# Design and Analysis of Flywheel Composite Material

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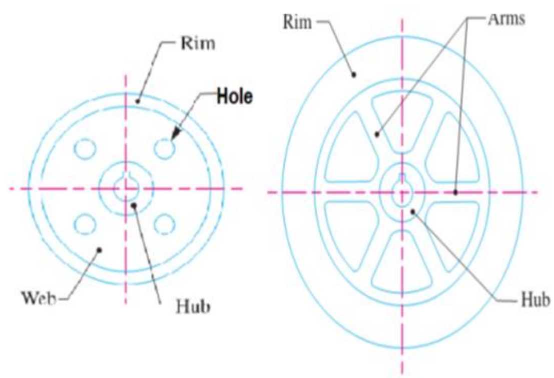
***Abstract***- *The widespread use of composite materials is due to there desired properties or flexibility to a variety of applications. Carbon fiber reinforced resin compounds are acquiring prominence owing to their outstanding real estate, such as great particular rigidity and strength, as well as chemical resistance, which are in high demand by the automobile sector. However, by modifying epoxy resins in reacting liquid rubbers or inorganic additives, their brittleness can be decreased. This investigation investigates the impact of carboxyl terminating butadiene acrylonitrile (CTBN), Nano silica, as well as hybrid (CTBN and nanosilica) alterations on the radial suspense-tension fatigue durability of Nano modified carbon fibre content-reinforced composites made of epoxy. After characterizing the mechanical properties of basic, plastic, and the nanosilica modified resin specimens, carbon fibre-reinforced Nano modified the epoxy composite panels are produced using Vacuum Assisted Resin Transfer Moulding (VARTM) or a centrifugal planetary mixer (THINKYTM). Two rubber and nanoparticle concentrations have been assessed under elastic, flexural, or comparable shear stresses, or the outcomes are contrasted with the results for an untreated mixture. This information is then used to perform extensive axial suspense-tension fatigue experiments on control, rubber-modified, nano-modified, and hybrid composites.*

***Keywords***- Composite materials, Light weight components, Carbon-fiber reinforced epoxy composites, Specific strength and stiffness, etc.

## I. INTRODUCTION

The flywheel used in a machine acts as a tank that holds energy if the supplied is greater than the demand and discharges it when the demand exceeds the source. A hybrid goods permits a higher speed of rotation, resulting in lightweight flywheel rotors with a high specific energy. Therefore, composite materials are preferable to metals when building flywheel blades. Theoretically, the particular potential produced by composite rotors is approximately five times that of metallic rotors. The concept of the fast speeds flywheel originated in the early 1970s. A researcher from Lawrence Livermore National Laboratory published a piece in Scientific American proposing a fresh approach to rotor design and suggesting the inclusion of the mixture products as opposed to metal.




(*a*) Flywheel with web. (*b*) Flywheel with arms.

Composite materials outperform metallic materials in terms of safety. Composite flywheels are smaller liable to disintegrate in free-flying projectiles if a prospective fail occurs at a high velocity angles or radial pressures exceed their material's strength. Instead, circumferential fractures form, as well as the flywheel progressively falls apart.

### Background

In an a century of intense competition, new difficulties for industrial manufacturing procedures include maximising productivity, assuring high output quality, or concurrently reducing production time and production cost. With modern engineering products requiring greater precision, the management of the outer roughness is growing increasingly essential. The operation of these procedures is based on a specific idea and makes use of particular properties.

### ANSYS

**ANSYS, Inc.** (NASDAQ: ANSS) is a developer of computer-aided engineering (CAE) engineering simulation software with headquarters in Canonsburg, Pennsylvania, United States. Dr. John A. Swanson founded the corporation in 1970 under the name Swanson Analysis Systems, Inc. ANSYS Multiphysics/Structure mechanics is the company's flagship product. The code in question is capable of undertaking static (stress) analysis, thermal analysis, motion evaluation, frequency response analysis, transition simulation, and linked field evaluation. Ansys multiphasic is capable of coupling diverse physical domains, including structural, radiative, and electromagnetics. Numerous researchers and engineers favour this module due to its Ansys Parametric Design Language (APDL) parametric language. The APDL enables users to carry out all reprocessing, solution, and postprocessing commands from a distinct text file defined as a macro.

