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WEIGHT REDUCTION OF WHEEL RIM USING 'PEEK' COMPOSITES

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Abstract

This work of research deals with the design of a wheel considering PEEK composite also known as Polyether Ether Ketone for the purpose of weight reduction in the automobiles specifically cars. So, after analyzing the designed wheel in the analysis software under the standard loading conditions, we are able to draw two basic points. Firstly, less deformation occurrence when compared to standard alloy wheel while experiencing same forces and secondly, the weight of the wheel is reduced by 40 to 50% when compared to the same design composed of an alloy. Hence, the main purpose of this project is achieved which is to reduce the un-sprung mass of an automobile helping us to achieve a better road grip, traction and handling of the vehicle. These types of wheels are preferable for high performance cars like formula one or where slightest change in the weight has a huge impact on the performance and cost is not an issue.

Introduction

A huge portion of the overall mass of the vehicle is supported by the suspension system which is called sprung mass and it includes mass of the driver, passengers, cabin, engine and all of the peripherals mounted above the shock absorbers or leaf springs, these absorbers help prevent the riders

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from the various bumping effect while providing a plush feel. The rest of the parts which are mounted below the shock-ups are considered in the category of un-sprung mass some of them are wheel axles, wheel, hub, brakes and steering rods.[1] As wheels have always been a topic of advancements with a great scope of weight reduction either by changing the design of the spokes (i.e. removal of material) or by replacing the core material for the achievement of better high-end performance parameters such as stability of the vehicle, faster acceleration and better traction control with this being mentioned, there are some downsides too, that comes along with the weight reduction of the un-spring mass if done off-limit and might lead to, losing the traction over the surface.[2] Hence, a sweet spot in between the weight of the wheel and the normal forces through the contact patches is very crucial to the performance of the vehicle.

The Fuel consumption of a vehicle is largely affected by the variation in the weight of the vehicle. Hence, to achieve the lower fuel consumption rate and higher mileage the first factor to be considered must be the vehicle's weight. [3] It can be done by finding the alternatives to the current best material (in this case aluminum alloy) being used in wheels while considering mechanical properties and weight of the same. One such material is Poly-ether Ether Ketone abbreviated as PEEK composite as it continues to outstand steel, aluminum, titanium, bronze and other high performance alloys because of its top- class mechanical, structural and thermal properties. With these, it also has great resistance towards various oils, corrosive or any other fluids present in any automobile. Thus, PEEK composite is an ideal replacement for the aluminum alloy. PEEK composites are basically of three types to be considered in general:

- PEEK with 30% glass fiber
- PEEK-90 HMF with 20% carbon fiber
- PEEK-90 HMF with 40% carbon fiber [4]

Objectives

To study the various stresses generated in PEEK composite wheel and comparing the results with that of an aluminum alloy wheel of the same dimensions and having the same structural design under the same loading conditions thus further emphasizing the superiority of PEEK composite material as a replacement for the standard wheel material used in F-1 car racing.

Significance

By using PEEK as an alternate material for the manufacturing a wheel for F-1 racing, following goals can be achieved:

- Reduction in overall weight of the F-1 car.

- Less fuel consumption rate as compared to traditional racing car having an aluminum alloy wheel due to less inertia of the vehicle.

- Better life cycle as compared to aluminum alloy wheel due to less stress generation.

- Due to the less rotational weight, energy required for acceleration and deceleration is lesser than compared to aluminum alloy wheels.

- By reducing the un-sprung weight, the suspension will rebound much faster thus providing better overall control on the track.

Design Specifications

Table 1. Wheel Specification.

S.NO	Specification	Value (mm)
1)	RIM WIDTH	364.4
2)	WHEEL DIAMETER	357.5
3)	OFFSET	226.77
4)	RIM THICKNESS	4
5)	BOLT DIAMETER	12
6)	NUMBER OF BOLT HOLES	18

- For comparison purposes, the design specification is kept same for both aluminum alloy wheel and PEEK.

• The average weight of a F-1 car is around 740 kg, therefore the load applied during analysis does not pushes the PEEK material to its elastic limit. Hence, the material is safe for the application.

Comparison between properties of aluminum alloy and PEEK composite considered for the research:

Table 2. Material Properties.

