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# Advances of composite materials in automobile applications – A review

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ABSTRACT

This paper emphasizes the benefits of using composite materials in manufacturing automobile components instead of conventional metal. Some unknown and unorganized information on the multifunctional phenomena of composite materials is guided by relevance for manufacturing. Researchers enhance the variation of composites to achieve better performance in every sector as well as the vehicle industry. Due to high durability, strength, lightweight, and corrosion tolerance, ballistic performance composites are used. Some other features, like fire and lightning protection behaviour, can be imposed within a very easy and economical fabrication process. Chassis, braking-related components, steering systems, battery and charging-related objects, and differential and suspension systems depend adequately on composite materials. Composite materials may look complex, but their overall significance is very lucrative for introducing new types of materials. Composites are already considered the new turning point of material science. Very shortly, it will provide a variety of scopes, like natural fibre used for ensuring biodegradability. Huge limitations of using composites are characterized in automobile components. Overall output is consistently developing modern technology and safety for both the environment and mankind. The price of manufacturing is quite high for different components and different features of metal. Even then, composite reduces overall cost than other traditional materials which improving opportunities for vehicle manufacturers. Some other new perspective like piezoelectricity, magneto strictive properties, self-healing capability electromagnetic sheilding can be accelerate this field in long term future which are discussed in this review paper.

## 1. Introduction

Composite materials consist of two or more materials that perform better than unique materials [1]. Egyptians and Mesopotamians first used it back in 1500 BC to make bricks with mud and a mixture. But in 1200 AD, Mongol's first use composite materials for making Bow. Thus, Composite materials are first used in military activities for elevated performance [2]. 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 [3]. The fibre reinforced composites were developed during World War II. After the war, those were introduced in other markets along with military weapon [2].

The first composite materials were introduced with automobiles in 1947 [3,4]. In 1974, Japan thought to reduce weight of the vehicle for decreasing high fuel consumption. That time they gave importance of composite materials in vehicle's bodywork [5]. Although Rolls Royce in UK was experimenting glass fibre reinforced thermoset polymers in gas turbine engine fan, this experiment didn't get significant success [6]. In between 1960 s and 1990 s, this period is considered as development period of composites in automobile industry. In these all periods, SMC type's composites were developed and in 1990, world first carbon road car was introduced by McLaren [7]. In 20th and 21st century, composites are signified as pioneer in automobile industry, due to their low

*Abbreviation:* CTE, Coefficient of Thermal Expansion; RTM, Resin Transfer Moulding; AFP, Automated Fibre Placement; ATL, Automated Tape Laying; CFRP, Carbon Fibre Reinforced Polymer; PFRC, Plantain Fibre-Reinforced Polyester Composites; FRP, Fibre Reinforced Plastic; LCM, Liquid Composite Moulding; MRI, Magnetic Resonance Imaging; SMCs, Sheet Moulding Compounds; GMTs, Glass Mat Thermoplastics; LFTs, Long Fibre Thermoplastics; BMC, Bulk Moulding Compound; VIP, Vacuum Infusion Process; GFRP, Glass Fibre Reinforced Polymer; PVB, Polyvinyl Butyral; CMCs, Ceramic Metal Composites; MMCs, Matrix Metal Composites; MPCs, Magnetostrictive Polymer Composites.

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weight, less fuel consumption, accidental safety [8]. Now natural fibre is also used in research and trial because of Green Technology. It controls pollutions, environmentally biodegradable and available in nature [9].

Composite materials are used because of some speciality such as low corrosion, easy maintenance and design variability [10]. The primary benefit of composite materials is their combination of strength, rigidity, and lightweight. Manufacturers may develop qualities that perfectly meet the needs of a specific construction for a particular purpose by selecting the right combination of reinforcement and matrix material [11].

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

Compared to other traditional materials, composite material shows some unique characteristics that can be fabricated according to necessity. Unlike other materials, composites have been used in the automobile industry and aerospace and military vehicles in recent times [12,13]. For high-performance and lightweight, composite materials are used in low-volume vehicles and motorsports [14]. Even for the natural fibre composites, it shows higher weight-to-strength ratio, than other homogeneous metal [15]. Composite materials show 15 times higher tensile strength than conventional material. That consumes low fuel economy [16]. In the case of thermal and corrosion resistance, this multipurpose material is economical in overall cost [17]. This eco-friendly material shows high damage tolerance properties for ensuring passenger safety [18]. Composite materials show some effects on recycling, which are very convenient for Green Technology. These materials are generally sufficient for environmental safety [19]. Though receiving good quality surface finishes at a cheap rate is challenging, it shows benefits in manufacturing, designing, repairing, lightweight, joining, and recycling and safety issues [20]. Comparing to performance and usage, overall cost is very low for composite [21]. Several easy fabrication techniques must be applied to reduce cost for fabricating composites such as moulding, lay-up, winding and so one [22].

Researchers are trying to progress of using composites for making eco-friendly [23] within reasonable cost [24]. In the contrast, it is quite impossible to improvise because of high fabrication cost. Additionally, the 3D printing technology was very limited for several types of materials. Though that is already generated to develop composites with 3D printing within limited cost [25]. These all-other problems can be solved by utilizing Natural Fibre Composite materials [26]. Besides, fire problems [27] and lightning damage [28] are substantially increased for vehicle. Moreover, self-healing and sensing properties, piezoelectricity and magneto-strictive characteristics should be taken consideration for the manufacturer. Researcher should imply importance in this phenomenon by using the effective characteristics of composite materials.

## 2. Advantages of composite materials

Composites now have a permanent place in modern production because of cutting-edge engineering methods that arise from the creative blending of various materials and chemical compounds [29]. The following are some benefits of using composite materials in the automotive industry over traditional materials:

### 2.1. Strength-to-weight ratio

The strength-to-weight ratio of a substance, commonly known as its specific strength, compares its strength to its weight. Composites' excellent strength-to-weight ratio is arguably their most significant benefit. Although carbon fibre is stronger and stiffer than both materials per unit of weight, it weighs approximately one-quarter as much as steel and 70% as much as aluminium [30]. Multilayer composite laminates absorb more energy than conventional single-layer steel, enabling high-end automotive engineers to reduce vehicle weight by as much as 60% while enhancing crash safety [31]. For instance, it is possible to make a composite material that will not bend in one direction where metal typically needs to be thicker to achieve the desired level of strength in one order, which increases weight. Composite materials can be robust without being heavy [32]. Table 1 show that Steel and Carbon Fibre as well as Aluminium and Laminated Fibreglass can be easily distinguished with respect to their mechanical properties such as Types of Materials, Tensile Strength, Density and Elastic Modulus.

**Table 1**
Comparison of material strength of different types of composites and alloys.

| Materials Name | Materials Type | Tensile Strength Σu (MPa) | Density ρ (kg/m$^3$) | Elastic Modulus E (GPa) | Ref. |
|---|---|---|---|---|---|
| Steel (S355) | Alloy | 500 | 7850 | 210 | [33] |
| Carbon Fibre (High Strength) | Composite | 7060 | 1820 | 294 | [34] |
| Aluminium (AA6082) | Alloy | 150 | 2710 | 71 | [35] |
| Laminated Fibreglass (FR4) | Composite | 317 | 2000 | 24 | [36] |

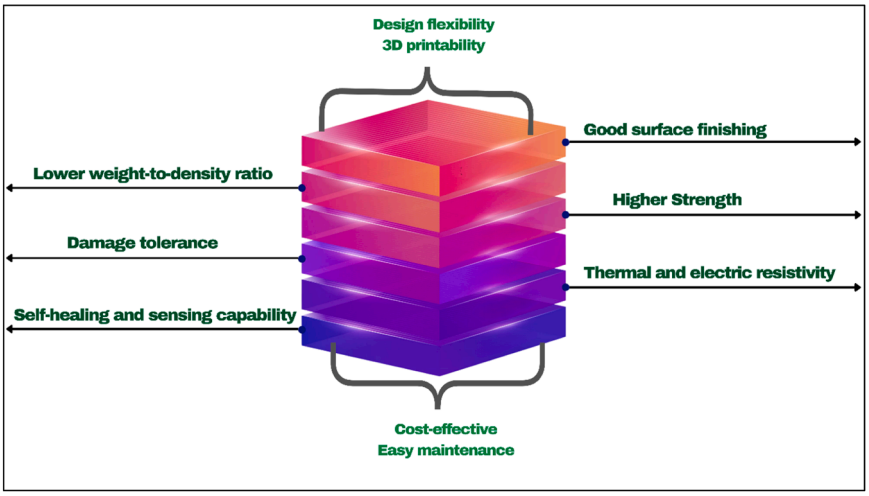



**Fig. 1.** Layers and characteristics of composite materials.

According to Table 1, Carbon Fibre and Laminated Fibreglass are higher in tensile strength than Steel and Aluminium. Their elastic modulus is also higher. Though their density is lower, Steel and Aluminium can be replaced by Carbon Fibre and Laminated Fibreglass respectively.

### 2.2. Durability and damage tolerance

Metals are susceptible to fatigue. The Aloha Airlines disaster in the 1980 s resulted from this [37]. Whether it's hot or cold and wet or dry, composites can maintain their shape without rusting because of their excellent dimensional stability. As a result, they are a preferred material for outside structures such as wind turbine blades for long-term stability [38].

### 2.3. Impact resistance

Composites can be designed to deflect blows, such as the sudden force of a bullet or the blast from an explosion. Due to this characteristic, composites are used to create bulletproof jackets and panels and protect buildings, military vehicles, helmets and aircraft from explosions [39].

### 2.4. Corrosion resistance

Composites-based products offer long-lasting resistance to harsh 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 [40]. 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. Because of this, composites are an essential component of maritime industries or companies that move products and chemicals through pipelines and into containers [41].

### 2.5. Thermal conductivity

Additionally, composite materials exhibit low heat and electrical conductivity, making them excellent insulators for components that require insulation [42]. But if it's necessary to create thermally conductive parts, thermally conductive materials can be incorporated into the composite part, so this attribute isn't lost in creating composite parts [43]. For example, Polyimide Composites are very high thermal conductive. It is less heavy than metals with a high glass-transition temperature. This material can be modified to have the best qualities dependent on the applications by switching out the carbon fibres which has low CTE [44].

### 2.6. Nonmagnetic

Since composites don't include any metals, they are not magnetic. Composite materials can be used around sensitive technological equipment. Large magnets used in MRI (Magnetic Resonance Imaging) apparatus operate more effectively without magnetic interference [45]. In Fig. 2, it can be observed that the contact angle remains the same after magnetic impact. The composite materials inside the micro-channel get magnetized when two rectangular permanent magnets of the same opposing polarity are positioned in the middle of the channel length, with their magnetization direction perpendicular to the channel wall.

### 2.7. Cost reduction

Composites are more affordable in terms of price per cubic inch and raw material price. A single one of them is a thermoset composite. The cost of thermoset composites is lower when compared to materials like thermoplastics, wood, and metal [46]. Furthermore, since thermoset composites contain little petroleum, they are not affected by price swings that affect petroleum-based products [47].

