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DESIGN AND ANALYSIS OF CAD BASED HUMAN POWERED FLYWHEEL MOTOR BY USING QUICK RETURN RATIO ONE MECHANISM

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ABSTRACT

The increasing energy demand, unemployment in developing countries like India, Increase awareness of people towards health are some of the driving forces for the development of humanly powered machines. The machine include manually powered brick making machine, chaff cutter, flour mill etc. the one of the component among all these flywheel motor and its mechanism which being subsequently used to drive respective process. Hence this paper present an literature survey on design and analysis of CAD based model of flywheel motor by using quick return ratio one mechanism.

KEYWORDS: Quick Return Ratio-One, Flywheel Motor, Analysis

INTRODUCTION

During 1979-99, Modak J.P. developed a human powered brick making machine for the manufacturing of bricks (Modak J.P. J.P. 1982, 1994, 1997, 1998) [**1**]. And since then various processes are energized by the human power such as wood turning, cloth washing, chaff cutter [**2**], potter's wheel, flour mill etc. All these machines are operated by the human power with one common mechanism among them- The Flywheel Motor. The Machine consists of flywheel motor, driven bicycle mechanism with speed increasing gearing, which drives the shaft of process of process unit through clutch and torque amplification unit (Gupta 1977) [**1**]. Since ever increasing fuel crises, energy crises, busy schedules of load shading, unemployment justify the need of human powered machines, the constants efforts are being continuously made to optimize the various parameters of these machines so as to provide the ease for the operator and consequently make efficient use of human energy. In an attempt, this paper presents the exhaustive literature survey on the flywheel motor throwing lights on the experimentation done on flywheel motor with double lever inversion for optimizing its performance.

FLYWHEEL MOTOR THE CONCEPT

Any machine, to power it by human energy, the maximum power requirement should be 75 Watts. Any machine or process requiring more than 75 Watts and if process is intermittent without affecting and product, can also be operated by human energy (Alexandrove 1981) [**3**]. This is possible with the provision of intermediate energy storing unit which stores the energy of human and supply periodically at required rate to process unit, this is called as "human powered flywheel motor." Modak J.P. and his associates are working on flywheel motor from 1977. A manually driven brick making machine was first of its kind in which manually energized flywheel motor is used for first time [**4**]. Essentially the flywheel motor consists of flywheel, which is being driven by a human through a simple bicycle mechanism and pair of speed increasing gears [**3**]. The schematic of flywheel motor is as shown in figure 1.

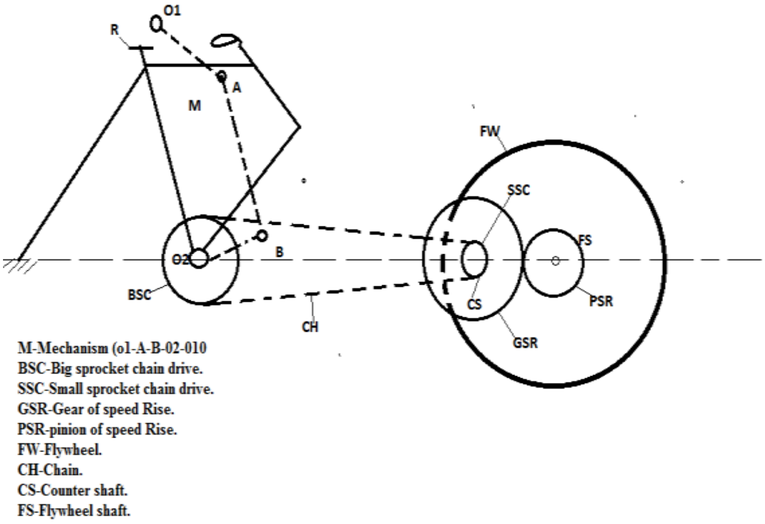


Figure 1: Schematics of Flywheel Motor

A rider pedals the mechanism “M” converting the oscillatory motion of thighs into rotational motion of counter shaft “C”. This countershaft “C” connected to flywheel shaft “FS“ with speed increasing transmission consisting of pair of speed gears [**4**]. Driver pumps the energy in flywheel at energy rate convenient to him [**4**]. In this way, the muscular energy of human is converted into kinetic energy of flywheel by this man machine and for its efficient use it is necessary to optimize its parameters [**4**].

