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Eco friendly composite laminates Exposed for sea water sustainable boat Structure

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Abstract--Eco friendly composite laminates exposed for sea water sustainable boat structure are hybrid laminates, built up from interlacing layers of thin metals and fiber reinforced adhesives. The aim is to explore alternative materials and technique that reduced environmental impact while maintaining structural integrity and durability. Competing materials like advanced metal alloys and fiber reinforced composites have potential to increase the cost effectiveness of the structure. These materials still have their advantages and disadvantages, like the poor fatigue strength of the metal alloys and the poor impact and residual strength properties of fiber reinforced composites. The idea of using the two materials to form a hybrid composite structural material to overcome most of the disadvantages of both materials. The advantage becomes highly evident if cracks start in one of the sheets of the laminate only, the adhesive layers behaving as crack dividers. Under these circumstances, the sheets that are still uncracked reduce the crack growth rate in the cracked sheet. The reduction in the crack growth rates persists until a crack is initiated in the neighbouring sheet also. These composites offer enormous advantages especially for structural applications on Marine environments to uplift of traditional fishing mankind.

Keywords: Aluminium. Fiber Reinforced Plastics. laminates. Mechanical properties. Natural fiber.

INTRODUCTION

Structural materials that are light in weight are invariably preferred in applications where weight reduction is paramount importance such as airplane and automobile structures. Composites are materials that consist of more than one phase. Composites have unique advantages over monolithic materials, such as high strength, high stiffness, long fatigue life, low density and adaptability to the intended function of the structure, additional improvements can be realized in corrosion resistance, wear resistance, appearance, temperature dependent behavior, thermal stability, thermal insulation, thermal conductivity, acoustic insulation, low cost and even a good combination of electric, magnetic and optical properties.

CHARACTERIZATION

In general, industries face major problems in using the new materials with an excellent property. To overcome the difficulties in using a specific material for applications, Fiber Reinforced Plastics (FRP‟s) is an important kind of material, which are used in structural and many other applications. A significant advantage of FRP is its load carrying capacity with low weight and low maintenance cost. Over a wide range of variation in temperature, composite materials especially. Carbon Fiber Reinforced Plastic (CFRP) composite materials exhibit a better dimensional stability. FRP provides high internal damping, which leads to reduced noise, vibration and better vibrational energy absorption. Tooling cost is less, and the material is lighter, when it is compared to the conventional structural materials and hence, the composite materials findan increased application in the industry.

THE DEVELOPMENT OF FIBRE METAL LAMINATES

Fiber Metal Laminate (FML) is a new variety of hybrid composite developed by Delft University of Technology, Netherlands in the late 1970s. It has thin layers of metal stacked alternately with Fibre Reinforced Polymer (FRP)or prepeg layers. FML shares the merits of both the metal and FRP. It also possesses essential properties such as high strength to weight ratio, resistance to fatigue from metal layer, resistance to corrosion and high impact resistance, and low density. The innovation of this new material has resulted in 20% weight savings in the field of composite material applications in addition to

benefits such as cost reduction and improved performance. So far, fibres such as aramid, glass and carbon along with polymer bond with aluminium metal resulting in different FMLs. The fiber metal laminates are light in weight as their specific gravity is very low when compared with that of metals. Fibers that have high modulus and strength gives the laminate high strength to weight ratio. FMP laminates are best suited for applications which call for weight reduction.

The reinforcement of aramid fibre in polymer bonded with Aluminium metal named as ARALL (Aramid Reinforced Aluminium Laminate) emerged during the year 1978 and its commercial product came out in 1982. ARALL showed good damage tolerance and fracture toughness along with resistance to crack growth . As an improvement of ARALL, the GLARE (Glass Reinforced aluminium Epoxy laminate) was discovered in the year 1990, which possessed better compressive properties, and was used in aeronautical applications in the year 1991. Aramid fibre has good specific strength and excellent impact resistance .However, its poor compressive strength is a major limitation for these hybrid laminates. To overcome this, CARAL laminates have been developed as an improvement of ARALL/GLARE laminates. They contain carbon/epoxy prepegs in place of either aramid/epoxy or glass/epoxy prepegs and have been proving their worth in aeronautical applications. Another category of FML was introduced with titanium in place of aluminium. It is named as Hybrid Titanium Composite Laminate (HTCL). All the above mentioned FMLs are currently used in different parts of the aircraft body and other automobile applications.

CARBON FIBRE

Carbon fibres are made by pyrolysis of organic fibres in three stages via stabilization, carbonization and plotitization. In 1860, Joseph Swan produced carbon fibers for the first time, for use in light bulbs.

Carbon fiber is most notably used to reinforce composite materials, particularly the class of materials known as carbon fiber or graphite reinforced polymers. The increasing use of carbon fiber composites is displacing aluminum from aerospace and industrial applications in favor of other metals because of galvanic corrosion issues. Reinforced carbon-carbon (RCC) consists of carbon fiber-reinforced graphite, and is used structurally in high-temperature applications.