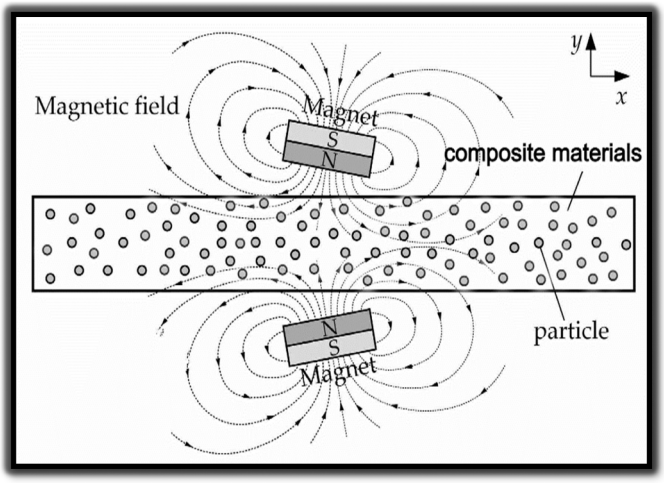



**Fig. 2.** Testing composite materials with the contact of magnet.

### 2.8. Design flexibility

Composite materials offer design flexibility in automotive applications, enabling engineers and designers to create structures more inventively and effectively than traditional metals [48]. Composite materials can be moulded into complex forms for aesthetic and economical designs, enhancing the aesthetic appeal and functionality of automobile exteriors [49]. Composites can be designed easily for maintaining environmental safety [50]. Engineers can customize composite materials' mechanical characteristics by altering fibre type, orientation, and stacking order, thereby ensuring components with precise stiffness, strength, and damping properties [51]. Composite materials can be combined into a single part, simplifying design and eliminating the need for multiple components by acting as a noise barrier, thermal insulator, and structural element [52].

### 2.9. Dimensional stability

Dimensional stability is crucial for the structural integrity and long-term performance of vehicle components. For this reason, composite materials are used in automotive applications to reduce mechanical stress and environmental factors [53]. The Low Coefficient of Thermal Expansion is a crucial design technique for automotive applications, as it minimizes size changes and maximizes dimensional stability due to temperature fluctuations [54,55]. Some composites, especially those with organic matrix, can cause dimensional changes due to moisture absorption, which can be minimized through design decisions and material selections [56].

### 2.10. Chemical resistance

Composite materials' high strength-to-weight ratio, corrosion resistance, and other benefits are driving their increasing use in automotive applications, with the type and environment determining their chemical resistance [57]. Glass fibres [58] and epoxy resin [59] are typically resistant to most chemicals, making them a popular choice for automotive applications due to their strong chemical resistance. Moisture absorption can significantly affect the performance of composite materials, even if some are designed to prevent it [60].

### 2.11. Electrically non-conductive

The electrical non-conductivity of composite materials is crucial in automotive applications to prevent issues like interference and short circuits, and its conductivity depends on the fibres, matrix materials, and additives used [61]. Glass fibres, being electrically non-conductive, make glass fibre-reinforced composites suitable for applications requiring electrical insulation [62]. Carbon fibres are naturally conductive, but their electrical conductivity decreases when implanted in a non-conductive matrix like epoxy resin, making them commonly used in situations requiring high electrical non-conductivity and strength [63]. Epoxy resins are suitable for applications requiring electrical non-conductivity due to their electrical insulation properties [64]. Fillers or additives can be used in composite compositions to enhance electrical non-conductivity and overall insulating qualities [65].

## 3. Fabrication techniques

The operations used to shape, cut, or mould materials into things are called fabrication techniques. Cutting, forming, punching, stamping, shearing, and welding are standard fabrication techniques [66].

Composite materials open up new design possibilities for its versatility. When used with proper tool design and operating circumstances, conventional machining techniques can be used on composite materials, including drilling, turning, sawing, routing, and grinding. Other unconventional methods have also been used on these materials, such as water-jet, laser, electro-discharge, and ultrasonic machining [67].

Depending on the type of composite being utilized and the particular application, many fabrication methods for composite materials are employed in automobiles. Here are a few typical fabrication methods:

### 3.1. Hand Lay-up

One of the earliest and most basic strategies is the hand lay-up which entails manually applying layers of reinforcement materials in a mould. A resin matrix is infused into the layers by hand lay-up. It is frequently utilized for prototyping or low-volume production [68]. For making composite leaf springs, numerous methods might be recommended. While the mandrels (male and female) in the present work were manufactured from plywood by the desired profile discovered through the current investigation, the by-hand lay-up suction bag process was initially used [69].

A type of reinforcement known as "prepreg" (pre-cut, pre-impregnated) is manually applied in individual layers or "plies" during the manufacturing process, known as "hand layup." This comprises countless fibres pre-impregnated with resin, bundled into tows, and either woven together or organized in a single unidirectional ply. Each ply must be manually formed into the desired shape before being firmly adhered to the surface of the previous layer or mould, leaving no space between the plies [70]. The hand lay-up method is frequently used to create fibreglass and composite automobile materials [71]. Composite materials that store strain energy well include E-Glass/Epoxy in the direction of the fibres. As a result, the layup is chosen to be unidirectional along the spring's longitudinal direction [72].

### 3.2. Resin Transfer Moulding (RTM)

Dry reinforcing materials are inserted into a mould cavity as part of the closed-mould Resin Transfer Moulding process, which involves injecting the resin matrix under pressure. After curing, the composite item is removed from the mould after the resin has flowed through the fibres. Resin Transfer Moulding enables greater control over the resin content and part thickness and is appropriate for medium-volume production [73]. Because of the potential for automation, intriguing product performances, and part reproducibility, which include RTM, appeal to the automobile sector [74]. Recent multi-gate Resin Transfer Moulding injection investigations have revealed that air voids are frequently created in weld lines, or the resin contact area, due to a front collision between opposing resin flows [75]. RTM is a manufacturing process used in the automotive industry to produce composite components and parts in high scale production rate. RTM is well-suited for manufacturing parts requiring high strength-to-weight ratios, excellent dimensional accuracy, and complex geometries [76]. RTM is a valuable manufacturing process in the automotive industry, enabling the production of lightweight and high-performance composite components that contribute to developing more efficient and advanced vehicles [77].

### 3.3. Compression moulding

For the mass manufacture of composite products, compression moulding is used. A prepreg, fabric is inserted into a mould cavity during this process. The mould is then sealed to cure the resin and shape the composite item [78]. Compression Moulding large and relatively simple composite pieces like body panels, hoods, roofs, and spoilers are frequently produced using the compression moulding [79]. Using thermoset or thermoplastic matrices, compression moulding is a well-known method for manufacturing polymer composite materials [80]. Rubber tires, glass mat thermoplastic materials like bumpers, and sheet moulding compounds for vehicle exterior panels are the most typical materials utilized in compression moulding [81]. The pre-impregnated intermediate products, such as thermoset Sheet Moulding Compounds (SMCs), Glass Mat Thermoplastics (GMTs), or Long Fibre Thermoplastics (LFTs), are processed via compression moulding to create semi-structural and structural composite components [82].

### 3.4. Automated Fibre Placement (AFP) and Automated Tape Laying (ATL)

Robotic devices use Automated Fibre Placement (AFP) and Automated Tape Laying (ATL) to automatically apply continuous fibres or tape to a mould surface. With great fibre precision and repeatability, these techniques produce complexly shaped composite pro-technology [83]. Numerous automated manufacturing techniques have been developed to create lightweight composite structures. Automatic tape laying and automated fibre placement are two of the most widely used prepreg technologies. AFP/ATL suits highly for complicated geometrical shapes and huge quantities [84].

Wide unidirectional prepreg tapes can be applied by ATL to a tooling surface with automatic ply backing removal. In contrast, AFP employs a band of thin prepreg material strips called tows [85]. AFP is a composite method to create intricate, superior, lightweight structures for advanced automobiles [86].

### 3.5. Filament winding

Cylindrical or tubular composite items, including drive shafts or pressure tanks, are frequently made using filament winding [87]. In this method, continuous fibres are incorporated in a particular pattern onto a rotating mandrel, and then resin is used to saturate the fibres. The portion is then dried and removed from the mandrel [88]. A filament winding procedure creates the axisymmetric components, including pipes, tubes, drive shafts, and pressure containers. Axisymmetric components are best suited for this method [89].

### 3.6. Sheet Moulding Compound (SMC) and Bulk Moulding Compound (BMC)

Composite materials offered in sheet or bulk form is Sheet Moulding Compound (SMC) and Bulk Moulding Compound (BMC), respectively. Chopped fibres resin, and additives make up these materials [90]. They are frequently utilized in compression moulding methods to create oversized, flat items like automobile body panels [91].

The automotive industry's most popular and effective use of fibre-reinforced thermoset composites is the Sheet Moulding Compound. The method makes it possible to build bulk composites at a reasonable cost [92]. A thermosetting resin matrix fortified with glass fibres and other additives makes up Sheet Moulding Compound, a particular kind of composite material. Typically delivered in sheet form, it is compressed-moulded or moulded to produce intricate forms and parts. SMC is implemented in automobiles: Body Panels, Bumper Beams, Engine Components, under body Shields, Interior Components, and Battery Enclosures [93].

Another form of composite material frequently utilized in the automobile industry and other production sectors is BMC. A polymer resin, several reinforcing fibres (usually glass fibres), and various additives make up Bulk Moulding Compound, a thermosetting plastic composite. It is prepared into a dough-like consistency that may be moulded into different shapes before being heated and compressed to cure it. Using Bulk Moulding Compounds in automotive applications such as Engine Parts, Exterior Trim and Body Parts, Under hood Parts, Structural and Reinforcement Parts, Electrical and Electronics Parts [94].

### 3.7. Vacuum infusion

Vacuum infusion involves putting dry fibres in a mould and using a vacuum to remove air from the mould [95]. After that, the resin is added to the mould, sucked in by the void, and infused into the fibres. The composite portion is removed from the mould after curing [96]. Large composite parts can be prepared using the flexible Vacuum Infusion Process (VIP), a low-cost and highly accurate production technique. The Carbon Fibre Reinforced Polymer (CFRP) is utilized extensively in automotive and space applications [97].

## 4. Application of composite materials in automobile

In the automotive industry, composites are being used more frequently, as has been extensively noted. This is why the new research on advanced composite is the main topic of this study. These new composites are made of long carbon, glass, and silver threads woven into metallic matrices for reinforcement [98]. Due to their distinct characteristics and benefits over conventional materials like steel and aluminium, composite materials have several uses in the automobile industry [99]. These materials are often created by mixing two or more components to produce a new material with improved qualities [100]. Several car parts have been seen most often to utilize composites, brake pads, hood, chassis, leaf springs, bumper, door, sunroof, engine cradle, fender, etc.

