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Structural Analysis of Petrol Engine Flywheel by Using Aluminium Alloy A360

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Abstract – A Flywheel is used in machines which is used to stores energy and energy is more than the requirement releases the requirement of energy is more than supply. A Flywheel is located on one end of the crankshaft and its inertia it reduces the vibration which outs the power stroke in each cylinder fires. The Flywheel is designed in 3D modelling CATIA. The analysis of the will be done by the prototype of Flywheel is done by using Cast Iron and aluminium alloy A360. The comparison can be done with the materials and the best material after the analysis is Flywheel aluminium alloy A360.

Index Terms – Flywheel, CATIA, A360, Aluminium.

1. INTRODUCTION

Modern technology has enabled a new application for the age old flywheel in advanced flywheel energy storage systems. Flywheel energy storage systems store kinetic energy in the form of a rotating flywheel typically made of composite materials. These systems are often called mechanical batteries since electrical energy is input, stored as rotational mechanical energy, and converted back to electrical energy to provide power on demand.

NASA Glenn Research Centre (NASA-GRC) expressed a need for a means to monitor the health of a composite flywheel constructed of concentric preloaded composite rings. In response, the University of Texas Centre for Electromagnetic (UTCEM) designed a flywheel that exhibits a change in mass

Eccentricity when fatigue, thermal expansion, or other phenomena cause a loss in preload of the outer ring. The design is such that the outer ring of the flywheel is only bonded to next inner ring on 180degrees of the contact area. As a result, centripetal acceleration causes the outer ring to grow asymmetrically if the preload is lost. The existence of preload or compression between the rings is important since it provides the structural integrity of the flywheel. The outer ring preload is designed to be maintained to just above maximum operating speed. Therefore, the asymmetric growth would only be sensed in the operating speed range if the preload was reduced. The most notable factor that would cause a reduction in the preload is fatigue. Fatigue in the composite material causes a reduction in the ring hoop stiffness which in turn reduces the preload. Texas A&M Vibration and Controls laboratory has been sponsored by NASAGRC to utilize a magnetic suspension system to develop health monitoring techniques utilizing the UT-CEM Preload Loss Monitor technology.

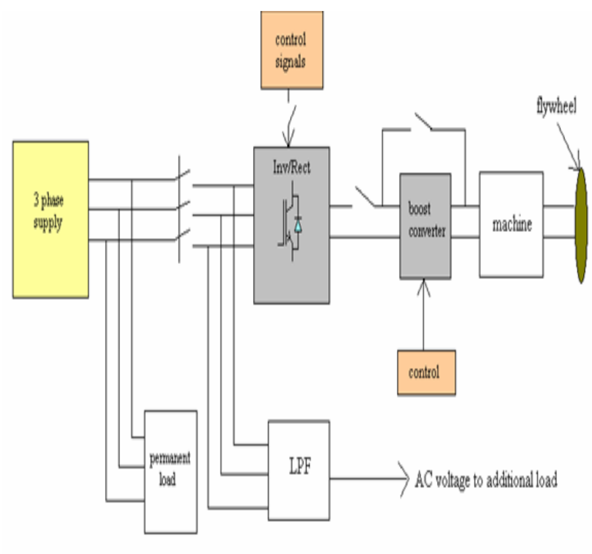


Fig: Block diagram of the flywheel energy storage system (FESS)

1.1 PRODUCT

The flywheel is charged using the principle of the Crookes Radiometer. The glass flywheel structure therefore is very important. Two materials properties of the glass are manipulated to allow charging. The refractive index and colour of the glass are used to control the absorption at the surface of the glass. Similar to the Crookes radiometer the glass flywheel has alternating faces that absorb different amounts of radiation. This is schematically shown in Figure 3 by black and white fringes at the surface of the flywheel.

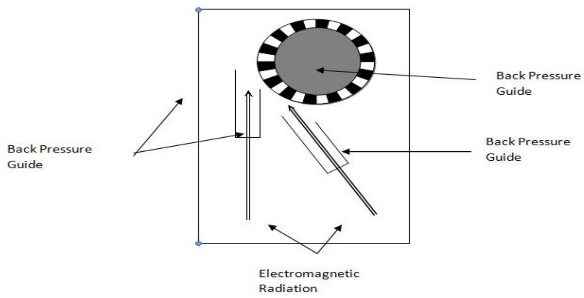


Fig: flywheel absorption edges and charging mechanism

1.2 Flywheel Concept

There are many ways that energy can be stored; in chemical bonds (fuel), in the energy to separate ions (batteries), in gravitational potential energy (pumped hydro), or in kinetic energy (flywheels).