MATRIX OFALUMINIUM 6061

The matrix selected is Al 6061 of commercial grade, which exhibits excellent casting properties and reasonable strength. This alloy is best suited for mass production of lightweight metal castings.

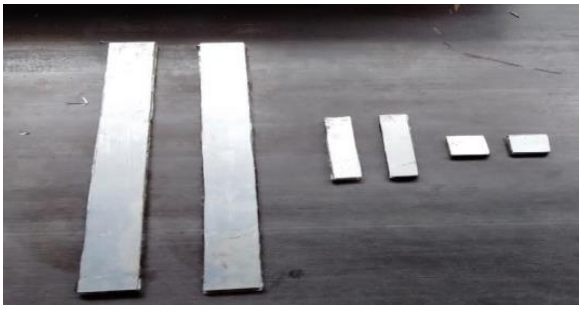
BINDER MATERIAL

Epoxy resins, also known as polyepoxides which are class of polymers which contain epoxide groups. Epoxy resins are the most commonly used resins; there is a wide range of resin/hardener combinations which suit for various applications, all of which have very low shrinkage factors and a high chemical resistance. Epoxy is made from a reaction between epichlorohydrin and bis- phenol. The matrix material used for fabrication of FML is epoxy resin which consists of a compound AV138. A hardener is required for fast curing of resin material during fabrication of FML and hardener of grade HV 988 is mixed with resin in the ratio 1:10.

FABRICATION METHODOLOGY OF FML SAMPLES

The fabrication of fibre metal laminate is carried out by following processes. Carbon fibre is used as reinforced material. The epoxy resin (AV138)and hardener (HV988) are used as a matrix material. The resin and hardener proportion of 10:1 was selected based on their literature report. The aluminium 6061-T6 with 1mm series was selected due to high strength-to-weight ratio.

The FML are fabricated using Hand layup method followed by vacuum bag molding. At first the releasing agent (poly-vinyl alcohol) was properly spread over a mould for easy removal FML. The pre-treated aluminium sheet is placed and the matrix (resin/hardener) is applied on it, then the four layers of unidirectional carbon fibre/epoxy in a cross-ply lay-up orientation according to [0/90]s is placed over it, a roller is used to evenly spread the resin- hardener mixture according to the required dimension. Then the second pre-treated aluminium sheet is placed over it. Finally, the another pre-treated aluminium sheet is placed. To eliminate the voids and excess resin, the fabricated laminates were kept at a pressure of 5 bar in a vacuum bag molding machine for 4 hours, this also aids in curing of the composite laminates. In this way ,the layers are placed to prepare the pretreated combination composites with 4mm thickness.



FML samples for mechanical testing

FML samples for corrosion test

TESTING ON FML'S

SALT SPRAY CORROSION TEST OF FML SAMPLE

To find out the corrosion rate on FML the corrosion test is done. Normally the corrosion test was carried out in room temperature. The salt spray test or salt fog test is a standardized and popular corrosion resistance of materials and surface coatings. Usually, the materials to be tested are metallic (although stone, ceramics, and polymers may also be tested) and finished with a surface coating which is intended to provide a degree of corrosion protection to the underlying metal. Salt spray testing is an accelerated corrosion test that produces a corrosive attack to coated samples in order to evaluate the suitability of the coating for use as a protective finish. The appearance of corrosion products (rust or other oxides) is evaluated after a pre-determined period of time. Test duration depends on the corrosion resistance of the coating, generally the more corrosion resistant the coating is the longer the period of testing before the appearance of corrosion or rust.

WATER ABSORPTION TESTING

Water absorption is used to determine the amount of water absorbed under specified conditions. Factors affecting water absorption in clued: type of plastic, additives used, temperature and length of exposure. The data sheds lights on the performance of the materials in water or humid environments.

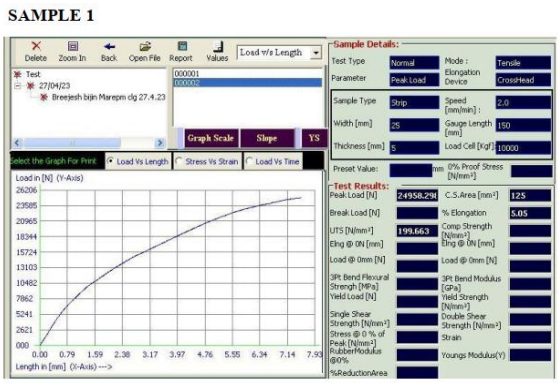
For water absorption test, the specimens are dried in an oven for a specified time and temperature and then placed in a desiccators to cool. Immediately upon cooling the specimens are weighted. The material is then emerged in water at agreed upon conditions, often 23oc for 24 hours or until equilibrium. Specimens are removed, patted dry with a lint free cloth, and weighed.

