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STRUCTURAL AND THERMAL ANALYSIS ON HONEY COMB STRUCTURE WITHDIFFERENT MATERIALS

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Abstract

Light weight is one of the primary goal for the development of wheels. A new type of automobile wheel is proposed in the present work. The wheel is divided into tread, spoke and wheel hub. The spoke layout is designed based on the honeycomb structure by considering load bearing performance of wheel. The analysis is carried out by the varying the material of core wall of honeycomb structure. Structural steel, aluminum alloy, carbon fiber and polyethylene are used as a core material. The mechanical performances are analyzed and results shows that maximum stress and deformation which can meet design requirements like strength and stiffness of the wheel.

Keywords: honeycomb structure, ANSYS, temperature distribution, strength-to-weight ratio, light weight and structural integrity.

Introduction

Honeycomb structures have been widely used in many engineering applications due to their high strength-to-weight ratio, energy absorption capability, and thermal insulation properties. These structures are composed of a series of hexagonal cells that form a uniform lattice structure. The lattice structure provides a high stiffness-to-weight ratio, which makes honeycomb structures an attractive option for lightweight and strong materials. In this paper, we present a structural and thermal analysis of honeycomb structures with different materials using finite element analysis in ANSYS software. The main objective of this study is to evaluate the mechanical and thermal properties of honeycomb structures made from different materials. The study investigates the effect of material properties on the performance of the honeycomb structure and compares the results for different materials. The honeycomb structure is modeled in ANSYS software using a 3D solid model with hexagonal cells. The mechanical properties of the materials, including the Young's modulus, Poisson's ratio, and density, are inputted into the software. The study analyzes the deformation and stress distribution under various loading conditions, including static and dynamic loads. Additionally, the study evaluates the thermal behavior of the honeycomb structure and compares the results for different materials.

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Statement of the Problem

Honey comb structures are known for the high strength to weight ratio and stiffness, which means they can support heavy loads and resist deformation under stress while remaining light weight. Honey combs can be made of variety of materials and each material offers different mechanical properties. Therefore, the objective of this paper is to perform a comprehensive analysis of honeycomb structures with different materials on wheel structure using finite element analysis with ANSYS software. The study will investigate the effect of material properties such as stress, strain, deformation, heat distribution and total flux on the structural and thermal performance of honeycomb structures. The results of this study will provide valuable insights into the selection of appropriate materials and manufacturing processes for honeycomb structures to optimize their structural and thermal performance. The study will contribute to the development of more efficient and cost- effective honeycomb structures for various applications.

Objectives of the study

- Investigating the effects of different materials on the structural and thermal properties ofhoneycomb structures.
- Comparing the strength-to-weight ratios of honeycomb structures made from different materials.
- Examining the thermal performance and thermal conductivity of honeycomb structures madefrom different materials.

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Review of Literature

Gadagottu et al. [1] analyzed, traditional materials for automobile chassis were replaced by composite materials and then Structural and, fatigue analysis will be carried out on three models to all materials and select the best material Impact analysis can also be done for the selection material in all models Software's used in this work solid works for modeling ANSYS 14.5 for analysis. Ingrole et al. [2] determined, novel design and performance improvement of new auxetic-strut structures were presented. A comparative study of in-plane uniaxial compression loading behavior of regular honeycomb, re-entrant auxetic honeycomb, locally reinforced auxetic-strut structure and a hybrid structure of combining regular honeycomb and auxetic-strut structure was conducted on 3D printed samples. Vijayan et al. [3] observed, pertinent information of an existing heavy vehicle chassis of EICHER is considered for modeling and analysis for polymer composite materials namely, Carbon/Epoxy, and cross-sections like C, I and Box type subjected to the identical load as that of a steel chassis. The numerical results are validated with analytical calculation considering the stress distribution and deformation. Thomas et al. [4] formulated, the behavior of honeycomb structure has been reported through experimentation, mathematical and numerical models. The influence of cell wall thickness, node length, cell size and loading has been studied in detail leading to some important findings which have not been addressed earlier. The crushing responses of honeycomb structure have been studied in both out-of-plane and in-plane loading condition. Alia, R. A., et al [5] analyzed, the compression properties and energy-absorbing characteristics of a carbon fiber- reinforced honeycomb structure manufactured using the vacuum-assisted resin transfer molding method (VARTM). Bonanno A et al [6] determined, to protect the operators from falling objects and it is usually made of a steel skeleton with a metal plate. In this study, sandwich panels were proposed as technical solution for the impact protection from falling objects in earth moving machines. Sri rama sarma et al. [7] presented, honeycomb structure has been offering best optimizing results when compared to bent spokes structure by performing experiment of 'Modelling and analysis of intelligent tyre alternatives for better performance. Murali B et al. [8] formulated, honeycomb structure wheel design is better suited for high load carrying capacity by doing experiment of Design and finite element analysis of resilient wheel with honeycomb structure. Zhaohua wang et al. [9] observed, design idea of 'wheel rim surface & rib' can solve the light weight problem of complex wheel rim structures by conducting experiment.

