JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 7, ISSUE 1, 2020

Review on Use of Carbon Fibre (Reinforced Plastics) in Automotive Sector

Ananda Babu[1], Abhishak Bhattacharya[2]

[1,2]Dept. of Mechanical Engineering, Sharda University, Greater Noida, Uttar Pradesh

Email Id- [1]abhishek.bhattacharya@sharda.ac.in, [2]ananda.babu@sharda.ac.in

Received: 02 November 2019 Revised and Accepted: 02 January 2020

ABSTRACT: Innovative and new production material are developed by using lightweight material nowadays in automotive industry. Carbon fibre offers many important properties like high strength-to-weight ratio, high fatigue strength, low coefficient of thermal expansion, high electric conductivity, light weight, high modulus elasticity-to-weight ratio, good corrosion resistance, low impact resistance and high damping. Manufacturers demand properties such as energy savings, robust equipment, increased flexibility and improved ergonomics from new materials. The ideal material possessing these properties is carbon fibre having excellent material property. This is the reason why the demand for carbon fibre is increasing specially among the sports cars and luxury car manufacturers. This paper focusses on the structure of the carbon fibre and its applications in the automotive industry. Though carbon fibre is an ideal material for the manufacturers still it has been used in limit because of its exclusivity, further other reasons have also been discussed below in the paper.

KEYWORDS: Automotive, Carbon fibre, damping, elasticity, fatigue, flexibility, fibre, strength, thermal expansion

I. INTRODUCTION

Carbon fiber was first developed in 1958 in OH, Cleveland on heating rayon strands and its result was poor strength and quality. After few years new manufacturing and chemical process were developed by Japanese which is used now also. The strength, quality and purity of these types of carbon fibers were much superior then those of previous rayon strands version.

Luxury British brand Rolls Royce in 1963, high quality, industrial sale production and strength was eventually achieved with new manufacturing process. At this stage carbon fiber was commercially feasible for some exclusive applications, however, the brittle characteristics of carbon fiber was not appreciated and eventually caused aero engine failures. At present manufacturing of carbon fibre changes from company to company but still they are only based among three chemical sources that is, PAN, Rayon and pitch (Petrol refined product). Carbon fibre manufacturing demands a lot of energy, very high temperature and finally relatively premium cost.

Carbon Fibre Structure

Graphite and carbon fibre have similar structure consisting carbon atom layers which are graphine sheets arranged in hexagonal pattern. Graphite, hybrid structure and turbostatic are the three types of carbon fibre layer planes which depend upon the manufacturing and precursors processes. In region of graphitic crystalline, the layers are arranged parallel to each other in regular way. The sp2 bonding is used for bonding of atoms in a plane and on the other hand contact between sheets is weak (Wander Waals forces). There is about 0.335 nm of d-spacing between the two graphene layers.

The lifting and gripper manufacturing industries are facing new challenges to meet high demands from both customers and manufacturers. Heavy equipment's are used such as aluminum, steel or combination of both in fixture and gripper devices for fixing geometry and transporting in Body- in-White (BiW). The other biggest disadvantage of using heavy metals in fixtures and gripper devices is when they fall down on the floor it results in loss of material as well as time. Lighter equipment with higher tolerance are desired and this generates demand for lighter material with high tolerance value and high strength. Conventional are much easier to use and the knowledge of maintaining and using them is well known.

ISSN- 2394-5125 VOL 7, ISSUE 1, 2020

The challenge which engineers encounter is to how to design and assemble them. Nonmetals cannot be welded and to bolt them together, drilling of holes is required. In using carbon fibre composite, drilling process will weaken the material by cutting the carbon fibre. Other option could be the use of pasting or gluing but this process as its own problem known as delamination which results in a major problem.