For example, in a flywheel, the inertia of a rotating mass is used to store energy. The potter's wheel is a low-tech example of this from antiquity. In a potter's wheel, the potter spins the wheel up from a stop by kicking it with her feet. Then when the potter moulds the clay with her hands, she kicks the wheel occasionally to maintain the speed of rotation against the frictional forces that sap its energy and slow it down. Some of the friction is in the bearings of the wheel, and some is from working the clay. The purpose of the wheel is to keep the clay moving in a circular path so that it can be shaped into a vessel of cylindrical symmetry.

The operation of a modern flywheel is somewhat like the heating system in your house, when operating under the control of a thermostat. It is sped up to its idling speed, it very slowly loses speed over some period of time, and then it is sped up to idling speed again. In the metaphorical comparison to home, heating, your furnace brings the house up to the set temperature, the furnace turns off, the house slowly cool sowing to the losses of heat through the walls, windows, and ceiling, and when the lower bound of the acceptable temperature range is reached, the furnace turns back on to raise the temperature to the top of the band again

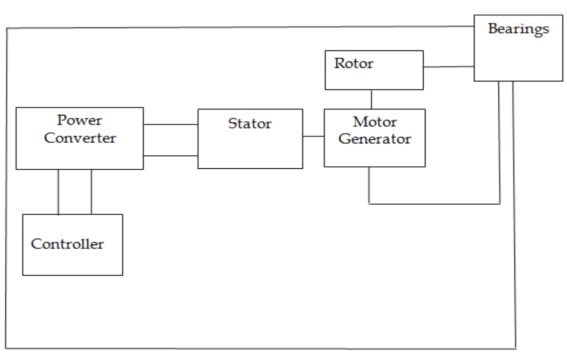


Fig: Flywheel Subsystems

2. LITERATURE SURVEY

Today's industries cannot survive worldwide competition unless they introduce new products with better quality (quality, Q), at lower cost (cost, C), and with shorter lead time (delivery, D). Accordingly, they have tried to use the computer's huge memory capacity, fast processing speed, and user-friendly interactive graphics capabilities to automate and tie together otherwise cumbersome and separate engineering or production thus reducing the time and cost of product development and production.

Computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE) are the technologies used for this purpose during the product cycle. Thus, to understand the role of CAD, CAM, and CAB, we need to examine the various activities and functions that must be accomplished in the design and manufacture of a product. These activities and functions are referred to as the product cycle. The product cycle described by Zeid is presented here with minor modifications.

2.1 DEFINITIONS OF CAD, CAM, AND CAE

As described in the previous section, computer-aided design (CAD) is the technology concerned with the use of computer systems to assist in the creation, modification, analysis, and optimization of a design [Grover and Zimmer's 1984]. Thus any computer program that embodies computer graphics and an application program facilitating engineering functions in the design process is classified as CAD software. In other words, CAD tools can vary from geometric tools for manipulating shapes at one extreme, to customized application programs, such as those for analysis and optimization, at the other extreme [Zeid 1991].

Between these two extremes, typical tools currently available include tolerance analysis, mass property calculations, and finite-element modelling and visualization of the analysis results, to name a few.

Process planning is also a target of computer automation; the process plan may determine the detailed sequence of production steps required to fabricate an assembly from start to finish as it moves from workstation to workstation on the shop floor. Even though completely automatic process planning is almost impossible, as mentioned previously, a process plan for a part can be generated if the process plans for similar parts already exist. For this purpose, group technology has been developed to organize similar parts into a family. Parts are classified as similar if they have common manufacturing features such as slots, pockets, chamfers, holes, and so on. Therefore, to automatically detect similarity among parts, the CAD database must contain information about such features. This task is accomplished by using feature-based modelling or feature recognition.

3. MODELLING OF FLYWHEEL

3.1 CATIA

CATIA (COMPUTER AIDED THREEDIMENSIONAL INTERACTIVE APPLICATION) is a multiple form CAD/CAM/CAE commercial software suite developed by French company Dassault systems. The software was created in late 1970s to develop Dassault's Mirage fighter jet, but was subsequently adapted in aerospace, automotive ship building, and other industries.