Research Methodology

Finite Element Method (FEM): FEM is a numerical method used to analyze complex structures by dividing them into smaller elements. FEM can be used to calculate stress, strain, and displacement within a honeycomb structure. The equations used in FEM are based on the principle of virtual work, and the stiffness matrix can be calculated using the following formula:

$$[K] = \int \{[B]T[D][B]\} dv$$

Where [K] is the stiffness matrix, [B] is the strain-displacement matrix, [D] is the material stiffness matrix, and dv is the differential volume element.

Thermal Analysis: Thermal analysis of honeycomb structures involves calculating the temperature distribution within the structure, as well as the resulting thermal stresses. The thermal conductivity of the material can be calculated using the following formula:

$$q = -k\nabla T$$

Where q is the heat flux, k is the thermal conductivity, and ∇T is the temperature gradient.

Below values shown in the table 1 represent the properties of the four materials that have been selected to perform structural and thermal analyses.

	Aluminum	Structural steel	Carbon epoxy	Polyethylene
Young's modulus	7500	2E+5	1.2334E+5	1100
Poisson's ratio	0.334	0.3	0.3	0.42
Yield strength	500Mpa	25Mpa	741Mpa	25Mpa
Density	2180	2770	1518	950

Table 1. Various properties of our selected materials

Below fig 1. Shows the meshing image of honeycomb structure wheel of a following dimensions

- Wheel diameter – 50 mm
- Tread thickness – 1 mm
- Internal hub diameter – 12 mm
- Hub thickness – 2 mm
- Wheel thickness – 18.5 mm
- Cell thickness – 1 mm

Fig 1. Mesh image of honeycomb structure wheel

Boundary conditions

Boundary conditions in various analyses like static, transient and thermal analysis were given as below shown in figures fig 2, fig 3 and fig 4.

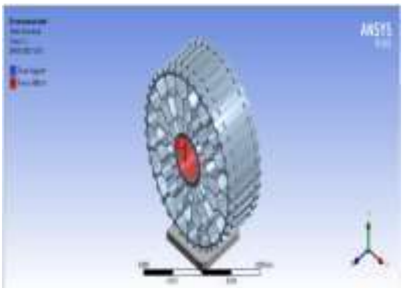

Fig 2. Static analysis

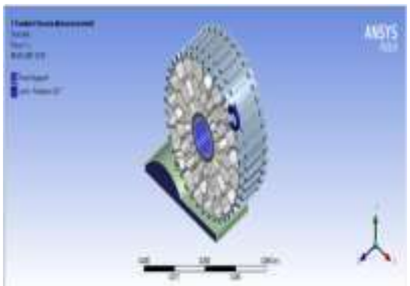

Fig 3. Transient analysis

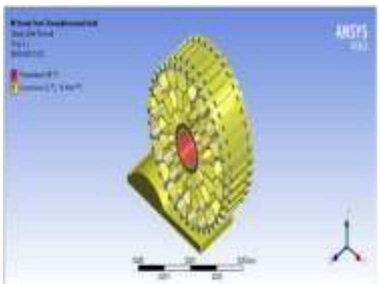

Fig 4. Thermal analysis

Results and Discussion

the basic difference between static analysis and transient analysis is the time duration. In static analysis the input conditions are given and the output results are obtained independent the time period. It will give the overall stress values for the given conditions. Whereas in transient analysis the output is dependent on the time. That means the result may vary based on the time period given.

