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REVIEW OF COMPOSITE MATERIALS IN AUTOMOBILE APPLICATIONS

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ABSTRACT

This essay highlights the advantages of utilizing composite materials for manufacturing automobile parts rather than traditional metal. There is some unspecified and disorganized information regarding the multifunctional behavior of composite materials that is directed by applicability for manufacturing. Scientists maximize the diversity of composites in order to obtain improved performance in all fields as well as the automotive sector. Because of high strength, lightweight, durability, and corrosion resistance, ballistic performance composites are utilized. Other aspects, such as lightning protection behavior, can be imposed with a very simple and cost-effective manufacturing process. Braking-associated parts, chassis, steering systems, battery and charging-associated items, and differential and suspension systems rely sufficiently on composite materials.

Composites seem to be complex, but the overall importance is very profitable for innovation in new materials of various kinds. Composites are already regarded as the new breakthrough of material science. Very soon, it will offer a range of scopes, such as natural fibre employed for the purpose of biodegradability. Large constraints of employing composites are defined in car parts. Overall production is always evolving contemporary technology and safety for the environment and humanity.

The cost of manufacturing is very expensive for various components and various aspects of metal. Even so, composite offers overall cost less than other conventional materials which improving prospects for automotive manufacturers. Other other new viewpoint such as piezoelectricity, magneto strictive properties, self-healing property electromagnetic sheilding can accelerate this field in long term future which are explained in this review paper.

Keywords: Automobile, Composite materials, Automotive composites, Fiber-reinforced polymers (FRP), Carbon fiber composites, Glass fiber composites, Natural fiber composites

1. INTRODUCTION

Composite material is made up of two or more materials that are better than single materials . Egyptians and Mesopotamians used it for the first time in 1500 BC to construct bricks with mud and a mixture. But in 1200 AD, Mongol's initially use composite material to fabricate Bow. So, Composite material is used first in military actions for high performance. The Modern era of composites was started in 1900 s by developing plastics (i.e. Polyester, vinyl). In 1935, first fibre composites were introduced due to their higher strength and lower weight. The fibre reinforced composites were developed during World War II. After the war, those were introduced in other markets along with military weapon .

The initial composite materials were presented with cars in 1947, . Japan in 1974 considered reducing vehicle weight for lowering high fuel usage. At that time they considered the significance of composite materials in bodywork of a vehicle . Though Rolls Royce in UK was testing glass fiber reinforced thermoset polymers in the fan of gas turbine engine, the test did not gain notable success . Between 1960 s and 1990 s, this era is taken as development era of composites in automobile sector. Throughout all these eras, SMC type's composites got developed and in 1990, world's first carbon road car came into existence by McLaren. In 20th and 21st century, composites are marked as pioneer in automobile sector, because they have low weight, less fuel consumption, accidental safety . Now natural fibre is also employed in research and trial due to Green Technology. It regulates pollutions, environmentally biodegradable and found naturally .

Composite materials are employed due to some specialty like minimal corrosion, simple maintenance and design flexibility . The major advantage of composite materials is their strength, rigidity, and light weight. Manufacturers can create qualities that are ideal for the application of a particular construction to a specific use by picking the appropriate combination of reinforcement and matrix material .

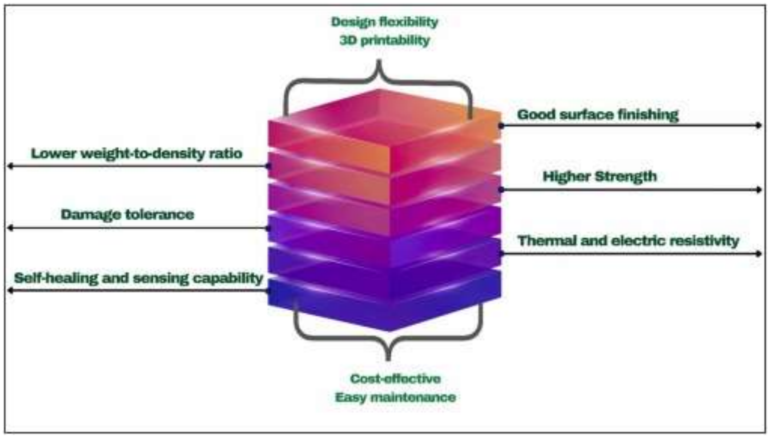

Fig. 1 shows the beneficial characteristics of composite materials. As composite materials have multiple layers, each of them combinedly carries different properties.

