OKU Fen Bilimleri Enstitüsü Dergisi
Cilt 3, Sayı 2, 97-102, 2020

OKU Journal of Natural and Applied Sciences
Volume 3, Issue 2, 97-102, 2020

Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi

Osmaniye Korkut Ata University Journal of Natural and Applied Sciences

Yarış Arabası Aerodinamik Kanatlarında Atık Granül Kauçuk Lastik ile Oluşturulan Kompozit Malzemenin Fizibilitesi

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Araştırma Makalesi

Makale Tarihçesi:
Geliş tarihi: 24 Haziran 2020
Kabul tarihi:17 Ağustos 2020
Online Yayınlanma: 15 Aralık 2020

Anahtar Kelimeler:
Kompozit
Yarış Aracı Kanadı
Geri Dönüştürülmüş Lastik
Hafifletme

ÖZET

Son yıllarda, araç maliyetini azaltmak, yakıt tüketimi ve egzoz emisyonlarını en aza indirerek çevre dostu araçlar üretmek otomotiv endüstrisinin ve araştırmacıların vurguladığı ana konular arasındadır. Bu şekilde çevre dostu olan araçlar üretilecek ve zararlı gazlar doğaya daha az salınacaktır. Bu çalışmanın ana konusu atık kauçuk granül malzemesi kullanarak daha hafif bir yarış kanadı elde etmektir. Doğrudan daha hafif malzemelerden araçlar üreterek araçların yakıt tüketimini ve egzoz emisyonlarını azaltmak mümkündür. Son yıllardaki hafiflik çalışmaları, daha iyi mekanik özelliklere sahip olan ve çok daha hafif parçaların üretilmesini sağlayan kompozit malzemelerin üretimi ile sağlanmaktadır. Bu çalışmada, köpük çekirdek gövdesi ve atık kauçuk granül uygulamasının Formula yarış aracı kanatlarına uygulanmasını karşılaştırmak için sonlu eleman analizi yöntemi kullanılmıştır. Analiz sonuçları şekillerde toplam deformasyon ve Von-Mises gerilmelerinin dağılımı olarak sunulmuştur. Sonuç olarak, atık kauçuk granül malzemesinin hem daha iyi mekanik özelliklere hem de makul maliyete sahip olduğu ve yarış araçlarında kullanılabileceği bulunmuştur. Özellikle, kilogram başına kullanılan parçaların maliyetinin onda bir oranında azaldığı görülmüştür.

Feasibility of a Composite Material Formed with a Waste Granular Rubber Tire on Racing Vehicle Aerodynamic Wings

Research Article

Article History:
Received: 24 June 2020
Accepted: 17 August 2020
Published online: 15 December 2020

Keywords:
Composite
Racecar wing
Recycled tire
Lightweight

ABSTRACT

In recent years, reducing the cost of vehicles, fuel consumption, and producing environmental-friendly vehicles by minimizing exhaust emissions are the main topics that the automotive industry and researchers emphasize. In this way, more environmental-friendly vehicles will be produced and harmful gasses will be released less into nature. The main subject of this study is to obtain a lighter race wing by using waste rubber granule material. Reducing the fuel consumption and exhaust emission emissions of vehicles is possible by producing vehicles directly from lighter materials. The light weighting studies in recent years are provided by the production of composite materials that have better mechanical properties and enable the production of much lighter parts. In this study, a finite element analysis method was used to compare the application of foam core body and waste rubber granule application to formula vehicle racing wings. The results of the analysis are presented in the figures as distribution of total deformation and Von-Mises stresses. As a result, it has been found that the waste rubber granule material has good mechanical properties and reasonable cost, and it can be used in racing vehicles. In particular, it has been found that the cost of parts used per kilogram is reduced by a tenth.

To Cite: Karaçor B., Akar MA., Özcanlı M., Serin H., Baş O. Yarış Arabası Aerodinamik Kanatlarında Atık Granül Kauçuk Lastik ile Oluşturulan Kompozit Malzemenin Fizibilitesi. Osmaniye Korkut Ata Üniversitesi Fen Bilimleri Enstitüsü Dergisi 2020; 3(2):97-102.

1. Introduction

Today, reducing the fuel consumption and exhaust emissions of vehicles are possible by producing vehicles directly from lighter materials. However, many parts of vehicles are traditionally made of metal materials. In recent years, these parts have been started to produce from composite materials that have similar mechanical properties and enable much lighter parts to be produced. Advances in materials science and their composite applications are also the focus of researches. Technological improvements help designers in a wide range, from reducing internal engine friction to achieving low aerodynamic friction values. Among these developments, the use of lightweight materials has played an important role in maintaining vehicle weight, against the additional weight of technological parts and passenger safety and comfort features[1].