Static Analysis

Total Deformation

Below figures fig 5, fig 6, fig 7 and fig 8 shows that total deformation values in various mentioned materials while performing static analysis.

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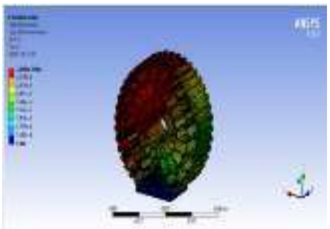
Fig 5. Aluminium alloy

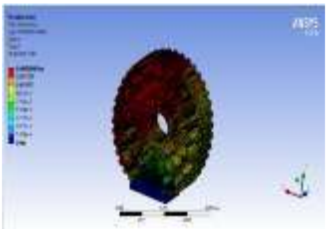
Fig 6. Carbon epoxy

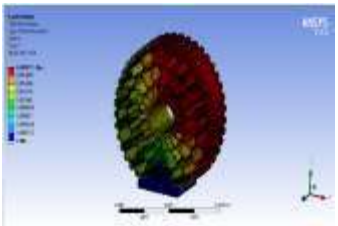
Fig 7. Polyethylene

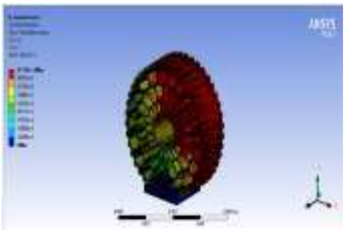
Fig 8. Structural steel

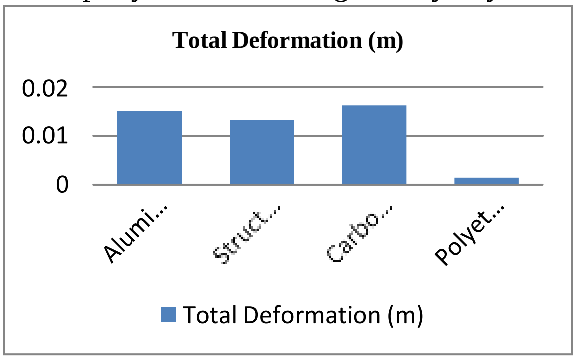

chart 1. Graphical representation of deformation values

By considering the basic load acting on the wheel be taken as 1000 N (approx. 100kg), the following are the deformations acting on the honeycomb spoke. And the above figure shows the max distribution of the deformation on different materials.

Equivalent stress

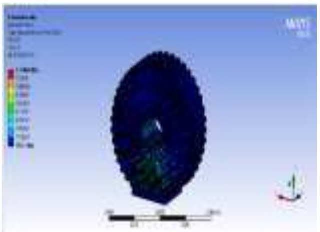
Fig 9. Aluminium alloy

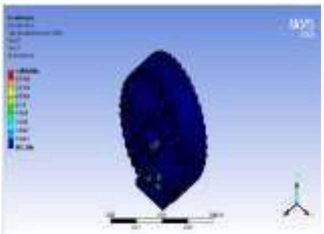
Fig 10. Carbon epoxy

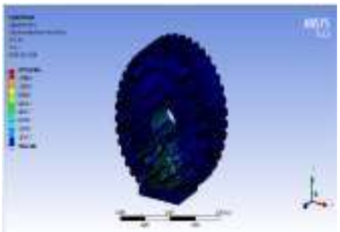
Fig 11. Polyethylene

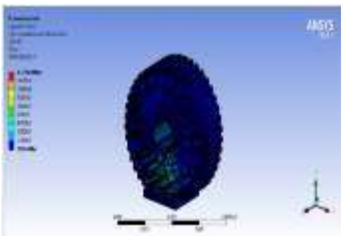
Fig 12. Structural steel

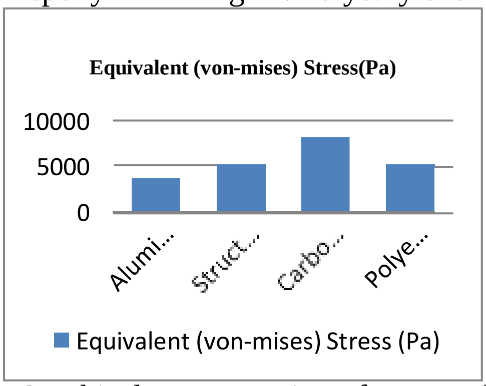

chart 2. Graphical representation of stress values

Above figures fig 9, fig 10, fig 11 and fig 12 shows that equivalent stress values in various mentioned materials while performing static analysis. Here the reaction force is acting from the lower end of the spoke and maximum stress is obtained at lower surface.

