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The use of Composite Materials in Motorsport

Academic Skills (ACHA4005)

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1 Introduction

This report investigates the use of composite materials in motorsport.

Some investigation is made of historical use of composites, how usage developed and became widespread across multiple applications in the field of motorsport.

The report identifies advantages and disadvantages of composites and in what direction composite usage may move in the future.

A commentary has been provided on how use of composite technology in motorsport is being transferred into production applications in road cars.

2 Background

The exploration contained within this report was prompted by an article in the Racecar engineering magazine by Gemma Hatton (2019).

The magazine article was a comprehensive overview of the different types of materials which are used to create composites, the fibres, the resins, processing and applications for motorsport but, being a magazine article, did not have the space to delve more deeply into each area of content.

Further research was required to discover more about the advantages and disadvantages of different materials, their environmental impact and potential future developments.

This report crystallises that research and provides the reader with guidance for further reading references which will allow the reader to gather the same knowledge without having to perform the same discovery exercise as the author.

3 Discussion

3.1 Historical Perspective

It could be argued that motorsport has used composite materials from the earliest days, taking advantage of whatever materials were available to the vehicle builder that might give an advantage on the track. In the early days of motorsport, through the 1920s and early 1930s, when homologation and rules were not quite as important as today. Many racecars were “one off” specials and could combine wood and metal or other materials in the search both for performance and to reduce cost (Savage, 2009)

While the first production car to successfully implement a composite monocoque chassis was the Lotus Elite, designed by Colin Chapman in 1957, it wasn't until 1962 that the first fibreglass composite race car was produced. This was the Chapparral 2, commissioned by Jim Hall and James Sharp, built by Troutman and Barnes and first raced in 1963.

Chapparral's approach was revolutionary, strong, light and stiff. During an extremely short period of time the Chapparral 2 was continuously developed, introducing adjustable wings in 1966 with the 2D and by 1970 had evolved into the extraordinary Chapparral 2J (Blake Z. Rong, 2017), see Figure 1.



Figure 1 Chapparral 2J "Sucker Car" (Kevin McCauley)

The 2J made extensive use of composites, not just for the monocoque, but using materials such as the newly invented, polycarbonate plastic “unbreakable” Lexan, to engineer side skirts which allowed ground effect techniques to dramatically increase downforce, grip and cornering speeds. Other manufacturers complained and eventually the car was banned, but it gave a preview of what was possible with the application of composites.

Over the last 50 years composites have become ubiquitous in motorsport, the first carbon fibre composite monocoque F1 car, as shown in Figure 2, was the McLaren MP4/1, introduced at the Argentinian Grand Prix in 1981.



Figure 2 The McLaren MP4 carbon fibre monocoque (Piola)

The use of carbon fibre allowed McLaren to create an extremely light structure with very high strength and torsional rigidity, containing inserts to which the other components of the race car could be attached without compromising structural integrity (Piola & Somerfield, 2022).

This was a breakthrough which other manufacturers followed very quickly subsequent to seeing the remains of John Watson’s Grand Prix car after his 1981 crash in the Italian Grand Prix. Although the rear end of the car was ripped off, the monocoque remained intact.

Today 85% of a Formula 1 car is constructed from composites yet those components contribute only 25% of the weight (Hatton, 2019) and are also a fundamental part of the safety features protecting the driver of a modern race car.

3.2 Composite Technology

From the earliest days of using glass fibre in the production of motorsport components such as bodywork or wings, composites have allowed designers to imagine and execute complex shapes which modify the behaviour of a race car and enhance aspects of performance.

A composite material is usually composed of two or more elements, known as “phases”.

- The Matrix, commonly some kind of resin
- The Fibre, usually for reinforcement purposes.

Other available phases include fillers, particles or flakes. The finished combination of phases is known as a composite material (Kumar & Adiseshan, 2023).

Many different fibres and resins are available now to create components which not only have advanced design in terms of shape but also specific mechanical properties such as stiffness in particular directions, managed flex characteristics or ability to cope with different load requirements.

3.2.1 Fibre Technologies

A motorsport designer can choose the correct composite for each of the engineering challenges being faced and the demands of the component. Table 1 provides a summary of the characteristics of some common fibre options (Hatton 2019).