DESIGN CONSIDERATION IN FLYWHEEL MOTOR

At the beginning, the flywheel motor was not based on any design data, rather it was built only on the institution of human [**4**]. Later with the numerous experimentation the design data is made available which is discussed below.

Modification in Existing Bicycle Mechanism

Modak J.P (1985) has established the relationship between the useful torques developed at the crank as function of crank position during its revolution [**5**]. Modak J.P. also observed that out of 360° rotation of pedal crank, only from 30°-115° of crank position from top dead center is useful. The rest of the period of crank position i.e. 0°-30° and 115°-162° is not effectively used and from 162°-360° is completely idle. Even when both the cranks are considered the useful driving angle is found to be 154. [**5**]. Consequently for maximum utilization of operators energy Modak J.P. suggested three modified mechanisms namely Quick return ratio one, Double lever inversion and Elliptical sprocket [**5**]. Based on his mathematical modeling he concluded improvement of 17%, 38%, and 18% in human energy utilization for Quick return ratio one, Double lever inversion and Elliptical sprocket respectively. This performance of various bicycle drives then was experimentally verified by Modak J.P, Chandurkar K.C. et, al (1987) and found almost matching with theoretical values [**6**].

Flywheel Speed and Moment of Inertia

Modak J.P(1987) during the experimentation has ob-served the maximum thigh oscillation for the average person of 165 cm stature from age group 20-22 years is 40. [**7**]. With the available chain drive for existing 22” bicycle frame the flywheel speed of 240 rpm was fair enough from point of total speed rise from pedals to flywheel shaft [**7**]. Further with calculation Modak J.P. (1987) has deter-mined the size of flywheel with the objective to store the maximum energy irrespective of speed fluctuations(180-240 rpm) [**7**]. The Flywheel rim diameter is found to 82 cm which gives the weight of flywheel as 150Kg and 266 Kg for 240 rpm and 180 rpm respectively. Hence Modak J.P. (1987) suggested the flywheel with 150 Kg @240 rpm[**7**]. Further Modak J.P.(1987) has also found that driving tor-que of pedal is unaffected by increasing flywheel moment of inertia and stores same energy for same frequency of thigh oscillation [**7**].

Gear Ratio

Modak J.P. (1987) suggested the value of gear ratio as 4:1 so as to reduce the effect of jerk induced at process unit shaft as result of energy or momentum exchange during the clutch engagement. If lower value of gear ratio is to be used then flywheel speed should be maintained higher than 240 rpm [**7**].

Quick Return Ratio-One

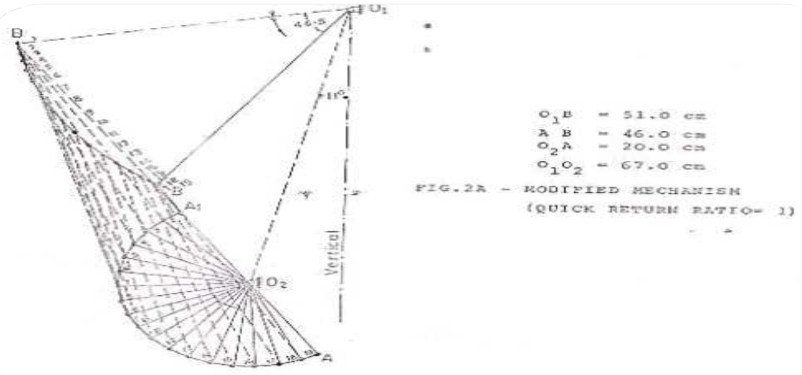


Figure 2: Modified Mechanism (Quick Return Ratio = 1)

From figure

- O_1B is thigh length,
- AB is length,
- O_2A is crank length,
- O_1O_2 is frame.

It is modified form of mechanism called as Quick Return Ratio One. In the existing mechanism, the ratio of forward travel to return travel is 0.82. In the Quick Return Ratio One, the ratio is one therefore, the second paddle will be immediately ready when the first one goes down.

In this, the thigh oscillation angle, thigh length and the leg length are kept same. In existing mechanism, the crank length is 18.5 cm and in QRR- one it is 20 cm.