Equivalent strain

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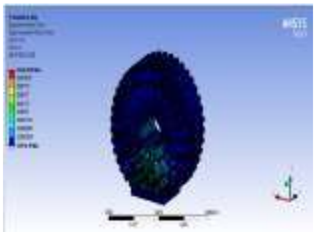

Fig 13. Aluminium alloy

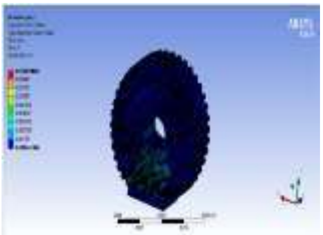

Fig 14. Carbon epoxy

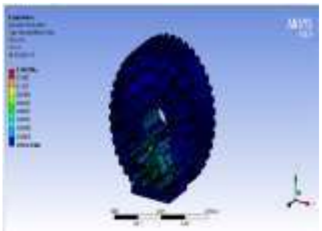

Fig 15. Polyethylene

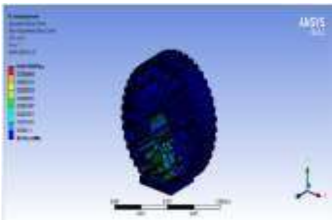

Fig 16. Structural steel

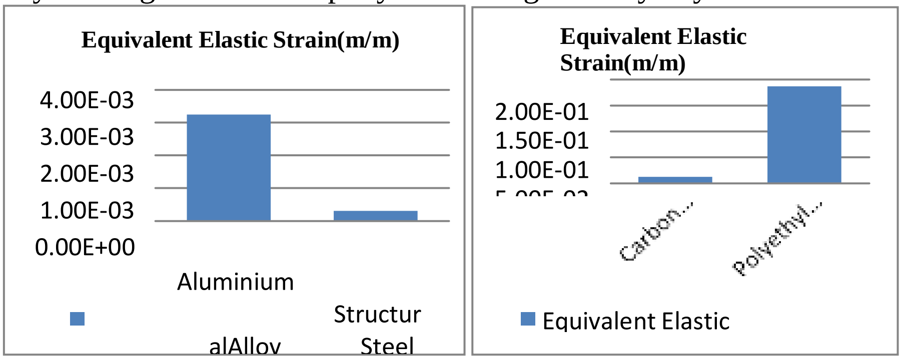

chart 3. Graphical representation of strain values

Above figures fig 13, fig 14, fig 15 and fig 16 shows that equivalent strain values in various mentioned materials while performing static analysis. The strain acting with respect to the direction in which reaction force is obtained or the portion where the stress is obtained as shown in the above figures.