At the present scenario majority of carbon fibre are made by using PAN precursor used in sports cars, luxury cars, aerospace and defense sector. In most cycles and sports equipment carbon fibres from pitch precursor and rayon precursor is not used any more in carbon fibre manufacturing. Currently different carbon fibre is been produced such as high-modulus, ultra-high modulus, intermediate modulus and low modulus. Companies like Toray Industries, Mitsubishi Rayon and Tenax are leading carbon fibre manufacturers having almost 50% of share. Carbon fibre is a composite material consisting of thermosetting resins and carbon fibres, it is much stronger than iron and lighter than aluminum and has higher elasticity than titanium.

These features are highly useful in high speed automobiles; another major advantage is it does not expand or contract in high or low temperature which is highly beneficial in automobile body. Carbon fibres are used heavily in bicycles, motorbikes and sports cars, mainly used in the parts such as handle bars, forks and frames to keep weight less than aluminum and yet retain high strength. 70 percent of CF results in 30 percent weight reduction.[1], [2]

Carbon fibres are unmatched when it comes to light weight material, securing occupants in high speeds, improve sound damping, eliminating denting and corrosion, reduction in tool investment, aerodynamic shapes, mass and facilitate sleek. However, carbon fibre can offer approximately 60% of mass reduction but at the same time it is 5 to 10 times costlier. In small cars safety is a major concern. [3]

II. LITERATURE SURVEY

Applications of Carbon Fibre

- **Bumper**

Bumper is used in the front and the rear end of an automobile, it is bulky therefore it has major weight contribution in overall weight of the automobile. It is used for protection of the vehicle from a collision therefore it requires high compressive strength and high specific tensile strength, therefore carbon fibre reinforced plastics are well suited for bumper production. Overall it helps in weight of the automobile. Fibres are the major load carrying member while neighboring matrix keeps them in required orientation and location and eventually helps in load transfer. It helps in absorbing high amount of kinetic energy during the impact and stay solid during the impact and at the same time providing strength. For this high amount of impact toughness material by which bumper is to be made should have high flexural modulus and high flexural strength. Low weight plays a major role in low fuel consumption, very light weight has directional strength properties. The physical property that is layout of carbon fibre and its proportion determines the property of the carbon fibre reinforced plastic, the biggest reason of using this material in sports cars and other automobiles is because of its low weight and high strength. Now these materials are not used heavily because of its cost factor and low availability but in spite of that it is heavily been used in high end sports cars and luxury cars to decrease their weight and increase strength simultaneously when compared to other standard materials. Generally bumpers of 3mm width are installed for the cars and provide weight saving of about half kg for individual bumper.[4][5]–[8]

- **Bonnet**

Bonnet is also one of the heaviest part which takes most of the impact during a crash along with the bumper. Carbon reinforced polymer hoods are used which have about $1/5^{th}$ of the density when compared to steel or aluminum but still have all the strength of steel and aluminum. Drawbacks of carbon fibre reinforced plastic is its high cost and scarce in availability, it becomes very expensive forming them into auto components but it is approximately 60% lighter and weighing less than 6 kg. [9]

- **Roof Panels**

Carbon fibre reinforced plastic composed automotive roof panels require bending stiffness and high strength to ensure passenger security during roll over crashes. As discussed earlier the property of carbon fibre depends upon its physical property that is its layout method therefore it should fulfill the bending stiffness condition. In

ISSN- 2394-5125 VOL 7, ISSUE 1, 2020

order to determine stiffness of the product finite element method is used and after the research it was found that 2mm thick panel can achieve the required stiffness.[10][11] as explained in table1.

Table 1

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

- **Chassis**

It is the load bearing framework of the entire structure hence it has to be strong and rigid to retain and absorb vibrations and movement because of the engine, axes and suspension. It should be light weight as much as possible to enhance the performance of the vehicle, fuel efficiency and in racing cars it improves the overall dynamics of the car. Carbon fibre reinforced plastic is twice as stronger and at the same time much lighter than aluminum or steel material. Carbon fibre lacks flexibility, whereas metals can be welded and melted. Carbon fibre do not bend, they are stiff, under extreme force they can crack and break and unfortunately there is no repairing option. As we know that acceleration is defined as the change in velocity therefore it can be said that decrease in the overall weight results in same force and greater acceleration and that means race car with less weight has greater capability to accelerate faster.[4]

Figure 1 Carbon Fibre Chassis

The high-performance and light-weight properties of the carbon fiber ideally over high costs are typically used in super-automobiles. Only a part of carbon fiber can be a frame. Carbon fibers can be recycled but loses their strength, where aluminum and steel can be recycled as illustrated in figure 1.

