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A REVIEW-EXPERIMENTAL STUDY OF COMPOSITE MATERIAL IN AUTOMOBILE APPLICATION

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ABSTRACT

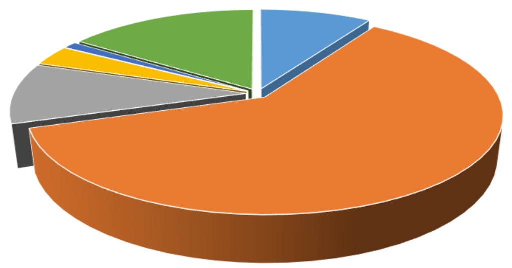
In This review we have studied about composite material which can be used in automobile and aerospace engineering applications. Carbon fiber composites weight about one-fifth as much as steel, but can be similar or better in terms of stiffness and strength, depending on fiber grade and orientation. These composites do not rust or corrode like steel or aluminum. The aim of this paper is to present the current scenario of carbon fiber composites in industries and go towards the approach of carbon fiber composites in future direction with its advantages, disadvantages and applications in industrial machinery. Various type of composites based on reinforcement shape also presented in this paper. This paper also shows the Properties, Characteristics, Challenges, Opportunities and Future Trends of Composites towards industrial environment. We have also discussed merits & Demerits of the material. There is also a brief Discussion on Different Researchers and their approach on composite material.

Keywords:- Carbon Fiber Composites, Composites Technology, Automobile, Sandwich composite and Applications.

1. INTRODUCTION

Over the last 25-30 years there has been an increasing requirement to lower vehicle mass. This has been driven by two factors; increasing petrol prices due to shortages in supply of crude oil and an increasing awareness of the environment and the need to reduce exhaust emissions [1]. Lowering the mass leads to less energy being required from the motor to accelerate and drive an automobile. A recent newspaper article has claimed every 100kg of weight saved in a car can save 0.2-0.4 litres of fuel per 100km, depending on the type of engine [2]. The automobile industry's drive for lower vehicle emissions and energy consumption has led to the development of alternative means of propulsion, in particular Battery Electric Vehicles (BEV) and Fuel cells [1]. BEV‟s have become feasible due to improvements in battery technologies. The improvements have increased battery energy density which allows substantial Improvements to driving range. Increasing range allows electric vehicles to be driven like conventional internal combustion engine vehicles [1]. Electric cars are emerging as a promising solution for the near future. Being battery powered, these vehicles do not perform as well as the conventional automobiles, and hence they need to be optimized effectively on all other fronts to derive maximum performance from electric power. The two most effective approaches to do this would be to improve the vehicle's aerodynamics and make it as light as feasible [3]. To overcome the problem of energy efficiency, various researchers suggested that different parts of vehicle could be replaced with different lightweight materials such as alloys and other traditional materials to reduce the weight of cars [4]. Every 10 kg of material reduction in a vehicle reduces the fuel consumption and leads to drop in carbon emission of 1g/km. More than half of the total volume in production of a modern car consists of cast iron and steel parts, about 11 % – plastics, aluminium alloys (9 %); rubber 7% and 3% respectively. The share of non-ferrous alloys (magnesium, titanium, copper and zinc) is about 1%; other materials (varnishes, paints, electric wires, facing materials, etc.) make 13.5 % as shown in table. 1.1[3]

Table 1.1 Various types of materials used for Manufacturing of car parts[3]



2. LITERATURE REVIEW

In 2008, Ryan Lovatt [1] made a lightweight chassis for a battery electric vehicle being developed at the University of Waikato. The chassis was designed around a predetermined body shape and suspension setup. A chassis, built from 20mm thick aluminium honeycomb sandwich panel, was designed and built to LVVTA standards allowing the car to be driven on public roads.

Gupta, N. S. (2006, 31 March 2006) [2] on the car that has been driven over 1800km with only one minor problem, indicating the chassis is reliable and well suited to its purpose. Titanium aluminide properties were researched to identify where titanium aluminides could be used in an automobile. Automotive applications identified that could benefit from the use of TiAl include valves, brake rotors and inside „in-wheel" electric motors.

