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Design and Analysis of Flywheel of a Heat Engine

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Abstract: *Due to the technological civilization the technologies are emerging day by day and there is a huge development in the automobile industries or we can say the automobile industry. The major consisting systems of the automobiles such as sedan or SUV or XUV or even different vehicles are either being improved or being replaced by some newer technologies. A flywheel is an energy storing device which is being used in the power train of the automobile systems rather it is independent of the type of fueling i.e. can be applied in both petrol as well as diesel engines. In this research paper a flywheel is designed using CATIA and the analysis i.e. numerical computation is carried out to know the various stress; strain; total deformation and the von misses stress using ANSYS software. ANSYS used FEM for solving the numerical problem by applying constraints and the result will be recorded according to the loading conditions. Thus this research article is presented for the analysis of the flywheel which is one of the most important components of the power train of the automobile transmission system.*

Keywords: - flywheel, ANSYS, CATIA, static and dynamic analysis, transmission system.

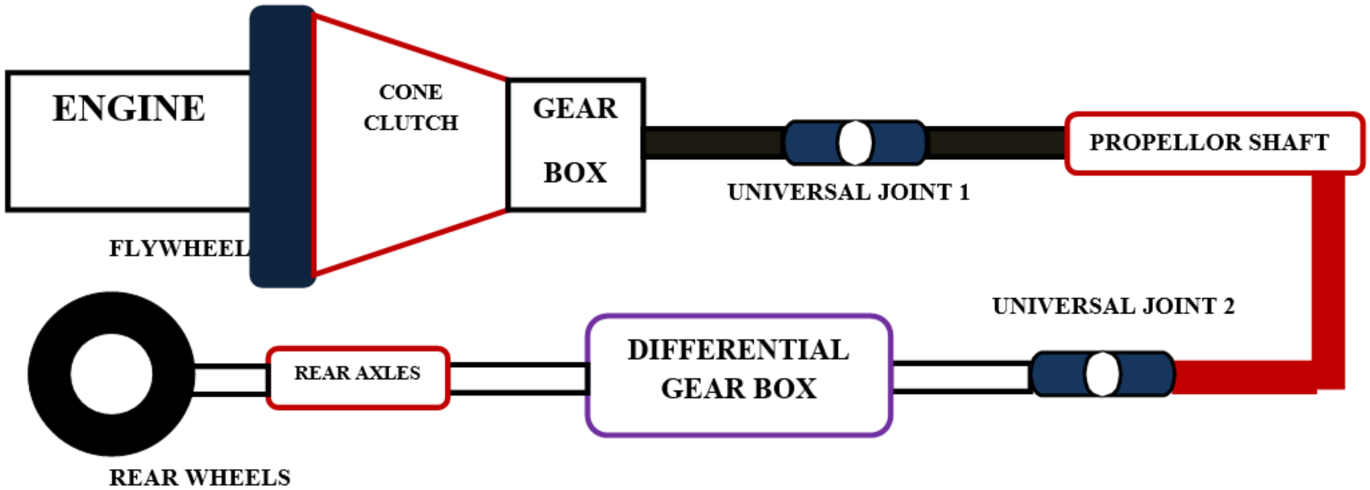
INTRODUCTION:

A flywheel is an energy storing device and also the starting torque is provided to the flywheel in the automobile transmission system. The overall automobile is divided into various associated systems which are classified below:

I. Automobile Power Plant.
II. Automobile Transmission System
III. Automobile Control Systems
    a) Steering System
    b) Braking System
    c) Suspension System
IV. Automobile Electric and Electronics Systems
    a) Starting System
    b) Charging System
    c) Lighting System
V. Automobile Body Engineering
    a) Body Design
    b) Stress Over the Body
    c) Resistances over the Body {Ra; Rr; Rw}
    d) Body Repairing
    e) Body Painting
VI. Automobile Servicing and Maintenance
    a) Preventive Maintenance
    b) Breakdown Maintenance
    c) Hourly Maintenance
    d) Kilometer Maintenance
    e) Reconditioning of engine
        i. Re-boring
        ii. Valve side cutting
        iii. Valve lapping
        iv. Valve grinding
        v. Honing
VII. Non-Conventional Automobile Vehicles

These are those vehicles that work on both conventional-based energy sources such as gasoline-based fuels and various non-conventional sources such as electricity. Example- NISSAN EV-1.

Now the flywheel is one of the important components of the automobile transmission system and is attached directly to the engine before the clutch as shown below.



BLOCK DIAGRAM SHOWING THE POWER TRAIN

OBJECTIVES:

- To design the flywheel using AUTOCAD software.
- Static analysis of the flywheel using one of the numerical computation software's "ANSYS" to get the values of various stress and strains.

LITERATURE REVIEW:

1) **A REVIEW OF FLYWHEEL ENERGY STORAGE TECHNOLOGIES AND THEIR APPLICATIONS, BY MUSTAFA E AMIRYAR* AND R.PULLIN* ON 16 MARCH 2017:-**

Here this paper has a clean representation of a critical review of FESS (Flywheel energy storage system) as well as various ESS (Energy storage systems) being used. As it is mentioned that these are the key elements that contribute towards the improvement in the stability and quality of electrical networks as well as they lead towards improving the efficiency of the electrical systems when the condition of imbalance occurs in the case of supply and demand. This has presented a skeptical review of FESS in relation to its main components, as well as its applications, which is an approach that was not being captured in the early reviews that were been done on this topic. Here the description of the flywheel structure, as well as its main components and applications, are provided. The topics that contributed are electrical machines, power electronics converter topologies, and the bearing systems which are being considered for use in flywheel storage systems are covered in this paper. The main and foremost application of FESS in power quality improvement, uninterrupted power supply, transportation, renewable energy systems, and energy storage are explained clearly. And the applications mentioned under these sectors are also explained. As we know that high power capacity instant response and case of recycling are the additional key factors. Given is the demand for ESS is increasing on a substantial basis, and that of FESS is increasing parallelly in the few years as if has there many unique at attributes, the upcoming future of FESS is very bright, within a time where the costs of Li-ion and other chemistry battery technology continue to reduce in terms of its productivity and applications. Here is the innovative design, which is based on steel helps in overcoming the concern which is related to safety for the highly stressed rotors, which can also operate at a much higher speed. This is considered safe for monolithic steel rotors.