In comparison to other conventional materials, composite material exhibits some special properties that can be manufactured as per requirement. Composites have been utilized in the automotive sector and aerospace and military vehicles in recent years . For lightweight and high-performance, composite materials are utilized in low-volume cars and motorsport . Even for natural fibre composites, it exhibits greater weight-to-strength ratio, compared to other homogeneous metal . Composite materials exhibit 15 times greater tensile strength compared to traditional material. That has low fuel consumption . Thermal and corrosion resistance in this multipurpose material is cost-effective in total cost . This green material displays high damage tolerance characteristics for safety in passengers . Composite materials display some aspect in recycling, which is very convenient in Green Technology. These materials are overall adequate for environmental safety . Despite the difficulty of obtaining good quality surface finishes at an affordable price, it displays advantages in manufacturing, designing, repair, lightweight, joining, recycling and safety concerns]. In comparison with performance and utilization, composite overall cost is extremely low . A number of simple fabrication methods need to be used to minimize cost when fabricating composites like molding, lay-up, winding and so on.

Scientists are attempting advancement of composites appication in producing environmentally friendly in affordable cost . On the other hand, it is very impossible to improvise due to high cost for fabrication. Moreover, the 3D printing technology was highly restricted for many types of materials. Although that is already developed to create composites with 3D printing in affordable cost . These all-other issues can be addressed by using Natural Fibre Composite materials . Apart from that, fire issues and lightning damage are significantly enhanced for vehicle. Additionally, self-healing and sensing capabilities, piezoelectricity and magneto-strictive properties need to be considered by the manufacturer. Researcher should suggest significance in this phenomenon by utilizing the effective properties of composite materials.

2. ADVANTAGES OF COMPOSITE MATERIALS

2.1.STRENGTH-TO-WEIGHT RATIO:

The strength-to-weight ratio of a material, often referred to as its specific strength, is a comparison of its strength relative to its weight. Composites' high strength-to-weight ratio is perhaps their greatest advantage. While carbon fibre is stronger and more rigid than both materials on a unit weight basis, it weighs about one-quarter as much as steel and 70% as much as aluminium .

Multilayer composite laminates take in more energy compared to traditional single-layer steel, allowing top-shelf automotive designers to shave weight from a car by up to 60% without sacrificing crash safety . For example, it can be designed that a composite will not bend in one direction when metal would otherwise have to be thicker in order to obtain the same amount of strength in one order, and this adds weight.

Composite materials are strong but not heavy . Table 1 illustrate that Steel and Carbon Fibre as well as Aluminium and Laminated Fibreglass are readily separable based on their mechanical properties like Types of Materials, Tensile Strength, Density and Elastic Modulus.

Table 1. Comparison of material strength of different types of composites and all9oys.

Materials Name	Materials Type	Tensile Strength Σu (MPa)	Density ρ (kg/m^3)	Elastic Modulus E (GPa)
Steel (S355)	Alloy	500	7850	210
Carbon Fibre (High Strength)	Composite	7060	1820	294
Aluminium (AA6082)	Alloy	150	2710	71
Laminated Fibreglass (FR4)	Composite	317	2000	24

From Table 1, Carbon Fibre and Laminated Fibreglass are more tensile-strength than Steel and Aluminium. They have a higher elastic modulus too. Even though they have a lower density, Steel and Aluminium can be substituted by Carbon Fibre and Laminated Fibreglass respectively.

