Automobile Design Using Carbon Fiber as an Efficient Material

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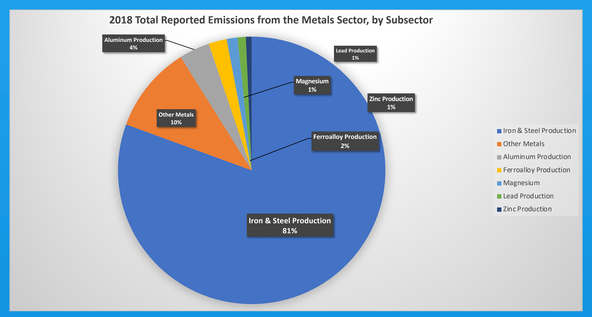
Introduction

Society depends on a variety of transportation means like cars, buses, trains, and airplanes. Vehicle manufacturing and transportation is one of the key elements of economies. Approximately 55 percent of a car's weight is steel, and involves a lot of solid waste that contain valuable products that can be reused economically. However, because of the growing steel demand, reuse is not in pace with production. The Iron and Steel production also causes 75 million C02e (Carbon emission), which is 80.5 % along with 19.5 % of other metals. However, there is an alternative material that some manufacturers are using instead of steel. Carbon fibers have high tensile strength and are very strong for their size. Although it's more energy-intensive than producing steel, and released significant amount of greenhouse gases. On the other hand, carbon fiber doesn't corrode, degrade, rust, or fatigue. This means it has a much longer lifecycle, so it potentially only has to be produced once where a steel part would have to be replaced multiple times. In consideration of these factors, This study explores the use of carbon fiber as an alternative material in designing transportation vehicles.



Objectives and Hypothesis

Aim: To explore the use of carbon fiber as an alternative material for transportation design

1.To study the current state of material in transportation

2.To evaluate the feasibility of carbon fiber as a material for planes, cars, and boats designs.

3.To develop a simple prototype of a typical transportation design (3D)

H_A: Current materials are inefficiency in transportation function

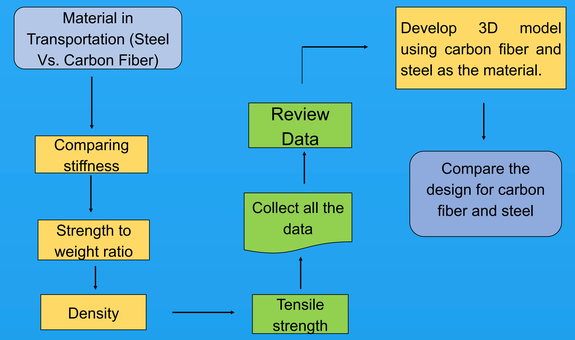
H_A: Carbon fiber is superior to other conventional materials

H_A: It is possible to incorporate Carbon fiber in 3D modeling for increasing efficiency

Background

Cheah (2010) observed that vehicle weight reduction is a known strategy to address the growing concern about greenhouse gas emission and fuel use by passenger vehicles. She found out that every 10 percent reduction in vehicle weight can cut fuel consumption by about 7 percent. Modaresi et al. (2014), also believes that a weight reduction of 10 percent results in a reduction of specific fuel consumption of 3-7 percent while maintaining the same functionality. According to Mainka et al. (2015), they develop a lignin-based carbon fiber. Lignin is the natural glue that holds wood fiber together. This can be used in a wide range of application which can be used in the automotive industry. In another study, carbon fiber/epoxy composites have been proven in difficult service applications like military helicopters and jet fighters for over 20 years. The material has infinite fatigue strength, as long as strain values are kept to a reasonable level, such as 0.3 percent (Brosius). Cobi (2012) designed a carbon fiber suspension system for FSAE applications. By bonding the aluminum insert and carbon fiber with surface preparation, it showed that it is 4 times stronger than the specimen with no surface preparation. Furthermore, Tsirogiannis (2015) finds that carbon fiber's density is similar to that of fiberglass, but what is worth noting is that it has the strength of aluminum alloy and the stiffness of steel.