Transient analysis

Total Deformation

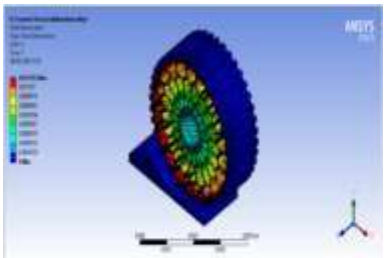

Fig 17. Aluminium alloy

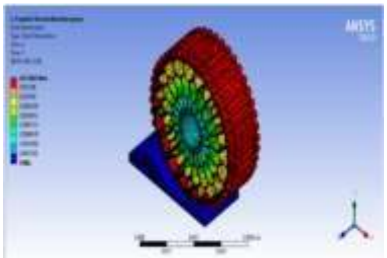

Fig 18. Carbon epoxy

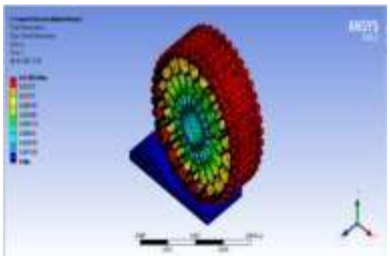

Fig 19. Polyethylene

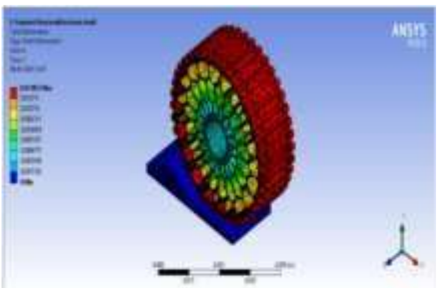

Fig 20. Structural steel

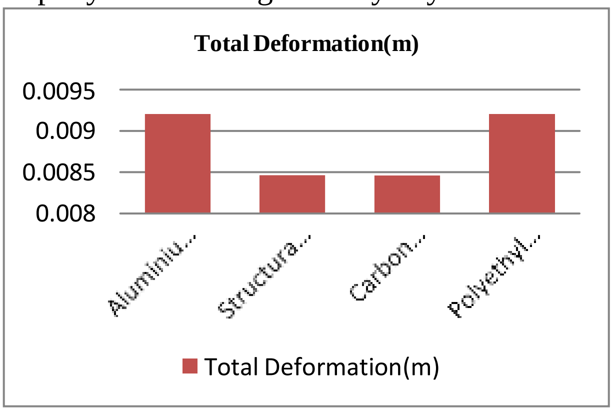

chart 4. Graphical representation of deformation values

Above figures fig 17, fig 18, fig 19 and fig 20 shows that total deformation values in various mentioned materials while performing transient analysis. Here the transient conditions are assumed as follows; a load of 1000 N acting on a body which is rotating at a speed of 30^{o} angle for 10 seconds.

Equivalent Stress

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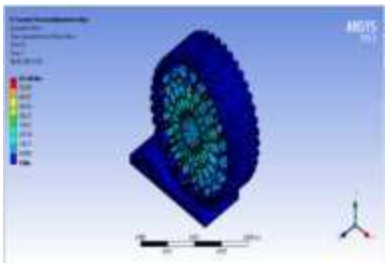