### 4.1. Brake pads

The brake pads are a crucial part of the car braking system. Materials used for brake pads should exhibit consistent and dependable frictional and wear characteristics under a range of load, velocity, temperature, and high durability circumstances [101]. Due to their high coefficient of friction and reduced wear at both room temperature and higher temperatures up to roughly 250°C, phenolic composites are frequently utilized in automotive brake pads [102]. In automobiles, polymer matrix composites are commonly employed as brake linings. Typically, rubbing against pearlitic grey cast iron, steel, or aluminium matrix composite material is a replacement component in a friction pair [103]. Traditional steel or iron brake pads are heavier than composite brake pads, which helps reduce total weight and enhance handling [104]. Composite materials generate less brake dust and less noise while braking [105]. Composite materials are used in braking systems as technology advances and consumer demand for high-performance, environmentally friendly automobiles rises highly. However, it's crucial to keep in mind that brake pad creation entails extensive testing and validation to guarantee safety and conformity with industry requirements [106]. Coconut fibre with Aluminium reinforced composite [107] and Aramid fibre [108] show already a good alternative for brake pad and brake disc. Here, the brake pad is free, effective and quite harmless. Still more research progress is required for sensitive purpose.

Fig. 3 shows that Brake pads consist of many layers. The underlayer, which is positioned between the friction material and the backplate, provides the glue that keeps the friction material from the other layers. Fig. 3 illuminates the Structure of the brake pad for friction materials. It has four types of friction materials: 1. Reinforcement, 2. Abrasive, 3. Filler, and 4. Binder or Resin [109].

### 4.2. Hood

In the automotive industry, composite materials are currently widely used, and their use is growing. Combining thermoset and thermoplastic polymers with reinforcing fibres (such as chopped, continuous, matting, and textiles) is common [110]. A hood is an excellent example because it often uses steel skin. The material used for this application must be recyclable and have good impact strength, low weight, and high stiffness [111]. Composites have excellent strength and impact resistance yet are lightweight. Composite hoods may provide superior crashworthiness, increasing the safety of the car occupants in the event of an accident [112]. Composite materials enable greater design freedom, allowing automakers to produce hoods with intricate curves and forms [113]. Composite materials are easily moulded into unique forms and sizes; automakers can create hoods customized for specific vehicle models or design ideas [114]. Composite hoods can help a vehicle accelerate and handle more effectively by shedding weight and increasing the power-to-weight ratio [115]. Natural flax fibre [116], Glass fibre Composite [117] and Carbon Fibre Composite [118] shows high impact of research. This research accepts that composite materials for hood lessen almost 30% weight and strength remains almost same for torsional and bending stress.

Fig. 4 shows the hood optimization with composite laminates. Both sides of the hood panel are manufactured using composite materials. It gives extra safety from accidental damage as well as weight reduction, increased fuel efficiency, performance enhancement; maintain heat resistance, reduced noise and vibration.

To develop the lightest possible design for the hoods, two alternative composite material systems are used in place of the metallic material [119]:

#### 4.2.1. Thermoset carbon fibre material

Toray Composites America (TCA) provides fibre/epoxy T700/2510 pre-preg. This material system's 132°C cure resin is solely intended for oven and vacuum bag curing. This composite material method uses flat

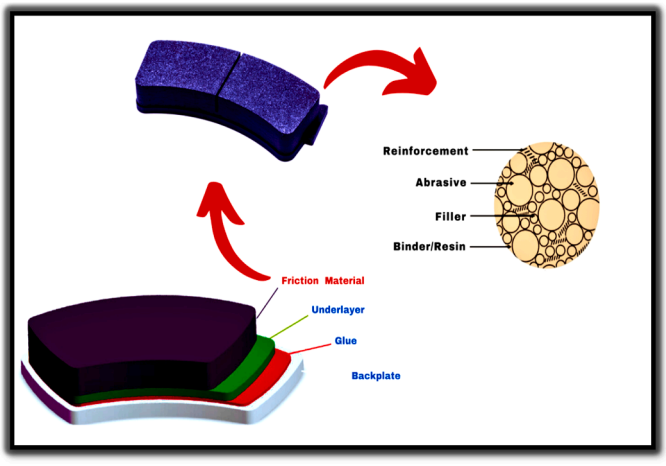



**Fig. 3.** Brake Pads Structure.

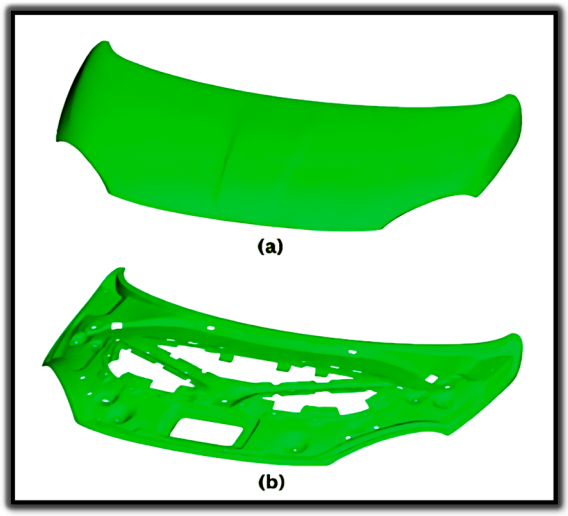



**Fig. 4.** (a) The hood panel of the outside, (b) The hood panel of the inner side.

woven cloth, plain weave (PW), and 12k tow shapes. For primary structures in general aviation, this material is frequently utilized.

#### 4.2.2. Thermoplastic carbon fibre material

TenCate Cetex provides fibre/polyamide T700/PA6 pre-consolidated laminates. A class of carbon fibre-reinforced nylon laminates appropriate for high-volume applications is T700/PA6.

Table 2 shows the characteristics of the two materials that have already been discussed. Based on some mechanical properties, the result may vary. But the differences are very marginal, as they behave in similar way.

### 4.3. Chassis

Due to their lightweight nature, high strength-to-weight ratio, and corrosion resistance, composite materials are increasingly used in the automobile sector [120]. Composite materials are being employed in the chassis, the vehicle's structural underpinning, to increase performance and economy [121]. Syntactic foam is also used as a core material in modern automobiles to strengthen the rigidity of thin gage sheet metal sandwich structures. Cost-prohibitive high-performance materials like Kevlar honeycomb core materials are used [122]. Using composite materials in the chassis contributes to the vehicle's total weight reduction, enhancing handling and fuel economy [123]. Composite materials have built-in dampening characteristics that lessen noise and vibration transmission through the chassis [124]. Composite materials may have excellent fatigue resistance, ensuring the chassis keeps its performance and structural integrity over a lengthy period of operation [125]. A lot of research is already completed and also some implementation is started for composite materials in automobile sector. Every study shows positive alternative [126,127] in terms of weight reduction, efficient fuel economy, damage tolerance for vehicle performance.

**Table 2**
Characteristics of thermoset and thermoplastic carbon fibre material.

| Property | Property | Thermoplastic T700/PA6 | Thermoset T700/2510 |
|---|---|---|---|
| Density | ρ (g/cm3) | 1.45 | 1.52 |
| Elastic modulus 1st direction | $E_1$ (GPa) | 55 | 55.9 |
| Elastic modulus 2nd direction | $E_2$ (GPa) | 50 | 54.4 |
| In-plane shear modulus | $G_{12}$ (GPa) | 2.5 | 4.12 |
| Major Poisson's ratio | $\nu_{12}$ (–) | 0.033 | 0.033 |
| Longitudinal tensile strength | XT (MPa) | 915 | 910 |
| Transversal tensile strength | YT (MPa) | 850 | 772 |
| Longitudinal compressive strength | XC (MPa) | 450 | 710 |
| Transversal compressive strength | YC (MPa) | 450 | 703 |
| Shear strength | S (MPa) | 85 | 131 |

### 4.4. Leaf spring

An essential component of a car's suspension system is leaf springs. They are made up of numerous layers of leaves that vary in size, with the most significant layer being on top and the layers attached. Leaf springs are directly linked to the frame, either at both ends or just one [128]. The Corvette has leaf springs made of glass fibre-reinforced epoxy polymer composite, with a more than five times longer fatigue life than steel. Compared to steel leaf springs, composite leaf springs offer a smoother ride and a quicker reaction to pressures brought on by road shock. Furthermore, compound leaf springs provide superior corrosion resistance and a lower likelihood of catastrophic failure [129]. Numerous methods might be recommended to create a composite leaf spring from Glass Fibre Reinforced Polymer (GFRP) [130]. Composite materials ' high strength-to-weight ratio provides comparable or even better load-carrying capability than steel leaf springs [131]. Leaf springs made of composite materials may help to quiet the car's suspension system [132]. Still more research is required. Like Fibre glass with Epoxy resin shows higher possibilities of weight reduction but stress is not sufficient [133]. A lot of experiment is required to install composite materials in suspension system.

### 4.5. Bumper

One of the primary components of an automobile with a little extra weight is the bumper [134]. Automobile bumpers are intended to absorb and distribute energy during low-speed crashes, minimizing harm to the car and its occupants [135]. A developing trend in recent years has been using composite materials in bumper construction because of their appealing qualities [136]. To develop a material with improved performance characteristics, composite materials are engineered materials created by combining two or more constituent elements with considerably differing physical or chemical properties [137]. Vehicle bumpers frequently employ carbon-fibre-reinforced and glass-fibre-reinforced polymer composites [138]. Composite materials with good impact absorption capabilities include Carbon Fibre-Reinforced Polymers (CFRP) and Glass Fibre-Reinforced Polymers (GFRP). This lessens damage to the vehicle and improves passenger safety by absorbing and dissipating energy during low-speed crashes [139]. Composite bumpers could be simpler and less expensive to repair than conventional steel bumpers in the case of minor damage [140]. Composites simplify integrating different features like sensors, parking assists, and lighting components. This simplifies the bumper's construction and improves the overall design's effectiveness [141]. It is possible to design composite bumpers to absorb and distribute impact energy efficiently, minimizing structural damage to the vehicle and lowering the severity of injuries in low-speed crashes [142]. As automakers work to enhance their vehicles' performance, safety, and design, composite materials are being used increasingly frequently in bumper construction [143]. Plastic fibre reinforced polymer such as carbon fibre plays a significant role in crashworthiness and weight reduction like other conventional materials [144]. But in future, more optimized structural design is required as well.

### 4.6. Door

Automotive doors of composite materials combine two or more distinct materials with varying properties, such as fibre and resin. Composite materials offer a high degree of stiffness and strength, which improves the automobile door's structural integrity and crashworthiness. They can withstand corrosion, wear, and fatigue more effectively

than metals [145]. The great strength and impact resistance of composites is well recognized. In an accident, composite doors can protect the people inside the car [146], allowing automakers to design doors with intricate curves and features. This gives them the ability to create doors that effortlessly complement the car's overall design, adding to its more elegant look [147]. Engineering composites can achieve a quieter cabin by having particular acoustic characteristics that can assist in lessening noise transmission through the doors [148]. Automotive manufacturers may produce doors that are lighter and more robust and contribute to increased safety and aesthetics by utilizing the advantages of composite materials [149]. Carbon fibre reinforced with epoxy resin absorbs more deformational energy than steel with 65% weight reduction [150]. But proper design and fibre orientation make effective more than previous research.