2.2. DURABILITY AND DAMAGE TOLERANCE

Metals can be fatigued. Aloha Airlines crash in the 1980 s was due to this . Whether hot or cold and wet or dry, composites will not lose their shape or rust due to their good dimensional stability. Thus, they are a good material for exterior structures like wind turbine blades for long-term stability .

2.3. IMPACT RESISTANCE

Composites may be made to bend away from impacts, like the impact of a bullet or explosion. Since they possess this quality, composites are utilized to make explosion-resistant jackets and panels and cover buildings, tanks and helmets and airplanes from explosions .

2.4. RESISTANCE AGAINST CORROSION

Products made from composites have long-term resistance to aggressive chemical and temperature environments. There have been numerous instances of glass fibre-reinforced polymer ductwork functioning in corrosive chemical conditions round-the-clock, every day of the week, for more than 25 years in chemical industrial facilities . Composite materials including carbon fibres, glass fibres, and rapid-cure resins have qualities that resist corrosion from oxygen and moisture as well as corrosive substances, saltwater, and humid environments. Due to this, composites are a key element of sea industries or firms that transport products and chemicals by pipes and into containers .

2.5. THERMAL CONDUCTIVITY

Composites also have low thermal and electrical conductivity and, as such, are great insulators for parts that need insulation . But if it becomes mandatory to fabricate thermally conductive components, thermally conductive elements can be included within the composite part, hence this property isn't lost during fabrication of composite parts . For instance, Polyimide Composites are highly thermally conductive. It is lighter than high glass-transition-temperature metals. This material can be altered to have the optimum properties reliant on the applications by replacing the carbon fibres which has low CTE .

2.6. NONMAGNETIC

As composites do not contain any metals, they are nonmagnetic. Composite materials can be utilized near sensitive technological devices. Big magnets utilized in MRI (Magnetic Resonance Imaging) equipment function better without magnetic interference . In Fig. 2, it can be seen that the contact angle does not change after magnetic influence. The composite materials within the micro-channel become magnetized when two rectangular permanent magnets of the same opposite polarity are placed in the center of the channel length, with their magnetization direction perpendicular to the channel wall.

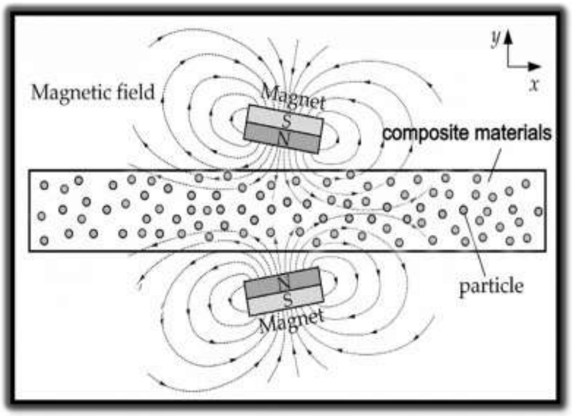

FIG. 2. TESTING COMPOSITE MATERIALS WITH THE CONTACT OF MAGNET.

2.7. COST SAVINGS

Composites are cheaper in price per cubic inch and raw material cost. One of them alone is a thermoset composite. Thermoset composites are cheaper compared to products such as thermoplastics, wood, and metal. Additionally, because thermoset composites use very little petroleum, they are not vulnerable to price fluctuations that impact petroleum-based materials .

2.8. DESIGN VERSATILITY

Composite materials allow design freedom in automotive engineering to enable designers and engineers to develop structures more innovatively and efficiently compared to conventional metals [48]. Composites may be shaped into intricate shapes for economical and aesthetic designs, which upgrade the aesthetic character and efficiency of automobile bodywork . Composites may be easily designed to ensure environmental security . Engineers may tailor composite materials' mechanical properties by changing fibre type, orientation, and stacking sequence and thus ensuring components with specific stiffness, strength, and damping capabilities . Composite materials may be integrated into a single component, making it easier to design and reducing the number of components required since it can serve as a noise barrier, thermal insulator, and structural component .