In 2020, Mohammad Aiyan, S Sumanth Sagar [3] performed a study aimed to design a chassis and body for an electric Car vehicle to accommodate 2 persons providing a suitable and efficient aerodynamic design and adequate stability and passenger safety with suitable torsional rigidity and structural strength, which has been successfully done as inferred from the results.

In 2012, Jianfeng Wang, Chengyang Shi, Na Yang, Haonan Sun, Yiqun Liu, Baoyu Song has defined In this study, carbon fiber-reinforced composite sandwich structures cured at high temperatures with aluminum honeycomb structures as the core material were investigated. Specifically, the effects of core thickness and density on the laminate material properties were studied by three-point bending and panel peeling tests. Fig 1 shows schematic diagram of composite material which has been fabricated.

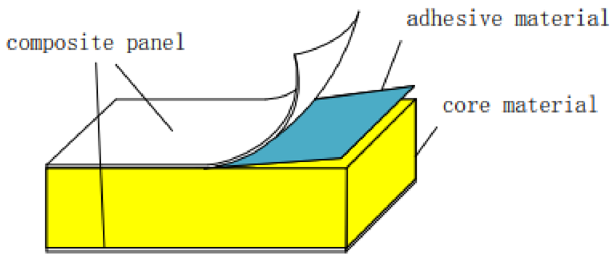


Fig 1 schematic diagram of sandwich composite

In 2018, RA Alia, O Al-Ali, S Kumar and WJ Cantwell investigates the compression properties and energy-absorbing characteristics of a carbon fiber-reinforced honeycomb structure manufactured using the vacuum-assisted resin transfer molding method (VARTM). The composite core materials were manufactured using a machined steel baseplate onto which hexagonal blocks were secured. After Inserting Carbon Fiber Fabric was inserted into o the slots and the resulting mold was vacuum bagged and infused with a two-part epoxy resin. . After curing, the hexagonal blocks were removed, leaving a well-defined composite honeycomb structure. . Samples were then cut from the composite cores and inspected in an X-ray computed tomography machine prior to testing. e. Finally, it was also shown that introducing a chamfer acted to reduce the initial peak force and precipitate a more stable mode of failure.

In 2020 H Ahmad, A A Markina, M V Porotnikov and F Ahmad did a review on carbon fiber materials in automotive industry. In present scenario, light weighting becomes a main issue for energy efficiency in automotive industry. The two main issues in automobile industry is emission of gases and fuel efficiency of vehicles. The best way to reduce Fuel consumption is by reducing overall weight of the vehicle parts. Research and development played an important role in lightweight materials for decreasing cost, increasing ability to be recycled, enabling their integration into vehicles, and maximizing their fuel economy efficiency. The application of carbon fibre reinforced plastic material offers the best lightweight potential to realize lightweight concepts. In automotive industry, the advantages of carbon fibre reinforced plastic are reduction in weight, part integration and reduction, crashworthiness, durability, toughness, and aesthetic appealing. Keeping in view the aforementioned advantages of carbon fibre reinforced plastic, the authors have presented a brief review on carbon fibre for automotive industrial applications.

In 2018, *H. Ersen BALCIOĞLU In this study, flexural behaviors of sandwich composites manufactured by using natural and recycled material were investigated. In this context, 9 different core materials, which were made by using 3 different granules size (1 mm, 2 mm and 4 mm) and 3 different core thickness (4 mm, 8 mm and 12 mm), were manufactured from waste vehicle tires. After, sandwich composites were produced by combining the core materials with natural jute fabric reinforced laminated composites. In order to test the usability of the produced sandwich composite materials as building material, the flexural behaviors of the sandwich composite were investigated under three-point bending load. Test results show that flexural behavior of the material varies according to the granular size and thickness of the core material.

In 2018, Leonard Hamilton, Peter Joyce, Chris Forero and Martin McDonald uses a carbon fiber reinforced plastic (CFRP) monocoque racecar frame was designed and constructed by students for the 2012 Formula SAE (FSAE) collegiate design series competition. Overcoming limitations imposed by locally available finite element analysis tools, a variety of tests were devised to determine required laminate thicknesses and layup orientations. . Based on the results of these tests, a sandwich construction using composite skins fabricated from carbon/epoxy prepreg and aluminum honeycomb core was selected.