Table 1 Comparison of Reinforcement Fibre Types

Fibre	Advantages	Disadvantages	Notes
Glass Fibre	Lower cost than other fibres Can be relatively strong when filaments are as thin as 20 microns Good impact strength Easy to use Wide range of rovings, mats and woven options	Significantly less stiff than carbon fibre.	
Carbon Fibre	5 x stronger than steel 2 x stiffer than steel Highest specific stiffness commercially available High tensile strength Corrosion Resistant Good fatigue Resistance	Impact strength lower than glass or aramid fibres	Specific stiffness is stiffness relative to density.
Aramid Fibre	Create an incredibly stiff composite	Low compressive strength	Commonly used as a lighter alternative

	High tensile strength Lighter than glass fibre		to glass fibre in bodywork
Natural Fibre	Can match or exceed the performance of synthetic fibres in certain applications Flax has a lower density than glass fibre but higher specific stiffness More environmentally friendly than synthetic fibres	Potential shorter lifespan of finished composite (Kumar & Adiseshan, 2023)	Natural fibres are less commonly used in motorsport applications. Sisal, hemp and Flax are all natural fibres that have been used for composites.

Other fibres are also being explored as matrix reinforcement phases. These include metal fibres, such as boron, and even ceramic fibres (Aimplas, 2022)

3.2.2 Fibre Formats

Whichever fibre is being utilised, it can be supplied in various formats according to the required characteristics of the finished composite product (Kumar & Adiseshan, 2023).

Common formats include:

3.2.2.1 Roving

A roving is a bundle of fibres to which a degree of twist has been added. The name is a term taken from the weaving industry. Rovings were the precursor stage to spinning of thread from wool or cotton, for example. The spun thread would then be woven into material.

Roving bundles can be laid directionally to provide directional stiffness or may be woven into mats of woven roving.

3.2.2.2 Non-woven mat

A non-woven mat consists of chopped reinforcing fibres which are randomly combined into a mat which is non directional using chemical binders. This is then typically laid in a mould and acts as reinforcement for the matrix.

Non-woven mat is typically used for components which do not have directional mechanical properties, such as bodywork.

3.2.2.3 Woven mat

Woven mats are woven from fibres such as carbon or can be woven from a combination of fibres, such as carbon-kevlar. Many patterns of fibres and weaves are available which have specific mechanical characteristics when combined with the cured matrix. The look of woven carbon fibre components is very familiar to the public today. Often road

vehicles will have carbon fibre trim or mock carbon fibre trim to give the impression of motorsport heritage see Figure 3.