2.9. DIMENSIONAL STABILITY

Dimensional stability is essential for the structural integrity and long-term performance of vehicle parts. For this purpose, composite materials are employed in automotive applications to minimize mechanical stress and environmental conditions . Low Coefficient of Thermal Expansion is an important design method for automotive applications, as it reduces size variation and maximizes dimensional stability due to temperature changes . Certain composites, particularly organic matrix ones, may lead to dimensional changes as a result of moisture absorption, which can be reduced by design choices and material selections .

2.10. CHEMICAL RESISTANCE

The strength-to-weight ratio, corrosion resistance, and other advantages of composite materials are making them increasingly popular in the automotive sector, with the environment and type defining their chemical resistance . Glass fibres and epoxy resin are generally resistant to a vast majority of chemicals and are the most sought-after for the automotive sector because of their excellent chemical resistance. Moisture absorption will have a significant impact on the performance of composite materials despite some being specially designed to avoid it .

2.11. ELECTRICALLY NON-CONDUCTIVE

Composite material electrical non-conductivity is significant in automotive use to avoid interference and short circuit problems, and its conductivity relies on the fibres, matrix materials, and additives . Glass fibres having electrical non-conductivity enable glass fibre-reinforced composites for application in situations involving electrical insulation . Carbon fibres are inherently conductive, but their electrical conductivity drops after being implanted in an electrically non-conductive matrix such as epoxy resin, hence they find common use in applications demanding high electrical non-conductivity and strength . Epoxy resins are appropriate for use in applications demanding electrical non-conductivity because of their electrical insulating ability . Additives or fillers may be incorporated into composite formulations to increase electrical non-conductivity and general insulating characteristics .

3. FABRICATION METHODS

The processes employed to form, cut, or shape materials into objects are referred to as fabrication methods. Cutting, forming, punching, stamping, shearing, and welding are common fabrication methods .

Composite materials provide new design options for its flexibility. With appropriate tool design and working conditions, traditional machining methods can be employed with composite materials, such as drilling, turning, sawing, routing, and grinding. Other non-traditional approaches have been utilized on these materials, like water-jet, laser, electro-discharge, and ultrasonic machining .

Depending upon the composite material being used and the specific application, several manufacturing techniques for composite materials are used in automobiles. Following are a few common manufacturing techniques:

3.1. HAND LAY-UP

One of the oldest and most simple approaches is the hand lay-up which involves applying reinforcement materials in layers manually inside a mould. By hand lay-up, a resin matrix is pumped into the layers. It is often used in prototyping or low-production volume . For composite leaf spring production, various methods may be suggested. Whereas the mandrels (male and female) in the current work were prepared from plywood by the desired profile identified through the current research, the by-hand lay-up suction bag technique was originally applied .

Pre-cut, pre-impregnated "prepreg" reinforcement in individual layers or "plies" is applied by hand in manufacturing, referred to as "hand layup." It consists of infinite fibres pre-impregnated with resin, being formed into tows, then either woven or being arranged within a single ply unidirectionally. Each ply should be shaped manually into the desired form prior to being firmly bonded onto the surface of the last layer or mould, with no gap between the plies]. Hand lay-up technique is often employed to produce fibreglass and composite car materials . Composite materials that have good strain energy storage are E-Glass/Epoxy in fibre direction. Consequently, the layup is made to be unidirectional in the longitudinal direction of the spring].

