

A Review on Usage of Carbon Fiber Reinforced Plastics in Automobiles

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Abstract

Today we are in need of fuel efficient and high speed transportation sector. So an important aspect is to achieve the greater fuel efficiency is reduction of weight in automobiles. Here in this paper we are going to discuss about the material usage in production of automobiles which has the greatest impact of fuel economy, high speed and safety concerns. Here in this paper we discuss about material that greatly suits these conditions Carbon Fiber Reinforced Plastics (CFRP) which are lighter than the conventional materials. Here we discuss about in detail with the benefits of usage of CFRP in each parts of car (bumper, hood or bonnet, roof and etc..). And there is detailed review about the properties which made CFRP suitable to make these parts.

Key Words:Fuel efficient, impact; bumper, hood or bonnet.

1. Introduction

Carbon fiber reinforced plastics (CFRP) is composite material consisting of various carbon fibers and thermosetting resins. Making its presence in areas of aerospace and automobile industries because of its features such as light weight and higher weight is to strength ratio. CFRP is similar to fiber glass. Carbon is woven into a textile material and resin such as epoxy is applied and allowed cure. This is resulting material that is very strong as it has the best strength to weight for all construction materials. It is an improvement of fiber glass but very expensive.

2. Methodology

Comparison between Conventional Materials and CFRP

CFRP is lighter than aluminum, stronger than iron and higher elasticity than titanium. CFRP is increasingly used automobile industries. CFRP materials have high tensile strength to strain and abrasion. There features is extremely useful automobiles where high speed is required.

CFRP has extremely low shrinkage and expansion against heat which is a strong benefit for automobiles body.

CFRP are used in manufacturing of expensive sport cars, bicycles, and motorbikes. Mainly CFRP are used in parts such as frames, forks, and handle bars to keep weight out of aluminum and yet retain great strength. 70 percent of CFRP results in 30 percent weight reduction.

Why CFRP Should Be Used in Automobiles

Carbon composites are unparalleled in their ability to reduction of mass, facilitate sleek, aerodynamic shapes, reduction tooling investments, eliminate corrosion and denting, improve sound damping and vibration and protect occupants even in high speed crashes.

Although CFRP can offer 50 to 60 percent mass reduction VS similar in steel the cost is 2 to 10 times. Higher when both materials and processing costs are considered as bid issue.

Safety is clearly a concern especially in small cars. Composites are having high specific energy absorption of all major structural materials.

CFRP can absorb 120kj/kg (approx.) of energy if made with thermoset matrix (epoxy) 250kj/kg in a thermoplastic matrix VS 20kj/kg (approx.) for steel. CFRP provides 20 percent mass of steel yet equally strong and 60 percent mass reduction, boosting fuel efficiency by as much as 30 percent via mass de-compounding but no loss in performance.

3. Applications of CFRP in Automobiles

Bumper

Bumper is the one parts lightly more weight component in automobiles. The bumper materials should have high specific tensile and compressive strength, controllable electrical resistance and suitability for production of complex shapes. CFRP is well suited for bumper production. Mainly it helps in overall weight of automobiles. Here fibers are the principal load carrying members while surrounding matrix keeps them in desired location and orientation and helps in load transfer. It absorbs the greater amount of kinetic energy during the impact and stay rigid during the impact conditions and has high impact toughness. For this impact toughness the materials should have high flexural strength and flexural modulus. The reduction of weight plays major role in fuel consumption. Extremely light weight, unlike others isotropic material CFRP has directional strength properties. The property of CFRP depends on the layout of carbon fiber and proportion of carbon fiber. The CFRP are used in automobiles due to its increased strength and appreciable reduction in weight and size of the frame. Until today the usage of CFRP is limited due to the expense involved in it. But they used in considerable amount in to get high end cars due to its increased strength and decreased weight compared to conventional materials. The bumpers of 3 mm to 2.5 mm are suitable to cars and they provide weight saving about 500g for each bumper and 2 kg per vehicle improvement of 11% compared with other conventional bumpers.

Hood (OR) Bonnet

Carbon reinforced polymer hoods can have about a one fifth of the density but all the strength of steel and stiffness of steel. They also provide automakers with greater design flexibility other than steel and aluminum. But drawbacks of CFRP high costs and slow manufacturing throughout are tough challenge not only are carbon fibers very expensive to make forming them into auto components takes much longer than the few seconds it takes to stamp out metal sheet. Production of steel hood the CFRP hood is around 60% lighter weighing less than 5 kg.

Automotive Roof Pannels

Table 1

Description	Weight
Steel roof	11.2 kg
Composite roof(CFRP)	5 to 5.5 kg
Weight reduction	6 to 6.6 kg

Automotive roof panels composed of CFRP require high strength and bending stiffness to ensure driver safety during roll over conditions. Generally the mechanical properties of CFRP products depend on layup method. Therefore it should satisfy the bending stiffness conditions. Finite element method is used to

predict the stiffness. According to researchers the 2mm thick panels was found to be achieve the stiffness required.

Tailgate

CFRP are also in production of tailgate. The design should consist of 1.5mm thickness to prevent torsion. The stiffness and reduced density made it possible to remove the two tailgate stabilizers which can reduce further weight. The removal of interior trims components as a result of quality of carbon fiber material which can be painted directly. The reduction in the number of parts has to be assembled. It will provide easy assembled and ability to provide the complex shapes.

Table 2

	Production SMC Mass	Prototype of CFRP Mass
Tailgate inner	5.7 kg	2.3 kg
Tailgate outer	3.2kg	0.9 kg
Spoiler mechanism carrier	1.1kg	0.2 kg
Total weight reduction	10 kg	3.4 kg

The combination of plastic with carbon fibers reducing the weight by 35% or 7 kg, but it is unsuitable for mass production of time consumption and researches states that material will be affordable for mass production within next three years.