- **Tailgate**

Tailgate is also produced with the help of carbon fibre reinforced plastics and according to the research the design should have 1.5mm of width (thickness) to prevent torsion.

It was possible to remove tailgate stabilizers because of the increased rigidity and reduced density which further reduced the overall weight of the car. Due to the quality of the carbon fiber material that can be painted directly, interior trim removal is carried out. It has to be designed to reduce the number of parts. It will allow the complex shapes to be easily assembled and delivered. The combination of carbon fiber with plastic helps in reducing the overall weight of 7 kg or 37%

ISSN- 2394-5125 VOL 7, ISSUE 1, 2020

- **Fender**

The fender made up of carbon fibers is more versatile and robust than single metal fibers, and since carbon fibers are much more compact than stainless steel, they have lesser weight that improves fuel efficiency. The resin coating the thermoset carbon fender makes them shiny and new, and the reflective fabric enhances their appearance. The textures of carbon fibers are much more noticeable than typical metals with scratches. Offers power dissipation, high efficiency, modular building and simple substitute advantages.

- **Side Doors**

The carbon fiber reinforced plastics version uses a reinforced structure designed to withstand different stresses, which eliminates additional weight of 4 kg per door when compared to aluminum and up to 11 kg as compared to steel. It is designed to handle specific stresses. Carbon fibre reinforced plastics offer high precision wall thickness, fibre orientation and layer structure design flexibility due to the material mixture. If more strength is needed, the material can be reinforced or fiber oriented without compromising the ultra-thin wall resistance in other areas. Cars manufacturers have widely used Carbon fibre reinforced plastics composites in sports cars and luxury cars, but only in a limited way for the driver's cars in shafts, bumpers, roof, pillars, fenders and interior structures as discussed above. Their composite material is a very versatile composite. The major factors limiting today's growth of the polymer composites in automobiles are long periods of production and fiber prices, high machinery investment and a lack of familiarity with the industry's carbon fiber material [12] as explained in table 2.

Table 2: Usage of carbon fibre in high end cars over the years

Model	Properties	Year
Porsche 959	Carbon fibre body panels / steel monocoque chassis	1987
Ferrari 288 GTO	Carbon fibre body panels / steel tubular space frame chassis	1985
Ferrari F40	Carbon fibre body panels + doors / steel tubular space frame chassis	1988
Ferrari F50	Carbon fibre body panels + doors / carbon fibre monocoque chassis	1996
Lamborghini Diablo SV	Mostly aluminum body panels, with carbon fibre bonnet + engine lid / steel tubular space frame chassis	1998
Lamborghini Diablo G	Mostly carbon fibre body panels + aluminum doors / steel tubular space frame chassis	1999
Mercedes McLaren F1	Carbon fibre body panels / carbon fibre monocoque chassis	1993
Mercedes Benz SLS AMG	Carbon fibre drive shaft, transmission tunnel for housing battery / aluminum space frame chassis	2011

ISSN- 2394-5125 VOL 7, ISSUE 1, 2020

Table 3: Drawbacks of Carbon fibre reinforced plastic

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
Reliability	1.Damagesare invisible 2.Ageingeffects are unknown 3.Highermaintenanceefforts
Production	1. Low tolerances 2. Expansive to tool hard to form– high scarp rate 3. Expansive materials