Fig 21. Aluminium alloy

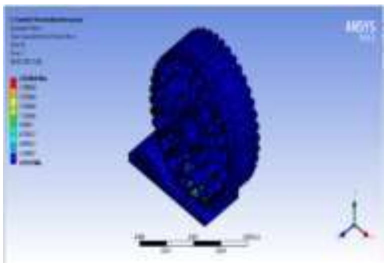


Fig 22. Carbon epoxy

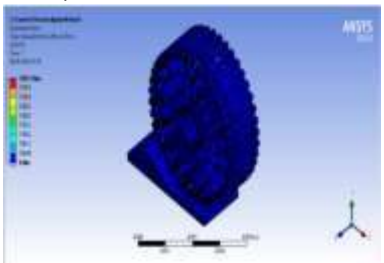


Fig 23. Polyethylene

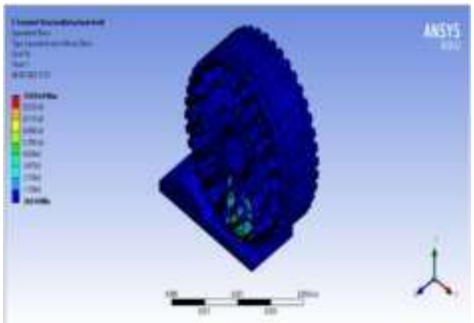


Fig 24. Structural steel

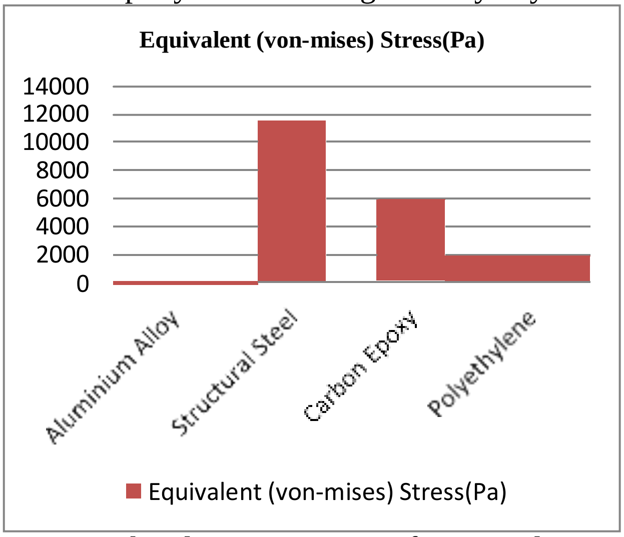


chart 5. Graphical representation of stress values

Above figures fig 21, fig 22, fig 23 and fig 24 shows that equivalent stress values in various mentioned materials while performing transient analysis. They show the stress distribution of the rotating member including the load acting on it.

Equivalent strain

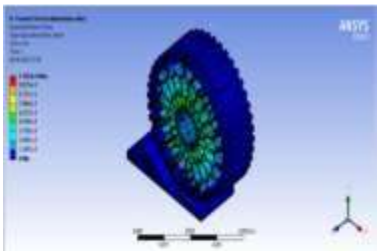


Fig 25. Aluminium alloy

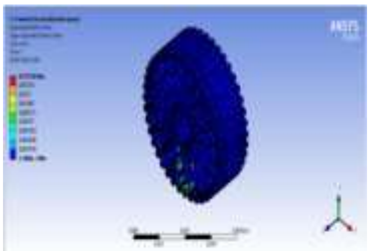


Fig 26. Carbon epoxy

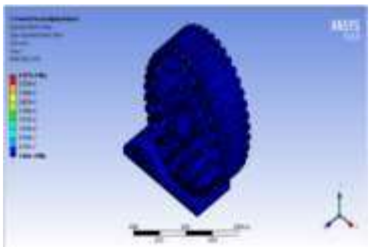
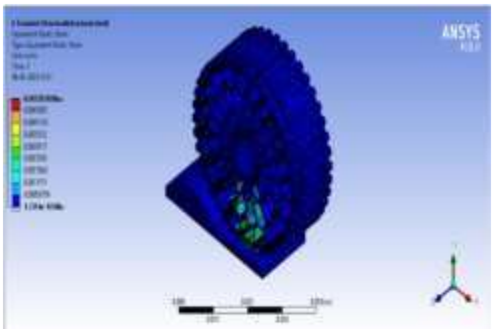
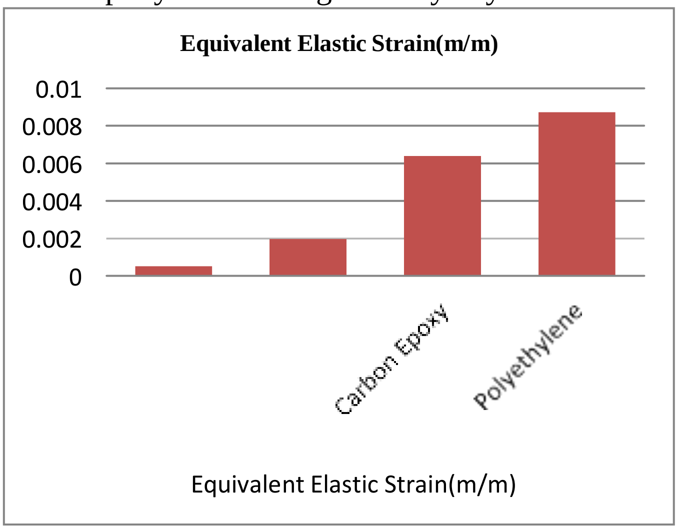


Fig 27. Polyethylene





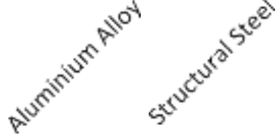


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Fig 28. Structural steel

chart 6. Graphical representation of strain values

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Above figures fig 25, fig 26, fig 27 and fig 28 shows that equivalent strain values in various mentioned materials while performing transient analysis. These shows the equivalent strain acting where the stress is obtained. And the equivalent elastic strain values are plotted on the above graph.