## II. PROBLEM DEFINITION AND OBJECTIVES

**Problem definition:**

Its weight increases its fuel consumption. It has an excessive inertia of rotation, which reduces the rate at which engine rpm can increase or decrease, thereby increasing engine stress. It must be precisely balanced to prevent excessive vibration. It increases the price for resources and production. The energy used to accelerate a flywheel is lost when it is decelerated unless special provisions are made to recapture it.

If a flywheel becomes dislodged during engine operation, it may result in catastrophic damage. This is a rare occurrence, yet it has occurred.

When transforming a trolley into a race car, installing a lightened flywheel is one of the modifications that is considered. The objective is to permit the vehicle accelerate more rapidly and to reduce the wasteful decrease in horsepower caused by shifting the flywheel's mass.

**Objectives:**

Composite material permits greater speed of rotation, resulting in lightweight flywheel rotors with an excessive particular energy. Therefore, composite materials are preferable to alloys when building flywheel rotors. Theoretically, the specific energy generated by composite rotors is approximately five times that of metallic rotors. The concept of the fast speeds flywheel originated in the early 1970s. A researcher from Lawrence Livermore National Laboratory published an article in Scientific American proposing an innovative approach to rotor layout, suggesting the use of material composites as opposed to metallic. Composite materials outperform metallic materials in terms of safety. Hybrid flywheels are less likely to break down in liberate-flying projectiles if the material's strength is exceeded by a potential breakdown at high speed angles or tangential pressures. Instead, circular cracks or gradual disassembly of the flywheel occur.
The project's primary objectives are:

- To decrease the total mass of a vehicle's flywheel using a composite material.
- To analyse the automobile flywheel using ANSYS (finite aspect modelling and simulation software) in order to optimise weight and determine the resultant stresses.

## III. LITERATURE REVIEW

Akshay P. Punde, G.K.GattaniIn the present investigation, a flywheel is created and analysed to counteract the need to level out the substantial oscillations in motion throughout the course of an I.C. engine. By calculating the stresses within the flywheel using Finite Element Analysis, we can contrast the design or study results to existing flywheels. The next inference can be taken from the preceding work on the flywheel or its optimisation methodologies. It is evident that flywheels made of cast iron experience greater Pressure or distortion. S Glass Epoxy can be used to store energy in fewer components in flywheels. It is also applicable for high-speed applications.

Palak J Patel, Arvind S. SorathiyaThe primary issue with flywheels is their increased mass, resulting in slower rotational speeds. Flywheel was created using a 3D modelling application. The 3-D model was then imported using the IGES format into ANSYS. Using finite element analysis, a static structural analysis of three distinct materials, namely Grey cast iron, 5059 H321 aluminium alloy, and Kevlar carbon fibre, was conducted, and their relative performance was observed. Using the tetrahedron solid element, this model was then idealised using finite elements. The analysis was conducted in a static state. Using FEA software, we calculate the sum of stretching, normal tension, and equivalent stress. Observing the results of static analysis, this paper suggests carbon fibre as a superior material for wheel design due to its lower weight. The flywheel model is created in Cre-o and then imported into ANSYS for processing. In the direction of rotation of a flywheel made of grey cast iron, 5059 H321 Al Alloy, and kevlar Carbon Fibre, an angular velocity of 471 rad/sec is applied and the flywheel's rim is fixed. The ones that follow are the conclusions drawn from the obtained results: The grey cast iron flywheel experiences greater total deformation than 5059 Al alloy and carbon fibre. The grey cast iron wheel is subjected to a greater amount of von-misses tension or normal stress than the 5059 H321 Al alloy as well as carbon fibre wheels. Kevlar carbon fibre weighs 80 percent less than grey cast iron or 5059 H321 Al alloy. Kevlar carbon fibre is resistant to erosion and corrosion. 5. Comparing all results suggests that kevlar carbon fibre is a superior material for wheel design over grey cast iron or 5059 H321 Al alloy.