Sr. No.	Properties	Alloy	PEEK
1.	Density (g/cc)	2.685	1.475
2.	Hardness (Rockwell-M)	120	101
3.	Tensile Strength (MPa)	483	140
4.	Yield Strength (MPa)	345	98
5.	Modulus of Elasticity (GPa)	69	21
6.	Poisson's Ratio	0.33	0.45
7.	Melting Point (°C)	500	343

• **Below design of a F-1 car wheel is considered for the study purposes:**

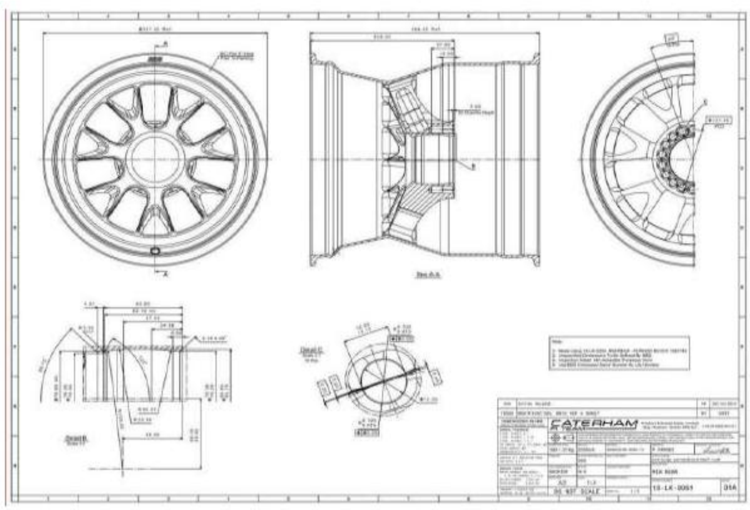

Figure 1. Wheel Drawing.

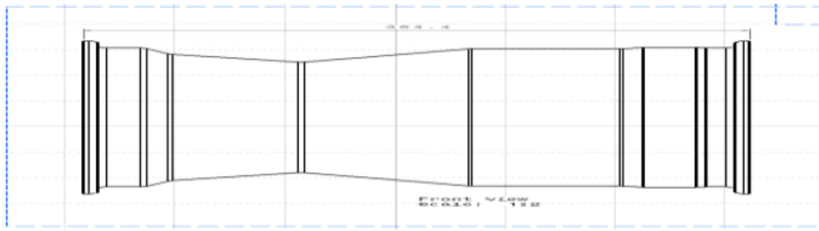

Figure 2. Front View.

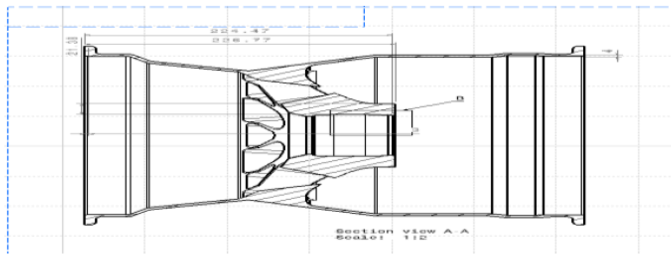

Figure 3. Sectional View.

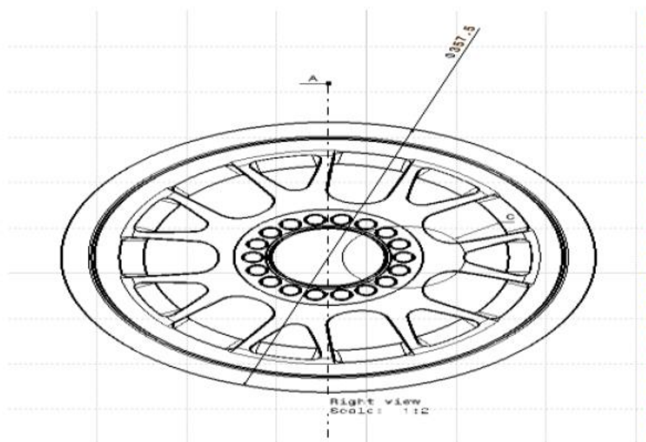

Figure 4. Side View.

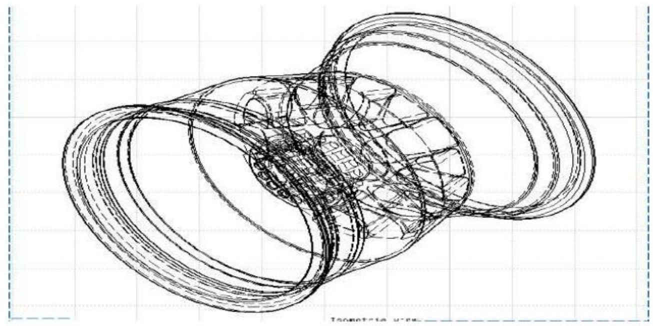

Fig. 5. Isometric View.

Software Used

CATIA: -

Computer Aided Three-Dimensional Interactive Application also abbreviated as CATIA. It is amongst the top designing software available in the market right now and has been used by multiple mechanical industries varying from small basic ones to the top-notch sophisticated industries. It offers many easy-to-use features for different requirements:

- Designing of parts: With the help of this feature one can easily design any part according to the specified dimensions.

- Wireframe: For any complex designing, this feature comes into the play and helps the designer to construct any complex geometry with ease.