3.2 HISTORY

CATIA started as in-house development by French aircraft manufacturer Avion Marcel Dassault's.

The software name was initially CATI (CONCEPTION ASSISTEE TRIDIMENSIONELLE INTERACTIVE- French for Interactive aided three dimensional Designs), but was renamed CATIA in 1981.

In 1990, General Dynamics/Electric Boat Corp chose CATIA as its main 3D CAD tool, to design the United States Navy Virginia Class Nuclear Submarine.

In 1992 CADAM was purchased from IBM .In 1996 CATIA V4 was ported from one to four UNIX operating systems.

In 1998, an entirely rewritten version of CATIA V5 was released with support for UNIX, Windows NT and Windows XP since 2001.

3.3 Where is CATIA USED?

CATIA is being used by designers, manufacturing facilities, assemblers, architects, industrial engineers etc. Have a Look around you. Everything and Anything you see had to be designed before manufacturing.

The desk you are using, the chair you are sitting in, your daily use appliances, your car, your home etc. The list is almost endless. Nearly everything is being designed on computers. CATIA plays a major role in the design process. CATIA is being used by the majority of automotive and aerospace industries for automobile and aircraft products and its auxiliaries and tooling design. Thousands of engineering companies throughout the world over are using CATIA. A Company using CATIA has suppliers using CATIA too, thus making CATIA an Essential tool.

As mentioned earlier, CATIA V5 has different workbenches such as the Part Design workbench, Assemble design workbench, and drawing workbench. The bidirectional associative that exists between all these workbenches ensured that any modify the dimension of a part in the part in the part design workbench; the change will be reflected in the assembly design and the drawing workbenches. Similarly, if you modify the dimensions of a part in the drawing views generated in the Drawing workbench, the changes will be reflected in the part design Assembly design workbenches.

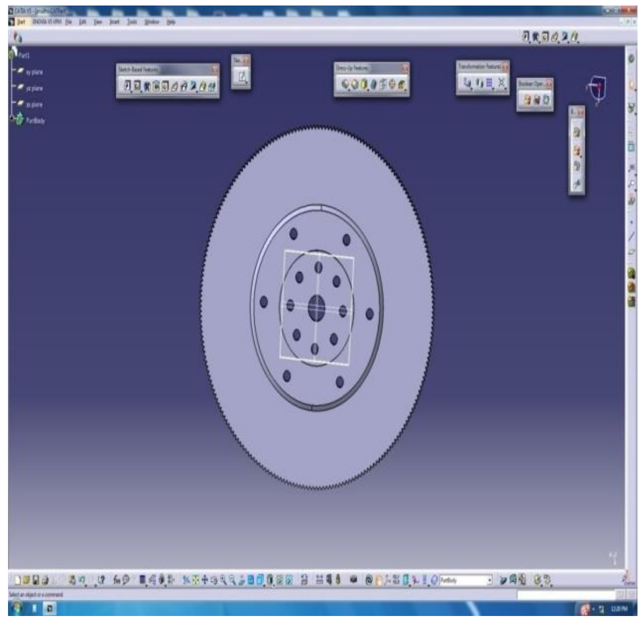
3.4 FILE EXTENSIONS FOR CATIA

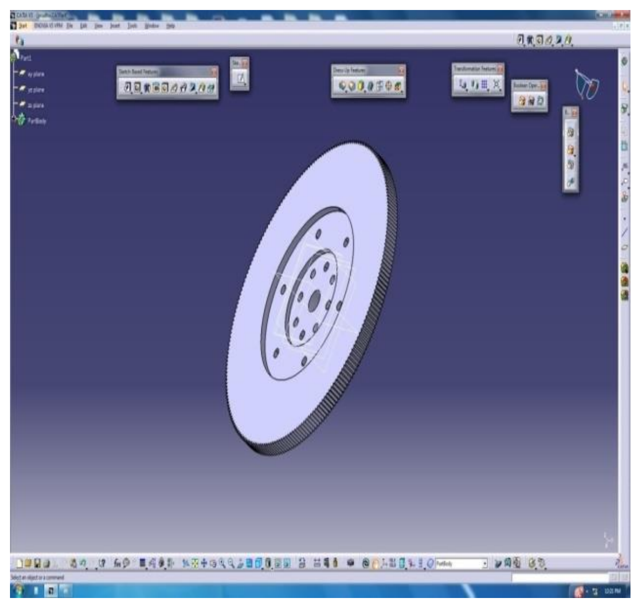
CAT Part:

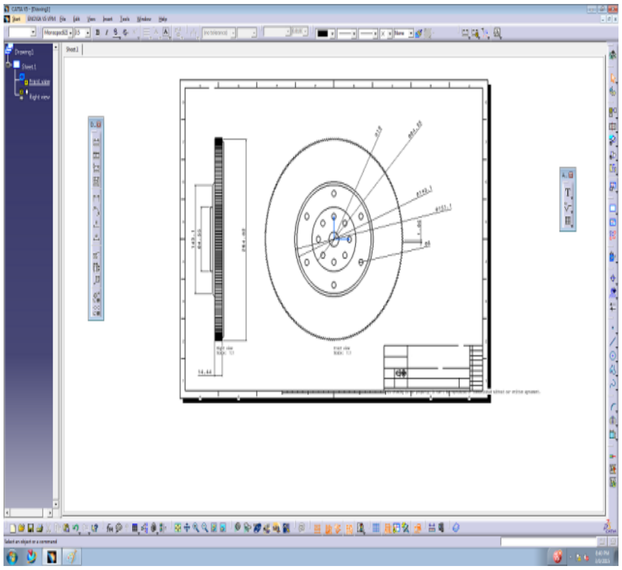
CAT Part is a file extension associated with at the files that are created in the sketcher. Part Design and wireframe and surface design workbenches of CATIA V5.

CAT Drawing:

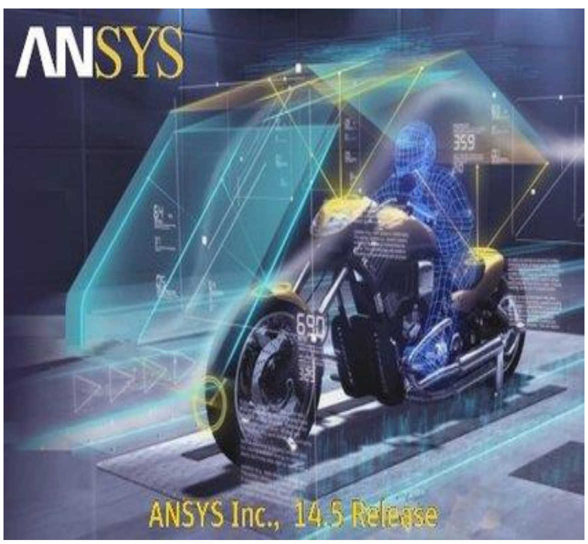
Cat Product is a file extension associated with all the files that are created in the assembly design workbench of CATIA V5.







4. PRE AND POST PROCESSING OF FLYWHEEL



Ansys is the standard FEA teaching tool within the engineering department at many colleges. Ansys is also used in civil and Electrical engineering, as well as physics and chemistry department.

Ansys provide a cost effective way to explore the performance of the products and processes in a virtual environment. This type of product development is termed as virtual Prototyping. With virtual prototyping techniques users can iterate various scenarios to optimize the product long before manufacturing is started. This enables a reduction in level of risk, And in the cost of ineffective designs. The multifaceted nature of Ansys also provides a means of ensure that users are able to see the effect of designs on the whole behaviour of the product, be it electromagnetic, thermal, mechanical etc.

4.1 GENERIC STEPS TO SOLVING ANY PROBLEM IN ANSYS

Like solving any problem analytically you need to define (1) your solution domain, (2) the physical model, (3) boundary conditions and (4) the physical properties. You then solve the problem and present the results.

In numerical methods, the main difference in an extra step called mesh generation. This is the step that divides the complex model in to small elements that become soluble in an otherwise too complex situation. Below describes the process in terminology. Slightly more attune too the software.

4.2 BUILD GEOMETRY

Construct a 2 or 3 –D representation of the object to be modelled and tested using the work plane coordinates system in Ansys.

4.3 DEFINE MATERIAL PROPERTIES

Now that the part exists, define a library of necessary materials that composed an object (or project) being modelled. This includes thermal and mechanical properties.

4.4 GENERATE MESH

At this point Ansys understands the makeup of the part. Now define how the model system should be broken down into finite pieces.

4.5 APPLY LOADS

Once the system is fully designed, the last task is to burden the system with constraints, such as physical loadings or boundary conditions.

