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Title of Report: Use of Carbon Fibre in Motorsport

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Abstract

Carbon fibre is a material that has revolutionised the world of motorsport engineering as it has an extremely high stiffness to weight ratio. Furthermore, it also has benefits when looking at how it absorbs energy and helps with crash structures. This report will review the properties of carbon fibre, manufacturing processes, and motorsport applications. Emphasis in this study is placed on how carbon fibre and design choices have an impact on performance and safety trade-offs.

Reference list

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Introduction

Carbon fibre was first introduced in the motorsport engineering world by McLaren in the 1980s. “In 1981 when McLaren introduced the MP4/1, the first Formula 1 car to feature a monocoque chassis made entirely from carbon fibre, the motorsport industry was changed forever” (Steve Bortolotti 2024). This shows that carbon fibre marked a turning point on the design of vehicles in motorsport. This is because it transformed vehicle performance and safety in a way that had not been seen before due to its lightweight, yet strong properties. This report explores the evolution, properties, manufacturing techniques, and applications of carbon fibre in motorsport. It also critically evaluates current research and considers future developments, including sustainability and cost-efficiency challenges.

Material properties and composition

Carbon fibre is made using a crystalline structure of carbon atoms. The fibres are usually intertwined into a fabric and combined with a polymer such as epoxy resin. This would then

result in the creation of carbon fibre reinforced polymers (CFRP) composites. This material has interesting properties such as:

- High tensile strength (up to 5650 MPa)
- Low density ($\sim 1.6 \text{ g/cm}^3$)
- High stiffness (elastic modulus $\sim 230 \text{ GPa}$)
- Corrosion resistance

Consequently, these properties make carbon fibre a solid choice when it comes to selecting a material for motorsport applications when weight reduction and structure are key factors. (Dionisis Semitekolos, , et al. 2024)

Historical Development in motorsport

Since McLarens first introduction of carbon fibre in motorsport in 1981 which displayed outstanding crash protection and reduced weight in comparison to aluminium counterparts. This development marked a cornerstone in the motorsport engineering industry and has resulted in carbon fibre becoming the standard material in F1 to this day.

Since then, the use of carbon fibre has expanded into a wide variety of motorsport branches. Examples of this would be endurance racing, rallying, and even electrical series such as Formula E. It is also used in various levels of motorsport competitions from professional racing down to amateur student level, like Formula Student.

Manufacturing techniques

The performance of carbon fibre can vary. This is down to a variety of manufacturing methods. Common examples include:

Prepreg Layup and Autoclave Curing: This is where high pressure and temperature is used to cure carbon fibre sheets that have been put into a mould. This manufacturing method results in high performance parts as it ensures that there is optimal resin distribution and fibre alignment.

Resin transfer moulding (RTM): This process consists of dry carbon fabrics being placed in a mould followed by resin being injected at a high pressure. Resin transfer moulding is a more suitable method for medium-volume production as it is a more cost-effective method.

Filament winding and 3d printing: This is an emerging manufacturing method. 3D printing allows for precise creation of carbon fibre parts with complex geometries. Furthermore, this method is also better with regards to waste material. However, this is still under development for high performance use in motorsport. (P.Phanindra Kumar, Dr. E.Siva Krishna, P.N.S.V.Jaswanth, B.Mahesh Babu 2024)

Applications in motorsport

The chassis and monocoque is the central structure of a race car. When constructed using carbon fibre they are extremely rigid and supply outstanding crash protection whilst keeping weight to a minimum. In F1 the monocoque is required to pass strict tolerances in FIA crash

tests from the front, side, and rear. Consequently, this supports the fact that carbon fibre is a solid choice for the monocoque as it has been passing test consistently across the years.

Aerodynamic components such as diffusers, undertrays, and front and rear wings are made from carbon. This is because it allows aerodynamic efficiency whilst maintaining a low mass. Furthermore, the stiff properties of CFRP ensures that deformation of the parts is kept to a minimum under high speeds of airflow.