Similarly, in existing mechanism the frame length i.e. crank centre to rider’s hip joint 74 cm and frame inclination to vertical is 20^0. But in QRR-one, the frame length i.e. Crank centre to rider’s hip joint 67cm and frame inclination to vertical is 11^0

Computer Aided Modeling of Flywheel Motor

CAD modeling is used by many designers to create elaborate computerized models of objects. CAD stands for computer-aided design. Engineers, architects, and even artists utilize computers to assist in their design projects. Computers allow them to visualize their designs and confront problems before they have expended any of the resources necessary to put them into physical form.CAD modeling takes many different forms depending on the type of project. Some models are simple two-dimensional representations of various views of an object. Others are elaborate three-dimensional cross-sections that show every detail in great depth. It is an important industrial art involved in automotive, aerospace, prosthetic, and artistic designs. The use of CAD modeling is massively widespread; anything from chairs to rockets can be designed with the aid of computer programs. CAD modeling has had a profound effect on the process's development. First, a general idea must be made to solve a specific problem. Next, CAD modeling is used to work out the specifics of the model's design. [9][10]

Type of CAD Modeling

Wireframe Models

Wireframe systems were developed in the early 1960's to automate design drafting. Most of the early 3D CAD systems used wireframe models. The very first systems were only 2D and the user had to construct a model point by point and line by line. A wireframe model is represented by tables defining edges and points. The start point and the end point of each edge are stored in the edge table. An edge may be a line or a curve. The coordinates of each point are stored in the point table. This representation is natural for a designer who is familiar with mechanical drawings, since it is the lines and curves in a drawing which define 3D shape. A wireframe model is stored very simply in a computer as a data structure. The storage space is small and the access time very short**.[11]**

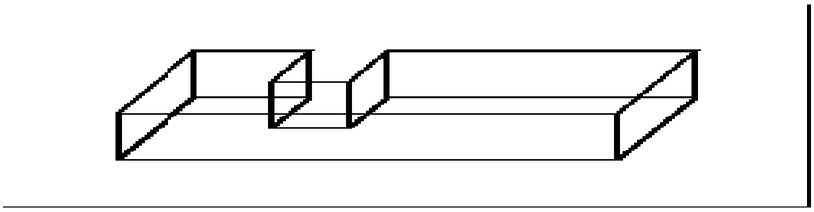


Figure 3: For Wireframe Model

Solid Models

Because there is no ambiguity in using a solid model to represent a real world 3D object, the importance of using solid modeling has been widely recognized. Solid models can support a wide range of activities, like interference check, computation of volume and surface area, finite element analysis, etc. In general, most solid modeling systems have adopted either constructive solid geometry (CSG) or boundary representation (B-Rep) as representations of solids. Solid models may be divided in two basic classes as follows:

- Decomposition models represent a solid as a collection of simple objects from a fixed collection of primitive object types, combined with a single gluing operation;
- Constructive models represent a solid as a combination of primitive solids. Each of the primitives is represented as an instance of a primitive solid type. Different types of constructive modeling representations are half-space representation and CSG.

Boundary models represent a solid in terms of its boundary. The boundary of a solid is a surface that is usually represented as a collection of faces. Faces again, are often represented as a bounded region of the surfaces. B-Rep represents a solid boundary as close skin around the object.

Surface Modeling

A surface model is represented by tables of edges and points, as is a wireframe model, but additional to wireframe, a surface model is represented by tables of faces. The face table stores information on which edges are attached to each face. In most conventional CAD systems for free-form surfaces, surface models have been used as internal representations. However, a surface model is a set of faces, and as such can be ambiguous when determining the volume of an object. Surface models play an important role in industry, because they give an accurate description of the surface of an object. An example of a very simple surface model is shown in Figure4.