Vehicle manufacturers expect that steel production will continue as the main body material, and they expect increased use of plastics/composites in certain parts of the vehicle. By using the hybrid use in this way and the combination obtained from such systems, the importance and versatility of the material technology will indicate how it will lead to applications in the vehicle bodies of the future[2]. Renewable, recyclable, and innovative lightweight materials are not a new feature in automotive design. However, more emphasis on the overall life cycle impact of a car has led to an increase in research and development in the field of material science in recent years. In the automobile industry, not only measures for renewability but also sustainability is another issue to focus on, so environmentally friendly and sustainable action is a goal for most automakers. Today, automakers are implementing methods such as effective waste management, increasingly using renewable energy sources, and developing materials that improve the vehicle's fuel efficiency[3]. With its high specific strength and modulus properties, fatigue and corrosion resistance, thermal expansion coefficient, ability to adapt to composites, it has been used not only in the automotive industry but also in the aviation industry as an alternative to metallic material applications. After a certain period of aviation, there has been an extraordinary growth in carbon fiber composites and it has been shown that structural plastics can be used in place of isotropic metals in heavily loaded applications. In case the repetitive production cost of composites is equal to or lower than an equivalent aluminum structure, it is more convenient to apply composites on a large scale[4].

The use of new and sustainable materials in some racing vehicles shows their effectiveness and suitability in a harsh environment. Producing some parts of the car from a recycled carbon fiber reinforced with a polyester resin containing recycled PET bottles affects the life of the parts as well as recycling them. The fact that some aerodynamic parts contain natural fiber reinforced composite components in this race vehicle shows not only the sustainability used in the production of the materials but also the consideration of the environmental impact when the end of use is over[5]. G. Savage[6] expressed that the usage of composite materials in racing cars increased gradually. With the developing technology in the field of materials, it was seen that the cars in the races were lighter, safer, and faster. It is stated that the change in racing vehicles is not only in certain regions but almost every point of the vehicle.

Optimization studies have become continuous in the field of materials to increase performance and improve competition with vehicles in the other team. Thus, vehicle parts that are lighter but equivalent to strengths in metal materials are produced. Narayana and Burela [7] studied the properties, structures, and areas of application of different types of multifunctional composite materials. The difficulties in the design and analysis of these structures and the advantages they provide to different areas (automobile, aircraft, space) were shown. Recently, significant improvements have been made on cost, component life, and weight of the material, with material changes in areas other than automotive, using different composite materials. These materials were produced with different production methods and the most suitable method was researched, and the theoretical comparisons of the parts were made by applying the finite element analysis method [8, 9]. Composite applications are increasing day by day due to their superior mechanical properties, low cost, sustainability, and less harm to the environment in the aviation industry apart from automotive. The weight of the composite parts used the increase in the part life, and the biodegradability increases the preference rates. These parts have been subjected to different tests and comparisons have been made with traditional materials, and optimization methods have been determined by theoretical analysis [10, 12].

2. Material and Method

Aero packages of vehicles designed and manufactured for racing have important effects on performance and emissions. As an aero package, there are two wings on the back and front of the vehicles. Wings are generally produced from sandwich composite materials. The materials generally consist of structural foam, carbon fiber, and epoxy resins. In this study, composite material was created with waste rubber granules and resin. The created material will be analyzed using the finite element method and the usability of the material in wing construction will be investigated and a comparison will be made with the carbon/epoxy composite material used. Default mechanical properties of carbon/epoxy composite according to ANSYS Workbench software program were performed. The values in that study [13] were used for the properties of the waste rubber granules. At the same time, the mechanical properties of the waste rubber granule material were created using general mixing rules (Eq.1) in composites. The ratio of the epoxy mixture in waste rubber granule composite was calculated by accepting 10% by volume. Material properties are given in Table 1.

$$E_c = \left(f \times E_f\right) + (1 - f) \times E_m \qquad (1)$$

E_f= Material properties of fiber

E_m= Material properties of the matrix

f= Volume fraction of fibers

Table 1. Material Properties

Properties	Waste Rubber Granule/Epoxy	Carbon Fiber/Epoxy		
Density (kg/m³)	1010	1490		
Young's Modulus (GPa)	7,701	X direction	Y direction	Z direction
		121	8,6	8,6
Tensile Yield Strength (MPa)	3600	X direction	Y direction	Z direction
		2231	29	29
Tensile Ultimate Strength (MPa)	5600	-		

