate surface as following features, highly roughened, control the contamination and steady with mechanically. The surface treatment is the most important process in the prior adhesive bonding technique, which is necessary to attain long term service capacity [25]. Solvent degreasing is evacuating contaminate materials which repress the development of the chemical bonds. Hence which encourage the long term surface bond durability when providing a perfect surface [24]. Initially aluminum alloy sheets are degreased prior to the proper surface pre-treatment process. There are different pre-treatment innovations utilized to alter metal surfaces will be clarified detail in following.

A.Mechanical Method

This type of surface treatment is an initial process in various stages, here the substrate surface scrubbing with abrasive sand paper. Hence this method creates physicochemical changes on the material surface, which leads to the wettable surface. Another important pretreatment process abrasion blasting . Several blasting methods are used in mechanical treatment but grit-blasting is one of the most prominent methods ever for aluminium component.

B.Chemical Method

Chromic–sulphuric acid etch is one of the most common chemical treatment method, which is comprised the inundation of the substrate in a solution of potassium dichromate and sulphuric acid [21,25]. Generally, acid etch is an intermediate treatment process between the degreasing and electromechanical treatment. Chromic-sulphuric acid, sulfo ferric acid and forest product laboratory are the most common acid-etching solutions in chemical surface treatment.

C.Electrochemical Method

Electrochemical surface treatment is a very adaptable assembling process that customarily utilizes thick, non-fluid and very acidic electrolytes to accomplish the ideal surface profiles on metallic parts. In this method the surface finishing is done with conversion of metal into the electric field. This is practiced in an electrolytic cell by applying a positive (anodic) potential to the workpiece and a negative (cathode) potential to the apparatus used to shape the workpiece.Anodizing process is the most preferable method in aluminium alloys for aircraft applications. Anodizing creates a thin oxide film on the workpiece surface, which leads to increase in the micro-roughness [24]. Chromic acid anodizing and phosphoric anodizing are the most preferable method, which increase the durability and adhesive bonding joint.

D.Dry Surface Treatment

There are different types of dry treatments for aluminium alloys. Laser texturing is change the surface into micro-structure which leads to high bonding strength and durability[19]. The ion beam beam enhanced deposition is the process to clean the surface with argon ions. In assembling ventures in which various blasted and bolted joints are utilized, the utilization of HBB innovation could be considered as a potential arrangement, so as to diminish the mass just as the assembling cost. Cold plasma treatment speaks to an option in contrast to regular forms as far as ecological effect. Plasma is an ionized gas containing both charged and fair-minded particles, for example, electrons, particles, particles, molecules and radicals.

V. DEVELOPMENT OF FIBER METAL LAMINATES

Aramid Reinforced Aluminium Laminate (ARALL), is the prominent fiber metal laminates, which developed by Delft University of technology. ARALL (Agamid Reinforced Aluminum Laminate), in view of aramid strands are the most commercially available fiber, metal laminates (FMLs). It's been broadly utilized in which higher harm notoriety texture with unrivaled weariness and weight sparing capacity lead. In the ARALL thought, unidirectional fiber prepregs are utilized, which is enormously liberal of material irregularity [10]. Aramid Reinforced Aluminum Laminate having good strength, high flexibility, low density, corrosion resistance and fatigue properties. The ARALL mainly developed for the lower wing skin panels of the previous Fokker 27 aircraft and the shipment door of the Boeing C-17 [6, 11].

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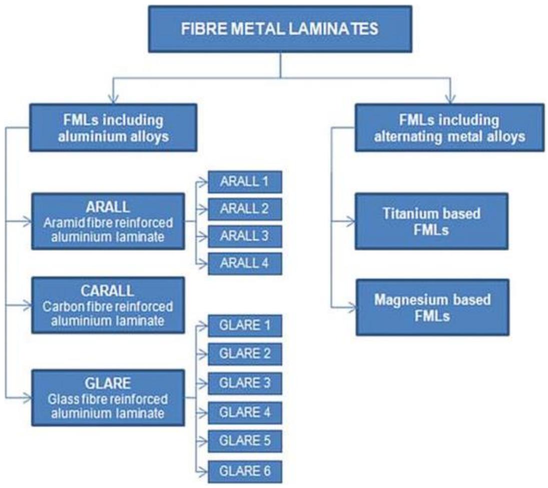

Fig. 2.Classifications of FMLs [8]

Afterwards, in order to enhance the mechanical properties of FML's, carbon fiber reinforced, glass fiber reinforced aluminium laminates are developed [12]. After introducing Aramid reinforced aluminium laminate the GLARE (carbon fiber reinforced) had developed in 1990 by Delft University [13]. The bond among the glass fibers and the adhesive is greatly advanced than ARALL. The most widely used FML in aviation structure is GLARE. Glass laminate aluminium reinforced epoxy(GLARE) consist of pitiful sheets of aluminium alloy clung to thin layers of high strength prepeg composite, Which is used in the driving of the aircraft vertical sharp edge and body of the edges and level stabilizers of the Airbus 380 plane. GLARE is additionally used on the doors of the Globemaster 3 C-17.