### 4.7. Sunroof

Composite materials are used to construct car sunroofs, which have unique characteristics. It gives the automobile natural lighting, ventilation, and aesthetic appeal and enhances acceleration [151]. Weight reduction is one of the main justifications for using composites in sunroofs. The efficiency of the vehicle as a whole may increase due to this weight decrease [152]. Composite materials have a high strength-to-weight ratio, which makes them desirable for lowering total weight while preserving structural integrity [153]. The glazing or outside surface may be made of composite materials for certain sunroofs. Compared to regular glass, laminated glass composites, which combine layers of glass with interlayer, made of polycarbonate or Polyvinyl Butyral (PVB), offer impact resistance and less weight [154]. Sunroofs may provide extra safety features, including impact resistance and a decreased danger of shattering after an accident, depending on the type of composite material utilized [155]. Carbon continuous fibre is played promising characteristics for sunroof in automotive industry [156]. There are many more alternative which has almost same potentiality comparing with traditional materials.

### 4.8. Engine cradle

Another usage for automobile composite materials is in the "Engine Cradle", the structural element that holds up the engine and other associated components. Advanced materials have become crucial for automobile lightweight and have been used in various vehicle elements, including engine cradles, front ends, and body structures [157]. One of the essential parts of the engine sub-system, the engine cradle, serves four primary purposes: supporting the engine, transmission, and suspension, distributing heavy chassis loads, lessening vibration and shocks, and assisting in stiffness and crash management [158]. Due to their natural thermal insulation qualities, composite materials can improve thermal management by reducing heat transfer from the engine to other vehicle parts [159]. The safety and crashworthiness of a car can be increased by designing composite engine cradles to absorb and disperse impact energy [160]. Composites help absorb collision energy because they may be constructed with appropriate impact-absorbing characteristics. Composite engine cradles can reduce crash forces and shield other essential vehicle parts in the case of a collision [161]. Using composites in the engine cradle can simplify integration with other elements, such as suspension systems and mounting points, leading to a more unified and effective vehicle construction [162].

### 4.9. Fender

Composite materials, created by mixing numerous materials to obtain particular qualities, are increasingly used in various vehicle components, including fenders [163]. The process used to develop the Plantain Fibre-Reinforced Polyester Composites (PFRC) fender included fibre extraction, fibre surface treatment, and the creation of laminates for experiments involving compression and impact, and the construction of automotive fenders [164]. The use of thermoplastic composites, which are polymer matrix composites that can be moulded by heating and cooling, uses composite materials for the fender. Thermoplastic composites can be stronger, stiffer, tougher, and more recyclable than thermoset composites. Fenders made of thermoplastic composites are strong, lightweight, and resistant to scratches and minor collisions [165]. It may be simpler to repair composite fenders than metal ones. Repairs may be more cost-effective since minor damage is frequently fixed with patching or composite-specific repair methods [166]. Composite fenders are commonly used on high-performance and sports cars to decrease weight and enhance the vehicle's overall performance [167].

Despite above parts, there are some other components where composites are used. Because of their salient function, composite materials show potentiality to acquire better result. Table 3 shows the various properties of composite materials together with considerations of use for several important automotive internal and external components functions. Certain properties of various composites for various applications enhance vehicle performance.

## 5. Types of composite materials used in Automobile

The concept of using composite materials is now at the pick of the table of manufacturer preference list. Multiples types of composites are used in automobile for various parts. Due to their variation of performance, they are used in different purpose.

Table 4 shows that how the different types of composite material such as Carbon Fibre Reinforced (Polypropylene), Glass Fibre Reinforced (Thermoplastic), Ceramic Matrix composites, Epoxy SMC, Aluminium Matrix Composite, Natural Fibre Composites, Synthetic Fibre Composites play significant roles in different components. Each classifications have own advantages which bound to manufacture different components for running a vehicle.

Despite Table 4, some basic classifications of composites are used in automobile parts. Based on their performance, characteristics and

**Table 3**
Specific properties of different Composites in Automobile applications.

| Applications in Automobile | Composite Materials | Specific factor of usage | Ref. |
|---|---|---|---|
| Air deflectors and spoiler | Polymer Composite | Efficient structural design | [168] |
| Pistons | Aluminium Hybrid Composite | High strength | [169] |
| Air-intake manifolds | Nylon 6,6 Composite | Moulded into intricate shape | [170] |
| Bearings | Aluminium-Metal Matrix Composite | High fatigue life | [171] |
| Battery casings | Carbon Nanotube Composite | Light weight | [172] |
| Exhaust Pipes | Ni-Cr Alloy Hybrid Composite | Low thermal expansion | [173] |
| Bumpers and bumper beams | Carbon Fibre Composite | Sudden load absorption | [174] |
| Brake disks | Aluminium-Metal Matrix Composite | Wear resistance | [175] |
| Lubricant of AC compressors | $Al_2O_3$–$SiO_2$/PAG Composite Nanolubricants | Higher cooling capacity | [176] |
| Windows | Reinforced Carbon Fibre Composites | Light weight | [177] |
| Clutch disks | Coconut Fibre Composite | Dry friction resistance | [178] |
| Front-end grill opening panels | Hemp-Polypropylene Composite | Moisture Stability | [179] |
| Water and fuel tank | Plastic Composite | Mass Reduction | [180] |
| Headlamp housings for forward-facing headlamps | Al-Carbon Fibre/Epoxy Composite | Variation of types | [181] |

**Table 4**
Types of composites used in different automobile components.

| Types of composites | Advantages | Usage in Automobile Components | Ref. |
|---|---|---|---|
| Carbon Fibre Reinforced Polypropylene | Tensile and Flexural Strength, Hardness, Impact Resistance | Chassis especially Bonnet | [182] |
| Glass Fibre Reinforced Thermoplastic | Light Weight, High Strength and Rigidity, Durability | Front End, Seat Frame, Engine Noise Shield, Bumper, Instrument Panel Bracket | [183] |
| Ceramic Matrix Composite | Elevated Hardness, Wear Resistance | CAM | [184] |
| Epoxy SMC | Dimensional Stability, Low Thermal Expansion | Tire Frame, Outer surface | [185] |
| Aluminium Matrix Composite | High Quality to Weight Proportion, Malleability, Modulus, Low Warm Coefficient, Wear and Consumption Obstruction | Exhausts, Liners, Cylinder, Brake Plate, Brake Drum, Drive Shaft | [186] |
| Natural Fibre Composite | High Strength, Stiffness and Ductility, Moisture Absorbability | Seatbacks, Door Panel, Brake Panel | [187] |
| Synthetic Fibre Composite | Good Flexural Strength, and Interlaminar Shear Strength | Seat Cover, Door Panel | [188] |

fabrication techniques, they are classified. The classifications of the composites and their usage in automobile section are described here.

### 5.1. Matrix constituent

In composite materials that are utilized in automobiles, in order to bind and maintain the reinforcing fibres or particles within the composite structure, the matrix constituent is an essential component [189]. Cohesion, strength, and weight transmission between the fibres or particles are all provided by the matrix material, which encircles and secures the reinforcement. The composite's overall qualities are greatly influenced by the matrix material selection [190].

#### 5.1.1. Organic Matrix Composites (OMCs)

In the context of automotive composites, Organic Matrix Composites (OMCs) usually refer to composites in which the matrix material is an organic polymer. The excellent strength-to-weight ratio, lightweight design, and manufacturing adaptability of these composites make them popular in a wide range of automotive applications [191]. Organic Matrix Composites (OMCs)are inexpensive, easily processed, and have strong fibre adhesion, which makes them useful for making body panels, hoods, fenders, and other external components [192].

*5.1.1.1. Polymer matrix composites.* Polymer Matrix composites, whether reinforced with fibres or particle fillers, are widely employed in the automotive sector. Epoxy resin is one of the most often used polymeric components, and it is occasionally mixed with other polymer materials. Thermoset and thermoplastic polymers are frequently employed as polymer matrix of these composites [193]. The most significant advantages of polymer composite materials over traditional metallic materials are their reduced thermal expansion, exceptional fatigue, higher tensile and flexural strength, and fracture resistance, capacity to meet strict dimensional stability requirements, specific strength properties with weight savings of 20–40%, and potential for rapid process cycles [194,195]. The use of polymer composites in weight management has helped the automotive industry achieve significant improvements in aerodynamic and acoustic emissions. Fibre-reinforced polymers, or FRP, have shown to be quite helpful in this context. The braking system, trunk lid, body stiffener, car body parts, engine hood, engine frame, and T-joint are a few examples of components used in the automotive industry that have been created utilizing FRP [196].

*5.1.1.2. Carbon-carbon Composites.* Carbon-carbon composites are frequently employed in high-temperature settings because of their exceptional heat resistance, high thermal shock resistance, high specific strength, high specific modulus, and chemical inertness. Nowadays, cast iron, the most common carbon-carbon material used in brakes, needs to be extremely big in order to meet the demanding requirements for braking performance of contemporary luxury and sports vehicles [197].

#### 5.1.2. Metal Matrix Composites (MMCs)

The automobile sector is expected to have a substantial area for metal matrix composites, or MMCs. MMCs will continue to find a home in cars because of their many valuable qualities, which also include wear resistance, high specific modulus and fatigue strength, and adaptable thermal expansion [198]. Consideration is being given to using lightweight metals more often in high-production-volume applications. Examples of this include the use of titanium alloys in engine valves and connecting rods, the invention of titanium-aluminides valves, the use of aluminium in vehicle body structures, chassis parts, and engine blocks, and the creation of quickly solidified aluminium compressor vanes [199].

#### 5.1.3. Ceramic Matrix Composites (CMCs)

Composites made of ceramic fibres embedded in a ceramic matrix are known as ceramic matrix materials. They may be helpful for a variety of applications, including automotive components, since they have a number of benefits, including high strength, low density, and resilience to high temperatures. CMCs have the potential to be used in automotive applications such as exhaust systems, lightweight, engine components, and brake systems [200].

### 5.2. Reinforcing form

The components of reinforced composites include fibres or other reinforcing materials woven into a matrix material. When the matrix and reinforcement are combined, a material is produced that has better mechanical qualities than when the matrix material is used individually. The following list includes some typical forms of reinforced composites found in the automotive sector [201].

#### 5.2.1. Fibre reinforced composites

The automobile industry relies heavily on fibre-reinforced composites because they offer a unique blend of strength, stiffness, and lightweight characteristics. In order to create a material with improved mechanical characteristics, strong fibres are usually embedded into a matrix material in these composites. Basically, fibre reinforced is better than any other composites in automobile [202].