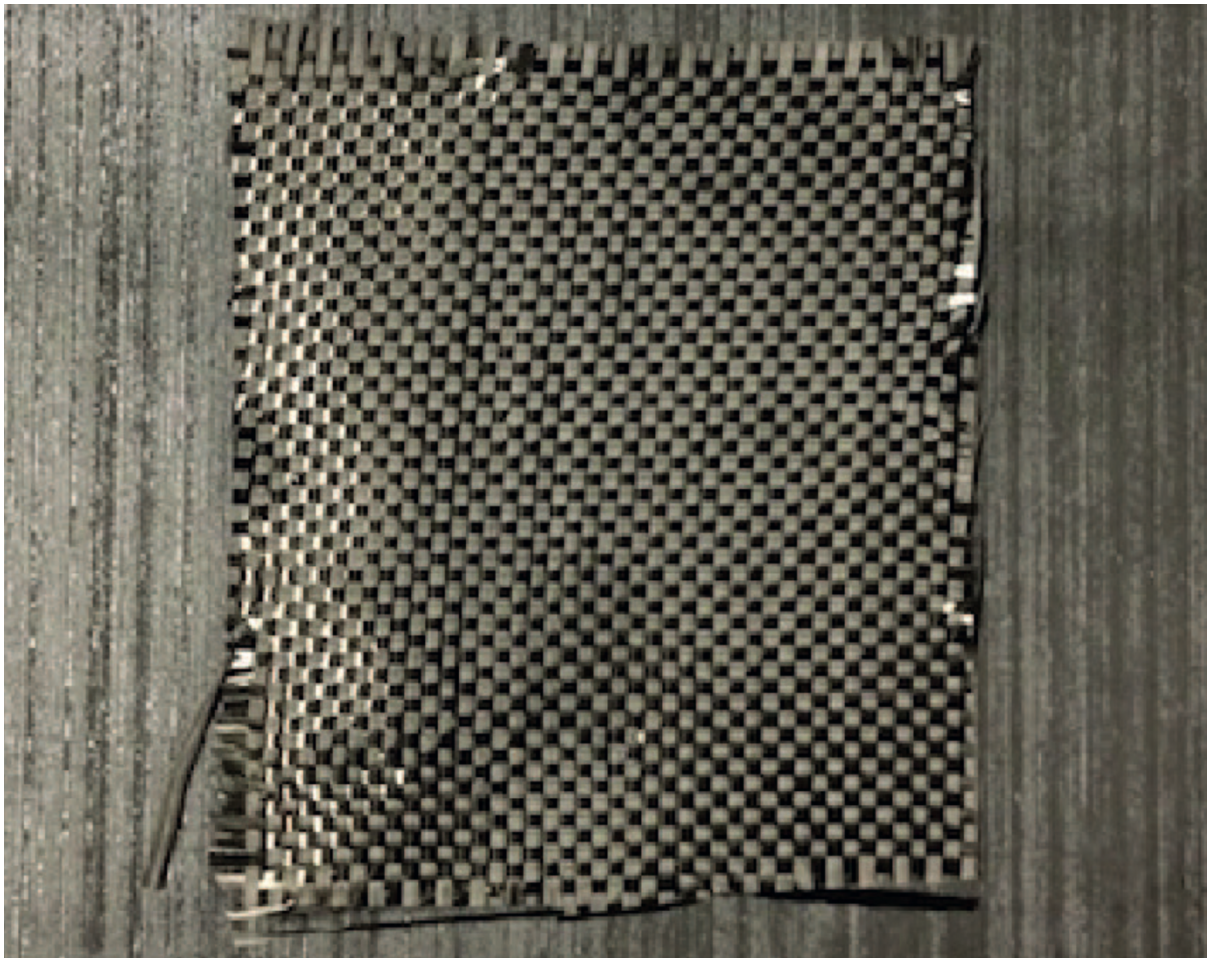


Figure 3 Typical non-impregnated carbon fibre woven mat (applemanbicycles)

3.2.2.4 Directional fibres

Uni-directional fibres are not woven at all but permit components to be made with rigidity in very specific directions. An example of a uni-directional composite element would be a suspension wishbone on a racecar.

3.2.3 Matrix Technology

The most common matrix technologies are organic matrices. These group into three common types: thermoplastic, thermosetting and elastomers. Most structural composite components in motorsport are manufactured using thermoplastic matrix (heat moulded) or thermosetting matrix (typically resin and hardener, such as polyester or epoxy resins) which can also be cured in ovens Figure 4.

MATRICES		
THERMOPLASTIC	THERMOSETTING	ELASTOMERS
Polypropylene (PP) Polyamide (PA) Polycarbonate (PC) Polyetheretherketone (PEEK)	Unsaturated polyester (UP) Epoxy resins Vinyl ester resins Phenols	Polyurethane (PU) Silicone (Si)

Figure 4 Types of Organic Composite Matrices (Aimplas, 2022)

Other components can make use of advanced matrices which could be metal or even ceramic. Ceramic matrices are particularly applicable for high temperature components such as exhaust manifolds (Kumar & Adiseshan, 2023).

4 Conclusions

There is no question that composite technology is here to stay in motorsport. From being used at the very highest level in Formula 1 racecars it has found its way into sportscar racing applications, Le Mans prototypes and even into road cars.

In the future even more advanced technology will be used to push the boundaries of motorsport performance.

This will also find its way into common usage for everyday motorists and can already be seen in the way composite plastic components are being used to reduce the weight but maintain rigidity in electric vehicles.

The research and development of engineering technology in motorsport continues to deliver advances for the public in general.

5 References

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