Sushama G Bawane, A P Ninawe1 and S K ChoudharyIn this research, a flywheel is created, optimised, or examined to satisfy the need of smoothing out the significant fluctuations in motion that occur throughout the cycle of an internal system. Utilising an optimising method, different variables such as substance and cost can be optimised for a flywheel, and the result may be contrasted to that of an existing flywheel by modifying working factors such as effectiveness, results, or battery ability. On a foundation of the dynamic tasks as well as system requirements, the fundamental characteristics of the flywheel are originally determined, and a comprehensive design study of the flywheel is conducted. The software is then utilised to conduct FEA ANALYSIS on an increasing number of designs in a variety of engineering disciplines. In addition to responding to forces exerted by other elements, FEA provides the capability to analyse tensions or displacements of a component or installation. This thesis describes the process of designing the flywheels or analyses the substance selection procedure. The FEA model is explained so that the mesh type, mesh size, or border constraints used to develop an effective FEA model can be comprehended. Lastly, the design objective may be to minimise the flywheel's material content in order to reduce its price. By applying tools intended to reduce 1kg of weight, 20% of the flywheel's circumference may be eliminated in the future. After finishing the analysis in CAE software, ANSYS 11.0, based on the concept of Similar stresses for substance transferring diseases, it is clear that these values are less compared to the allowed pressures for the particular chemical in the used conditions, so the structure is safe.

SudiptaSaha, Abhik Bose, G. Sai Tejesh, S.P. Srikanth Mainly, The effectiveness of a flywheel is determined by three key factors, namely the durability of the substance used, the geometry of the flywheel's cross-section, and the speed at which it rotates. This study aims to examine the impact of flywheel shape on the Specific Energy, which refers to the energy storage and delivery capacity per unit mass. It is worth noting that the strength of the material plays a crucial role in determining the quantity of kinetic energy that can be safely generated when combined with rotor speed. According to the findings of the suggested computer-assisted analysis and optimisation technique, the intelligent configuration of flywheel geometry has the potential to considerably influence the specific energetic efficiency and reduce the operational stresses imposed on the shaft/bearings during high rotational velocities as a result of decreased mass. The present study centres on an examination of the five most commonly occurring geometries, specifically those that are two-dimensional and either straight, concave, or convex in shape. The current flywheel design exhibits potential for further enhancement, particularly with regard to optimising efficacy as the primary goal. The operational circumstances of the system impose a limited margin for energy storage, thus even minor enhancements can significantly impact the overall achievement of the whole thing. The present research demonstrates the importance of appropriate flywheel geometry selection and its impact on energy storage efficacy. This study demonstrates the utilisation of a computer-assisted analysis and optimisation methodology through the presentation of sample cross-sectional data. The primary aim of the issue is articulated in relation to the maximisation of specific energy by selecting the most suitable geometry from the five pre-established cross-sectional options. By leveraging contemporary technology, it is possible to achieve significant progress in advanced fields of study that require the use of flywheels. Engineers often face challenges related to the load capacity of magnet gears, size limitations, and overall effectiveness in this domain.

## IV. METHODOLOGY

**Flywheel Origin:**

The development or utilise of gyroscope technology for energy storing started during the Industrial Revolution, several centuries ago. Dr. A. Stodola's dissertation in the conceptual load limits of rotating discs was translated into English for the first time in 1917, making it one of the earliest contemporary papers on the subject. In the 1970s, sophisticated flywheel development commences.

The flywheel is considered to be a single of the first people creations or had been widely employed for an extended period of time. Initial combat vehicles in ancient China were built using four timber flywheels. Around 2,500 years ago, the ancient Egyptians fabricated the earliest chariots featuring flywheels made of timber. According to Genta (1985), flywheel systems were widely utilised in everyday activities, such as the use of water wheels for water circulation and wind-powered flywheels for energy production. The historical development of flywheels and their utilisation has been significantly impacted by the progressions in machinery content and the internet, and also by fortuitous circumstances or necessity, as noted by Horner et al. (1996). The initial noteworthy progressions were achieved during an epoch of Industrial Revolution that occurred in the 18th century.