Several fibre-reinforced composites that are frequently seen in

**Table 5**
Different Types of Fibre-Reinforced Composites as well as its applications and advantages.

| Fibre Reinforced Composites | Applications | Advantages | Ref. |
|---|---|---|---|
| Carbon Fibre-Reinforced Polymer (CFRP) | Body panels, chassis parts, and interior elements. | Improved fuel efficiency and overall vehicle performance | [203] |
| Glass Fibre-Reinforced Polymer (GFRP) | Body panels, bumpers, etc. | Provides good strength and stiffness | [204] |
| Aramid Fibre-Reinforced Polymer (AFRP) | Armour panels and protective elements. | Excellent impact resistance. | [205] |
| Natural Fibre-Reinforced Composites (NFRC) | Interiors, door panels, and non-structural components | Renewable, lightweight, and environmentally friendly | [206] |

automobiles are given in Table 5. It shows the advantages of their usage and where it is used in automobile. CFRP, GFRP, AFRP and NFRC are very frequent composites used in automobile.

#### 5.2.2. Particle reinforced composites

In particle-reinforced composites, some qualities are improved by adding particles such as metal or ceramics to a matrix material. The automobile industry uses these composites for a variety of purposes to enhance mechanical or thermal qualities such as strength, hardness, and wear resistance [207].

#### 5.2.3. Flake reinforced composites

The possible use of graphite flakes and a single layer of carbon atoms organized in a hexagonal lattice as reinforcing elements in composites have been researched. These materials have great conductivity and strength, among other mechanical qualities. Graphene or graphite flakes added to composite materials may improve their conductivity and structural performance, which might be advantageous in some automobile applications [208]. Flakes have the potential to enhance mechanical and thermal conductivity. Metallic flake-reinforced composites may be taken into consideration in the automobile sector for applications that call for strong thermal stability or heat dissipation [209].

#### 5.2.4. Filler reinforced composites

In the automotive industry, composite materials that have a matrix reinforced by fillers are commonly referred to as filler-reinforced composites. Fillers are solid materials added to the matrix to improve certain composite qualities. These materials are frequently in the form of fibres or particles. To meet certain performance objectives, these composites are utilized in a variety of automotive applications [210]. Composites used in car body panels, interior components, and structural elements can be made by adding fillers like fibres, microspheres, or nanoparticles to polymer matrices (such as thermoplastics or thermosets) [211]. Fillers can enhance the composite's dimensional stability, thermal conductivity, and mechanical qualities of automobiles. They could also help with weight loss and cost savings [212].

### 5.3. Layer composites

In layered composites, several layers of distinct materials are stacked to produce a composite structure with improved qualities. These tiered constructions are adaptable to the unique performance demands of the automobile sector [213]. Automotive body panels, including fenders, doors, and hoods, are made of layered composites. For increased strength, impact resistance, and safety, layered composites can be used in automotive windshields and glass. Reduced unsprung mass, enhanced performance and better handling are all benefits of using layered composites in suspension components [214].

### 5.4. Structural composites

In the context of automobiles, structural composites refer to materials that are employed throughout the building process to offer structural integrity and support. The combination of high strength, stiffness, and low weight that these composites are intended to provide enhances the vehicle's overall performance, safety, and fuel efficiency. Automobile makers are using more and more structural composites in their vehicles as a way to save weight and increase economy without sacrificing structural integrity or safety [215].

In the automobile industry, sandwich structures and laminates are frequently employed to improve a vehicle's structural performance. The combination of strength, stiffness, and lightweight provided by these structural composites improves overall performance and fuel economy [216].

### 5.5. Aluminium hybrid matrix composites

Aluminium alloy is used for long time in automotive industry due to its improved properties [217]. But Aluminium Hybrid Matrix Composites are more widely used in automobile sectors. Due to its several mechanical and tribological characteristics, it is used significantly [218]. There is huge benefit for casting polymers; aluminium can be used as cast polymer [219]. Al MMCs decrease weight and increase efficiency of the engine [220]. Engine cylinder is manufactured by casting with this Al MMCs, which gives better cost efficiency [221]. Moreover, it has worn resistance properties and low coefficient of friction [222]. Because of this metal's additional qualities, which include high hardness, heat resistance, a low thermal coefficient, medium conductivity, and corrosion resistance, auto manufacturers have a careful eye on it [223].

## 6. Benefits of using composite materials in automobiles compared to other materials

Composite materials, including fibres and resins, come with benefits that their components do not have individually. Improved strength, fatigue life, toughness, corrosion resistance, damage resistance, stiffness, thermal insulation, and wear resistance are just a few of the characteristics a composite material that has been correctly developed and manufactured may display above its constituent parts. Additionally, the mechanical features of composite materials, such as their specific strength (MPa/kg/m$^3$) and modulus, are several times higher per unit density than conventionally engineered metallic materials [224].

Fig. 5 shows the positivity of composite material in different characteristics. The weight and thermal expansions of composites are relatively lower than those of steel and aluminium. Besides, stiffness, strength, and fatigue resistance are higher than steel and aluminium. These properties make composite materials useful and effective [225].

These composites' distinguishing qualities result from the unique traits of the pieces that make them up and how those elements are arranged and distributed within the material system. Composites can be made to fulfil certain geometrical, structural, chemical, mechanical, and even aesthetic criteria based on the intended purpose. These synthetic materials are used in a variety of industries, including construction (for example, in buildings and bridges), the automotive industry (for example, in vehicle bodywork), the aeronautical and naval (for instance, in ships and boats) areas, as well as the biomedical sector [226].

One of the critical areas of activity in the automobile industry is substituting metallic materials currently in use with composite materials [227]. New automakers are utilising a substantial proportion of composite materials to reduce bulk and increase the range of battery-electric and hybrid vehicles. Traditional manufacturers use composites in their high-profile supercars and sports cars to improve performance while still

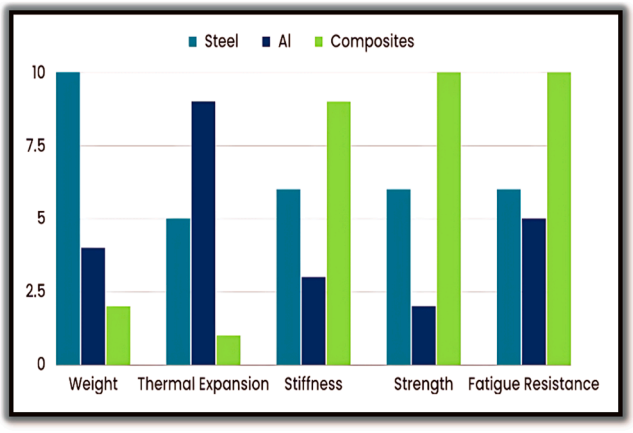



**Fig. 5.** Comparison between composite and pure materials [225].

adhering to stricter emissions regulations and giving the vehicles a certain air of high-tech cachet. Additionally, composites are making their way into more widely used modes of transportation, such as energy-absorbing composite crash elements and natural fibre-reinforced interior trim panels and bins for family cars, pickup truck storage systems, large panels for commercial buses and medium-duty trucks, and entire cabs for heavy trucks. Composites are also being used in more and more everyday forms of transportation [228,229]. These are a few benefits that composite materials offer over traditional materials: lightweight, high strength and stiffness, easily moulded into intricate shapes, quick to bind, low thermal expansion and electrical conductivity, good fatigue resistance, part consolidation to reduce system costs overall, low radar visibility, and storing and releasing internal energy [230]. Besides, high strength and elastic modulus, resistance to crack spread, high collision and notch toughness, resistance to fire, vibration absorption capacity, surface quality, corrosion resistance, ballistic properties, electrical conductivity, and renewable usability are just a few of the qualities that make materials useful [231].

### 6.1. Lightweight

Unfortunately, the weight of vehicles has risen over time, notably in the automobile sector, due to the addition of electronic systems, frontal impact standards, and general crash regulations, among other contemporary car utilities. For instance, a 2004 Volkswagen Golf MK5 weighed 1300 kg, but a 1974 Volkswagen Golf MK1 weighed just ~780 kg [232]. Lightweight design is a significant factor in lowering $CO_2$ emissions in the automotive and transportation sectors. To create light parts and automotive components, the rising demand for electric and hybrid vehicles necessitates the development of innovative ideas as well as lightweight technologies and techniques. A constructional concept known as lightweight seeks to minimize the weight of individual parts and modules [233]. Table 6 gives the idea about some composite materials is used in several models for various parts in the automobile industry. Every part of a vehicle must weigh less for it to operate smoothly. For this reason, composite is used by several well-known firms in different parts of different models [234,235].

### 6.2. High strength and modulus of elasticity

Micro-filled composites have an elasticity modulus of around one-third that of composites with macro filters. In comparison to composites having finer macro filters, those containing comparatively coarse macro filters have a larger elastic modulus [236]. Composite materials made of FRP are considered acceptable substitutes to replace heavy metals and create more advanced, energy-efficient automobiles [237]. The flexural strengths and elastic moduli of the various composite materials varied. The composite containing nanofillers were reported to have higher values [238].

Fig. 6 illuminates that the Young's Modulus of elasticity remains just between the metals and ceramics. It is not more than ceramics and not less than metals. It is also higher than polymers.

Composites provide favourable crash performance, high stability, minimal splintering, and favourable eco-balance during vehicle operation due to weight savings [239]. For the automotive sector to produce high-tech, high-volume CFRP composite materials, actual composite knowledge that can duplicate or come close to the high-strength steel application design guides and automotive steel design manuals is required [240].

**Table 6**
Some models use composite materials for different components.

| Components | Examples and Models | Application |
|---|---|---|
| i. Body | Audi A2, A4, A6, | Seatback, door panel, and lining |
| ii. Bumper beam | A8 | |
| iii. Frontal bonnet | BMW 3, 5, and 7 | - |
| iv. Door panel | Series | |
| v. Cargo area | Ford Mondeo CD | Boot liner, floor tray, and B-pillar |
| vi. Seatback | 162 | |
| vii. Lining | Rover 2000 | Rear Storage compartment, |
| viii. Body panel | | insulation |
| ix. Insulation | Lotus Eco Elise | Body panel, seat, and spoiler |
| x. Wheel box | Fiat Punto, Brava | Door panel |
| xi. Instrumental | Peugeot 406 | Front and rear door panels |
| panel | Volkswagen Golf | Boot liner, door panel, boot-lid |
| xii. Windshield | A4 | finish panel, seatback |
| xiii. Pillar | Honda Pilot | Cargo area |
| xiv. Dashboard | Mitsubishi Space | - |
| xv. Rear storage | star | |
| shelf | GM Cadillac | - |
| xvi. Floor tray | Deville | |
| xvii. Hood | Citroen C5 | Interior door panelling |
| xviii. Roof cover | | |

### 6.3. Easily moulded into intricate shapes

Simplifying assumptions makes it easier to model composite materials' elastic behaviour. Assuming the two components have the same Poisson's ratios is one example of a simplification [241]. Applications for composite materials in structures primarily subject to compressive loads are promising [242].

Fig. 7 gives an important idea about shape changes. In this method, the form is altered by stretching with pressure. Getting an item to vary both its diameter and length without causing any impacts will be helpful. The aim is to identify a material's microstructure that reduces a pillar's compliance when a force is applied to it.