4.5 OBTAIN SOLUTION

This is actually a step because Ansys need to understand within what state (steady state, transient… etc.) The problem must be solved.

4.6 PRESENT THE RESULTS

After the solution has been obtained there are many ways to present Ansys results, Choose from many options such as tables, graphs and contour lots

4.7 SPECIFIC CAPABILITIES OF ANSYS

4.7.1 STRUCTURAL

Structural analysis is probably the most common application of the finite element method is as it implies bridges and buildings, naval, aeronautical and mechanical structure such as ship halls, air craft's and machines housing as well as mechanical components such as pistons, machine parts and tools. Static analysis issued to determine displacement; stresses etc. under static loading conditions ANSYS can compute both linear and non-linear static analysis. Non linearity can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surface and creep.

4.7.2 TRANSIENT DYNAMIC ANALYSIS

Used to determine the response of structural to arbitrary time varying loads. All non-linearity's mentioned under static analysis above are allowed.

4.7.3 BUCKLING ANALYSIS

Issued to calculate the buckling loads and determine the buckling mode shape. Both linear and non-linear buckling analysis is possible.

In addition to the above analysis types, several special purpose features are available such as fracture mechanics, composite material analysis, fatigue and both p-Method and beam analysis.

4.7.4 THERMAL

ANSYS is capable of both steady state and transient analysis of any solid with thermal boundaries condition.

Study state thermal analyses calculate the effects of steady thermal loads on a system or component. User often performs a steady state analysis before doing a transitional thermal analysis to help establish initial conditions. A steady state analysis also can be the last step of a transient thermal analysis; performed after all transient effects have diminished. ANSYS can be used to determine temperatures, thermal gradient, heat flow rate and heat fluxes in an object that are caused by the thermal loads that do not vary over time. Such loads include the following

- Convection
- Radiation
- Heat flow rate
- Heat fluxes (Heat flow per unit area)
- Heat generation rates (heat flow per unit volume)
- Constant temp. boundaries

The steady state thermal analysis may be either linear, with constant material property, or non-linear with material properties that depend on temperature. The thermal properties most material varies with temperature. This temperature dependency being appreciable, the analysis becomes non-linear. Radiation boundary conditions also make the analysis non-linear. Transient calculations are time dependent and ANSYS can both solve distributions as well as create videos for time incremental displace of models.

4.8 COUPLED FIELDS

A coupled field analysis is an analysis that takes into account the interaction between two or more fields of engineering. A peizo electric analysis, for example handles the interaction between the structural and electric fields: it solves for the voltage distribution due to applied displacement or vice versa. Other examples of coupled field analysis are thermal stress analysis, thermal electric analysis and fluid structure analysis.

Some of the applications in which coupled field analysis may be required are pressure vessel, fluid structure analysis, induction heating, ultrasonic transducer, magnetic forming and micro electro mechanical system (MEMS)

4.9 MODEL ANALYSIS

A model analysis is typically used to determine the vibration characteristic of a structure or a machine component while it is being designed it can also serve as a starting point of another, more detailed, dynamic analysis, such as a harmonic respond=se or full transient dynamic analysis.

Model analysis, while being one of the most basic dynamic analysis types available in ANSYS, can also be more computationally time consuming than a typical static analysis. A reduced solver, utilizing automatically or manually selected master degrees of freedom is used to drastically reduce the problem size and solution time.

4.10 HARMONIC ANALYSIS

Used extensively by companies who produce rotating machinery, ANSYS harmonic analysis is used to predict the sustained dynamic behaviour to consistent cyclic loading. A harmonic analysis can be used to verify whether or not a machine design will successfully overcome resonance, fatigue and other harmful effects of forced vibrations.