Methods



- The current state of the materials in transportation design is studied through literature research. Google scholar will be used to research literature. The topic study will be limited to material design in transportation, carbon fiber uses in cars, and 3D modeling.
- The CES Database 2019 will be used to collect data on mechanical properties of the material. Comparative analysis will be used to study carbon fiber and steel.
- SolidWorks 2019 will be used to create a simple 3D model of an automobile and evaluate its mass properties.

Results and Discussion

Results 1

The common materials that are currently being used today to create millions of transportations whether it be in the automotive, aviation, or maritime industry are steel, rubber, plastics, and aluminum. Steel, which is one of the most used metals in the industry, is produced from iron ore (98% is to make steel). On average, 900 kilograms of steel are used in every car to construct a car's chassis and body, roof, door panels, and beams between doors. Steel is often used in mufflers and exhaust pipes. There's a global effort to improve the efficiency of ground vehicles, such as automobiles, buses, trucks, and trains to reduce the massive pollution that it produces. To tackle this problem, one of the solutions is reducing the weight of the vehicle by material substitution. It is found that reducing the weight of the car can reduce the fuel consumption and result in lesser emission. Instead of using cast iron and steel, aluminum, magnesium, plastic, or polymers such as carbon fibers are used. Material substitution is not an easy task. They are determined by the economic viability at large production values, weight savings potential, physical properties such as strength, stiffness and formability, safety performance, and environmental benefits.

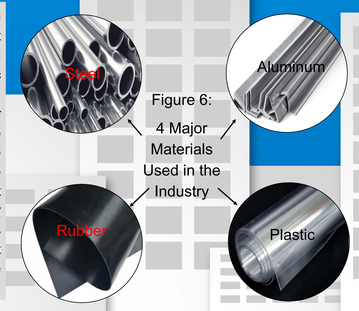


Figure 6: 4 Major Materials Used in the Industry

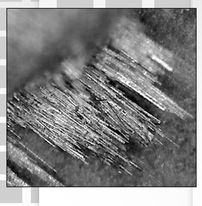
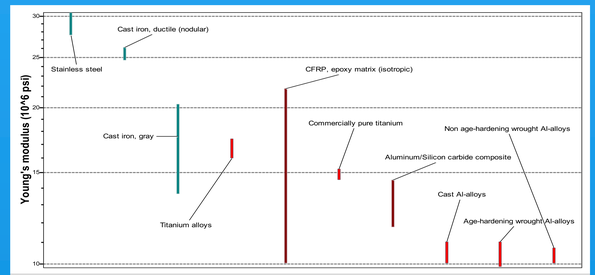
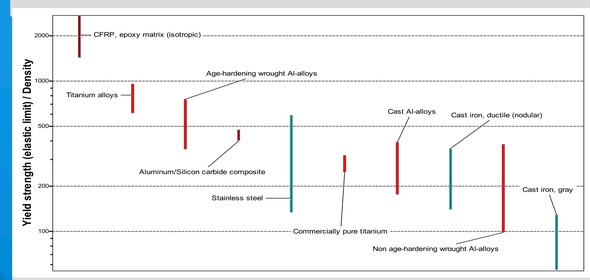


Figure 7: Carbon Fiber

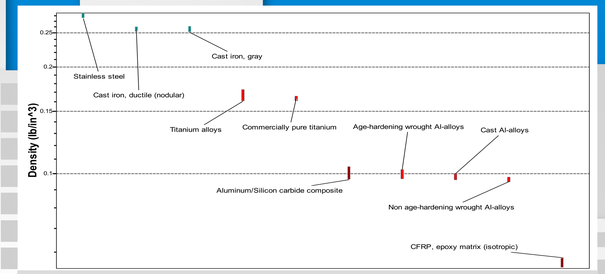
Carbon fiber is a flexible fabric-like material that offers a lot of advantages compared to today's material like steel or aluminum. By understanding and comparing its mechanical properties with other materials used in the manufacturing industry, we can determine how carbon fiber is an efficient material. Through the use of the CES Database, we can graph materials and compare its mechanical properties such as stiffness, strength to weight ratio, tensile strength, and density. By graphing its young's modulus, which determines the stiffness of the material, we can see that carbon fiber along with cast iron and stainless steel, it's one of the top 3 materials that have a high resistance to deformation (See figure 2). The next analysis is the strength to weight ratio of carbon fiber and other materials. We can see that out of all other metals, the tenacity of carbon fiber rises above all of it (See figure 3). Another property that was analyzed was the tensile strength of carbon fiber and other metals. Tensile strength is the resistance of a material to breaking under tension. By graphing it in the CES Database we can see that carbon fiber has a high tensile strength which pars with titanium alloy and stainless steel (See Figure 4). The last mechanical property that was analyzed was the density of carbon fiber and other metals. We found that carbon fiber is not very dense compared to other metals. It's at the bottom of the graph. That's why carbon fiber is an efficient material for reducing the weight of cars and other transportation (See figure 5). By considering this factor, we can create efficient transportation that reduces carbon emission and fuel consumption.