3.2. RESIN TRANSFER MOULDING (RTM)

Reinforcing material dry is placed inside a mould cavity in the closed-mould Resin Transfer Moulding process, with the resin matrix injected under pressure. The composite product is extracted from the mould after curing once the resin has transferred through the fibres. Resin Transfer Moulding allows for more control of resin content and part thickness and is suitable for medium-volume production]. Due to the possibilities of automation, interesting product performances, and reproducibility of parts, which encompass RTM, are of interest to the automobile industry . Recent multi-gate Resin Transfer Moulding injection studies have shown that air voids are often formed in weld lines, or the resin contact region, by a front impact collision between counter-resin flows . RTM is a production process employed in the automotive sector to fabricate composite parts and components in high scale rate production. RTM is most appropriately used to make parts with high strength-to-weight ratios, precise dimensions, and intricate shapes]. RTM is an important process for manufacturing lightweight, high-performance composite parts that assist in making more efficient and technologically advanced cars .

3.3. COMPRESSION MOULDING

Compression moulding is employed in mass production of composite products. A prepreg, fabric is placed in a mould cavity at this stage. The mould is closed to allow the resin to cure and shape the composite part]. Compression Moulding large and comparatively simple composite parts such as body panels, hoods, roofs, and spoilers are commonly manufactured by compression moulding. By employing thermoset or thermoplastic matrices, compression moulding is a widely recognized technique for the manufacturing of polymer composite materials . Rubber tyres, glass mat thermoplastic products such as bumpers, and sheet moulding compounds for automobile body exterior panels are the most common materials used in compression moulding . Pre-impregnated intermediate forms, including thermoset Sheet Moulding Compounds (SMCs), Glass Mat Thermoplastics (GMTs), or Long Fibre Thermoplastics (LFTs), are manufactured through compression moulding to produce semi-structural and structural composite parts.

3.4. AUTOMATED FIBRE PLACEMENT (AFP) AND AUTOMATED TAPE LAYING (ATL)

Robot systems employ Automated Fibre Placement (AFP) and Automated Tape Laying (ATL) to place continuous fibres or tape onto a mould surface automatically. With high fibre accuracy and repeatability, these methods fabricate highly shaped composite pro-technology [83]. Various automated manufacturing methods have been established to fabricate light composite structures. Automatic tape laying and automated fibre placement are among the most prevalent prepreg technologies. AFP/ATL is particularly well suited to complex geometrical structures and large numbers .AFP uses a broad unidirectional prepreg tape which can be directly applied to a tool surface using automatic ply backing removal. AFP, on the other hand, uses a band of narrow prepreg material strips referred to as tows .AFP is a composite technique for manufacturing complex, better, lighter structures for future automobiles .

3.5. FILAMENT WINDING

Cylindrical or tube-shaped composite parts, such as drive shafts or pressure vessels, are commonly produced by filament winding [87]. In filament winding, continuous fibres are placed in a specific pattern on a rotating mandrel, and resin is used to impregnate the fibres. The section is dried and stripped off the mandrel [88]. A filament winding process produces axisymmetric parts, such as pipes, tubes, drive shafts, and pressure vessels. Axisymmetric components are most suited to this technique .

3.6. SHEET MOULDING COMPOUND (SMC) AND BULK MOULDING COMPOUND (BMC)

Composite materials available in sheet or bulk condition is Sheet Moulding Compound (SMC) and Bulk Moulding Compound (BMC), respectively. Resin, chopped fibres, and additives constitute these materials [90]. They are often used in compression moulding techniques to produce oversized flat components such as car body panels .

The most widespread and successful application of fibre-reinforced thermoset composites in the automotive sector is the Sheet Moulding Compound. The process allows bulk composites to be constructed at a reasonable price . Thermosetting resin matrix reinforced with glass fibres and additives constitutes Sheet Moulding Compound, a specific type of composite material. It is generally supplied as a sheet, compressed-moulded or moulded to form complex shapes and components. SMC is used in automotive: Body Panels, Bumper Beams, Engine Parts, underbody Shields, Interior Parts, and Battery Enclosures .

Another composite material often used in the automotive sector and other manufacturing industries is BMC. Bulk Moulding Compound, a thermosetting plastic composite, consists of a polymer resin, a number of reinforcing fibres (usually glass fibres), and additives. It is formulated into a dough-like state which can be shaped into various forms prior to being subjected to heat and pressure to dry it. Application in the automobile industry such as Engine Parts, Exterior Trim and Body Parts, Under hood Parts, Structural and Reinforcement Parts, Electrical and Electronics Parts.