2) **A DETAILED REVIEW ON STUDY OF FLYWHEEL BY SHELKE SUBHAM, PAY MODE AKSHAYDEEP, SHELKE VISHAL, SHALUNKHE ARUN, PROFESSOR S.N TAPASEE, ON 2018:**

Here it is clearly mentioned about the flywheel is basically a mechanical device with a significant moment of inertia which is used as a storage device for the rotational energy. It resists some changes in its rotational speed, which leads to the rotation of the shaft when a fluctuating torque is acted upon it through a power source like the reciprocating engine {Piston Based). Flywheel also became a subject of extensive research as the power storage device being used in vehicles as well as the power plant. For increasing the flywheel motor performance, it becomes crucial for the prevention of delamination by the decrease in the radial tensile stresses. Flywheel also resists change in its rotational speeds leading to steady rotation in its power tip for the easy rotation of the shaft when the fluctuating load being applied onto it by the powern source. Flywheel energy storage systems are the best alternative been considered to electrochemical batteries by the increase in radial tensile stresses. Hybrid motors of composite materials with differing stiffness as well as density have also been used for decreasing the radial stresses. The flywheel energy storage systems are basically considered as the best alternative in comparison to the electrochemical batteries because of the factors of higher stored energy density, higher life term, and also the ecologically clean nature. Modern high-speed flywheels differ in form of their forebar which is lighter and much faster spinning. As the energy which is being stored in the flywheel increases linearly with respect to the moment of inertia and is directly proportional to the square of rotational speed. By the use of FFA analysis, the best material is suggested for the flywheel design purpose. The best-suggested materials are [ceramics, CFRP, GFRP (composite, Berylium, High strength steel, High strength Al alloys, High strength Mg alloys, Lead alloys, cast iron.

3) RESEARCH ON STRUCTURE FOR FLYWHEEL STORAGE SYSTEM IN LONG LIFETIME UPS, BY VIKASH SHRIVASTAV, ON NOVEMBER 2017

It is mentioned about some of the latest developments done in this paper. As it is known about the Flywheel storage energy system which is not a new technology, its application in various power systems has increased in recent decades. While in addition, various researches has been applied in order to develop the better feature which FES can offer, when exposed in terms of power excellence improvement or improvement in field of network advance stability. While its concentration is been lately focused in additional application in the major field of satellite engineering as well. In most of the case it is been exposed to voltage dips problems. This is in association with power electronics converters, which in addition offers effective compensation for network. This paper demonstrated concept of most of technical papers based on FES System. This paper concluded about the recent developments in Flywheel industry. Which should most of the power system reliability problems in case of low voltage distribution network.

4) SELECTION OF FLYWHEEL MATERIAL USING MULTICRITARIA DECISION MAKING FUZZY TOPSIS, BY PULKIT PUROHIT AND M.RAMCHANDRAN, ON DECEMBER 2015

Here it has been clearly mentioned about the amount of energy being stored in a Flywheel which is directly proportional to its rotational speed square. Here the materials that are used for the Flywheel are Carbon steel 1065, Alloy steel AISI 4340, Maraging steel 18NT, Alloy steel AISI E9310, Stainless Steel. The methodology behind the selection is based on cost, yield strength, density, etc. This is been done as per the decision makers. The properties chosen were on the basis of density, hardness, young’s modulus, bulk modulus as well as poison’s ratio. They applied TOPSIS as well as MCDM for selection of alternate materials in order for making the engine flywheel. The TOPSIS method can also be used for material selection in the manufacturing sector.

5) FLYWHEEL ENERGY STORAGE FOR AUTOMOTIVE APPLICATIONS, BY MAGNUS HEDLUND, JOHAN LUNDIN, JUAN DE SANTIAGO, JOHAN ABRAHAMSSON AND HANS BERNHOFF, ON 25 SEPTEMBER 2015

Here it mentioned clearly about the Flywheel energy storage technology on which review was done. It is also Known that 26 university and 27 companies had did major contribution to Flywheel technology development. Various comparisons has been carried out on case of bearings which is magnite and mechanical bearings comparison is done magnetic bearings are more successful when compared in terms of stiffness, industrial standards, as well as vacuum operations, etc. Other comparisons were also been carried out in terms of power transfer, induction machines, reluctance machines, materials, as well as cycle life time. The application of it are like buses, cars, container cranes/straddle carriers, construction machines, garbage trucks, charging stations, cable ferries, train station, frequency regulation, etc.