A different FML is ARALL -Aramid Aluminum Laminate is made from aluminum alloy and aluminum sheets made from aramid synthetic resin is epoxy. ARALL have outstanding impact damage resistance, however, its use in spatial structures is proscribed once wetness enters the aramid epoxy layer, that decrease the reliability of the fibre fabric. Remarkable models are ARALL and GLARE which are FMLs with correspondingly aramid and glass filaments embedded in the epoxy framework. ARALL and GLARE laminates are presently being utilized as structural materials for manufacturing aircrafts, automobile body parts and railway locomotive body panels [14]. Despite the fact that GLARE has been explicitly gone for utilizations of the aircraft body, changing the constituents in the FML-idea could bring about countless diverse FML-variations.

VI. MANUFACTURING PROCESS OF FML

There are various methods available in FML manufacturing: hand lay-up, Prepreg Forming, Filament winding and fiber placement, Resin Transfer Molding, Structural Resin Injection Molding, Structural Resin Injection Molding, Assisted Resin Injection, Vacuum Assisted Resin Transfer Molding [15].

A.Hand Lay-Up

The hand lay-up process is most generally utilized to create a procedure in the marine business. The most generally used fabricating technique in the marine and aircraft industry is hand lay-up, which is simply Includes setting the prefabricate at the pattern and sooner or later making use of resin either through brush or roller.. The main advantages are low cost apparatus and extensive mixture of products and the Disadvantages are time overwhelming undesirable and circumstance intended for works in view of the unsafe gases to resins discharge, easy to create air bubbles [16].

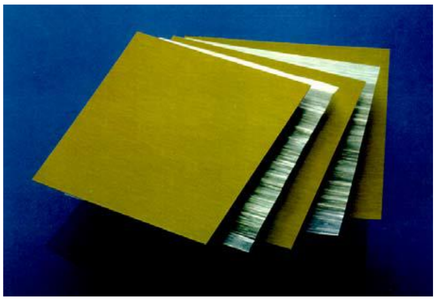

Fig. 3.Typical GLARE lay-up

B.Prepreg Forming

The word "Prepreg" is the source of Pre-impregnated. The most efficient method for aerospace applications is prepreg. This method is preferred since it has superior mechanical strength and low void content. Even though prepreg contains the best properties, it has some drawbacks such as high price, short shelf life and circumstances that need convenient temperature and humidity [16]. Also, this method is a tedious one to fabricate complex shapes and structures. The production cost is more expensive to fabricate GLARE with prepreg in autoclave. In addition to this, prepreg has a constraint in dimensions.

C.Resin Transfer Molding (RTM)

In automotive engineering, the RTM plays a crucial role to yield composite body panels at high volumes and relatively low costs. It is suitable for complex parts, which may be difficult to lay up using pre-impregnated reinforcements, and for parts that require detailed features, surface finish and dimensional stability. This method of producing is primarily based on closed-mould low-stress procedures that permit fabrication ranging from easy, low overall performance of complex, high performance articles and in length from small to large.. Large and hollow shapes can also be molded using this process. A low viscosity resin system has numerous advantages in the RTM process: it is easier to mix and Degas, faster to inject, wets the fibers more rapidly and leads to a better impregnation of the perform [13].

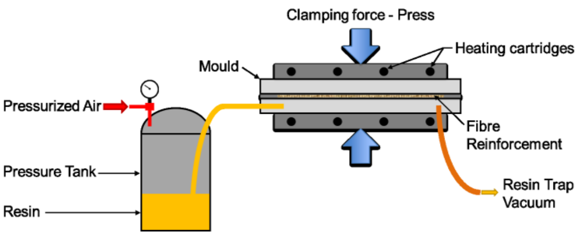

Fig. 4. Resin transfer molding setup used to manufacture the composite panel

D.Vacuum Assisted Resin Injection

Vacuum assisted resin infusion (VARI) molding is a one of the best manufacturing methods of natural fiber reinforced polymer composites with superior quality and low cost liquid composite molding. VARI process also called as a vacuum infusion process (VIP), which is suitable for economically manufacturing large composite structures, such as wind turbine, boat hull, wind blade, aircraft structures and automotive body panel. Because of the low outside stress the fiber content material of composite is lower than the hot press process, which bring about low mechanical houses, especially for fiber-ruled performances.

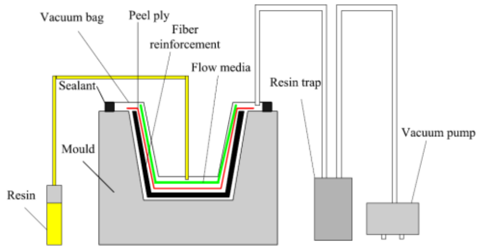

Fig. 5. Vacuum assisted resin infusion method [13]

VII. CONCLUSION

From this review paper, we have concluded that the Fiber metal laminates increasing finer mechanical properties, lowering the burden and cost in structural programs. ARALL and GLARE are the most preferred material in fiber metal laminates. There are different manufacturing process have been discussed for various applications.Adhesive bonding provide more tesile resistance,static strength and reduce the weigth of the structures compare to the mechanical joint method.

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