In 2017, V.A. Horns, M.I. Shkarupa, A.K. Velis The article discusses the classification and features of the use of composite materials in modern engineering. An attempt has been made to present the most important information about the applicability of composites and their role in the development of mechanical engineering in a simple and relatively accessible way.

In 2022, Asep Indra Komara, Bagus Budiwantoro, Rachman Setiawan. In this paper, the authors examine the state-of-the-art technology in geometry, applications, and manufacturing of various cellular structures carried out by researchers to obtain an overview of the current conditions for further development of these cellular structures. Limited manufacturing capabilities encourage researchers to design an optimal cellular structure to be applied to a particular function but have high manufacturability. The development of additive manufacturing technology has provided opportunities for researchers to produce an optimal cellular structure commercially soon.

In 2018, I.M. Low r discusses the development of composites based on MAX phases, geopolymers, and cold ceramics. Spark plasma sintering and strong magnetic field alignment are highlighted as emerging techniques for the synthesis and densification of CMCs. Emerging or potential applications of selective CMCs are highlighted.

In 2021, Faheem Muhammed attempts to capture the various parameters that have led to increased permeability, as well as outlining process modifications that have demonstrated influence over the carbonized microstructure. In addition, this review seeks to differentiate itself by systematically outlining research advances that have been made in each step of the fabrication process. In doing so, scientific gaps that exist can be expounded upon while simultaneously summarizing what is necessary to advance the field.

3. METHODOLOGY

PROPERTIES OF COMPOSITE MATERIALS

Composite as an industrial material, mostly used for their outstanding resistance to chemicals and most forms of corrosion This property, even though conventionally important, is hardly the only useful property. There are many other important and useful properties are: [7]

- Low cost and low mass,
- Unequalled manufacturing and processing possibilities,
- Complex material body are easily produced,
- Tooling cost is very low,
- Appropriate to very small products and very large product,
- Satisfactory surface finish can be an integral feature.

ADVANTAGES OF COMPOSITE MATERIALS

The composites materials have some advantages over conventional materials are as follows [7]:

- Lightweight,
- High specific stiffness and strength,
- Easy moldable to complex forms,
- Easy bondable,
- Good dumping,
- Low electrical conductivity and thermal expansion, • Good fatigue resistance,
- Part consolidation due to lower overall system costs,
- Low radar visibility,

- Internal energy storage and release

DISADVANTAGES OF COMPOSITE MATERIAL

There is no such ideal composite, which has only merits of composed materials. The important point for the person who designs the system is that he must create a break through idea and realize it. In other words, all materials should be used according to the systems under design [7].

- Composite material structure has more complex mechanical characterization than a metal structure
- Repairing process of composites is complex as compared to that for metals
- Composites material do not have a the quality of high combination of strength and fracture toughness compared to metals
- High cost of fabrication of composites
- It is not compulsory that composites give greater performance in all the properties used for material selection: corrosion resistance, affordability, formability, join ability, strength, and toughness

TYPES OF FABRICATION PROCESS FOR MANUFACTURING COMPOSITE

A typical manufacturing process starts with receiving the materials that may include tapes, broad goods, and adhesives. The materials are checked by quality assurance personnel to verify that the materials meet the necessary specifications. The materials are then stored in the freezer. As per the drawing requirements, the prepreg is cut to the required shape either manually with a knife or with a reciprocating cutter, or with a controlled knife. The required tooling is matched with the prepreg. The tool, cut prepreg, and paperwork is taken to the lay-up area where the actual hands-on lay-up process takes place. Process coupons are simultaneously fabricated to investigate the fabrication quality by destructive tests. Quality assurance people check the lay-up prior to the bagging/sealing operation. The inspected bagged and sealed lay-up is placed in an autoclave for curing. After the cure, the part is separated from the tool [10].

Vacuum Bagging

This process uses a flexible film or rubber bag that covers the part lay-up. The bag allows the evacuation of air from the part to apply atmospheric pressure. Using the vacuum bag pressure for consolidation is a common practice. The only limitation of the vacuum bag process is the limited pressure that can be applied. In the autoclave process much higher pressure can be applied which may be necessary in fabrication of some complex parts.

