Optimization of the Vehicles Production by Using Lightweight Carbon Fibre Composite Materials

Minfeng Lin¹ and Qiang Mei²

¹ School of Management, Jiangsu University, Zhenjiang, Jiangsu Province, 212013, China
² School of Management, Jiangsu University, Zhenjiang, Jiangsu Province, 212013, China

*Corresponding author’s e-mail: Minfeng.lin@cranfield.ac.uk

Abstract: Through a brief introduction of the current application of lightweight materials in the automotive market, it is proposed that carbon fibre composites are a promising application. Therefore, it is constructive to study the advantages and disadvantages of the application and then put forward suggestions for improvement.

1. INTRODUCTION

1.1 Relevance to reducing carbon fossil-fuel consumption

The energy required for moving a vehicle is, except for aerodynamic resistance, directly proportional to its weight (Ford, no date). It is known to us that a lighter vehicle needs less fuel to get moved or accelerated, so the weight reduction in a vehicle could lead to saving of fossil-fuel consumption.

Using carbon fibre composites in automotive can leads to an average of 10 per cent weight saving in
an overall vehicle since this material is 60% lighter than steel, a traditional material (Pervaiz et al., 2016)\(^2\). Additionally, the weight reduction of one part often leads to secondary weight savings in other parts. For example, when the carbon fibre composite material is used to manufacture the car body, allowing manufacturers to use lighter bearings to match the weight-reduced body. For large parts, there is a common assumption that a 50% secondary saving is associated with 100% initial weight reduction. It has been shown that each kilogram of initial weight reduction could save on average 0.95 kilograms of secondary weight theoretically (Alonso et al., 2012)\(^3\).

To be more specific, there is a test which shows that a 10% reduction in vehicle weight could save 6%-8% fuel consumption (To et al., 2010)\(^4\). Another search on the LCA (lifecycle assessment) of engine cover shows that 30 per cent of weight saving of a part in the vehicle body could bring 21 kg of CO2 emission reduction in the lifespan of the vehicle (Pervaiz et al., 2016)\(^2\).

Currently, available lightweight materials include magnesium alloys and aluminium alloys. The reasons why I recommend introducing carbon fibre composites in the automotive industry are that they have the advantages of a lightweight, high rigidity, secure processing and forming, strong impact resistance, good durability, and excellent comfort. Using them in a vehicle is one of the most effective ways to reduce fuel consumption and emissions.

### 1.2 Additional benefits

#### 1.2.1 Energy security

Except for the excellent performance in combating CO2 emissions, using lightweight materials in the automotive industry also benefit to energy security on a regional basis, especially considering that short of energy has become a thorny problem in many countries (Pervaiz et al., 2016)\(^2\).

#### 1.2.2 Safety

The weight reduction of the body can move the centre of gravity down, which will improve the stability of handling, making the operation of the vehicle much safer, especially in a demanding driving situation. Additionally, carbon fibre composite materials perform exceptionally well in the area of energy absorption. The absorption capacity of collision energy is nearly six to seven times that of steel, which also improves the safety of automobiles.

#### 1.2.3 Comfort

Carbon fibre composites have higher vibration damping. It takes 9 seconds for light alloys to stop vibrations, but carbon fibre composites can stop for 2 seconds. The contribution in the performance of NVH (noise, vibration, and roughness of vibration) is also excellent, which enhance the conform of the vehicle to some extent.

#### 1.2.4 Road preservation

The weight saving of unsuspended parts, such as wheels, can also benefit to road preservation. A lighter vehicle reduces the hammering effect on roads, which can save the cost of road maintenance in the long run.

### 2. Objectives

The targets set for Europe about CO2 emission is 95 g CO2/km in 2020 (British Government, 2017)\(^5\). Pervaiz argued that in order to achieve this goal, we need to cut 200–300 kg in vehicle weight (Pervaiz et al., 2016)\(^2\). As production companies, in addition to considering the environmental benefits of lightweight vehicles, they also need to think about whether it is economically feasible. There have been a series of experiments about the relationship between weight reduction and the cost, and an assumption is that costs less than 6 dollars each kilogram of weight reduction were cost-effective(Brooker, Ward and Wang, 2013)\(^6\).
Compliance with the objective of pursuing weight-saving in a cost-effective way, two solutions are often be mentioned. One of them is to use high-strength steel wire replaces of carbon fibre composites in the hoop direction, leaving carbon fibres to provide longitudinal reinforcement. The other method is committed to the development of full automation of the installation process (Pridmore et al., 2015).

3. SUCCESS MEASUREMENT
Using carbon fibre composites to take the place of conventional materials could decrease the fossil-fuel consumption and hence carbon emissions during the use phase. However, the production of these lightweight materials generally calls for more energy and generates more GHG emissions. It is one of the factors why it is hard to measure the effects of weight reduction to energy consumption. Other factors, including the vehicle characteristics, such as dimension, driving habit and road gradients, also will affect energy consumption (Helms and Lambrecht, 2008). Therefore, it is essential to decide a proper method to measure the overall consequences of weight reduction to carbon emission. Life cycle assessment (LCA), which assess a product or system all stages of its service life (‘from the cradle to the grave’), is thus arguably the most appropriate approach for the evaluation (Cecchel et al., 2018).

4. RECOMMENDATION
Although the application of carbon fibre composites has shown us a promising future, there are still several technical issues that need to be taken into consideration.

First of all, the cost is one of the main reasons that limit the use of carbon fibre in the automotive industry currently. Recycling materials without degrading their properties is an essential means of reducing costs in this industry. Therefore, the recovery and reuse of carbon fibre is a critical area that needs to be researched (Kawajiri, Kobayashi and Sakamoto, 2020).

Another issue combined with using this material in a vehicle is that it is hard to repair when broken. The network structure of carbon fibre composite materials determines its higher hardness, but on the other hand, it also causes them challenging to improve when the structure is broken. Due to the characteristic of the automotive industry, the improvement of repair technology is one of the issues that must be considered.

Other skills needed in the application of this material, including the joining and assembly techniques and the quality assurance techniques. Additional knowledge required is about the long-term performance in the automotive use, environment durability and damage tolerance, and production cycle time (Mallick, 2010).

In order to produce a lighter vehicle that can be accepted by the market, a comprehensive project team needs to be established first. Team members need to be both market-oriented and research-oriented.
There are still some consumers in the current automotive market with the misconception that the weight of a car determines safety. The company's market personnel need to gradually change this misunderstanding through some campaigns, which can be launched by the company who produces the vehicle or cooperated with other companies in the same industry. Moreover, a company can joint relevant organizations or institutions to promote the benefits of weight saving in a vehicle to the environment and the performance of the vehicle, thus increase consumer demand for lightweight vehicles.

5. CONCLUSION
Although the application of carbon fibre composite materials in the production of the vehicle still faces some challenges, including the high manufacturing cost, difficult maintenance and the misunderstanding from some consumers. None of these difficulties can conceal the tremendous progress that carbon fibre materials can bring in reducing carbon emissions and improving automobile safety performance. The application of carbon fibre composite materials in the field of automobile production is an option that meets the requirements for energy saving and emission reduction.

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