3. Finite Element Modelling

The vehicle wings of the Cukurova Racing team, which are currently designed and manufactured within the Automotive Engineering department, were used as a reference for the study. The chassis of the car has a length of 2199 mm and a width of 675 mm. Besides, the height of the main hoop is 1075 mm and the front hoop's height is 500 mm. The car can reach a maximum speed of 83 km/h. The air wings were designed by using a computer-aided design program; it is shown in Figure 1. This design was analyzed in CFD and the required lift force was calculated with this program. Using this formula [Eq.2] lift force was obtained. While making these calculations, analysis calculations in these studies[14,15] were also used.

$$F_L = \left(\frac{1}{2}\right) \times \rho) \times V^2 \times S \times C_L \qquad (2)$$

F_L= Lift force
ρ = Air density
V= Velocity
S= Planform Wing area
C_L= Lift coefficient

The static analysis was used for the finite element method. The length and width of the main flap are 850 mm and 395 mm respectively. The upper and middle flaps are equal in length and are designed as 850 mm and 199 mm. The width of the side supports of the wings is 725 mm, while its height is 583 mm. The analysis was applied depending on the following assumptions:

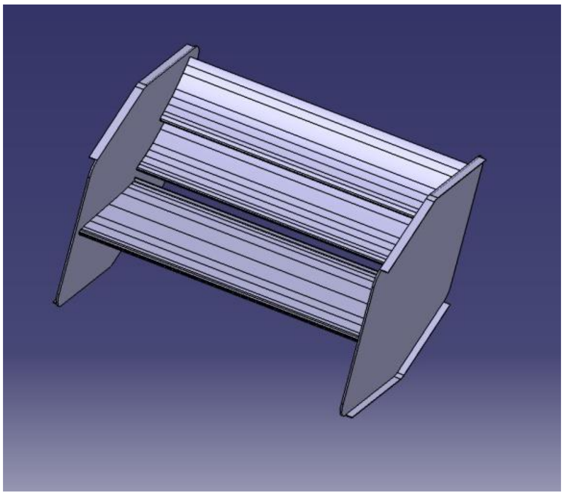

Figure 1. 3-D model of the rear wing

- According to race rules[16], aerodynamic parts should stand a force of 200 N and in the load bearing direction that should not deviate by more than 10 mm. It should also be able to resist a force of 50 N applied from any point in any direction, and its deflection should not be more than 25 mm. The average speed to which the wings will be exposed in the races was accepted as 80 km/h with the previous racing experiences and the racing car wings were analyzed with FEM. The racing wings were analyzed both independently and on the vehicle.
- As a result of this numerical analysis calculation, the pressing force applied to the main flap was 272 N, the middle flap was 127.5 N and the force on the upper flap was 42 N.
- First, carbon/epoxy material was applied to the wing surfaces and then analyzed. Then, waste rubber granule material was applied to the wing surfaces and static analysis was performed.
- Carbon fiber material was applied to the wing side supports.

4. Result and Discussion

The finite element analysis showed that the highest deformation was occurred for waste rubber granule aerodynamic wing design due to the mechanical properties. When the weights of the wing designs are compared, it can be seen that the waste rubber granule wing design is the lightest. However, the highest deformation occurred for waste rubber granule aerodynamic wing design. The stress value of carbon fiber aerodynamic wing design was greater than waste rubber granule wing designs. The analysis results are shown in Table 2. In Figure 2, Figure 3, Figure 4 and Figure 5, von-misses stress and deformation distribution of materials are shown.