6) A REVIEW OF FLYWHEEL ENERGY STORAGE SYSTEMS;STATE OF ART AND OPPORTUNITIES, BY XIAOJUN LI, ALAN PALAZZALO, ON 5 JUNE 2021

Here it is mentioned about the state of the art as well as the future opportunities which are being required for the flywheel energy storage system. Here it is also mentioned about the FEES {Flywheel Energy Storage System} that is an interdisciplinary, complex subject which also involves electrical, mechanical, magnetite subsystems. The various choice made on the subsystem and also about their impacts upon the performance of system are represented in this paper. For its unique advantages, different FEES systems are been built as well as applied in various wide range of applications, which includes renewable energies, transportation, utilities, etc. That review focuses mainly upon the developed FEES, like the utility scale as well as low cost flywheel. Finally the identification about the future development for FEES technology was done. Usage of new materials as well as compact design increases specific energy as well as the energy density which helps in making the flywheel more competitive in comparison to the electrochemical batteries the various other opportunities includes newest applications in energy harvest, hybrid energy systems and flywheel secondary functionality apart from its energy storage. This review basically focuses on the state of art of FEES technologies, which is for the commissioned or prototyped. This all are the factors which are contributing the FEES to prosper when compared to the electrochemical batteries and the energy storage flywheels are used now everywhere which are supported by active magnetic bearing (AMB) systems for avoiding the friction loss. Thus, helping in storing energy at higher efficiency over a longer duration of time.

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MATERIAL SELECTION:

The materials for the manufacturing of the flywheel or the various engine components are chosen
in such a way that they should bear the properties of high strength and should have good wear and tear characteristics ; non corrosive or in either way they should be have high corrosion resistance and at last they should be cost economic and should meet all the standardizations requires in the design criteria and should have high reliability.

1) Cast Iron
2) Stainless Steel
3) Aluminum

These are the most common materials used for the manufacturing and design fulfillment of flywheel due to its relative simplicity and other perspectives.

TABLE SHOWING THE CHEMICAL COMPOSITION OF THE ABOVE MATERIALS:

Table 1: - Chemical Composition of Stainless Steel

Elements	Composition
Carbon,C	0.25-0.290
Copper,Cu	0.20
Iron,Fe	98.0
Manganese,Mn	1.03
Phosphorous,P	0.040
Silicon,Si	0.280
Sulphur,S	0.050

Table 2: -Chemical Composition of Grey Cast Iron

Elements	Composition
Carbon,C	3.35
Silicon,Si	2.21
Manganese,Mn	0.34
Phosphorous,P	0.15
Sulphur,S	0.091
Selenium Se	1.01
$T_{odl}{}^{0}c$	1330

DESIGN PARAMETERS:

The design of the flywheel is done using AUTOCAD modeling software.

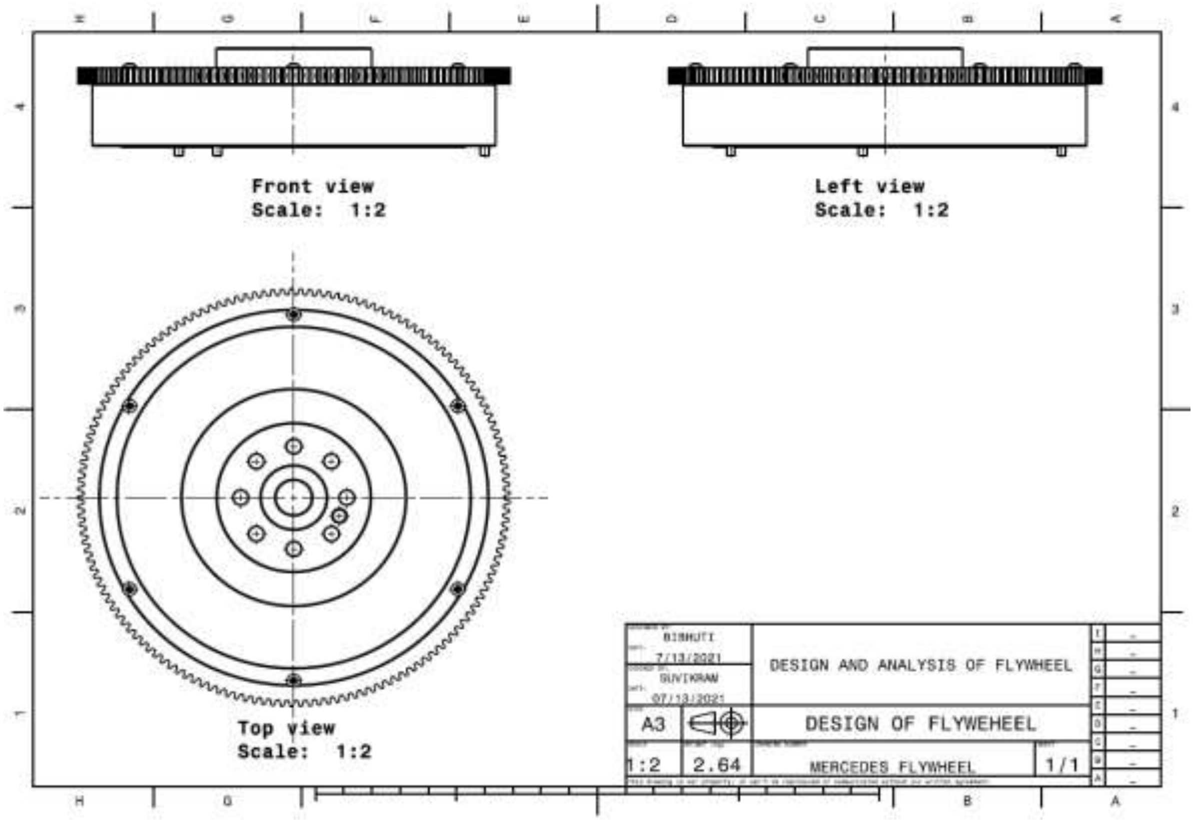
SOFTWARES USED:

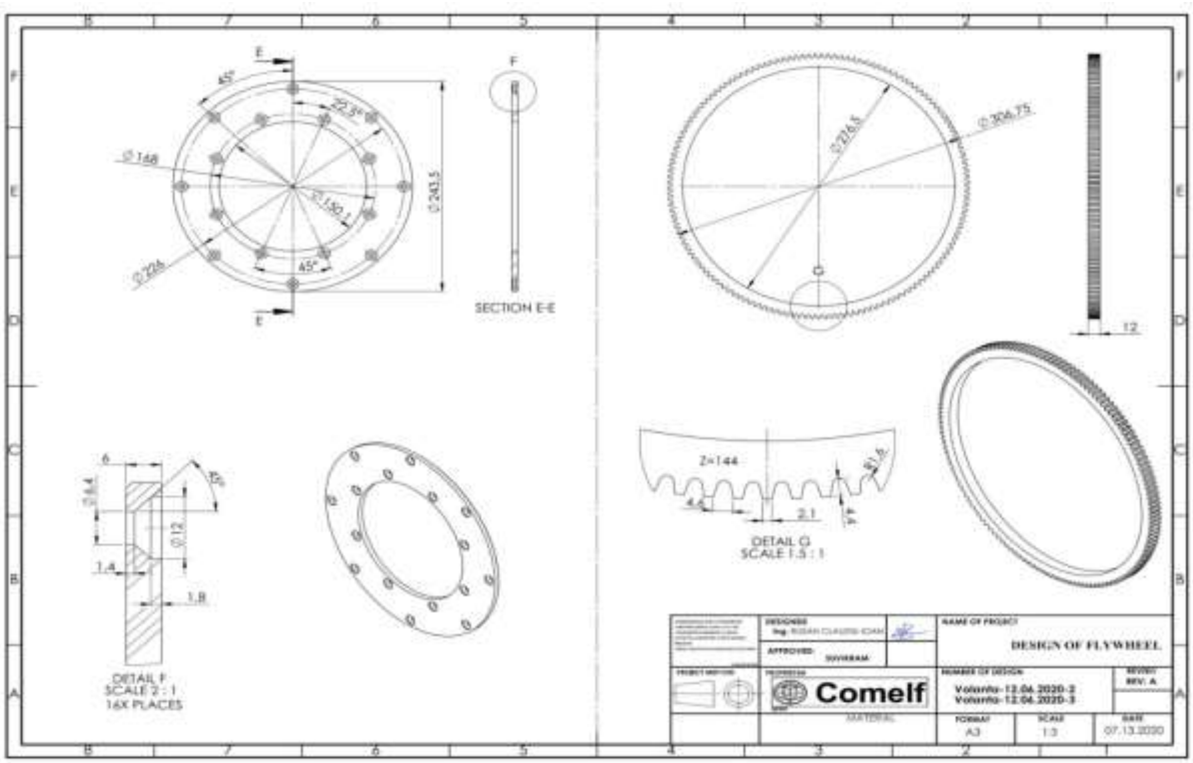
1) CATIA (source: - https://en.wikipedia.org/wiki/CATIA)

CATIA stands for Computer-Aided Three-dimensional Interactive Application. Which was developed by a French company named Dassault System. Initially, it was named CATI (conception assistée tridimensionnelle interactive – French for interactive aided three-dimensional design) which later changed to CATIA. The first version v1 was released in 1981 and the popular version v5 was released in 2001 which is still in use. CATIA is not only a CAD (Computer-Aided Design) software but also a package that supports CAE (Computer-Aided Engineering), CAM (Computer-Aided Manufacturing), and PLM (Product Lifecycle Management) which is largely used in the engineering field particularly in aerospace and automobile industries. The companies that are using CATIA are Boeing, Airbus, Porsche, Audi, Volkswagen, Tata Motors, Mahindra & Mahindra Limited, etc.

DESIGN PROCESS

FIGURES SHOWN IN DIFFERENT VIEWS WHILE DESIGNING IN CATIA





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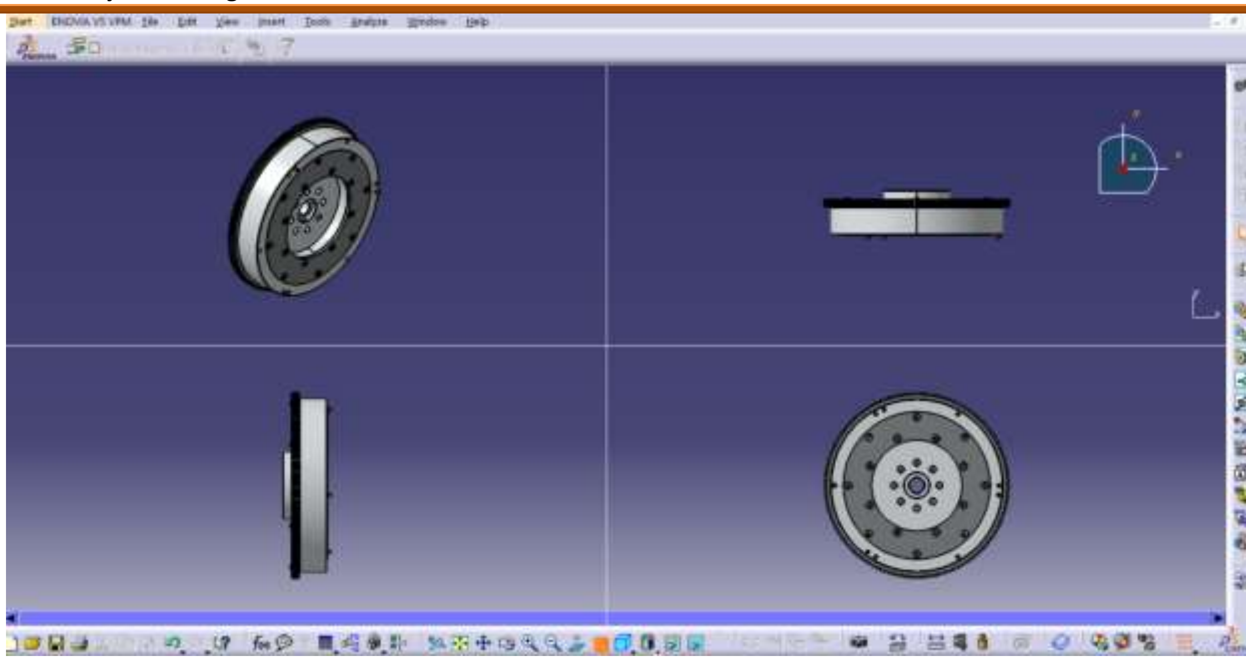