Single or multilayer, circular or dogbone, and with or without holes, composite materials can be easily configured with the help of different types of composite materials [244].

### 6.4. Quick to bind

Due to their capacity to stabilize performance during laying-up and impregnation as well as to improve the fracture toughness of the resulting composites, which is crucial in the manufacture of aviation, automobiles, ships, and other similar products, binders, also known as tackifiers, have become widely used in the production of new composite materials by Liquid Composite Moulding (LCM) techniques [245]. Only two materials are typically used to create composites. A group of fibres or fragments of a significantly stronger substance (the reinforcement) are encased and joined together by another material (the matrix or binder) [246]. Both mechanical adhesion and improved electrical conductivity are functions of the binder composite, which is made of polymer and conductive material. Additionally, this is necessary under mechanical stress brought on by volume changes brought on by

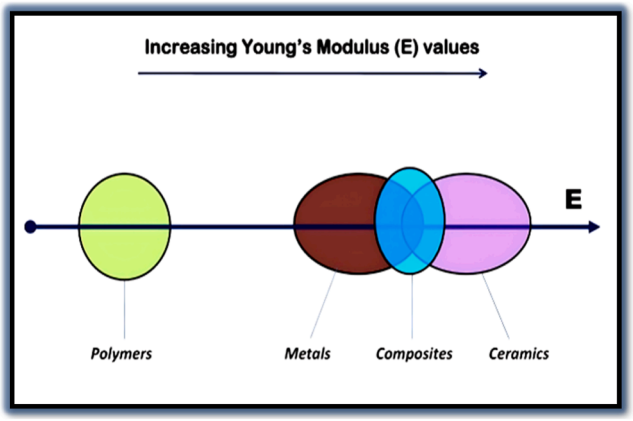



**Fig. 6.** Young's Modulus of Elasticity of Different Classes of Materials.

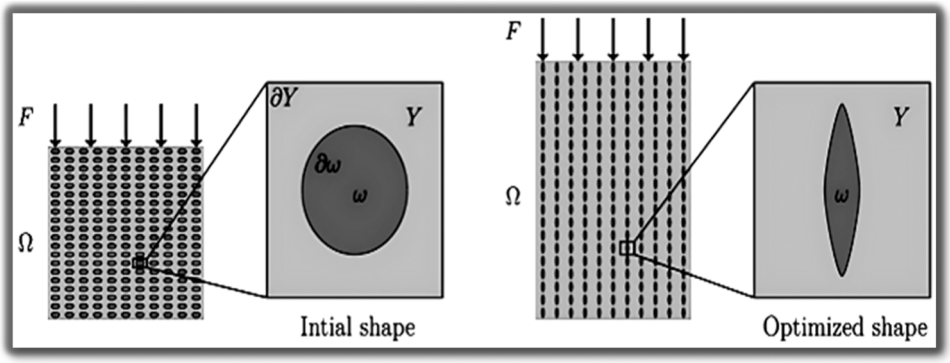



**Fig. 7.** Optimizing the shape of composite materials for linear elasticity [243].

lithiation and de-lithiation [247]. Formaldehyde resin-$CO_2$ is experimented previously for binding together into different layer. It shows the binding is very hard and waste very less time [248].

### 6.5. Good fatigue resistance

For constructions subject to cyclic stress, fatigue is the primary failure mode. For monolithic materials like metals, extensive study has been done, and advancements have been achieved in the creation of fatigue-resistant materials and life prediction algorithms. Then the importance of composites shows up and gives them usefulness [249].

The damage index is the ratio between the initial and reduced resistance capacities of a material. In Fig. 8, the damage index is much higher with respect to the per-cycle ratio for composite materials than for homogeneous materials. It means the damage resistance is higher than in homogeneous materials. The number of cycles at any given time divided by the fatigue life is known as the cycle ratio.

A car's parts and assemblies experience various operating pressures, increasing their brittleness and raising the risk of road accidents, which is particularly harmful in corrosive environments [250,251]. Structural material performance characteristics alter at every level of the metallurgical breaking range [250,252,253]. Increases in a car's dependability and lifespan are strongly encouraged by the high cost of metallic materials used in automotive manufacturing. Therefore, investigations on material fatigue characteristics [250] are essential because they aid in optimizing material selection during the development stage, reduce metal consumption, and identify cutting-edge technical processing techniques [250–252,254]. Carbon fibre-epoxy material has the experimental value to fatigue resistance for load transferring activities [255].

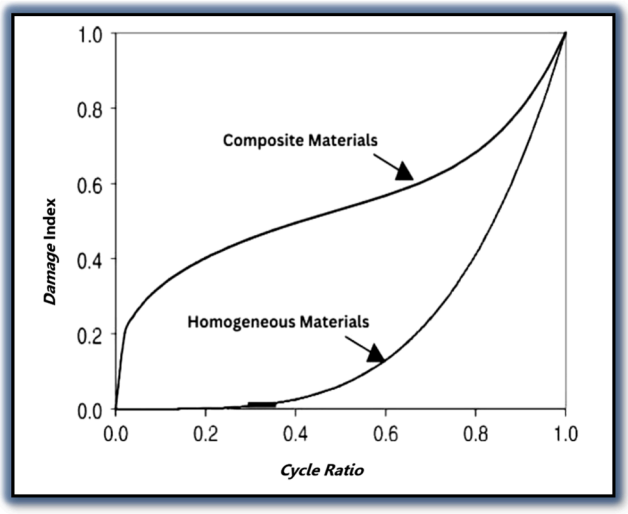



**Fig. 8.** Fatigue damage build-up in sketches [249].

### 6.6. Low thermal expansion

The fibres chosen and how they are laid out in the matrix affect an FRP composite's coefficient of thermal expansion. The manufacturer should provide the coefficient of thermal expansion numbers for each composite product [256]. The Coefficient of Thermal Expansion is relatively lower than other materials [257].

Fig. 9 shows that the thermal expansion rate is much lower for composite ceramics than for homogeneous metals. This indicates that composite ceramics maintain their structure when exposed to heat because they expand less but homogeneous metals expand more.

The system can be started cold in temperatures as low as −40°C, quickly heated to temperatures over 100°C, or quickly cooled after beginning at temperatures above 100°C. These are all eventualities that automotive designers must take into account. Because of the rapid temperature fluctuations, materials and liquids inside the car expand and compress, putting stress on other components and connections [259]. When adequately engineered composite materials, they may yield thermal expansion coefficients that lie both in a single direction and in a plane much outside the range displayed by homogeneous materials. In comparison to single materials, far lower negative values, as well as higher positive values, may be generated [260].

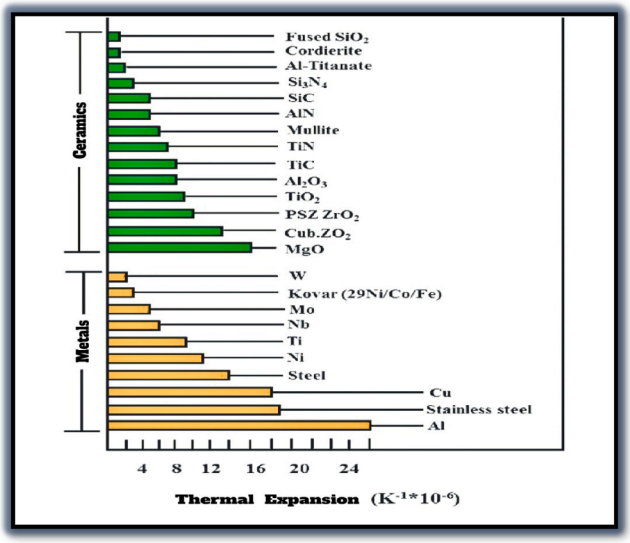



**Fig. 9.** The thermal expansion rates of metals and ceramics are contrasted [258].

### 6.7. Resistance against crack propagation

When compared to their non-magnetic counterparts, mechanical meta-materials with magnetic inclusions have been shown to have improved impact resistance. The system's overall structure has improved impact resistance as the size of the magnetic moment linked to the magnetic inclusions has grown. The system's magnetic inclusions can reduce the harmful consequences of a collision with an outside body. In light of the preceding, it is concluded that using composite materials reduces the damage brought on by automobile collisions and enhances the effectiveness of current protective devices. As a result, these materials are anticipated to be beneficial in various applications, including military-related protective devices and exterior body parts for automobiles [261–265]. Alumina-epoxy composite results toughness for consistence growth of crack propagation under various load of the materials [266].

### 6.8. Vibration-absorbing ability

Composite materials often exhibit more excellent damping capability as compared to metals. The primary explanation is the polymeric matrix's visco-elasticity. One may adjust composite attributes, including stiffness, strength, and damping, by carefully selecting composite constitutive characteristics like fibre aspect ratio, stacking order, and constituent qualities [267]. High-damping materials are utilized to minimize vibration in aeroplanes and other machinery because mechanical damping's adsorption of vibration energy is a significant difficulty in many engineering designs. The advantages of damping treatment include improved component durability, dependability, service life, and decreases in weight, noise, and costs [268,269]. Materials that boost sound absorption, offer good insulation or provide mechanical dampening can all be used to reduce car noise and vibration. Composites have been employed in the industry for decades to meet these goals. Metals are still being replaced by composites in new automobile applications [270]. Polyethylene terephthalate is investigated as a new type of rubber based composite materials, which have high vibration absorption ability [271].

### 6.9. Ballistic resistance

Impacts that cause partial or complete composite structure perforation can occur occasionally [272]. The benefits of low density, high specific strength, and high specific modulus of high-performance ballistic fibres have led to their widespread application in anti-ballistic constructions, such as military vehicles [273]. Composite material is used as glass armouring in car glass manufacturing, which has more accuracy for resisting bullets and accidents [274]. $Al_2O_3$-$ZrO_2$ is one of the composite materials which shows bullet protection significantly. In this ceramic composite, hardness and fracture toughness is very high for ballistic resistance [275].

### 6.10. Low system cost

Composite materials show cost-effectiveness in all sectors [276]. Compared to other materials, the overall design, production, labour, and tooling costs are much lower than any other materials for automobiles and aeroplanes [277]. It is very cost-effective to produce larger or bulkier products for the automobile industry [278].

In Fig. 10, Compared to Carbon-reinforced thermoplastic and glass-reinforced thermosets, steel is far less expensive. However, compared to steel, the cost of tooling and equipment is far cheaper. The total computation indicates that the greatest quantity of materials calls for the least number of tools and equipment. The labour cost of carbon-reinforced thermoplastics is likewise significantly less than that of glass-reinforced thermosets. For a certain number of demands, the cost of the materials is relatively constant. However, because different

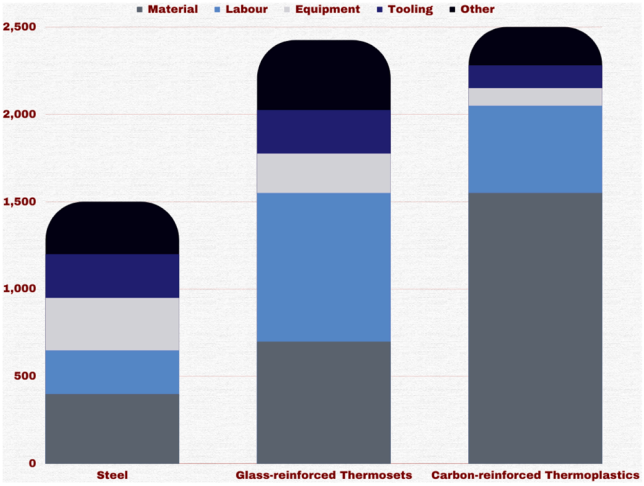



**Fig. 10.** Comparison of the Cost Structure of Body-in-White Design [279].

materials have different costs, so do labour equipment, and tooling expenses. In terms of the total cost of producing composite materials, this leads to overall sustainability.