The bag in the vacuum bag process serves two purposes namely-

1) It removes volatiles during cure, and 2) It provides pressure of one atmosphere.

A proper vacuum bag process must meet the following requirements:

- Impervious to air passage
- Apply uniform pressure
- Must not leak
- Good vacuum path must be provided to evacuate air between the bag and tool

Autoclave Process

An autoclave process uses a pressure chamber to apply heat and pressure during the consolidation and cure process. Autoclave method is the most common method used in the aerospace industry to make composite parts. The autoclave process is an economical method for making structural parts. The commonly used autoclave is capable of applying pressure of up to 200 psi (1400 KPa) and temperature of at least 350F (about 180C) and up to 600F (about 300C). The autoclaves are generally programmable and temperature/pressure history can be automated.

Compression Molding

The compression molding (matched die) process uses large presses to compress the prepreg material between two matched steel dies. The present use of this process is limited to discontinuous fiber composites. The process has application to the use of secondary structural parts.

Filament Winding

Filament winding is a mechanically automated process making parts of simple geometry by wrapping a male tool with filaments impregnated with matrix. This process is well suited for parts which are curved in shape (cylindrical or spherical). Filament winding process has been widely used in helicopter industry for making drive shafts, tail booms and rotor blades. The filament winding process is named dry if it utilizes prepreg material and wet if it uses fibers passed through a resin bath. The fibers can be continuous fibers of glass, aramid or graphite.

Pultrusion

Pultrusion is a mechanically automated process used to produce shapes by pulling rovings through a shaped and heated die. The process utilizes pre-impregnated rovings or rovings that are pulled through a resin bath to impregnate the fibers. The rovings go through a heated die that represents the cross section of the finished part. The curing is done by heating the die and /or microwave curing. The process is used to make shapes of constant shape such as I-beam, box or tube.

Braiding

The braiding process involves the weaving of fibers into the shape by repeatedly crossing them back and forth over a mandrel. The method is a product of textile technology and uses equipment adapted from textile industry. The main advantage this process offers is a rapid, automated method for forming an interwoven structure [10].

APPLICATIONS OF COMPOSITE MATERIALS TOWARDS AUTOMOBILE INDUSTRIES

Researchers have found wide adoption in various applications such as sandwich panels, packaging, cooling layers, catalytic, and heat exchange. On the other hand, cellular structures have also begun to be widely applied to vehicle structure construction, collision feasibility technology, and even cooling systems for batteries, power electronics, and electric motors. [8]

Sandwich structures are widely applied in many areas due to their superior energy absorption capacity, high specific stiffness, low density, high strength, and favorable mechanical properties. Sandwich structures using honeycomb have been investigated for many years, and currently, the focus of sandwich structure development is on using origami models as sandwich cores [8].

Application for vehicle structure

The importance of the safety aspect and the need for a lightweight construction on the vehicle is something that cannot be avoided. Various efforts were made by researchers and engineers, ranging from determining vehicle dimensions to the application of cellular structures as vehicle structures. The structure of the vehicle is designed in such a way that it can absorb energy during a collision and must be able to protect passengers [8].

Application for vehicle crashworthiness

A vehicle's crashworthiness is the vehicle's ability to absorb energy at the time of a collision, according to the Motor Vehicle Safety Standards. The crashworthiness evaluation can be ascertained by a combination of tests and analytical methods based on numerical simulations. Passenger safety is the most important and challenging requirement in vehicle design [8].

Researchers have widely published the ability of vehicle structures to protect passengers, cargo, or batteries in electric vehicles during collisions in recent decades. Crashworthiness design for urban electric vehicles due to side impact with impact absorbers placed inside the door in the form of a structure filled with aluminium and complementing the battery storage compartment with canal structure impact absorbers was carried out by Setiawan and Salim. . Facts show that some lithium-ion batteries can catch fire while others can catch fire in accidents leading to death. Battery packs are designed for safety-related challenges such as mechanical, electrical, and thermal abuse [8].

Hao et al. optimized the battery pack's structure to improve electric vehicles' feasibility through frontal simulation. Xia et al. investigated cell and battery pack damage due to ground impact. Based on the simulation results of a frontal collision, it turns out that vehicle acceleration can be reduced by designing a flexible battery compartment structure. Two critical factors that can increase the feasibility of impact absorption are the structure of the battery compartment and the working pressure. The position of the battery pack is also an important issue because the battery pack is quite heavy and requires a large amount of space. The safety requirement aspect of this system is very important [8].