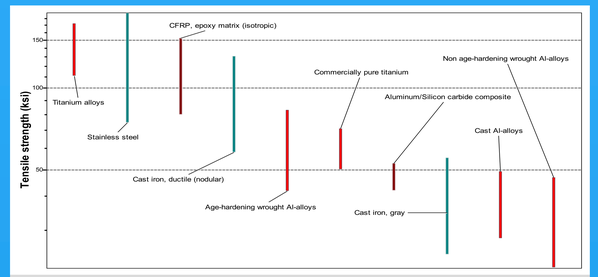
Stiffness of Carbon Fiber and Other Metals (Young's Modulus)



Strength To Weight Ratio of Carbon Fiber and Other Metals



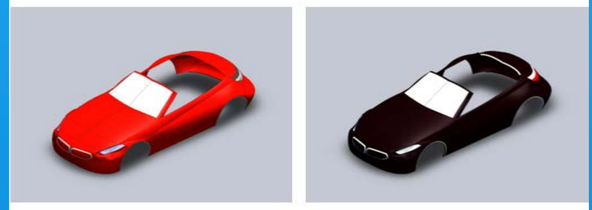
Density of Carbon Fiber and Other Metals



Tensile Strength of Carbon Fiber and Other Metals

To develop a simple prototype of typical transportation, SolidWorks is used as a CAD software. The design is based on the BMW Z4 Roadster. By creating this 3D model, the mass, volume, and density of the design is determined. These properties in solid works can be accessed by clicking the evaluate tab then mass properties. Two models, one using carbon fiber and one using steel are created. The mass of steel is almost 4 times greater than of carbon fiber. This proves that carbon fiber can have a massive weight reduction if the material is used (see figure 8). The density of steel is almost 4 and a half greater than carbon fiber. This is also another indicator that carbon fiber is lightweight (See figure 8).

Figure 8 :3D Car Models Using Carbon Fiber and Steel



Material:	Carbon Fiber (Red)	Carbon Steel (Black)
Mass	2.83 x 10^4 grams	1.11 x 10^5 grams
Volume	1.42 x 10^3 cm^3	1.42 x 10^3 cm^3
Density	1.78 x 10^{-2} g/cm^3	7.86 x 10^{-3} g/cm^3

Conclusions

- Through this research, it is observed that through material substitution, we can replace iron and steel with carbon fiber, aluminum, magnesium, or plastic as an alternative for manufacturing vehicles. This can reduce weight which cuts off fuel consumption which also reduces carbon emissions.
- Carbon fiber can par with steel and titanium alloys because of its high tensile strength, low density, stiffness, and its outstanding strength to weight ratio. The application of carbon fiber is not limited to ground vehicle, it can also be applied to the aviation and maritime industry.
- By comparing the use of carbon fiber and steel to the 3D model, it was determined that carbon fiber has less mass and it's less dense compared to the carbon steel which is heavier and denser

Future Research: Carbon fiber gives a ton of advantages but like any other material, it also has its disadvantages. Carbon fiber requires a lot of energy to be made and it's a slow process because the material is very delicate. Also, it's very expensive to manufacture on a large scale. There's a need to develop a better and cheaper process for producing carbon fibers. Lowering the cost of carbon fiber makes it a viable solution for vehicles and a wide variety of clean energy applications.

Acknowledgement

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