Table 2. Analysis Results

	Carbon Fiber/Epoxy	Waste Rubber Granule/Epoxy
Weight(kg)	23,445	22,145
Total Deformation(mm)	0,17	0,59
Maximum Stress (Mpa)	1,459	1,226

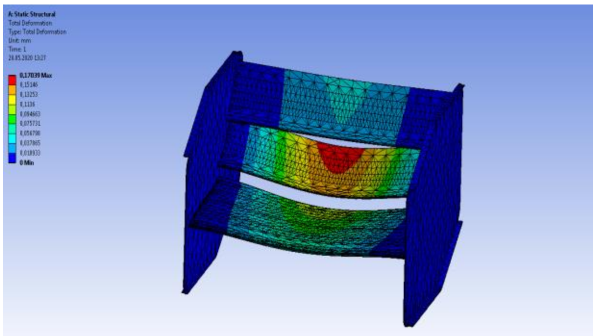

Figure 2. Equivalent stress & deformation distribution of Carbon fiber/epoxy aerodynamic wing

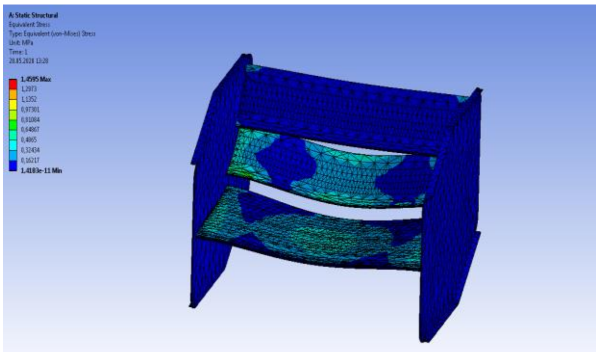

Figure 3. Equivalent stress & deformation distribution of Carbon fiber/epoxy aerodynamic wing

Total deformation is 0,17 mm when carbon/epoxy composite material was used as seen in the figure also equivalent stress is obtained 1,459 MPa. The total deformation value of carbon fiber aerodynamic wings is lower than the waste granule aerodynamic wing design.

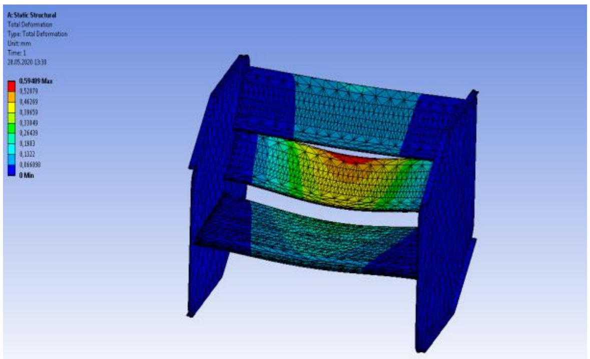

Figure 4. Equivalent stress & deformation distribution of Waste rubber granule aerodynamic wing

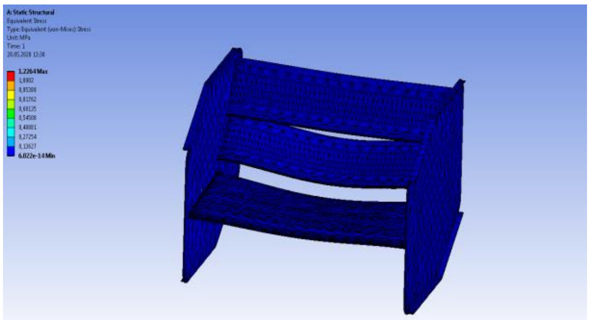

Figure 5. Equivalent stress & deformation distribution of Waste rubber granule aerodynamic wing

Total deformation is 0,59 mm when the waste rubber granule/epoxy composite material was used in the figure also equivalent stress is obtained 1,226 MPa. The maximum stress using waste rubber granule/epoxy material is lower than carbon fiber/epoxy aerodynamic wing design.

5. Conclusion

In this study, stress and deformation distribution of waste rubber granule aerodynamic wing design was investigated and the comparisons of waste rubber granule aerodynamic wing design were made with Carbon fiber/epoxy aerodynamic wing design. Throughout the study following conclusions were obtained;

- The lighter wing design was obtained with 22.145 kg waste rubber granule aerodynamic wing.
- Using waste rubber granule aerodynamic wing provided a significant weight reduction. The aerodynamic wing weight is reduced by 5,54% approximately.
- The deformation was found 0.59 mm by waste rubber granule which is higher than the deformation of carbon/epoxy material.
- The highest von Mises stresses value was achieved using Carbon fiber/epoxy aerodynamic wing design. The value of equivalent stress was noted 1,459 MPa as waste rubber granule aerodynamic wing was observed 1,226 MPa.
- It also affects the cost by using waste rubber granule material. The cost of waste rubber granule material is about $ 2,93/kg, while carbon fiber material is about $ 30/kg.

Acknowledgment

The authors would like to thank the Cukurova University Scientific Research Project Coordination (FBA-2019-11936) for financial support for this project.

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