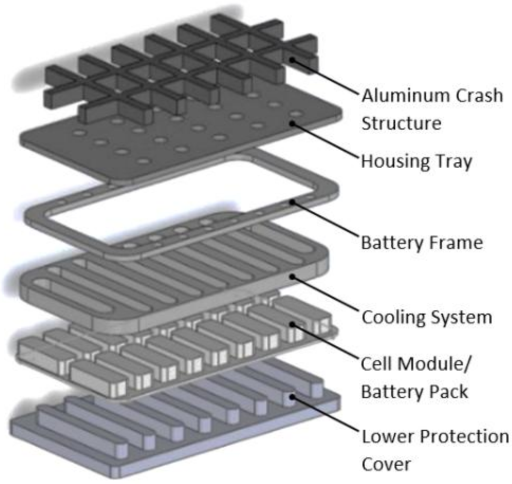


Fig 2 Illustration of a multi layered housing for battery casing [8]

Application for cooling system

Various possible battery failures due to accidents include mechanical abuse, electrical abuse, thermal abuse, and internal short circuits. Mechanical abuse can trigger electrical abuse, whereas electrical abuse releases heat and induces thermal abuse. To avoid these accidents Development of optimization methods to optimize the lattice structure as an effective refrigerant channel through the liquid and thermal runaway mechanism of lithium-ion battery for electric vehicles should be researched thoroughly [8].

OTHER APPLICATONS OF COMPOSITE TOWARDS INDUSTRY

Composite materials contain construction, marine goods, aerospace, transportation, sporting goods, and further newly infrastructure, with construction and transportation being the biggest [7].

Aerospace Applications

Aircraft applications are the maximum significant uses of composites. Unlike other vehicles, commercial aircraft, essential to lay greater stress on safety and weight. They are realized by using materials through great specific properties. A modern civil aircraft designed as to encounter the several criteria of power and safety [7].

Composite Material used in Marine Applications

In marine applications ships are under unbroken attack, both from the elements of nature and the enemy. The huge majority of ship hulls are created from common carbon steels, that are noticeably vulnerable to corrosion, but they also make different thermal and electromagnetic signatures simply noticeable from long distances [7].

Composite Material used for Electronics and Electrical

The composites are fitted with high quality electric insulation, spark-free and good antimagnetic agents. They also have good adhesion toward glue & paint. Composite also possess self-extinguishing qualities due to which it is used for the construction of distribution pillars, link boxes and profiles for the separation of current-carrying phases to prevent short circuits etc.

Hybrid Thermoplastic Application

Thermoplastic composites which used for mass producing lightweight structural parts because it has long held potential properties. On the other hand thermoset constructed composites, which undergo time consuming chemical cross linking throughout processing; thermoplastic based composites are typically treated using simply heat and pressure.

Table 1.2 Other automotive application for MMCs with CFRP

Property	Materials	Application
Wear resistance	Sic-, Al2O3-, and/or graphite-reinforced micro and Nano MMCs	Bearing surfaces, cylinder liners, pistons, cam shafts, tappets, lifters, rockers, brake components
Light weight, energy absorption	Fly ash cenosphere- and low-density ceramic micro balloon-reinforced syntactic foam MMCs	Crumple zones, frame members and reinforcements, pedestrian impact zones, batteries

Self-cleaning	MMCs with hydrophobic reinforcements, biomimetic coatings, and surface finishes	Water pumps, water jackets, exposed metallic components
Self-lubricating	Micro and Nano MMCs incorporating graphite, MoS2, TiB2, hexagonal BN, or other solid lubricants	Bearing journals, cylinder liners, pistons, cv joints, gear surfaces
Self-healing	MMCs incorporating shape memory alloys or hollow reinforcements filled with low-melting healing agents	Difficult-to-access, fatigue prone, and critical components, such as driveshafts, wheels, steering knuckles and columns, and connecting rods
High thermal conductivity	Micro and Nano MMCs reinforced with high conductivity carbon, diamond, or cubic boron nitride (CBN) powder	Cylinder liners, water passages, brake components turbo/supercharger components, catalytic converters, electronics packaging
High strength	Micro and Nano MMCs reinforced with SiC orAl2O3 particles, carbon nanotubes (CNT), carbon or Nextel fibers, and in-situ ceramics	Connecting rods, brake callipers, brake rotors, brake callipers
Low cost	MMCs containing fly ash or waste sand as fillers	Intake manifolds, accessory brackets, low-load brackets, oil pans, valve covers, alternator covers, water pumps