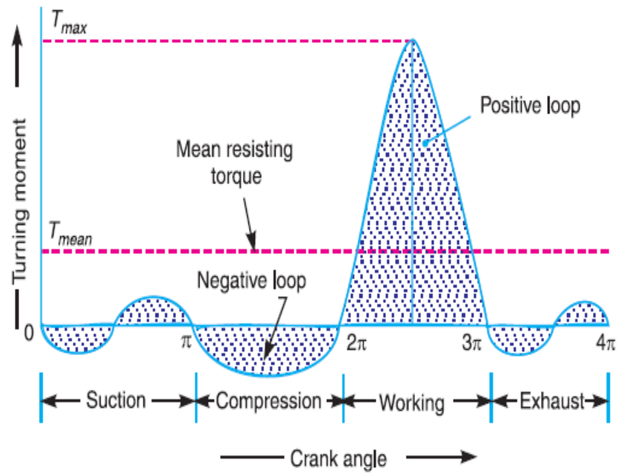



*Fig. 2: Turning moment diagram for a four-stroke cycle I. C. Engine*

**Energy stored in a flywheel:**

You recognise that a flywheel's motion increases when it absorbs energy and decreases when it releases energy. Let,

m = Mass of the flywheel in kg,

k = Radius of gyration of the flywheel in metres,

I = Mass moment of inertia of the flywheel about its axis of rotation in kg-$m^2$

= m.$k^2$

$N_1$ and $N$= Maximum and minimum speeds during the cycle in r.p.m.,

$\omega_1$ and $\omega_2$ = Maximum and minimum angular speeds during the cycle in rad/s,

N = Mean speed during the cycle in r.p.m. = $\frac{N_1 + N_2}{2}$

$\omega$ = Mean angular speed during the cycle in rad/s = $\frac{\omega_1 + \omega_2}{2}$

$C_S$ = Coefficient of fluctuation of speed = $\frac{N_1 - N_2}{N}$ or $\frac{\omega_1 - \omega_2}{\omega}$

We know that the mean kinetic energy of the flywheel,

$$E = \frac{1}{2} \times I \times \omega^2 = \frac{1}{2} \times m.k^2 \times \omega^2$$

As the speed of the flywheel changes from $\omega_1$ to $\omega_2$, the maximum fluctuation of energy,

ΔE = Maximum K.E. – Minimum K.E.

$= \frac{1}{2} \times I \times \omega_1^2 - \frac{1}{2} \times I \times \omega_2^2$

$= \frac{1}{2} \times I \times (\omega_1^2 - \omega_2^2)$

$= \frac{1}{2} \times I \times (\omega_1 + \omega_2)(\omega_1 - \omega_2)$

$= I.\ \omega(\omega_1 - \omega_2)$

$= I.\omega^2 \left(\frac{\omega_1 - \omega_2}{\omega}\right)$

$= I.\omega^2.C_S$

$= m.k^2.\omega^2.C_S$

$= 2.E.C_S$ ……. ( in N–m or joules)

The radius of gyration (k) may be taken equal to the mean radius of the rim, because the thickness of rim is very small as compared to the diameter of rim

**Types of Flywheel Applications:**

There are three distinct types of applications of flywheels

1. Constant driving torque and variable load torque.
2. Variable driving torque and constant load torque.
3. Variable driving torque and variable load torque.

**Constant driving torque and variable load torque:**

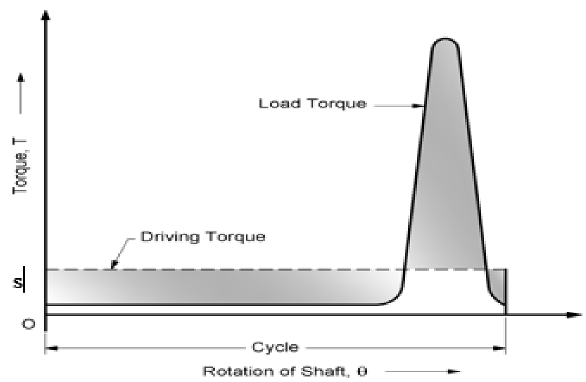



*Fig. 3: Constant Driving Torque and Variable Load Torque*

**Variable driving torque and constant load torque:**

As displayed in Figure 4, in this type of flywheel use, the driving force supplies energy at various rates while the machine requires energy at a constant rate.