Thermal Analysis

With the temperature assumed to be 80° at the hub, the temperature distribution and the amount of heat transferred is determined as follows.

Temperature

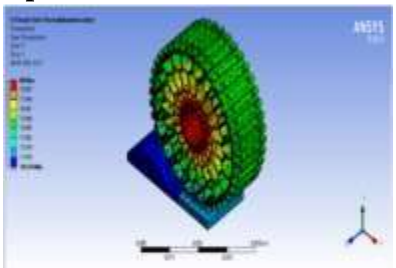

Fig 29. Aluminium alloy

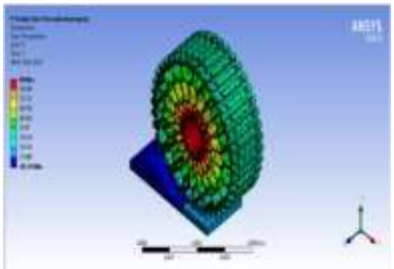

Fig 30. Carbon epoxy

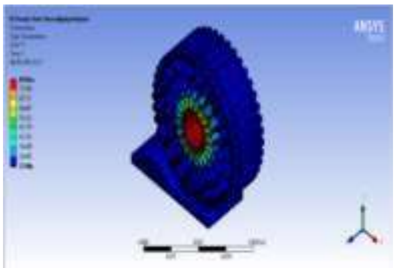

Fig 32. Structural steel

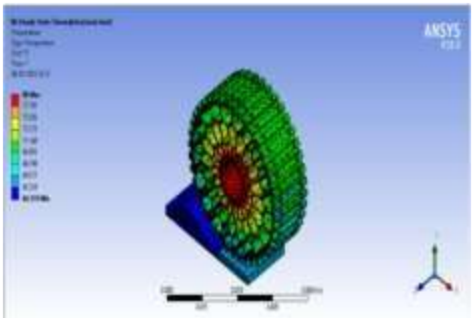

Fig 31. Polyethylene

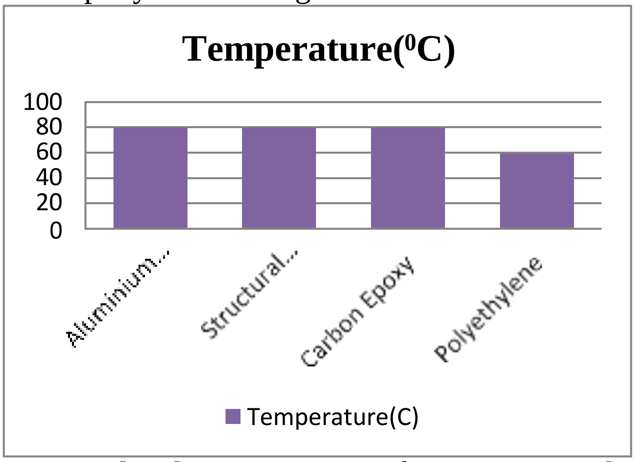

chart 7. Graphical representation of temperature values

Above figures fig 29, fig 30, fig 31 and fig 32 shows that temperature values in various mentioned materials while performing thermal analysis analysis.