- Dynamic Simulation: As just designing is not enough, world class industries requires dynamic/kinematic solutions too [5].

Figure 6. CATIA V5.

ANSYS

This is one of the most user-friendly and easy to use software amongst its competitors in the market and is capable of solving any type of complex problems, may it be for structural or thermal analysis. It can determine every bit of flaw in great depth with the help of its various engines performing simultaneously some of the parameters it provides are stresses, deformations, modal analysis for vibrational characteristics of the component. While its advanced features are useful for the determination of complex material behavior properties and various dynamic effects. [6]

The geometries of various complex components designed in designing tools like Creo, CATIA or solid- works can be imported with just a click and then the desired type of analysis can be performed along. As far as, results are concerned, it provides us with the easy to understand graphical images, signifying the areas to be modified for optimal performance.

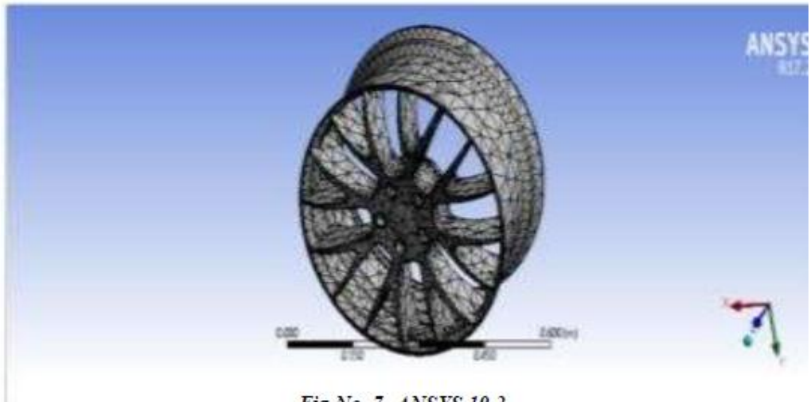

Figure 7. ANSYS 19.2.

ANALYSIS

Note: Applied load is 1000Pa on both Aluminium alloy and PEEK composite and via analysis we are trying to compare the Total deformation of the rim, Equivalent Elastic Strain through ansys and Equivalent Stress.

Aluminium Alloy:

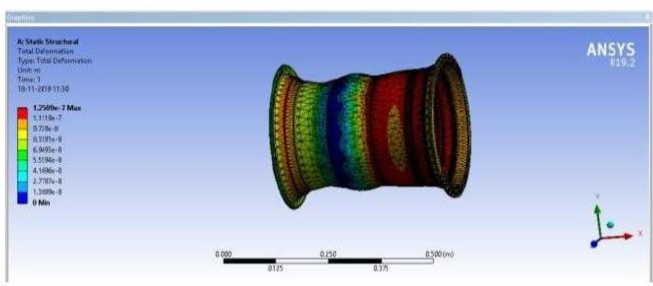

Fig. 8. Total Deformation.

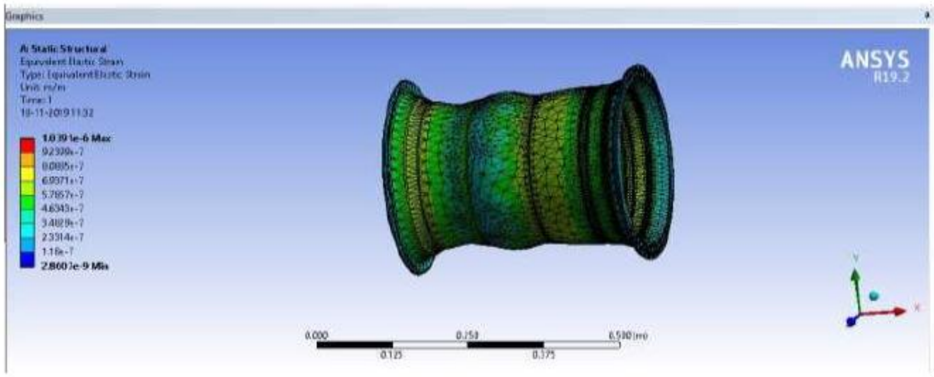

Figure 9. Equivalent Elastic Strain.

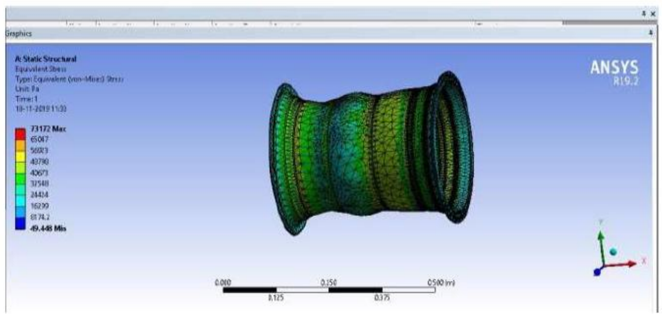

Fig. 10. Von Mises Stress.