This form of wheel utilisation is illustrated by a four-stroke gasoline engine operating a centrifugal pump.

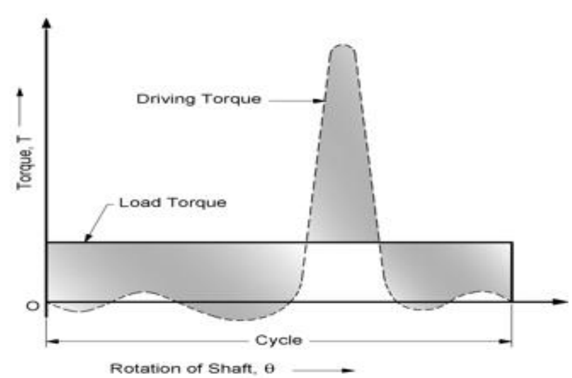



*Fig 4: Variable Driving Torque and Constant Load Torque*

**Variable driving torque and variable load torque:**

As stated in Figure 5, in this form of spinning use, the engine supplies energy at a variable rate, while the machine's energy demand is also variable.

The aforementioned type of flywheel implementation entails the utilisation of the internal combustion engine to power the rotary compressors and to operate the rock crusher, between other potential applications.

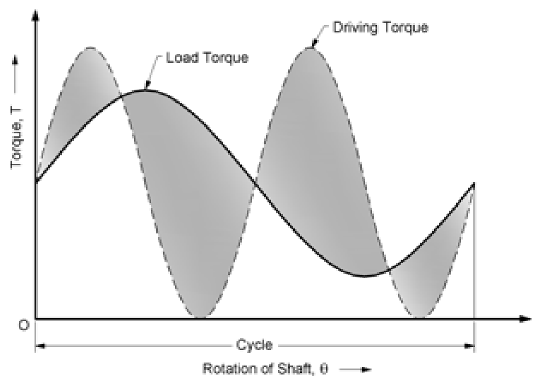



*Fig. 5: Variable Driving Torque and Variable Load Torque*

**CAD modeling:**

The software suite known as CATIA (Computer Aided Three-dimensional Interactive Application) has been developed by the French company Dassault Systems and encompasses CAD/CAM/CAE functionalities. It is available on multiple platforms and is a commercial software. CATIA, which is developed in the C++ programming language, serves as the foundation of Dassault Systems' software suite for managing the product lifecycle.

The CATIA software offers a means of designing intricate and sophisticated products through the utilisation of systems engineering principles. The aforementioned elements encompassed in the process are the delineation of prerequisites, the establishment of the systems architecture, the modelling of behaviour, and the creation of a virtual product or embedded software. Application Programming Interfaces (APIs) enable the customization of CATIA software. The customization of CATIA V5 and V6 is achievable through the utilisation of programming languages such as Visual Basic for Applications and C++.

Whilst NURBS were eventually incorporated into subsequent versions of CATIA V4, piecewise polynomial surfaces were predominantly utilised in this version. The CATIA V4 software utilises a solid, non-manifold computational engine. The CATIA V5 software features a solid and surface-based package that is parametric in nature and utilises NURBS as its main exterior depiction. Additionally, the software offers several workbenches that facilitate Knowledge-Based Engineering (KBE).

The flywheel CAD model is established using CATIA V5. The complete model includes the body, hub, web, and rim. The various design parameters are derived directly from the TOYOTA TF105 flywheel, and for the internal structure, appropriate simplifications and assumptions are made.