Total heat flux

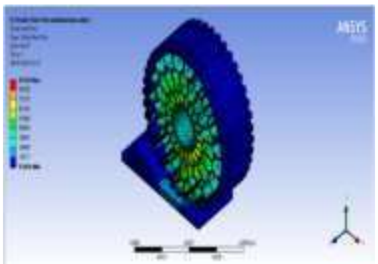

Fig 33. Aluminium alloy

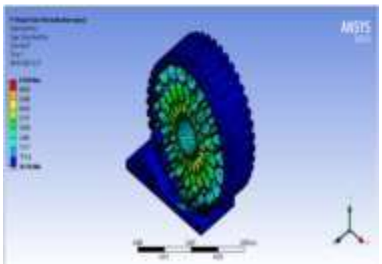

Fig 34. Carbon epoxy

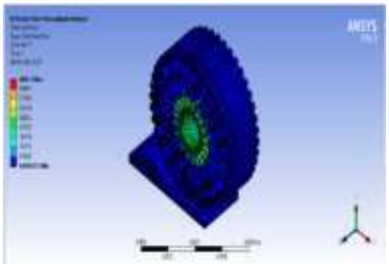

Fig 35. Polyethylene

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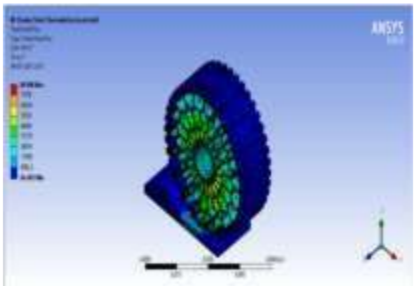
Fig 36. Structural steel

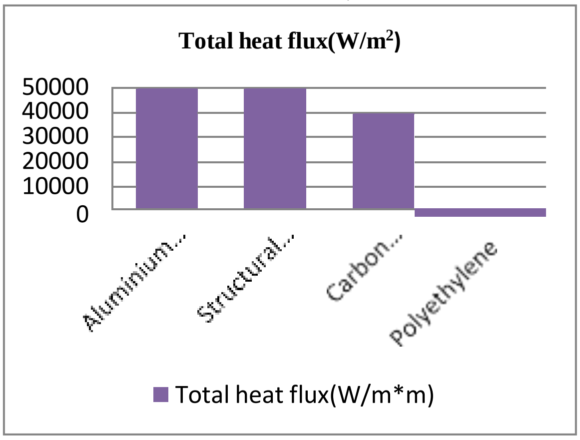

chart 8. Graphical representation of heat flux values

Above figures fig 33, fig 34, fig 35 and fig 36 shows that total heat flux values in various mentioned materials while performing thermal analysis.

Results

Static Analysis

By comparing the static analysis results from the table 1 we can observe that polyethylene has more elastic strain as compared to the other materials; that means polyethylene is used at places where there will be more damping will be there i.e. at off road condition.

Material	Equivalent Elastic Strain	Equivalent (von-Mises) Stress	Total Deformation
Aluminium Alloy	3.25E-03	3801.780186	0.015068609
Structural Steel	3.06E-04	5575.611967	0.013229994
Carbon Epoxy	1.23E-02	8230.943712	0.016213346
Poly Ethylene	1.87E-01	5262.118735	0.00140864

Table 2. Tabular representation of static analysis values

Transient Analysis

Here in the transient analysis by taking the time into consideration aluminum alloy is the better choice for the continuous cycle as the stress distribution is taken uniformly as compared to the other materials.

Material	Equivalent Elastic Strain(m/m)	Equivalent (von-Mises) Stress(Pa)	Total Deformation(m)
Aluminium Alloy	0.000512044	196.8466667	0.009203367
Structural Steel	0.001958467	11511.56546	0.008465367
Carbon Epoxy	0.006380867	5676.739904	0.008460567
Polyethylene	0.008717044	995.155	0.009203367

Table 3. Tabular representation of transient analysis values

Thermal Analysis

For thermal analysis independent of the time, aluminum alloy and the structural steel are better choices as both are metals and metals are good conductors of heat, therefore better distribution of

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heat energy is done.

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Material	temperature (^oC)	Total Heat Flux (w/m^2)
Aluminum Alloy	76.74275	47614.66667
Structural Steel	71.6225	46874
Carbon Epoxy	71.46475	39547
Polyethylene	54.222	2262.28

Table 4. Tabular representation of thermal analysis values

Conclusion

The conclusion of static, transient and thermal analysis on a honeycomb wheel of four different materials i.e., Aluminium Alloy, Carbon Epoxy, Structural Steel, Polyethylene each can be used to understand the equivalent stress, elastic strain and Total deformation. From the above data we can conclude that Aluminium Alloy has the least Total Deformation, Equivalent stress and Equivalent Elastic strain values for both Static Structural Analysis and Transient Analysis When compared to other materials. In Steady State Thermal Analysis, the Average surface temperature of Aluminium Alloy is not the optimum but since it has the highest Heat flux value therefore the heat dissipation is high. The heat does no remain trapped. Therefore, the material Aluminum alloy of the abovementioned properties is the optimum material.

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