3.7. VACUUM INFUSION

Vacuum infusion puts dry fibres in a mould and utilises a vacuum to extract air out of the mould . The resin is then placed within the mould, drawn by the void, and infused into fibres. The composite component is extracted from the mould upon curing. Large composite components can be made by the versatile Vacuum Infusion Process (VIP), a cost-effective and precise manufacturing method. The Carbon Fibre Reinforced Polymer (CFRP) is used widely in the automotive and space industries.

4. USAGE OF COMPOSITE MATERIAL IN CAR

In the automotive sector, composites are becoming increasingly utilized, as widely documented. This is the reason why advanced composite is the primary focus of this research based on the latest study. The new composites consist of long threads of carbon, glass, and silver that are woven into metallic matrices to be used for reinforcement [98]. Because of their unique properties and advantages over traditional materials such as steel and aluminium, composite materials find a number of applications in the automotive sector [99]. Composite materials are usually formed by combining two or more elements to form a new material with enhanced properties [100]. A number of automobile components have been found most commonly to employ composites, brake pads, hood, chassis, leaf springs, bumper, door, sunroof, engine cradle, fender, etc.

4.1. BRAKE PADS

Brake pads are an essential component of automobile braking systems. Brake pad materials must have stable and reliable frictional and wear properties under a variety of load, velocity, temperature, and high durability conditions [101]. Because of their high friction coefficient and lower wear at room temperature and at elevated temperatures up to approximately 250°C, phenolic composites are often used in automobile brake pads [102]. In vehicles, polymer matrix composites are traditionally used as brake linings. Generally, friction against pearlitic grey cast iron, steel, or aluminium matrix composite material is a substitute component in a friction couple [103]. Steel or iron conventional brake pads are heavier than composite brake pads, which contributes towards minimizing overall weight and improved handling [104]. Composite materials produce less brake dust and noisier braking [105]. Composite materials are applied to braking systems as technology improves and the demand for high-performance, eco-friendly

vehicles increases highly. Nevertheless, it is important to remember that the production of brake pads involves thorough testing and verification to ensure safety and compliance with industry standards [106]. Coconut fibre with Aluminium reinforced composite [107] and Aramid fibre [108] already demonstrate a good substitute for brake pad and brake disc. Here the brake pad is free, effective and rather harmless. Further more research development is needed for sensitive purpose.
Fig. 3 indicates that Brake pads are made up of numerous layers. The underlayer, which lies between the backplate and the friction material, serves as the glue that holds the friction material away from the other layers. Fig. 3 clarifies the Structure of the brake pad for friction materials. It contains four categories of friction materials: 1. Reinforcement, 2. Abrasive, 3. Filler, and 4. Binder or Resin [109].