Poly-ether-ether-ketone:

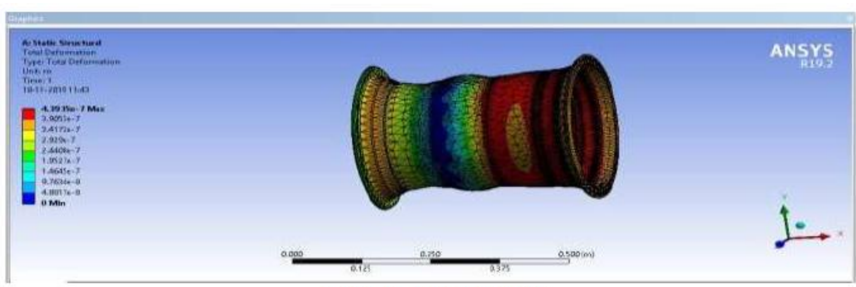

Figure 11. Total Deformation.

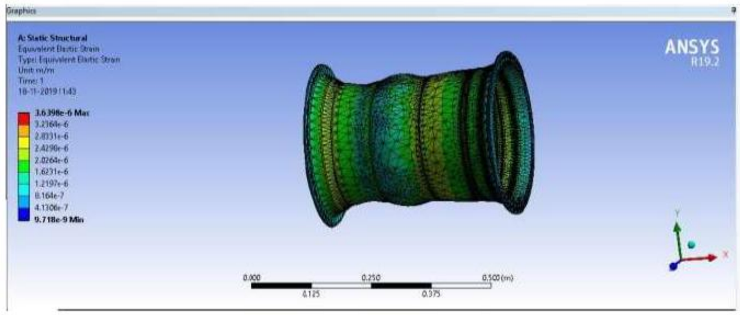

Figure 12. Equivalent Elastic Strain.

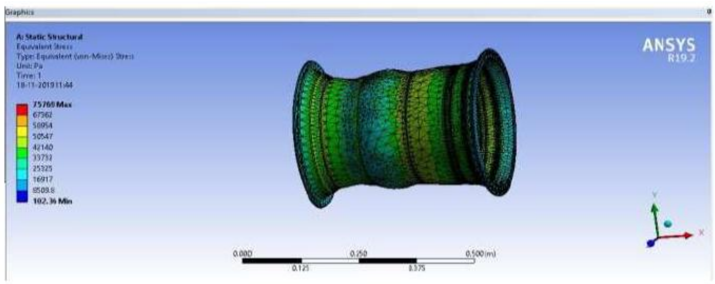

Figure 13. Von Mises Stress.

Results and Discussion

Table 3. Results of Materials.

Sr. No.	Material	Weight	Deformation (m)	Von- Mises
1.	Aluminium Alloy 2024	7.1kg	1.2509e-7	73172Pa
2.	PEEK	4.3kg	4.3935e-7	75769Pa

There is noticeable weight reduction of approximately 40% in the wheel rim.

• While studying, we found out that PEEK is the far superior material as compared to aluminum alloy as shown by different Ansys analysis.

• While considering Von Mises stresses, all materials show similar properties almost as same as obtained values.

• We can conclude that PEEK can sustain more stresses under the same specified conditions as aluminum alloy and hence, would deform less.

Conclusion

Thus, by replacing the core material we will be able to achieve a 40% of weight reduction in the wheels using PEEK material while comparing it to the Aluminum Alloy material. Also, the deformation of PEEK material is less than the Aluminum alloy wheel. However, the Von Mises stress of both the material is quite comparable. Finally, from the results it is clear that PEEK composite is the best material to replace the Aluminum Alloy for F-1 car wheel manufacturing material owing to reliability and safety aspects.

References

[1] Arun Nair, Dhiraj and K Bhandarkar, Performance enhancement and analysis by reducing weight of un- sprung mass of formula student racing car, International Journal of Mechanical and Production Engineering, ISSN(p): 2320-2092, ISSN(e): 2321- 2071 Volume- 6.

[2] R. Manivannan, R. Rajasekar and V. K. Gobinath, Modelling & analysis of four-wheel rim by using PEEK composites Material Science & Engineering 2(6) (2018), 177-183.

[3] Chaitanya Sureddi, Design, Material Optimization and Dynamic Analysis on Automobile Wheel Rim, DOI: 10.29322/IJSRP.8.11. 2018. p. 8353.

[4] Daniel Antony and Prince Jerome Christopher, Design and analysis of two-wheeler alloy, DOI:10.15680/IJIRSET.2016.0505219.

[5] https://www.designtechcadacademy.com/knowledge- base/catia-training.

[6] https://www.cadit.com.sg/Solutions/Products/ANSY S_Structural_Mechanics.