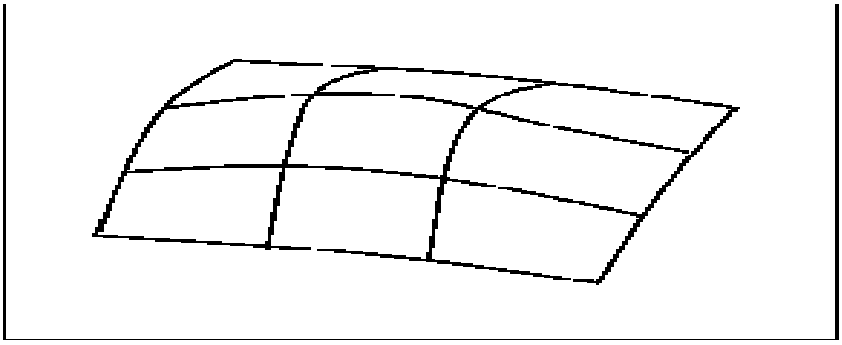
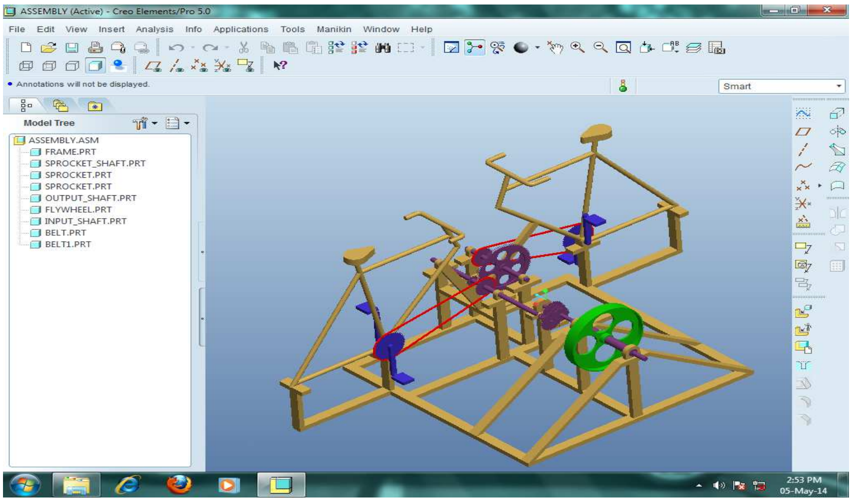


Figure 4: Surface Modeling

CAD Modeling of Flywheel Motor Using PRO-E

Keeping these advantages in mind the CAD model of the flywheel motor was developed using Pro –E Creo software. All the components of the flywheel motor are such as base frame, bicycle frame, elliptical sprocket, freewheel, chain drive, gears, shafts, flywheel etc are modeled separately in part environment of Pro –E Creo software and then all the components are assembled to get final assembly. Some of the sample pictorial views of the model development are shown below



Annotations will not be displayed.

Figure 5: Assembly Mechanism of Cad Modeling of Fabricated Human Powered Flywheel Motor with Quick Return Ratio One by Using Pro-E

Figure 6: Practical Model of Quick Return Ratio One in Flywheel Motor

COMPUTER AIDED ANALYSIS OF THE EXPERIMENTAL SET UP BY USING ANSYS

Introduction

This chapter covers the FEM analysis of Experimental set up. The structural static analysis is carried out on the cad model of the system. This analysis is carried out for the maximum input force applied at the pedal. The cad model of flywheel motor was prepared in PRO-E and it was imported in ANSYS v11 for meshing. Finally the model is solved in ANSYS v11 to obtained results for static structural analysis.

Overview of Structural Analysis

Structural analysis is probably the most common application of the finite element method. The thermo structural (or structure) implies not only civil engineering structures such as bridges and buildings, but also naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

The following structural analysis topics are available:

- Types of Structural Analysis
- Elements Used in Structural Analyses
- Material Model Interface
- Solution Methods

Types of Structural Analysis

The seven types of structural analyses available in the ANSYS family of products are explained below. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are displacements. Other quantities, such as strains, stresses, and reaction forces, are then derived from the nodal displacements.

Structural analyses are available in the ANSYS Multiphysics, ANSYS Mechanical, ANSYSStructural, and ANSYS Professional programs only.

You can perform the following types of structural analyses. Each of these analysis types arediscussed in detail in this manual.

Static Analysis: Used to determine displacements, stresses, etc. under static loading conditions. Bothlinear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, largedeflection, large strain, hyper elasticity, contact surfaces, and creep.

Modal Analysis: Used to calculate the natural frequencies and mode shapes of a structure. Differentmode extraction methods are available.

Harmonic Analysis: Used to determine the response of a structure to harmonically time-varyingloads.

Transient Dynamic Analysis: Used to determine the response of a structure to arbitrarily timevaryingloads. All nonlinearities mentioned under Static Analysis above are allowed.

Spectrum Analysis: An extension of the modal analysis, used to calculate stresses and strains due toa response spectrum or a PSD input (random vibrations).

Buckling Analysis--Used to calculate the buckling loads and determine the buckling mode shape. Both linear (Eigen value) buckling and nonlinear buckling analyses are possible.