III. RESULTS AND DISCUSSIONS

Carbon fiber reinforced plastics have been used for decades in high-performance race cars, but only recently it has started to be introduced in traditional auto manufacturing. The carbon fiber car bodies are not only solid, but they are also highly resilient and can withstand the extreme conditions of driving. Automotive manufacturers typically use isotropic sheet metals which are joined through welding as illustrated in table 3. Composite materials such as CFRP have a laminated structure of carbon-fibers, providing support in two perpendicular directions. They are anisotropic/orthotropic. The anisotropic properties can be tailored in the desired directions to specific applications with different types of fiber reinforcements. These CFRP designs can give the safety of steel or aluminum at a high level of the crash. The composite material can also provide complex forms as one part and reduce the number of machining operations and joints. Nevertheless, there are also significant technical problems, as the coefficients for thermal expansion, electrical conductivity and composite surface finish vary from steel. For composite material characterization, designers need inexpensive and efficient simulation tools.

IV. CONCLUSION

Using highly advanced material is a very big task in an era were usage of steel is on full swing. Carbon fiber or carbon fiber reinforced plastic material is one option that has excellent properties. This paper discloses that if an alternative material is being used then it is possible to achieve both enhanced performance and lighter automotive at same time. The lighter automotive body also enjoys many ergonomic advantages. Racing cars are only meant for high speed and best stability which is offered by carbon fibre, if the racing car is lighter it will enhance its power to weight ratio and overall improving its performance and if carbon fibre reinforced plastic is used in body parts such as hood of the car, roof and boot then it helps in decreasing the overall center of mass of the vehicle and improves the dynamics of the car.

V. REFERENCES

[1] G. Zhao, J. Cao, T. Liu, N. Yang, and H. Zhao, “Research on the compressive strength of a passenger vehicle roof,” in *AIP Conference Proceedings*, 2017, vol. 1839.

[2] M. R. Bambach, “Fibre composite strengthening of thin-walled steel vehicle crush tubes for frontal collision energy absorption,” *Thin-Walled Struct.*, vol. 66, pp. 15–22, 2013.

[3] J. Fleischer, A. Ochs, and F. Förster, “Gripping Technology for Carbon Fibre Material,” in *International Conference on Competitive Manufacturing*, 2013.

[4] H. Petersson, D. Motte, and R. Bjärnemo, “Carbon fiber composite materials in modern day automotive production lines - A case study,” in *ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE)*, 2013.

[5] A. Al Mamun, M. A. Sawpan, M. A. Nikousaleh, M. Feldmann, and H. P. Heim, “Carbon fiber composite materials,” in *Lightweight and Sustainable Materials for Automotive Applications*, 2017, pp. 203–238.

[6] J. Z. Zhang, “Study on carbon fiber composite materials in sports equipment,” in *Applied Mechanics and Materials*, 2013, vol. 329, pp. 105–108.

ISSN- 2394-5125 VOL 7, ISSUE 1, 2020

[7] A. Chiru, L. Rad, T. Heitz, and D. Dogariu, "Calculus and technology of automotive parts in composite materials reinforced with carbon fiber," in *FISITA 2016 World Automotive Congress - Proceedings*, 2016.

[8] M. Y. Wu, M. L. Tong, Y. W. Wang, W. Ji, and Y. Wang, "Study on carbon fiber composite materials cutting tools," in *Applied Mechanics and Materials*, 2013, vol. 401–403, pp. 721–727.

[9] R. Masilamani, N. V Dhandapani, K. V. Kumar, and K. T. Mani, "A Review on Usage of Carbon Fiber Reinforced Plastics in Automobiles," *Int. J. Pure Appl. Math.*, 2017.

[10] T. Varun Kumar, V. Manoj Mohan Prasad, D. Santhosh, C. Prasanth, and K. Ranjith, "Evaluation of mechanical and interfacial properties of carbon fiber reinforced polymer (CFRP) composite materials," *Mater. Today Proc.*, 2019.

[11] M. R. Bambach, "Fibre composite strengthening of thin steel passenger vehicle roof structures," *Thin-Walled Struct.*, 2014.

[12] S. Mubashir and S. B. Muttana, "Carbon fibre composites: Outlook for the automobile sector," *Auto Tech Rev.*, 2012.