5. RESULTS AND DISCUSSIONS

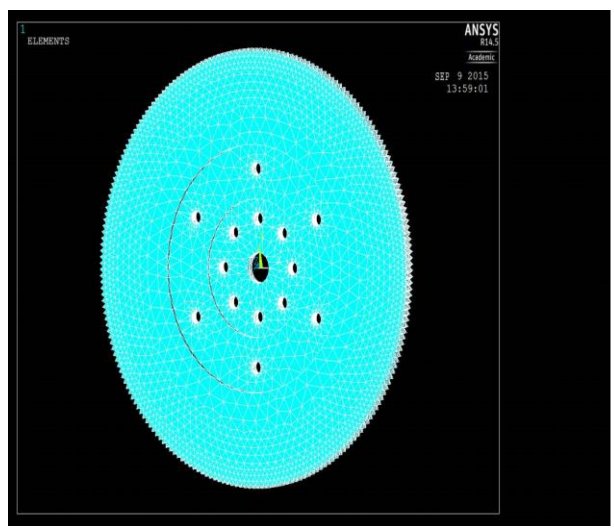


Fig: Imported model from CATIA

Element Type : solid 20 nodes 95

Material Properties

Young's modulus (EX) : 103000N/mm^2

Poisson’s ratio (PRXY) : 0.33

Density : 0.0000071Kg/mm^3

5.1 Meshed Model

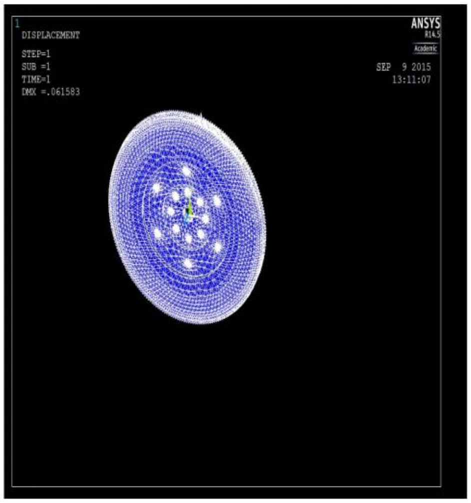


Fig: Meshed Model

Loads

Pressure : 0.036N/mm^2

Poisson’s ratio (PRXY): 0.33

Density : 0.0000071Kg/mm^3

5.2 Post Processor

General Post Processor–Plot Results-Contour Plot-Nodal Solution-DOF Solution-Displacement Vector Sum

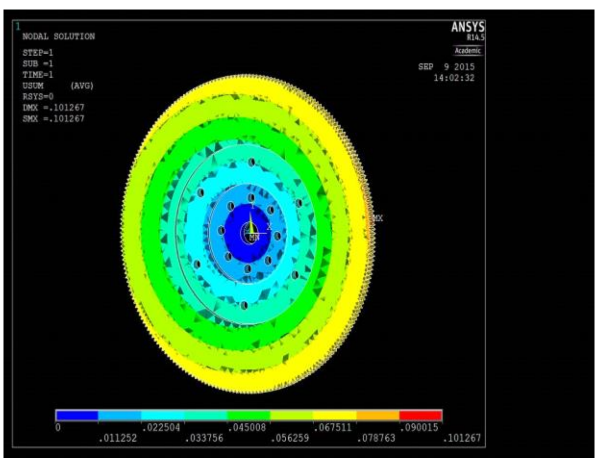


Fig: Displacement Vector Sum

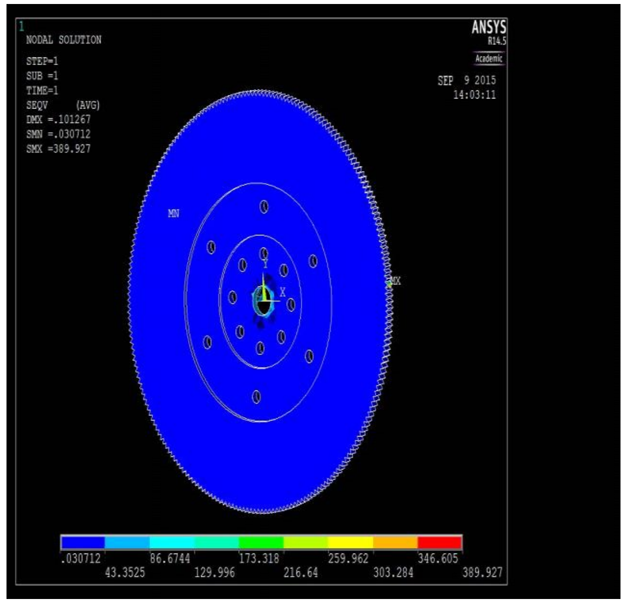
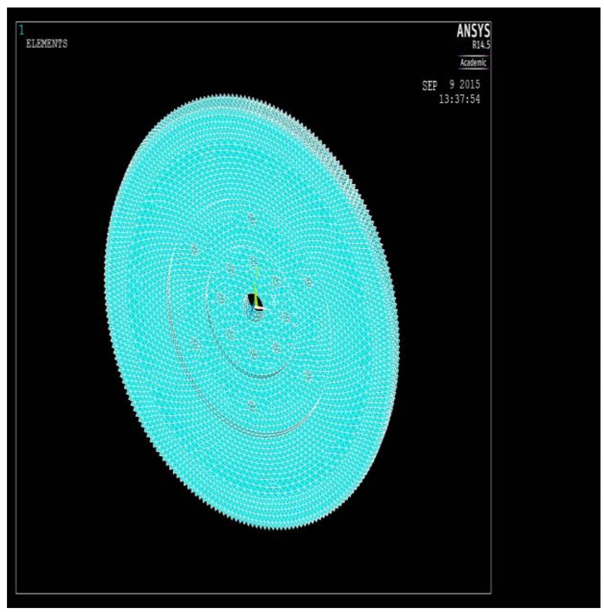