### 6.11. Renewable usability

Composite materials can be reused for differences in shape, surface area, and size [280]. The automobile industry produces composite materials in a way that can be reused easily [281]. Composites are already used for global alarming. Shortly, natural composites will be the only materials for production in the automobile industry [282]. Natural Fibre already earns significance for its numerous qualities, especially its recycling ability [283].

### 6.12. Storing and releasing internal energy

Due to the variations of shapes and structure, composite materials can store energy, charge by themselves, and then release energy [284]. Without these qualities, materials face problems with thermal conductivity and maintaining constant shape. Traditional materials meet these types of issues [285]. The cabin must be managed appropriately for an air-conditioning system, which is effectively done by composite materials [286,287]. Epoxy resin with paraffin wax shows a repeated effect of storing and releasing internal energy which leads natural convection highly [288].

There are some other properties of composite materials which are not mentioned or used as main factor in Automobile before. But after the study about composites' unconventional characteristics, this sector can be benefitted.

- Mechanical Convenience

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### 6.13. Fire resistance

Sometimes the car interior is burned for leakage of electric lines. It causes huge damage to whole car as well as risking passenger's life. Many Composite Fiber Reinforced Polymers are used to enhance durability as well as fire resistivity for building strengthens. This type of materials such as Composite Structural Insulated Pannels (CSIPs) [289], can be used in chassis and interior Pannel. CFRP types of composite materials are also good enough for post fire mechanical performance [290]. Moreover, polymer nanocomposites are used as flame retardant in various applications [291]. So, this can be used in Automobile

applications.

Table 7 illustrates that some of inorganic composite materials for fire resistivity. Only inorganic composites are fire resistive because organic materials are composed in high temperature. That is why only inorganic composite materials can be used as fire resistance feature.

Carbon fibre reinforced composite with epoxy resin shows much higher temperature to degrade. That means it is highly protective than other materials in fire resisting and inflammatory activities [301].

### 6.14. Lightning protection

Lightning problems are considered highly for building constructions. But it should be reflected in the Vehicle manufacturing scenario. Many accidents occur in the time of Lightning. As some of the composites are less electricity conductive, it will perform anti-lightning performance. Like Carbon Fibre composite is used already in Air-craft [302]. Carbon Nanotubes MMCs protects aircraft from lightning strike [303]. It can be used to vehicle for protecting lightning strike by ensuring passenger safety. Composite with Metalized Fibre, The qualities of Carbon Fibre Reinforced Polymer (CFRP) and Intrinsically Conducting Polymer (ICP) are enough for a Lightning Strike Protection solution [304]. During lightning, composites made of polymers, such as polyaniline, polypyrrole, and polythiophene, have the capacity to absorb and transfer extremely high voltage [305]. In order to safeguard cars during strong storms, these kinds of materials ought to be put in the top of the chassis.

- Economical Convenience

.

### 6.15. 3D printing ability

Although 3D printing gives breakthrough in electronics and biomedical applications [306], it can be used in Automobile application. It gives higher accuracy for complex design [307]. The main problems of 3D design are – (i) It has very limited materials, and (ii) It has restriction on build size [308]. Defects are also created in 3D printing, but it can be minimized by treatment [309]. With the help of 3D printing, it is not possible to imply on high load bearing issues. But some other particular components can be manufactured by 3D printing.

Table 8 shows some possible types of composite materials for 3D printing. This table also shows the possible use in automobile components. In the table, some of example of composite materials are provided. The possible applications are given based on similarity of characteristics.

## 7. Current challenges

In the automobile industry, composite materials might be more expensive to create and repair than conventional materials like steel or aluminium; therefore, lowering manufacturing costs while maintaining quality will be a never-ending struggle [328]. Sustainability is becoming more and more critical to automobile manufacturers. Because recycling composite materials can be difficult, it will be crucial to develop recycling techniques and sustainable sources for composite materials in the automobile industry [329]. The automobile industry demands large production volumes, and optimising manufacturing processes for composite materials to meet these demands is still a challenge [330]. The automobile sector has challenges when adopting new materials, which is made even more difficult by the numerous worldwide rules and safety requirements [331]. Composite component repairs in the automotive sector might be more complex than conventional materials. It will be essential to develop affordable repair methods [332]. It can be challenging to scale manufacturing to satisfy the automobile industry's demands and maintain a secure and effective supply chain for composite materials, especially during disruption [333]. A continuous problem for the automotive industry is the development of novel composite materials with enhanced qualities, such as higher strength, sturdiness, and heat resistance [334]. Using composite components in these new vehicle designs requires careful thought and adaptation as cars grow more technologically advanced with features like electric propulsion and autonomous systems [335]. The constant challenge is to retain or improve vehicle performance, safety, and handling qualities while balancing weight reduction for better fuel efficiency and emissions [336]. Providing a steady and dependable supply of premium composite materials and parts to prevent production bottlenecks is essential to serve the automobile industry [337]. The norms and laws governing composite materials may be less well-established than those governing conventional materials in the automobile sector [338]. Due to the lack of standards, it may be challenging to guarantee composite components' quality and safety [339]. Despite these obstacles, composite materials are anticipated to play more significant part in future automobile designs as technology develops and consumer demand for more environmentally friendly and fuel-efficient vehicles rises [340]. Analysist must consider the problems of composite materials that it is fragile and less load carrying capacity for longer version of usage in automobile issues. The damage is very high in accidental performance. So, identifying and synthesising perfect combination is very important for researcher to manufacture parts properly.

**Table 7**
Types of Inorganic Composites for Fire Protection.

| Types of composite materials | Examples | Constituents | Ref. |
|---|---|---|---|
| Inorganic Fiber | Glass | Bamboo Scrimber & Phenol Formaldehyde | [292] |
| | Carbon | Boron Carbide Nanoparticles | [293] |
| | Basalt | $SiO_2$, $Al_2O_3$, FeO, Alkaline and Alkali metal | [294, 295] |
| | Ceramic | $Al_2O_3$ and $SiO_2$ | [296] |
| Inorganic Matrix | Polysialate | $Al_2O_3$ and $SiO_2$ | [297] |
| | Geopolymer | Na, K and $3Al_2O_3.2SiO_2$ | [298] |
| | Metals | Structural Steel, C, $N_2$ and Mo | [299] |
| | Marble | CaO, $SiO_2$, $Al_2O_3$, $Na_2O$, MgO and $MgCO_3$ | [300] |

**Table 8**
Some of 3D printable composites and their possibility to Automobile applications.

| Types of Composites | Examples for 3D Printing | Ref. | Possible Automobile Applications | Ref. |
|---|---|---|---|---|
| Fibre Reinforced Composites | ABS Composites | [310] | Steering wheel cover | [311] |
| | Epoxy Resin Composites | [312] | Bumper beam, Hoods, Fenders, Roof panels, | [313] |
| | Nylon Composites | [314] | Alternator bracket | [315] |
| | Polylactic Acid Composites | [316] | Dashboard components | [317] |
| Particles Reinforced Composites | Polystyrene Composites | [318] | Under the roof | [319] |
| | Acrylate Composites | [320] | Chassis | [321] |
| | Polyamide Composites | [322] | Hinge components | [323] |
| | Polyurethane Composites | [324] | Seat, Insulator of roof and facade panels | [325] |
| | Polycarbonate Composites | [326] | Body | [327] |

## 8. Future aspects

Composites are very well used in the automotive industry and can potentially develop further.

- Compared to conventional compounds, composites have better mechanical, thermal, impact and adhesion properties. Therefore, creating structural combinations with qualities like biodegradability and recycling is difficult. It needs more research to improve the properties [341].
- Composts are needed in large quantities and can be expensive to produce. This high cost is the most prominent problem for composites. Polymerization relaxation can be pre-optimized during composite preparation to obtain maximum output at a minimum cost. Also, a more detailed study on composite composition's effect on producing improved microstructures during the preparation process is needed [342].
- Growing global fibre demand in the automobile sector is projected to decline shortly. In addition to more preparative techniques, modelling and assembly complications still exist. Therefore, there is an imperative need for more research and practical application of composite manufacturing methods in the automobile sector [343].

### 8.1. Insinuating natural fiber composite

Natural fibre is basically cellulose which is a biopolymer of living source [344]. Natural fibre has potential mechanical, physical and thermal properties which can be easily achieved by 3D printing technology [345]. This cost-effective material is very worthy for environmental sustainability [346]. It has several types and each of them have individual special properties.

Table 9 shows the properties of different types of natural fibre. Each of them has some unique features. These all of features can be used in automobile. Hence, the probable application of where these composites can be used is illustrates in the Table.

After all, Natural fibre is a green composite which is biodegradable as well as biocompatible [359,360]. Recently, it is proven that it is sufficient enough for load bearing activities in structural phenomenon [361–363]. Most important factor is, it is much more available in the surrounding which has very low cost and sometime no cost required. Comparatively other cost, manufacturing related cost is higher for natural fibre which is also near to reduceable [364]. Moreover, natural fibre can be replaced within limited cost as other composites are unable to solve the repairing problem in limited price. So natural fibre composite is a better alternative for automobile applications. But still every natural fibre is not enough for protecting cars in accidental damage.