Structural Static Analysis

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

Static analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The types of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)
- Fluencies (for nuclear swelling)

More information about the loads that you can apply in a static analysis appears in Apply the Loads.

Performing a Static Analysis

The procedure for a static analysis consists of these tasks:

- Build the Model
- Set Solution Controls
- Set Additional Solution Options
- Apply the Loads
- Solve the Analysis
- Review the Results.

Structural Analysis of the Experimental Set Up

As mentioned above the static structural analysis of experimental set up is carried out for the maximum value of input force applied during pedaling. The maximum force applied at the pedal was calculated at max RPM of the flywheel ---- and this maximum value of force is found to be 59.32 N thus by considering this as input force the structural analysis for the each of the component is carried out and the value of maximum deflection, maximum stress, safe stress is found out. The analysis details are shown below.

Flywheel

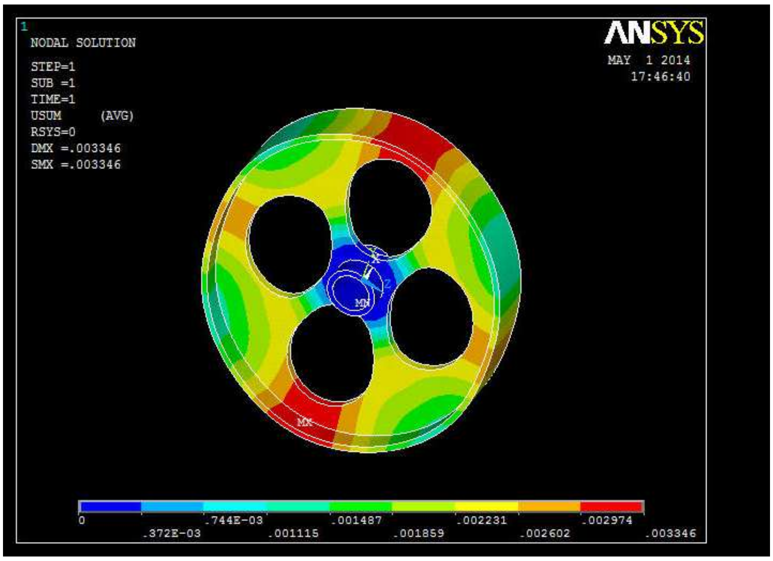


Figure 7: Deflection in Flywheel Due to Load