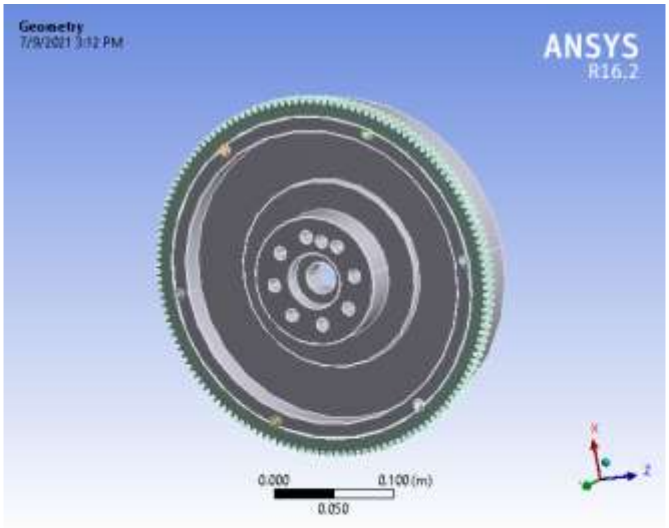


FIGURE SHOWING CAD MODEL FIGURE 1.1

2) ANSYS (source:- https://www.ozeninc.com/products/ansys-mechanical/)

ANSYS Mechanical software is a comprehensive FEA analysis (finite element) tool for structural analysis, including linear, nonlinear, and dynamic studies. The engineering simulation product provides a complete set of elements behavior, material models, and equation solvers for a wide range of mechanical design problems. In addition, ANSYS Mechanical offers thermal analysis and coupled-physics capabilities involving acoustic, piezoelectric, thermal–structural, and thermo-electric analysis.

ANALYSIS OF FLYWHEEL:

The analysis of the object is done using one of the numerical computational techniques known as FEM {FINITE ELEMENT ANALYSIS}. Here the whole cad model is divided into small fragments by meshing and overall simulation analysis is carried out using "*ANSYS R16 MECHANICAL".*

MESHING:

It is one of the steps in the FEM in which several nodes and parts are created and the following information was obtained:
No of Nodes = 382961
No of Elements = 194318

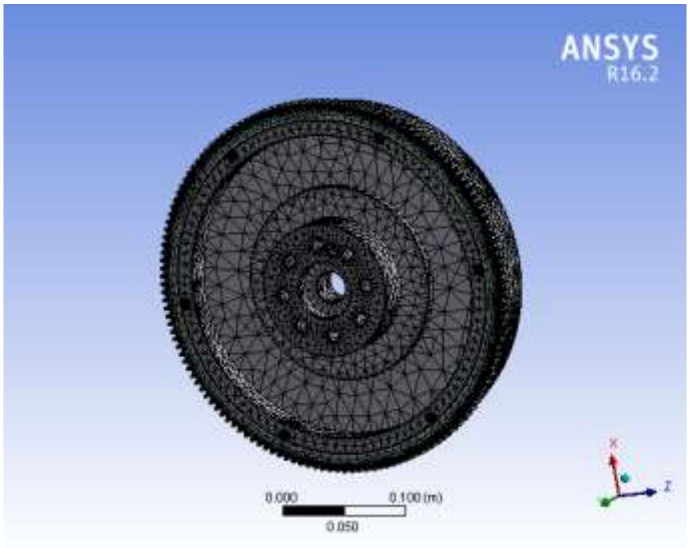
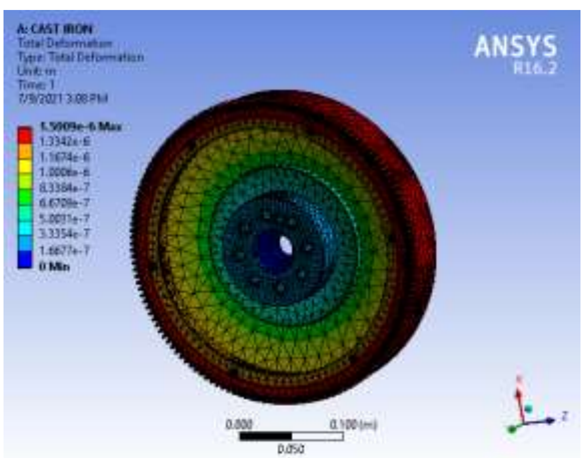
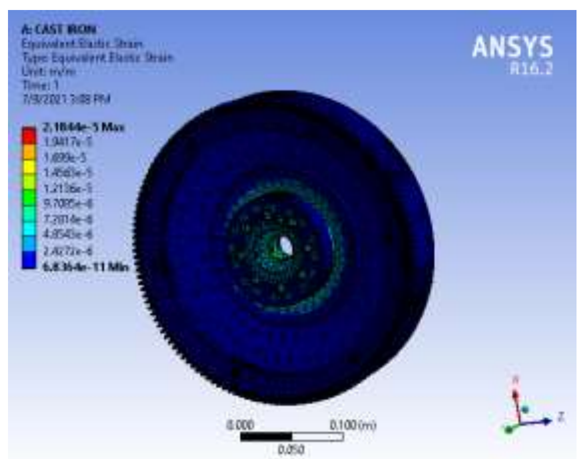