**Flywheel specifications:**

- Model – FORMULA 1 CAR
- Power (P) = 552KW
- Speed (N) = 19000 rpm
- Torque (T) = 274 Nm

**Flywheel layout:**

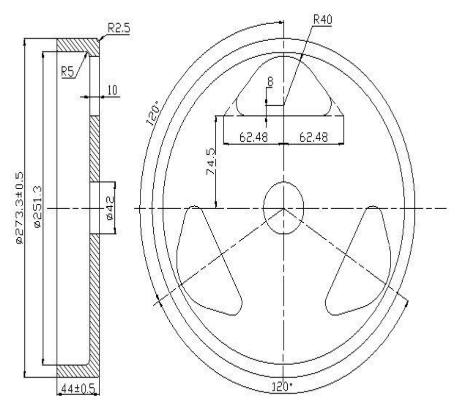



*Fig. 6: Flywheel layout*

**Principle dimensions for parametric model:**

*Table 2: Principle dimensions of flywheel*

| Sr. No. | Description | Dimensions(mm) |
|---|---|---|
| 1 | Outer diameter | 273.3 |
| 2 | Mean diameter | 262.3 |
| 3 | Hub diameter | 149 |
| 4 | Shaft diameter | 42 |
| 5 | Rim Width | 44 |
| 6 | Rim thickness | 10 |

**Modeling of assembly in ANSYS**:

The analysis's pre-processing phase is crucial because it needs additional memory.

Resources and equipment. The pre-processing phase consists of the that follows steps:

- Engineering Data
- Geometry
- Discretization

**Engineering Data:**

*Table 3: Material properties*

| Sr. No. | Material Properties | Unit | Steel | Carbon Fiber |
|---|---|---|---|---|
| 1 | Density | $kg/m^3$ | 7850 | 2150 |
| 2 | Poisson's ratio | - | 0.3 | 0.23 |
| 3 | Young's Modulus | MPa | $2\times10^5$ | $2\times10^5$ |
| 4 | Tensile Yield stress | MPa | 1300 | 1040 |
| 5 | Tensile Ultimate Stress | MPa | 1550 | - |

**Step 1:** Collecting information and data related to flywheel.

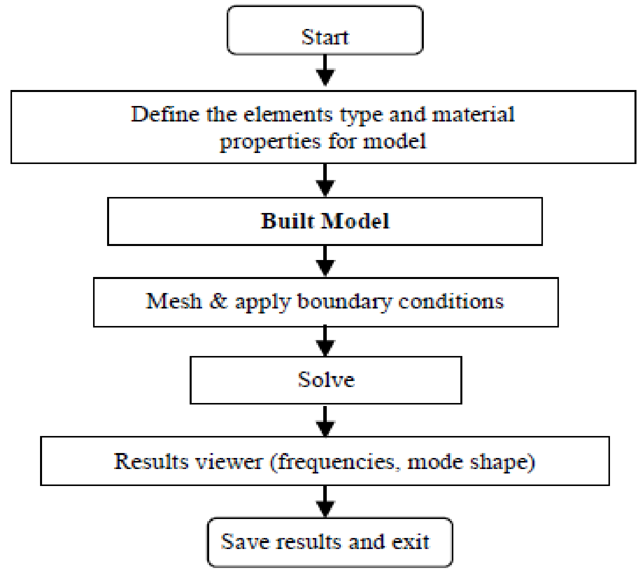
**Step 2:** A fully parametric model of the flywheel is created in CATIA V5 software.

**Step 3:** Model obtained in Step 2 is analyzed using ANSYS 14.5, to obtain the stresses and mass of flywheel.

**Step 4:** Manual calculations are done and results are compared with those obtained in ANSYS.

**Step 5:**Lastly, we examine outcomes derived from ANSYS or manual calculations for various flywheel materials, including steel, carbon fibre, and composites.

To accomplish this assignment, we will use the accompanying flowchart to complete the steps in the correct order.