Fig: Vonmises Stresses

5.3 Structural Analysis of Flywheel using Aluminium alloyA360

Imported model from CATIA V5 is drawn in CATIA



Element Type : solid 20 nodes 95

Material Properties

Young’s modulus (EX) : 240000N/mm^2

Poisson’s ratio (PRXY : 0.33

Density : 0.0000071Kg/mm^3

5.4 Meshed Model

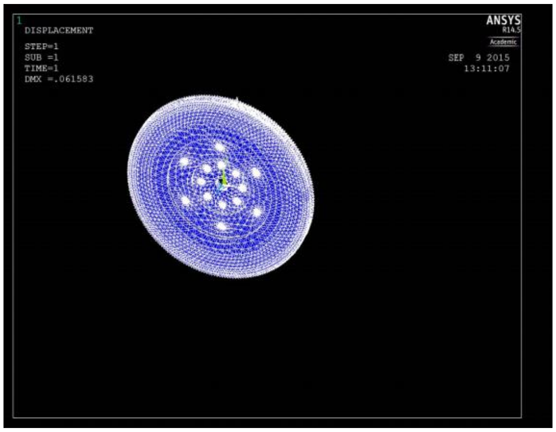


Fig: Meshed Model

5.5 Post Processor

General Post Processor–Plot Results-Contour Plot-Nodal Solution-DOF Solution-Displacement Vector Sum.

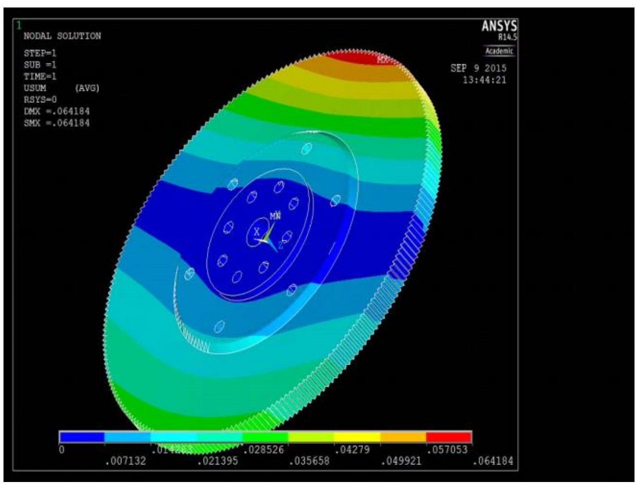


Fig: Displacement Vector Sum.

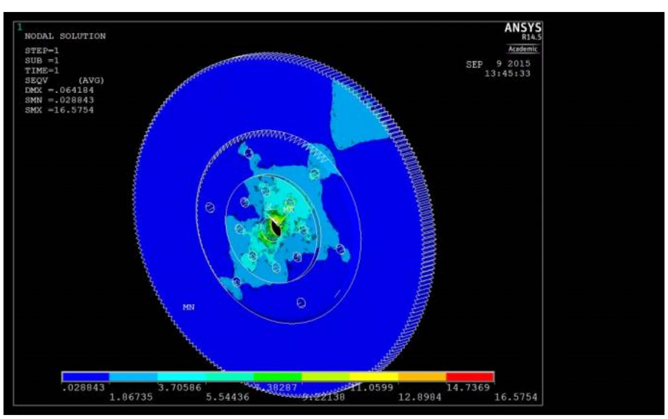


Fig: Vonmises Stresses

6. COMPARSION OF RESULTS

CAST IRON:

LOAD STEP=1

SUBSTEP=1

TIME=1.0000

LOAD CASE=0

The following degree of freedom results are in the global coordinate system

NODE	UX	UY	UZ	USUM
1	0.20436E-01	-0.74158E-01	0.83753E-02	0.77377E-01
2	0.20109E-01	-0.76900E-01	0.79079E-02	0.79879E-01
3	0.19448E-01	-0.78895E-01	0.77396E-02	0.81624E-01
4	0.18097E-01	-0.77680E-01	0.71470E-02	0.80079E-01
5	0.17392E-01	-0.79702E-01	0.69378E-02	0.81872E-01
6	0.16042E-01	-0.78373E-01	0.64296E-02	0.80256E-01
7	0.15238E-01	-0.80512E-01	0.63486E-02	0.82187E-01
8	0.13913E-01	-0.79134E-01	0.58981E-02	0.80564E-01
9	0.12760E-01	-0.81920E-01	0.59689E-02	0.83122E-01
10	0.10778E-01	-0.79677E-01	0.58904E-02	0.80618E-01
11	0.99567E-02	-0.81423E-01	0.55286E-02	0.82216E-01
12	0.85597E-02	-0.79655E-01	0.51369E-02	0.80278E-01
13	0.78348E-02	-0.81132E-01	0.47690E-02	0.81649E-01
14	0.65731E-02	-0.79565E-01	0.43323E-02	0.79953E-01
15	0.57834E-02	-0.81031E-01	0.39401E-02	0.81333E-01
16	0.45786E-02	-0.79463E-01	0.35121E-02	0.79672E-01
17	0.37064E-02	-0.80904E-01	0.31561E-02	0.81050E-01
18	0.25622E-02	-0.79350E-01	0.27343E-02	0.79438E-01
19	0.16336E-02	-0.80759E-01	0.23682E-02	0.80811E-01
20	0.53580E-03	-0.79215E-01	0.19682E-02	0.79241E-01

ALUMINIUM ALLOY A360:

LOAD STEP= 1

SUBSTEP=1

TIME=1.0000

LOAD CASE=0

The following degree of freedom results are in the global coordinate system

NODE	UX	UY	UZ	USUM
1	0.17167E-02	-0.96981E-02	0.83629E-02	0.12921E-01
2	0.17097E-02	-0.97166E-02	0.77677E-02	0.12557E-01
3	0.95640E-03	-0.43715E-02	0.77835E-02	0.89781E-02
4	0.15215E-02	-0.83753E-02	0.77644E-02	0.11522E-01
5	0.13344E-02	-0.70410E-02	0.77625E-02	0.10565E-01
6	0.11453E-02	-0.57194E-02	0.77721E-02	0.97175E-02
7	0.98245E-03	-0.42934E-02	0.83807E-02	0.94676E-02
8	0.11670E-02	-0.56484E-02	0.83622E-02	0.10158E-01
9	0.13480E-02	-0.69978E-02	0.83498E-02	0.10978E-01
10	0.15329E-02	-0.83444E-02	0.83512E-02	0.11905E-01
11	0.10619E-02	-0.50147E-02	0.80734E-02	0.95632E-02
12	0.16199E-02	-0.90303E-02	0.80593E-02	0.12212E-01
13	0.10053E-02	-0.42958E-02	0.92335E-02	0.10233E-01
14	0.17508E-02	-0.97397E-02	0.92196E-02	0.13525E-01
15	0.11916E-02	-0.56566E-02	0.92242E-02	0.10886E-01
16	0.13770E-02	-0.70216E-02	0.92172E-02	0.11669E-01
17	0.15634E-02	-0.83738E-02	0.92149E-02	0.12549E-01
18	0.16405E-02	-0.90412E-02	0.87861E-02	0.12713E-01
19	0.10864E-02	-0.49701E-02	0.87982E-02	0.10163E-01
20	0.17554E-02	-0.97240E-02	0.97897E-02	0.13910E-01

7. CONCLUSION

This project deals with modelling of a flywheel. A 3D model is designed by using 2D drawings in CATIA and CAD tool.

Structural analysis is done on the flywheel using the materials cast iron and aluminium alloy A360.

By observing the stress values from the results, the values are less than their respective permissible values for both the materials. So it can be concluded that design is safe.

By comparing the displacement and stress values for both materials, the values are less for aluminium alloy A360 when compared to cast iron.

So we can conclude that as per the analysis done, the best material for flywheel is aluminium alloy A360.

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