FIGURE SHOWING CAD MODEL AFTER MESHING FIGURE 1.2

CAE ANALYSIS {STATIC STRUCTURAL} OF THE DESIRED FLYWHEEL WHEN THE ENGINE IS STATIONARY:

1) CAST IRON





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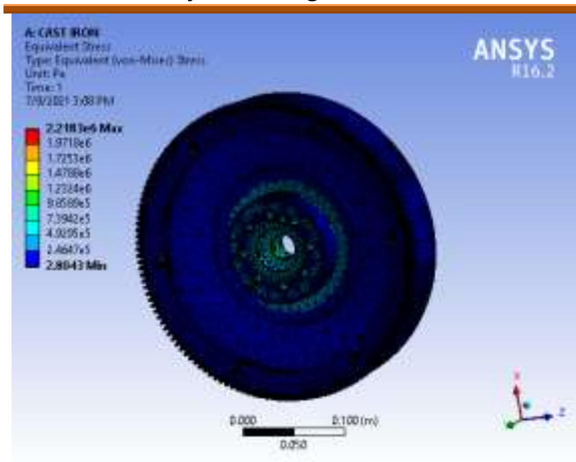
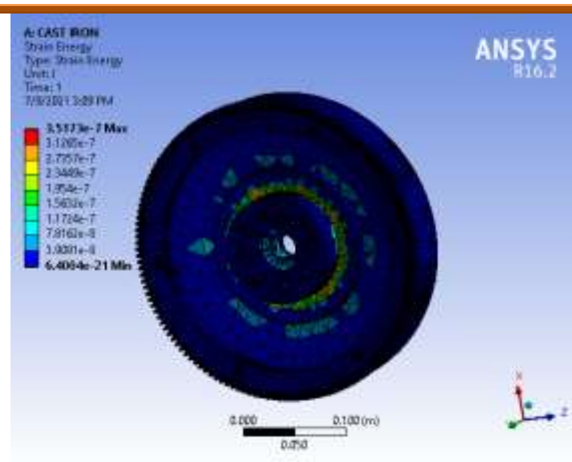
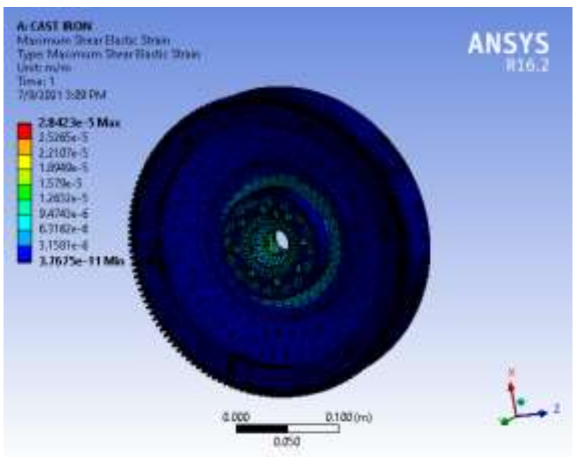
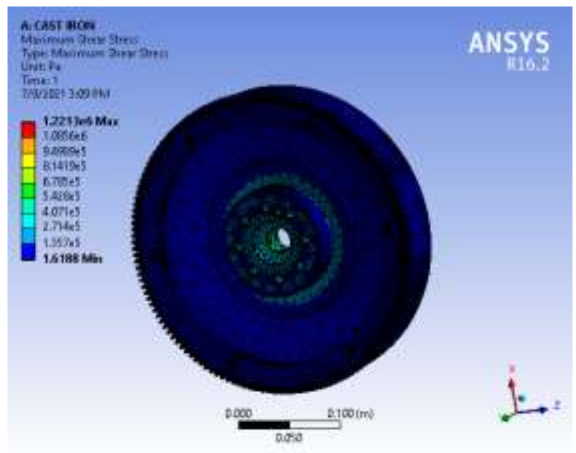
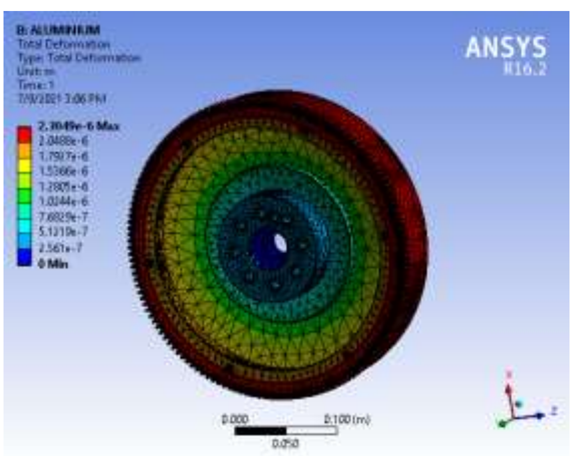