**Table 9**
Types of Natural fibre composites and their probable applications in Automobile.

| Types of Natural Fiber | Unique Beneficial Property | Probable Application | Ref. |
|---|---|---|---|
| **Wood** | High Electric Resistivity ($10^{12}$ Ω) | Electric Component in Interior | [347] |
| **Sisal** | Ability to Strech | Seat Belts | [348] |
| **Hemp** | Bacterial Protection | Air Filter in AC | [349] |
| **Coconut** | High Resistance to Rotting and High Yield Strength | Chassis | [350] |
| **Cotton** | Better for Skin | Seat Covers | [351] |
| **Kenaf** | High Tensile Strength | Engine Pulley Belt | [352] |
| **Flax** | Lustrous | Exterior design of Front Grill | [353] |
| **Jute** | Moderate Moisture | Inside of the Trunk | [354] |
| **Abaca** | Water Resistance | Rain Wiper | [355] |
| **Banana Leaf** | Fire Resistance | Electric Wire Cover | [356] |
| **Bamboo** | Anti-UV Protection and Strong | Window Glass Paper | [357] |
| **Wheat Straw** | Light Weight and Durable | Headlight Cover | [358] |

### 8.2. Preferences in acoustic properties

Acoustic properties are extremely important to the automobile sector for improving cars' safety and comfort. Acoustic materials are used to insulate the interior of the vehicle, reducing the transmission of outside noise into the cabin. If Acoustic technology is used in the automobile, the overall comfort of the passengers improves by providing a quieter driving experience [365]. Vibrations in the chassis, body panels, and interior components of the car can be reduced by using acoustic materials. This increases riding comfort by reducing vibration transfer. Acoustic properties are essential for designing and optimizing in-car audio systems. Using Acoustic Properties to boost sound quality, minimize vibrations, and improve the overall acoustic environment within the car [366,367]. Using acoustic materials can contribute to the safety of the vehicle by providing additional insulation in critical areas, helping to absorb and dissipate energy during a collision [367,368]. Car acoustics management aims to reduce or remove unwanted sound qualities and improve noise and vibration in automobiles. The responsiveness, luxurious appeal, and dynamic performance of a car are all impacted by improved acoustic systems [369]. Natural fibre composite is the best alternative, for these acoustic properties due to their high sound absorption properties. Because of twisting path, higher flow resistivity, higher surface area and low porosity, it absorbs sound simultaneously [370,371]. As it is the secondary objective for a vehicle, composite is not used. But overall cost and benefit is high. Unlike other materials, Epoxy Resin is more suitable for noise absorption than rubber. But still epoxy resin is quite unavailable. The scenario may be fluctuated for automobile applications.

### 8.3. Enhancing sensing potentialities

To increase safety, improve driver assistance, and enable a variety of autonomous functions, cars must have sensing capabilities. Sensors like lidar, radar, and cameras can be used to keep an eye on the surroundings and identify potential collisions. Automated emergency braking is one of the ADAS components that works to avoid or reduce accidents [372]. Sensor capabilities may be used for parking assistance systems, pointing out obstacles, keeping eye on blind areas and alert drivers when a car is in the next lane. The air quality & occupant health is tracked by sensors installed in the interior [373]. Composite fibre like hybrid steel fibre [374] is a very good example for self-sensing properties. Multi wall Carbon Nanotube/ cement composite can be used to sense strength and failure sensing [375]. This way composite can be used in automobile for sensing application. But undoubtedly it is quite challenging for composite materials to work simultaneously as traditional materials. Some composite has very lower absorption and readability power which is the main crisis in this scenario. Still, it can be solved by more research and sophistication.

### 8.4. Opportunities magneto strictive

Magneto strictive technology can be used in automobiles for various applications. The term" Magnetostriction" describes a material's ability to alter its form in response to an applied magnetic field. Magneto strictive materials can be used to create sensors with varying parameter measurements. Magneto strictive sensors, for example, are used in many automotive systems for accurate measurements of pressure, torque, and displacement [376]. Magneto strictive materials are basically composite materials. Magnetostrictive polymer composites (MPCs) are one of the genres of composite materials. It has some unique properties like changing dimensions and elasticity simultaneously under the presence of a magnetic field. Comparing with bulk magnetostrictive metals, its resistivity response ability, formability and mechanical properties are very high [377]. Fe–Ga (Galfenol) alloy, Fe–Pd alloy, Cobalt-ferrites, Carbonyl-iron can be used for perceiving magneto strictive properties. It can be used in active suspension systems that need adaptive

dampening [378]. Magneto strictive actuators can be utilized in some fuel injection systems to regulate the opening and shutting of fuel injectors accurately. This may lead to improved fuel economy and more effective combustion. Magneto strictive materials can be used by active noise control systems placed in cars. The engine control system can make use of magneto strictive sensors to track the location of different parts, which helps the engine run more smoothly [379]. New world also raises highly with this technology. Researcher should research for those updated technology so that it can be implying in automobile applications. Thus, composite materials will be used in this sector significantly.

### 8.5. Signifying piezoelectricity

The capacity of piezoelectricity to transform mechanical vibrations and stress into electrical energy has several uses in the automobile sector. Piezoelectric composite materials like Epoxy Resin and carbon black mixture [380] may be used in a vehicle's many components to convert mechanical vibrations into electrical energy [381]. The car's battery can be charged or low-power electrical components can be operated with this collected energy to improve energy efficiency [382]. Piezoelectric sensors can be used in tire pressure monitoring systems (TPMS). Pressure variations cause the piezoelectric material to distort, which results in electrical impulses that tell the car's monitoring system about the tire's condition. Piezoelectric sensors may be used to detect temperature and pressure, among other engine characteristics. The engine's performance may be carefully managed to maximize emissions and fuel economy [383]. Piezoelectric materials can be used by active suspension systems to enable precise and fast suspension modifications based on the condition of the road. This leads to better handling and increased riding pleasure. Piezoelectric components may be employed in brake systems to capture energy during braking. Braking generates electrical energy, which may be stored for later use or applied to power various automotive systems [384]. However, it is easily deformed for brittleness. That is why more sensitive research is required for using it.

### 8.6. Self-healing capabilities

In automobiles, "self-healing capabilities" refers to a material's or system's capacity to mend or recover from harm without outside assistance. Using self-healing technology in cars can improve the vehicle's overall longevity, safety, and durability, among other advantages [385]. Self-healing composite materials like Shape memory polymer with Carbon Nanotube [386] can withstand and mend damage from abrasion, impacts, and environmental conditions. This adds to the car's overall durability. In the case of an accident, self-healing composite materials can offer some impact resistance, strengthening the car. Because of its increased resilience, collisions will have less of an impact, improving passenger safety [387]. Auto owners may save money on maintenance by using self-healing technology to reduce the need for regular repairs or touch-ups. Vehicle owners stand to benefit if it is utilized more in the future. Self-healing materials can be connected to basic components, such as sensors and wiring, to anticipate or repair harm caused by wear and tear, natural components, or minor mischances. Self-healing coatings can shield the outside of the car from things like pollution, acid rain, and UV rays [388]. Composite self-healing capabilities have lots of positive things for automobiles. If it is used more in the future then overall performance will increase.

### 8.7. Possibilities as electromagnetic shielding

Composite materials as electromagnetic shielding for automobiles have possibility to hold several potential benefits for the future. Electrical equipment within the car, outside signals, and the increasing number of electric and hybrid cars are some of the sources of electromagnetic interference. Sensitive electrical components in the car can operate properly because of shielding composite materials resist electromagnetic interference [389]. Composite shielding materials can improve overall vehicle performance by reducing electromagnetic interference. Carbon based composite, polymers like polyaniline, polypyrrole are good example of electromagnetic shielding [390]. A more responsive system can function more smoothly when there is an uninterrupted connection between its many electrical components [391]. Electric cars' high-voltage systems cause them to produce electromagnetic fields. To protect and maintain the integrity of the car's internal electronics and external communication systems, composite shielding can assist in controlling and confining these fields. Composite shielding can assist automobiles in meeting the more stringent emissions and electromagnetic compatibility (EMC) regulations [392]. The reliability, safety, and performance of next-generation cars are probably going to be greatly dependent on composite electromagnetic shielding in cars. Making it better suited for usage in the future [393].

The discussed future enhancement must be examining highly for betterment of automobile sectors. More research of natural fibre composite can unlock the huge advancement of future. It will revolt the modern technology of automobile one. Beside two of uncommon factors of composite materials are piezoelectric and magnetostrictive effect can be implied by $BaTiO_3$, $CoFe_2O_4$ and $CoTi_2O_4$ mixture [394]. After all, self-healing and electromagnetic shielding capabilities can stimulate the benefits of automobile users. So, research progress must be carried to figure out the other benefits. Sensing properties and acoustic phenomenon are one of main concern for passenger safety and comfort. More research is required for implementing composite materials.

## 9. Conclusion and discussion

From the above description, it can be concluded that composite materials are not only an option but also a mandatory implementation in the automobile industry. The taste of composites in the automobile industry has gained significant attention with their attractive and efficient properties. Multiverse properties provide variations in materials. With the help of single composite materials, multiple features are ensured compared to numbers of homogeneous materials. The main advantage of using composite materials is their light weight with high strength. This type of adverse conditions can not be compiled by single traditional metals. Lots of composite materials are signified already, but more working will tie up variable benefits to every sectors.

With the increasing demand for composite materials in the automobile sector today, its use is expected to spread successfully in the future. The development of composite materials for use in automobiles has fundamentally changed the automotive industry, providing a multitude of advantages that improve sustainability, efficiency, and performance. Various composite applications have been included, like chassis, brake pads, hood, bumper, fender, engine cradle, interior and exterior essences, tires, sunroof, etc., to achieve lightweight, high strength, good fatigue resistance, toughness, damage resistance, stiffness, thermal insulation, wear resistance, and other worthy properties within a reasonable cost. Because of their outstanding strength-to-weight ratios, composite materials are perfect for use in a variety of automotive structural components.

The main concern of automobile is passenger safety by resisting accidental damage. Their increased strength and resilience help to raise vehicle safety standards. Composites are the best fire and lightning protective because they are less conductive. The thermal and electrical conductance is very negative for composites which protects from accidents and danger from interior to exterior components. Another factor of thought is cost reduction after consumption. Vehicle weight reduction is largely dependent on composite materials. Lower emissions and increased fuel efficiency are the results of this weight reduction. 3D printing ability also reduces labour costs allow for different shapes and qualities as per requirement of a car. Many types of composites can be used simultaneously for different types of parts which are very unusual. Scientists have already found out the beneficial property of ongoing

automotive technology. Still accidental damage is one of the major concern which must be reduced and more research needs to be conducted.

Environmental safety and sustainability will be uplifted throughout using composite for less fuel consumption. Additionally, Natural fibre composite opens the door of outstanding future. It is biodegradable, biocompatible, recyclable, and available in the environment. In recent future, it can be used for broader applications. Furthermore, composite can be used as acoustic control, magneto strictive and piezoelectric properties in succeeding future. Self-Healing, sensing, electro-magnetic shielding properties can be ensured by composites which can be adapted in future vehicle performance. Still more research required to ensure these properties before applying in automobile industry.

Even with all their benefits, there are still drawbacks, like excessive production costs, problems with recycling, and the requirement for standardized manufacturing procedures. The number of research are very less for reducing cost of production and synthesize. Lots of variations can be generated but fabricating cost should be reduced by future research. Perfect fabricating process ca be implied to reduce cost for individual composites. Researcher must identify the perfection for betterment. Weight, safety, and design were major issues that the automotive industry faced, and which have been resolved by advancements in composite materials. Composite materials will probably become more important as technology develops, helping to create cars that are more efficient, environmentally friendly, and technologically sophisticated.

Productive work must be implemented more on the basis of the composites. Though lots of technology and science confirm the superiority of respective genre of materials in vehicle industry, some adverse effects need to localized. The negative effects of different constituents of composites should be come into light for each particle. The strength reduction for consistent use of materials, must be monitored in future. Above all, composite make a significant revolution in automobile industry as well as other industry.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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