Chassis

A chassis being the frame of the vehicle has to be rigid or strong to absorb and retain movements and vibrations from engine, suspension and axes. It should also be as light as possible to improve the vehicles performances and fuel efficiency. CFRP is suitable because it is approximately twice stronger but much lighter than steel or aluminum. A carbon fiber chassis is stronger and weaker areas are similar to using different alloy in metal. Carbon fiber body lacks flexibility. For instance metals can be melted or welded. Carbon fiber will not bend, once the force of impact is large enough it will crack or break and repairing is not option. With acceleration defined as change in velocity it can be said that decrease in the weight of vehicle results in the same force greater acceleration. This means that a race car with less weight has the capability to increase speed more rapidly and change directions more quickly.

A chassis is usually used in super cars where the strong and light weight property of carbon fiber takes preferences over high cost. A chassis can only be a part of carbon fiber. Carbon fiber can be recycled but loses its strength where steel and aluminum can be recycled and become just strong and useful as before.

Fender

Carbon fiber fender makes it more flexible and durable than made out of single

piece of metal and since carbon fibers are significantly less dense than steel it is more weight which increases fuel efficiency. The resin that covers thermoset carbon fender also keeps them looking shiny and new long after they are installed and the shiny fabric makes the appearance better. Scratches are much noticeable on the surfaces of carbon fibers fenders than traditional metals. Offers high-performance, energy dissipation capabilities, modular construction and easy replacement benefits.

Side Doors

The carbon fiber reinforced polymer (CFRP) prototype features a layered structure designed to withstand specific stresses, saving an additional 4kg of weight per door compared to aluminum and as much as 11kg compared to steel. Pinpoint strength thanks to material mix CFRP provides design potential for high-precision shaping of the wall thickness, fiber orientation and layer structure: where more strength is required, the material can be reinforced or the fiber orientation adjusted without affecting the ultra-thin wall strength in other areas. Thus, it is possible to dispense with reinforcement sheets used in standard systems against stress caused by door lowering, wind forces and torsion in the door inner panel. Aramid fibers with increased ultimate strain for crash-relevant areas ensure crash safety whereas carbon fibers are used in areas requiring great strength and/or stiffness. The concept door also features an integrated side impact beam.

4. Draw Backs of CFRP

Table 3

Reliability	1.Damagesare invisible 2.Ageingeffects are unknown 3.Highermaintenanceefforts
Environment	1.Onlypartially recyclable 2.Higherenergy consumption for production and risk for negative co2 impact
Physical parameters	1. Challenges to install a plant 2.Limited crash simulation available
Production	Workforce 1.Little experienced workforce 2.Little experience with production technologies Tooling 1.Lowtolerances 2.Lowturnoverdueto long curing time 3. Expansive to tool hard to form– high scarp rate. 4. Expansive materials

5. Conclusion

The key driver is weight save due to the increase in specific strength and stiffness that carbon composite offer. The key enabler is using carbon fiber is low cost– high cost generally it makes carbon fiber components prohibitive unless additional revenue can be made.

Table 4

Conventional Material	Weight Reduction in Using CFRP	Costlier because of CFRP
Steel	60% reduction in weight	*20 times costlier
Aluminum	40% reduction in weight	*10 times costlier

Further researches should be done to decrease the cost, time of making, production processes. Many researches are required to be done to make to reduce the curing time of CFRP and make it suitable for mass production. Finally every 10 kg of reduction of a vehicle lowers the fuel consumption and leads to a drop in carbon emission of 1g/km.

References

- [1]Ghassemieh E., Materials in automotive application, state of the art and prospects, In New trends and developments in automotive industry, In Tech., (2011).
- [2]Lukaszewicz D., Design Drivers for Enhanced Crash Performance of Automotive CFRP Structures, In 23rd International Technical Conference on the Enhanced Safety of Vehicles (ESV), (2013).
- [3]Gourav Gupta, Ankur Kumar, Rahul Tyagi, Sachin Kumar, Application and Future of Composite Materials: A Review, International Journal of Innovative Research in Science, Engineering and Technology 5 (5) (2016).
- [4]John A., Alex S., A Review on the Composite Materials used for Automotive Bumper in Passenger Vehicles 4 (4) (2014), 98-101.
- [5]Shama Rao N., Simha T.G.A., Rao K.P., Ravi Kumar G.V.V., Whitepaper Sponsored by Sigmatex (UK) Ltd., (2002).
- [6]Carbon Fibre, Saleel Visal Swapnil U.D., Reinforced Composite Car A Review Paper on Properties of Carbon Fiber Reinforced Polymers.
- [7]Praveen Kumar A., Sameer Belagali, Bhaskar, Comparative Study of Automotive Bumper with Different Materials for Passenger and Pedestrian Safety, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) 11 (4) 60-64, (2014).
- [8]Sanjay Mazumdar, Opportunity and Challenges in Automotive Composites Industry Presented To Lucintel Webinar, lucintel insights that matter, (2013).
- [9]Ueda M., Tsuji T., Jeong T.K., Controlling the Energy Absorption Capability of a Unidirectional Carbon Fiber Reinforced Plastic Tube

Using a Double-Sided Plug, Open Journal of Composite Materials 5(01) (2014).

[10] Shida R., Uzawa K., Ohsawa I., Morita A., Takahashi J., Structural design of CFRP automobile body for pedestrian safety, In 10th Japan International SAMPE Symposium & Exhibition, (2007).