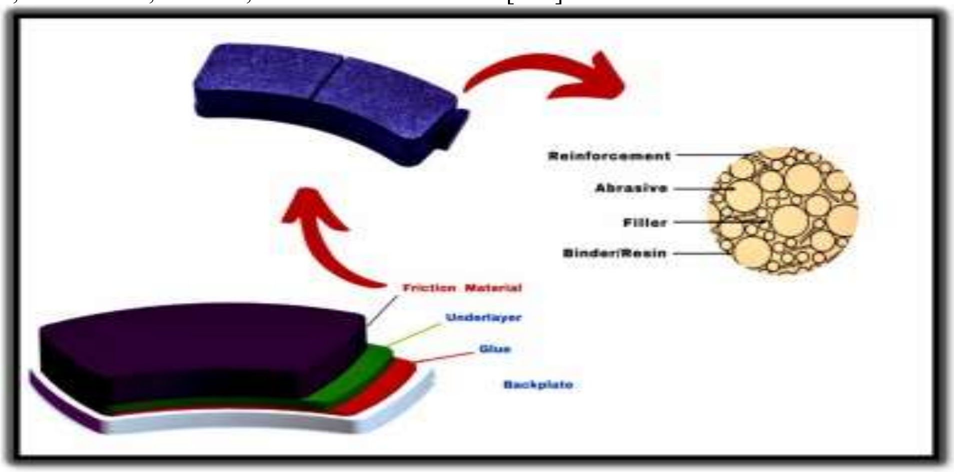

Fig. 3. Brake Pads Structure

5.CONCLUSIONS
From the above explanation, it can be said that composite materials are not only a choice but also a compulsory application in the automobile sector. The flavor of composites in the automobile sector has attracted a lot of attention with their pleasing and effective properties. Multiverse properties offer diversity in materials. Single composite materials ensure multiple features with the help of which compared to quantities of homogeneous materials. The most important benefit of composite material usage is light weight with high strength. This kind of extreme conditions can not be compiled by individual conventional metals. Many composite materials are represented already, but additional working will bind variable advantages to each sectors.
Due to the growing use of composite material in the automotive industry nowadays, its application will spread successfully in the future. The creation of composite materials to be used in cars has revolutionized the automobile industry, bringing with it a myriad of benefits that enhance sustainability, efficiency, and performance. Several composite applications have been incorporated, such as chassis, brake pads, hood, bumper, fender, engine cradle, interior and exterior essences, tires, sunroof, etc., to provide lightweight, high strength, good fatigue resistance, toughness, damage resistance, stiffness, thermal insulation, wear resistance, and other valuable properties within affordable cost. Due to their high strength-to-weight ratios, composite materials are ideal for application in numerous automotive structural parts.
The primary issue of automobile is the safety of the passengers against accidental damage. Their higher strength and hardness promote car safety levels. Composites are the most protective against fire and lightning as they are less conductive. The thermal and electric conductance is extremely negative for composites which safeguards against accidents and harm from interior to exterior elements. Another aspect of thinking is the reduction of cost after use. Composites account for most of the vehicle weight reduction. Reduced emissions and improved fuel efficiency are the outcomes of weight reduction. 3D printing capability also decreases the cost of labor enable various shapes and characteristics based on the need of an auto. Most composites can be utilized together to create various kinds of parts which are extremely unique. Researchers already discovered the useful characteristic of continuing auto technology. Nevertheless, accidental damage is amongst leading concern which has to be minimized and further research has to be done.
Environmental safety and sustainability will be enhanced during utilization of composite for reduced fuel consumption. Moreover, Natural fibre composite opens the gate of excellent future. It is biodegradable, biocompatible, recyclable, and present in the environment. In near future, it can be utilized for wider applications. In

addition to that, composite can be utilized in acoustic control, magneto strictive and piezoelectric qualities in coming future. Self-Healing, sensing, electro-magnetic shielding properties can be guaranteed by composites that can be utilized in future vehicle performance. More research needed to guarantee these properties prior to its utilization in automobile industry.

Despite all their advantages, there are also disadvantages, such as high costs of production, issues with recycling, and the need for standard manufacturing processes. Number of research are very minimal to decrease cost of production and synthesize. A lot of variations can be made but cost of fabricating should be minimized by future research. Ideal fabricating process ca be assumed to minimize cost for individual composites. Researcher has to recognize the perfection for improvement. Weight, safety, and design were paramount concerns with which the auto industry struggled, and which have been addressed by advances in composite materials. Composite materials will likely become more significant as technology continues to advance, assisting in the production of cars that are more efficient, green, and high-tech.

Fruitful labor has to be applied more on the basis of the composites. Although plenty of technology and science validate the excellence of respective genre of materials in vehicle sector, some negative consequences must be localized. The ill effects of various constituents of composites should be brought into light for every particle. Reduction of strength for continuous usage of materials, must be tracked in the future. Above everything, composite make a huge revolution in automobile industry as well as other industry.

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