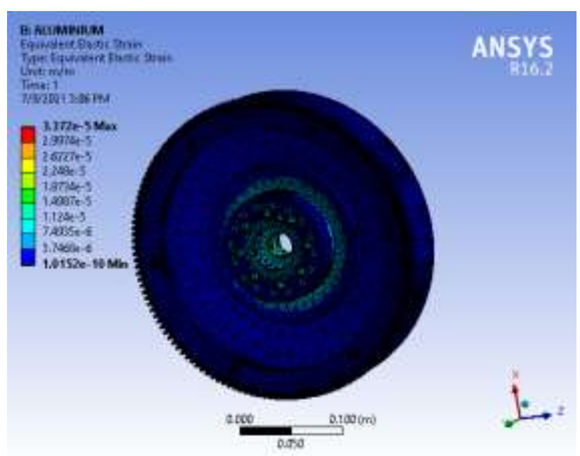


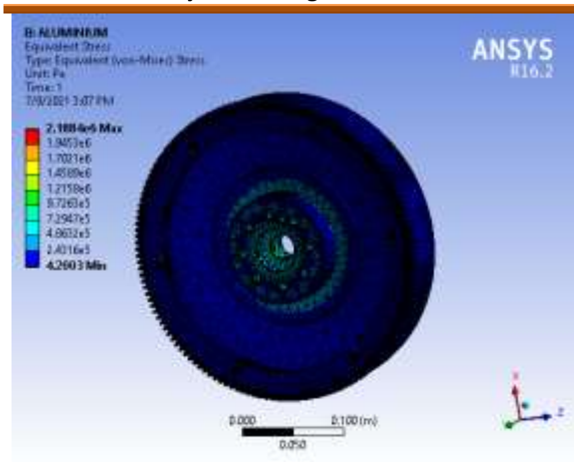


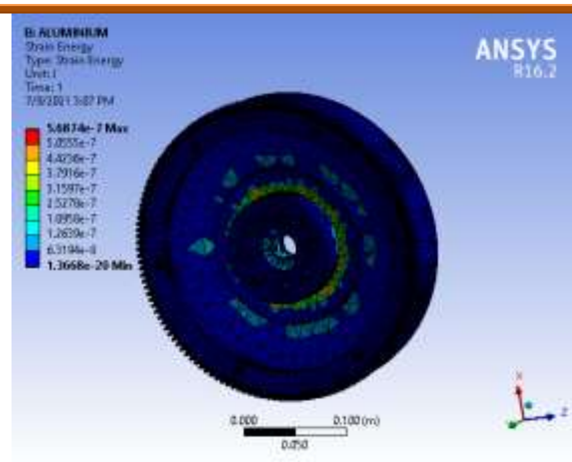


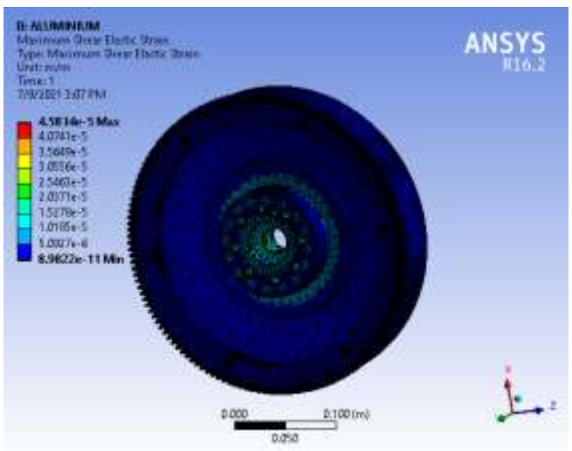
2) ALUMINIUM

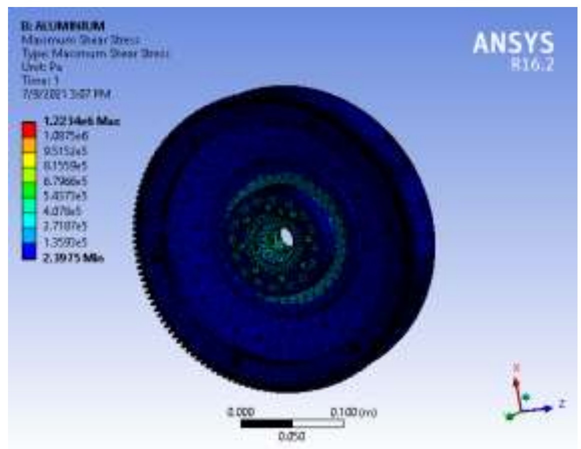




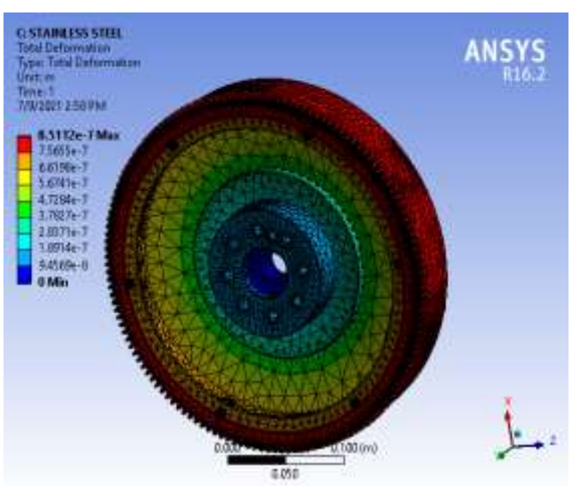


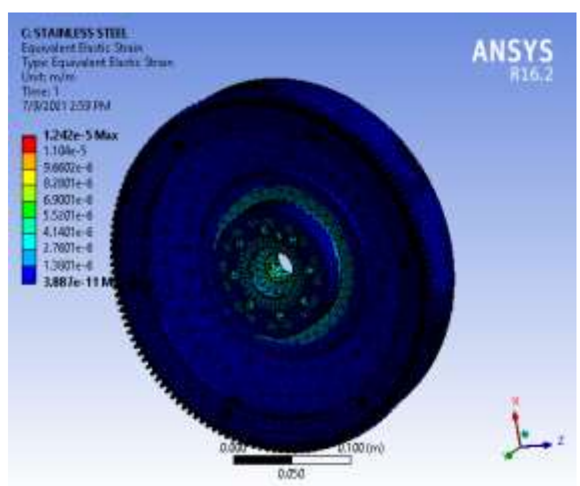


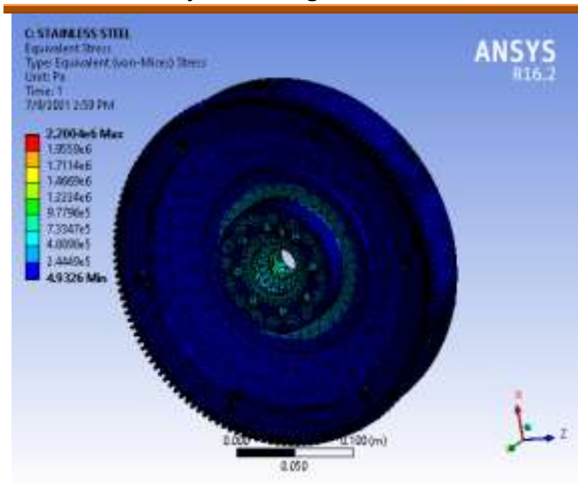


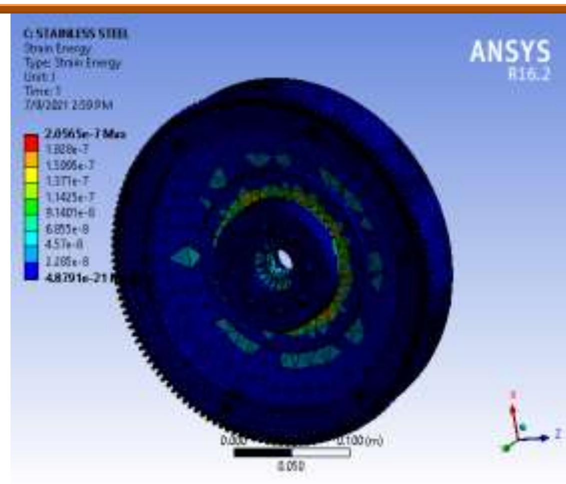


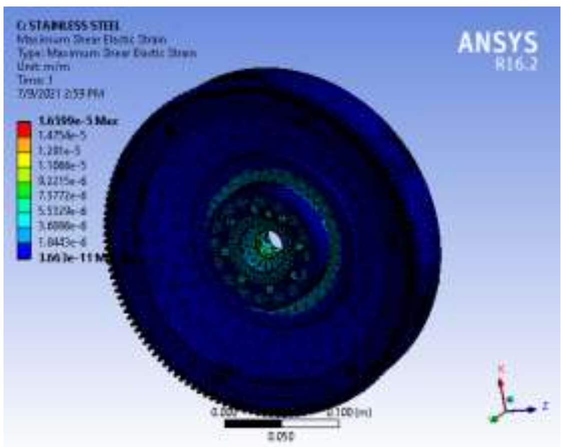
3) STAINLESS STEEL

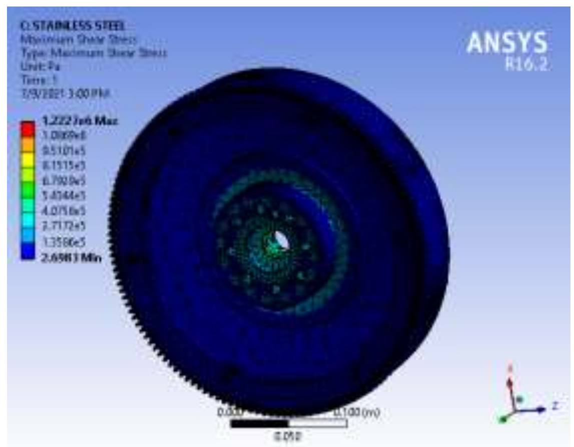












RESULTS AND RESULT TABULATION:

From the above experiments, we have formulated the CAD model of the *FLYWHEEL* that is used in almost all the internal combustion engines or engine powered vehicles and have done the analysis of it using ANSYS software and got various results and those are described below:

TABULATION 1.1

S.NO	SI UNITS	PARAMETERS		CAST IRON	ALUMINIUM	STAINLESS STEEL
1.	**m**	Total Deformation	***min***	0	0	0
	m		***max***	1.5009e-6	2.3049e-6	8.5112e-7
2.	**m/m**	Strain	***min***	6.8364e-11	1.0152e-10	3.887e-11
	m/m		***max***	2.1844e-5	3.372e-5	1.242e-5
3.	**Pa**	Stress	***min***	2.8043	4.2003	4.9326
	Pa		***max***	2.2186e6	2.1884e6	2.2004e6
4.	**J**	Strain Energy	***min***	6.4004e-21	1.3668e-20	4.8791e-21
	J		***max***	3.5173e-7	5.687e-7	2.0565e-7
5.	**m/m**	Shear Strain	***min***	3.7675e-11	8.9822e-11	3.663e-11

	m/m		***max***	2.8423e-5	4.5834e-5	1.6599e-5
6.	**Pa**	Shear Stress	***min***	1.6188	2.3975	2.6983
	Pa		***max***	1.2213e6	1.2234e6	1.2227e6

CONCLUSION:

All the material selections for the automotive industries are chosen in such a way that they should be meeting some of the desired criteria. The most important criteria are as follows:

1) Good wear and tear characteristics.
2) Less weight.
3) High corrosion resistance.
4) Cost economic.
5) Reliable.
6) Conformation to national or international standards (ISO 9001, ISO 14001).
7) Lessor maintenance requirement.

Now the above-selected materials are fulfilling those criteria and can be used for manufacturing the flywheel unit of a HEAT ENGINE i.e. an Internal or External Combustion Engine and as per the analysis results shown above cast iron is showing the least deformation and quite fullfilling all the desired criteria i.e. it can be taken in account that cast iron is most suitable for the manufacturing of flywheel of the vehicles running on IC or EC engines.

ACKNOWLEDGMENT:

The authors would like to thank all the persons who are involved and helped in the completion of the above research and the enthusiasm and willingness to learn about the systems discussed above kept the work on track and its completed in some sort of time.

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