PARTS OF AUTOMOTIVE FABRICATED BY COMPOSITE MATERIALS

Engine Block Cylinder Liners –

In modern aluminium engine blocks, grey cast iron cylinder liners are used to protect the block. These weight about 9kg per block but MMC liners weight 3.5kg less. Al MMC liners can improve engine operating efficiency by reducing knock (heat transfer from the cylinder to water jacket is improved due to increased thermal conductivity). Blocks with MMC liners have increased rigidity as compared to the blocks with coated bores, which may be translated into increased cylinder roundness and reduced engine friction. Honda has successfully used in situ formation of an MMC cylinder via die-casting non-metallic cylinder preforms. In a new approach to achieve a further weight reduction, researchers will developed a new aluminium engine block which has the cylinder bore surface reinforced with short hybrid fibers of alumina and carbon.

Main Bearings –

Copper-lead bearings are used in crankshaft main bearing caps can be replaced with lead free aluminium or copper matrix composites containing graphite particulates. Gr is nontoxic and the use of Gr reinforced Al or Cu composite bearings as a replacement for leaded copper reduces weight. The Gr reinforced MMC bearings also improve the wear characteristics because deformation of the Gr particulates results in the formation of a continuous graphite film, which provides self-lubrication of the component, allowing for improved component longevity.

Connecting Rods –

With the advent of nanostructured materials, new materials have been developed with exceptional properties exceeding those expected for monolithic alloys or composites containing micron-scale reinforcements. For example, carbon nanotubes reinforced composites have ultrahigh strength and modulus. In another example reinforcements of only 10 vol. % of 50nm alumina (Al_2O_3) particulates to an Al alloy matrix using the powder metallurgy process increased yield strength to 515MPa. This is 15 times stronger than the base alloy, 6 times stronger than the base alloy containing 46 vol. % of 29µm Al_2O_3 and over 1.5 times stronger than AISI 304 stainless steel

Accessories –

For components not exposed to extreme loading, further cost and weight reductions can be realized by reinforcing of fly ash (a waste by-product of coal power plants) in metal (e.g., aluminum, magnesium, lead, and zinc) matrix. Replacing components such as A/C pump brackets, alternator housings, timing belt/chain covers, valve covers, transmission housing and intake manifolds with Al reinforced with fly ash composites can reduce the vehicle cost and weight. Fly ash reinforced Al MMCs used for accessories can reduce emissions and save energy. It also reduces its coefficient of thermal expansion and increases its wear resistance along with making lighter and less expensive material

Chassis –

The performance of vehicle can affect by the strength and toughness of the chassis. Hollow ceramic microspheres reinforced metal matrix results in a syntactic foam product. Its density is about one half as compared to the matrix and it can able to absorb large amounts of energy per unit weight upon impact as compared to the monolithic alloys and open cell foams.

Bumper –

Bumper is the one of the main part of an automotive vehicle having slightly more weight. We can employ composite materials in the bumper without sacrificing the safety. Polymers composite have been a major part of the automotive industries for several decades but the technical barriers and economic have constraint their use. At present, carbon fiber reinforced and glass fiber reinforced polymer composite are commonly used for automotive bumpers

4. CONCLUSION

The objective of this review paper is to find out the materials for automotive which are commonly used and to give an overview on the optimized composite materials. From the above literature review, it is clear that the Composite play a crucial role in industrial applications due to its unique properties. The unique properties of MMCs With reinforced CFRP are excellent strength to weight ratio, dimensional stability, thermal conductivity, low specific density, low coefficient of thermal expansion and high specific stiffness. Thus, it become suitable for various industries such as aerospace industries, automobile industries, railways and naval applications.

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