**Parametric modeling using CATIA V5:**

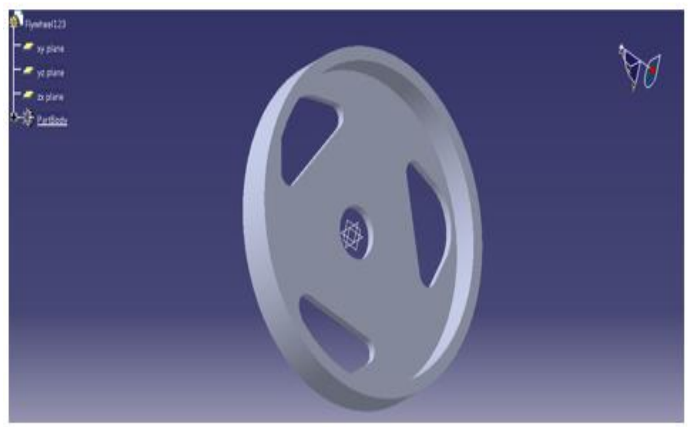


*Fig. 7: Flywheel model in CATIA V5*

Fig. 8: Model of Flywheel Body (Carbon Fiber)

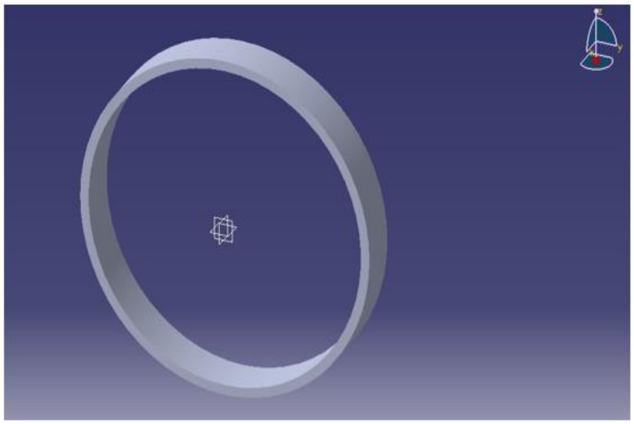
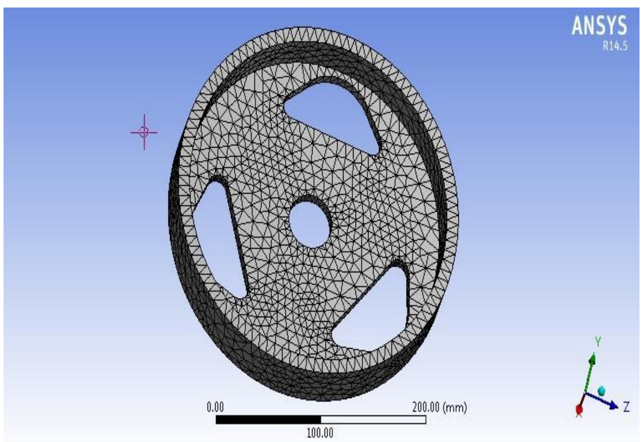


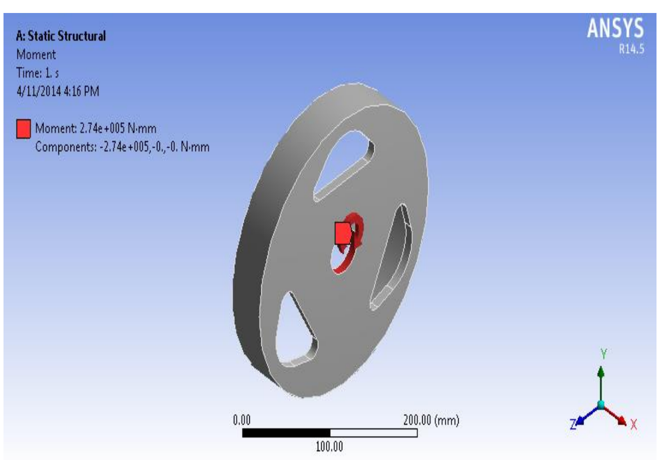
Fig. 9: Model of Flywheel Rim (Steel)