Carbon fibre is also used in suspension and braking components. This is because the lightweight and thermal resistant properties of CFRP are essential. This is especially important in high performance brake discs as it allows for high performance without significant structural degradation

Carbon fibre is further used in safety systems such as crash boxes, the halo and side panels. This allows these parts to absorb and dissipate energy in the event of a collision. Thus, carbon fibre is essential in F1 for driver safety. (Steve Bortolotti 2024, Rozaini Othman, et al. 2019)

Performance and safety benefits

The main advantage of carbon fibre is the high strength to weight ratio. This has a direct effect on acceleration, braking and cornering as a car with less weight requires less power to move. This has a linear effect on fuel efficiency and tire wear, allowing cars to spend less time in the pit lane. Furthermore, the rigid properties of carbon fibre aid with aerodynamic stability and handling.

With regards to safety carbon fibre is a useful material. This is because the structure of carbon fibre allows for great energy absorption. This reduces the impact of the crash on the driver in the event of a crash. This is proven by the FIA's crash tests which demonstrates the materials ability to protect drivers in high-speed collisions. In addition to this, the halo which was added in 2018 is made from carbon fibre. This addition has further improved the safety of the cockpit, and it has been credited with saving lives in recent years. ((Dionisis Semitekolas, , et al. 2024)

Challenges and limitations

The high cost of raw materials and manufacturing processes limit the use of carbon fibre to high budget teams. This restricts the use of carbon fibre in smaller teams and consumer vehicles.

Furthermore, carbon fibre is difficult to repair. This is because it does not deform plastically as metals typically would. Damage often causes internal delamination which is hard to detect and repair. As a result, damage to carbon fibre parts often requires a full replacement of the part. Consequently, this causes issues with maintenance costs. (P.Phanindra Kumar, Dr. E.Siva Krishna, P.N.S.V.Jaswanth, B.Mahesh Babu 2024)

Future developments

With the development of 3D printing as a production method for manufacturing carbon fibre components. This would be done using carbon reinforced polymers which offers the potential

for faster and cheaper production. The advancements in this method of production are looking promising. As a result, it is likely that carbon fibre is accessible for lower tier motorsport teams or even road cars. (Rozaini Othman, et al. 2019)

Critical evaluation of literature

(Dionisis Semitekolos, , et al. 2024) provided a good analysis of the mechanical properties of carbon fibre and common manufacturing processes. Their reason for its dominance in motorsport is well supported by data.

(P.Phanindra Kumar, Dr. E.Siva Krishna, P.N.S.V.Jaswanth, B.Mahesh Babu 2024) They review the use of carbon fibre in the automotive sector. This is done by highlighting the benefits of carbon fibre, however, there is a lack of understanding for the economic and environmental issues that come with this widespread adoption of carbon fibre.

(Steve Bortolotti 2024) This article highlights the history of carbon fibre and how it found its way into the motorsport industry. It also gives valid insight into how carbon fibre has improved the racing industry over the years. However, as this article was published by Pfaff Technologies, there is likely to be commercial bias as they lean towards promotional content.

Figure

Figure 1:

Comparison of Material Properties Relevant to Motorsport Applications
(Adapted from Kumar et al., 2024)

Material	Tensile strength (MPa)	Density (g/cm ³)	Elastic modulus (GPa)
Aluminium	310	2.7	70
Steel	550	7.8	200
Carbon fibre	5650	1.6	230

Conclusion

Overall, carbon fibre has transformed the motorsport industry as it allows for lighter, stronger and safer vehicles. This combination of properties has made it a solid material of choice for chassis, brake systems, suspension, safety components and aerodynamic components. However, the downside to carbon fibre is ultimately the excessive cost of materials and manufacturing processes. Additionally, the limitations to repairing carbon fibre are also a downside. However, this could change with future developments as they are helping lower the cost of carbon fibre.