RESULTS AND DISCUSSION

MECHANICAL CHARACTERIZATION

TENSILE TEST

Tensile tests of the hybrid fibre face sheets are carried out as per the ASTMD 3039M-08. The stress-strain curve of fabricated laminates is shown in Figure. The tensile load-deflection curves are nonlinear and when it reaches the maximum value, there is a sudden drop. From Figure, it is observed that the hybrid fibre has ruptured rather than the de-bonding between the fibre and the resin. The tensile strength of the hybrid laminates is found.



Load v/s Length curve for specimen 1

Stress v/s Strain curve for specimen 1

The ultimate force is found as 23.82KN and ultimate stress of 190.569 N/mm2. The total elongation is found to be 4.830% with thickness of 4.60mm, width of 25mm and area of 125 mm².

SAMPLE 2

Load v/s Length curve for specimen 2

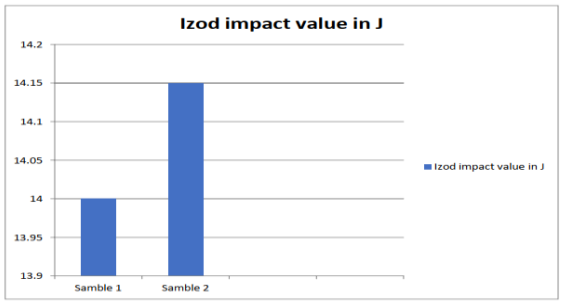
Stress v/s Strain curve for specimen-2

The ultimate force is found as 24.958KN and ultimate stress of 199.663 N/mm². The total elongation is found to be 5.050% with thickness of 4.60mm, width of 25mm and area of 125 mm².

IMPACT TEST:

The overall toughness of the material is determined. Toughness is the ability of the polymer to absorb applied energy when polymers are subjected to impact loading. Crack is initiated in the polymer surface. The energy to initiate a crack is called crack initiation energy. If the load exceeds the crack initiation energy, the crack continues to propagate. When the load exceeds the crack propagation energy, dropped from an angle of 135 degrees to impact the specimen. The amount of energy absorbed during the fracture of the specimen is noted and represented in Figure. The impact tested specimens, as well as the impact properties of FMML composites, are shown in Table.

failure occurs. Izod impact setup is employed to perform the impact test. In this test, the pendulum is



Impact results

SPECIMEN	ENERGY ABSOBED(J)
1	14
2	14.15

Impact properties of FML's

SALT SPRAY CORROSION TEST

The salt spray test, also known as the salt fog test or salt mist test is a standardized corrosion test conducted to evaluate the resistance of materials and coatings to corrosion caused by salt-laden environments during a salt spray test the chamber is filled with a salt water solution typically a 5% sodium chloride (NaCl) solution, which is then atomized and sprayed as a fine mist in to the test chamber. The test specimens or coated samples are placed in the chamber and exposed to the salt spray for a specified duration which can range from few hour to several weeks or more. The purpose of the salt spray test is help asses the durability and corrosion resistance of a materials as well as the effectiveness of protective coatings are surface treatments.

WATER ABSORPTION TEST

The absorption test is a method used to determine the amount of water absorbed by a material the test is particularly relevant for porous materials such as polymers composites, and some building materials. The water absorption test provide valuable information about the materials ability to absorb moisture which is essential for understanding its behavior in real world application. Its help evaluate the materials dimensional stability durability and potential changes in mechanical properties due to water absorption.

SPECIMEN	WEIGHT BEFORE TEST IN GRAMS	WEIGHTBEFORE TEST INGRAMS (24hrs)	% OF WATER ABSORPTION
1	3.72	3.73	0.3
2	3.41	3.42	0.3

Water absorption properties of FML's

MICRIO VICKERS HARDNESS TEST
The micro Vickers hardness test is a method used to measure the hardness of the materials particularly thin film , coatings , small parts, area with limited space. It is a various of the Vickers hardness test, specifically designed for micro indentation testing. In the micro vicker hardness test the diamond indenter with a square based pyramid shape is pressed into the material surface under a specific load. The load applied is typically very small, ranging from a few grams to a few kilograms. The duration of the load application is usually a few seconds.

SPECIMEN	LOAD IN KILOGRAM	MPERATUREIN °C	VICKER HARDNESS NUMBER (VHN)
1	0.1 kg	27°C	120
2	0.1 kg	27°C	120
3	0.1 kg	27°C	119

Hardness properties of FML's

CONCLUSIONS

Caron fiber composites have exceptional strength and stiffness properties, making them advantages in terms of structural performance aluminium, on the other hand, has good strength but is less stiff compared to carbon fiber composite, glass fiber falls in between in the term of strength and stiffness. If high strength and stiffness are critical, and aluminium carbon fiber would be a preferred choice. According to the investigation of various composites reveals that substitution of carbon fiber and aluminium by laminating them improves the mechanical properties appreciably higher than the conventionally used glass fiber. According to the various test results such as tensile, impact, hardness, water absorption, and salt spray corrosion testing are show that aluminium carbon fiber composite laminate are perform well when compare to conventionally used glass fiber.

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