**Some input conditions applied in ANSYS during simulation:**

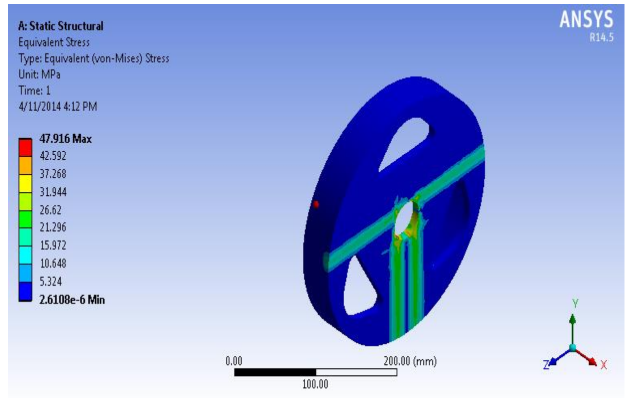
**Fine Meshing (Tetrahedrons Method ):**




**Moment:**




**Carbon Fiber:**




**CFRP (Carbon Fiber Reinforced Polymer)**

**Mean rim speed, $v = \frac{\pi DN}{60}$ . . . . . . .(PSG 7.120)**

**Where, D = mean diameter of rim (m)**

**N = speed (rpm)**

**$\therefore v = \frac{\pi \times 0.2623 \times 19000}{60}$**

**$\therefore$ v = 260.945 m/sec**

**Tensile stress due to centrifugal force, $\sigma = \frac{\gamma \times v^2}{g}$ . . . . . . . . (PSG 7.120)**

**Where, ϒ = specific weight = ρ×g**

**g = gravitational acceleration ≈10 m/$sec^2$**

**Comparison:**

| Material | Density [kg.m-3] | Strength [MN. m-2] | Mass [kg] | Equivalent Stress [MPa] (Theoretical) | Equivalent Stress [MPa] (Ansys) | Comment |
|---|---|---|---|---|---|---|
| Steel (AISI 4340) | 7850 | 1800 | 6.08 | 178.17 | 17.826 | Safe (heavy) |
| Carbon Fiber (60 vol% carbon) | 2050 | 2400 | 1.63 | 46.19 | 47.916 | Fail (Light) |
| Composite (Steel rim + carbon fiber body) | 3650 | - | 2.80 | 82.84 | 63.482 | Safe (Lighter than steel) |

## V. CONCLUSION

In conclusion, designing and analysing composite materials for flywheels is a challenging and crucial procedure in the discipline of mechanical engineering. In comparison to more conventional materials like steel, the use of composite materials in flywheels has a variety of benefits, including less weight and greater strength. However, careful consideration of elements including material characteristics, design parameters, and manufacturing processes is needed when designing and analysing these materials. The use of composite materials in flywheels has the potential to greatly increase their performance, especially in terms of energy storage and efficiency, according to comprehensive study and analysis. To guarantee the best performance and safety, the design process must be precisely adapted to the unique application and operating circumstances. Overall, designing and analysing composite materials for flywheels is a difficult and continuous topic of study in the discipline of mechanical engineering, therefore it will continue to be a key area of concentration for advancements in this area**.**

## REFERENCES

[1] PSG Design Data Book Of Engineering, pg. no. 7-121, 7-122.

[2] R. S. Khurmi, Machine Design, S. Chand Publication, pg. no. 776-819

[3] V. B. Bhandari, Design of Machine Elements, Tata Mc Graw Hill Publication, pg. no. 750-757

[4] Akshay P. Punde, G. K. Gattani, Associate Professor, Department of Mechanical Engineering BNCOE, Pusad, Amravati (MS) Vol.3, Issue.2, March-April. 2013 pp-1097-1099

[5] Anonymous, "ANSYS Structural Analysis Guide", ANSYS Release 5.7. ANSYS, Incorporated, (2000), New York, USA.

[6] Bathe, K.J. and E.L. Wilson, "Numerical Method in Finite Element Analysis", Prentice-Hall, Englewood Cliffs, New Jersey, (1976).

[7] R. S.Khurmi and J. K. Gupta, “Theory of machines”, S. Chand publications, New Delhi, 2005 pp. 909-910.

[8] Cook R.D, Malkus D.S, Plesh M.E. 1985. “Concepts and applications of Finite Element Analysis”, Wiley International, 3rd Edition.