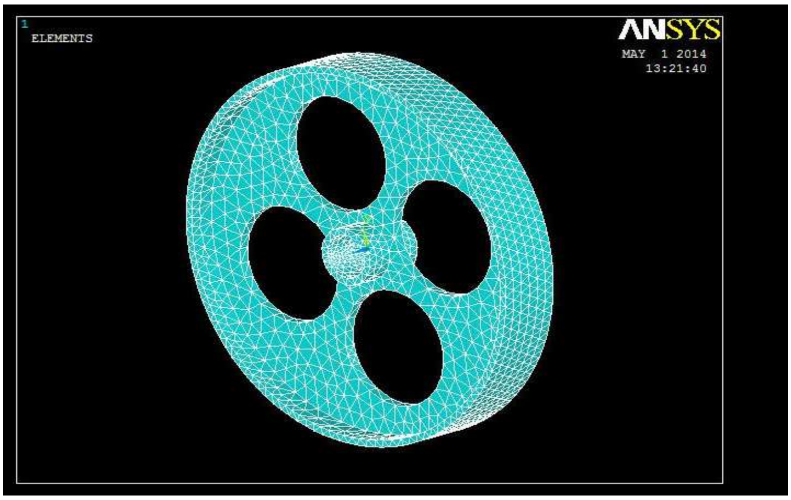


Figure 8: Meshing of the Flywheel

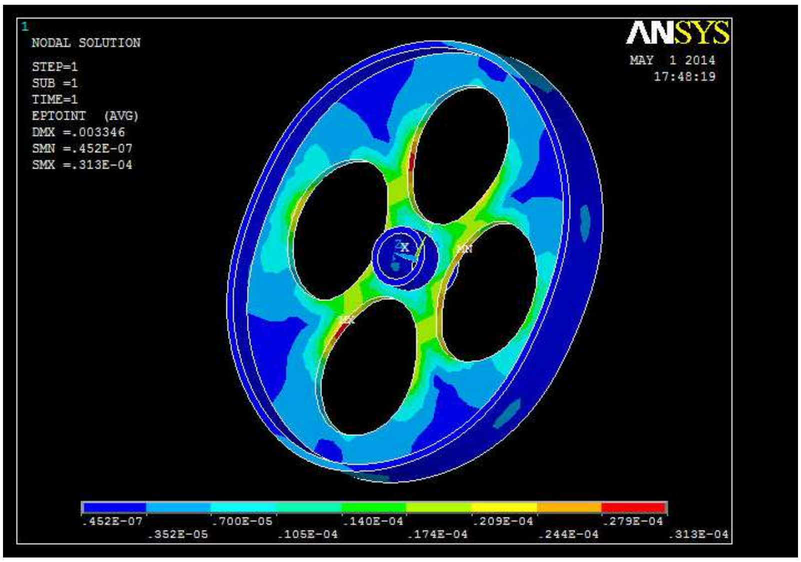


Figure 9: Stress Intensity in Flywheel Due to Applied Load

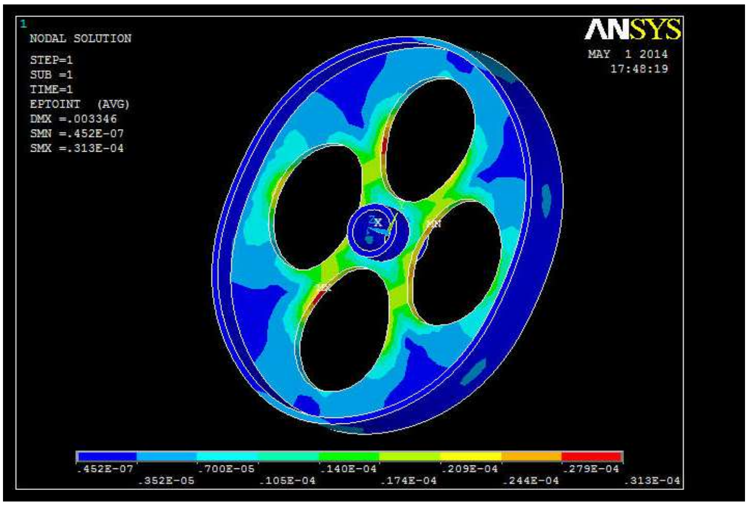


Figure 10: Stress Intensity in Flywheel Due to Applied Load

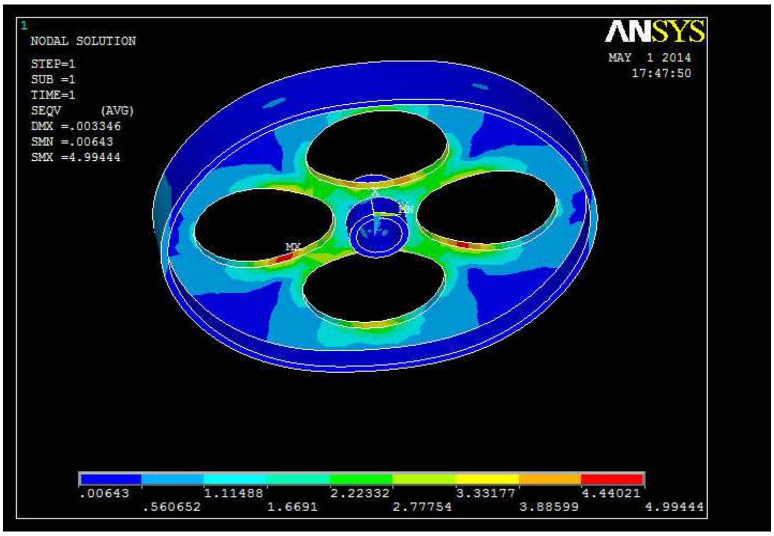


Figure 11: Von Mises Stresse

Circular Sprocket

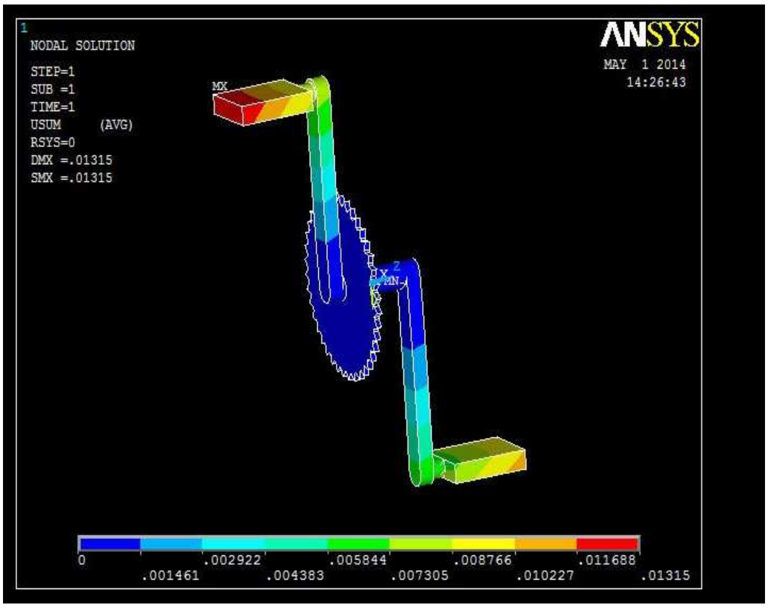


Figure 12: Deflection in Elliptical Sprocket

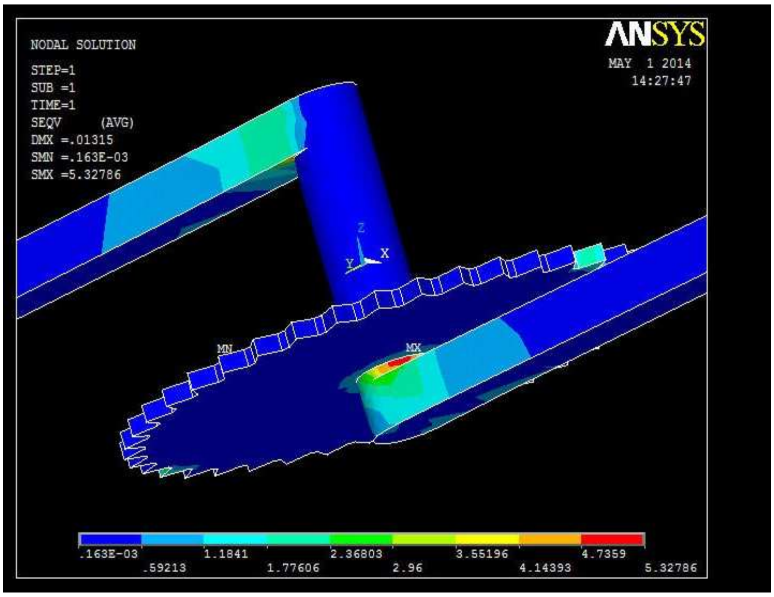


Figure 13: Von Mises Stresses

Gear Box Input Shaft

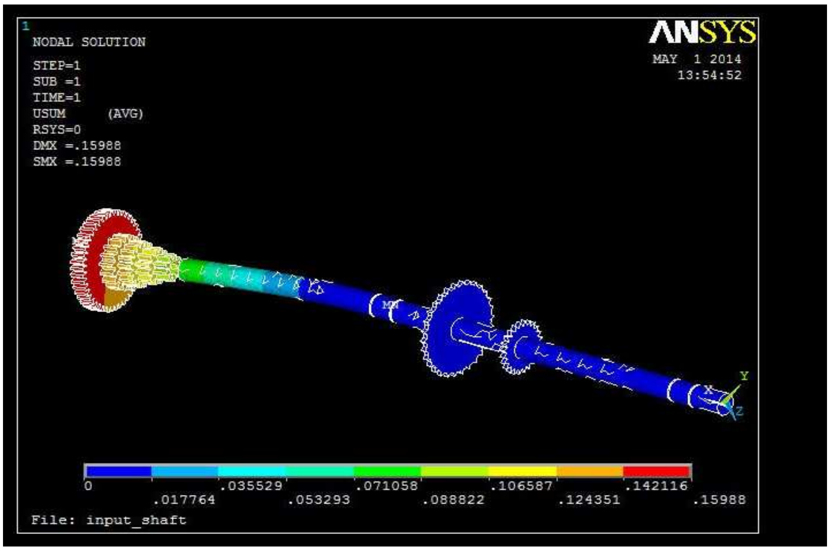


Figure 14: Deflection in Gear Box Input Shaft

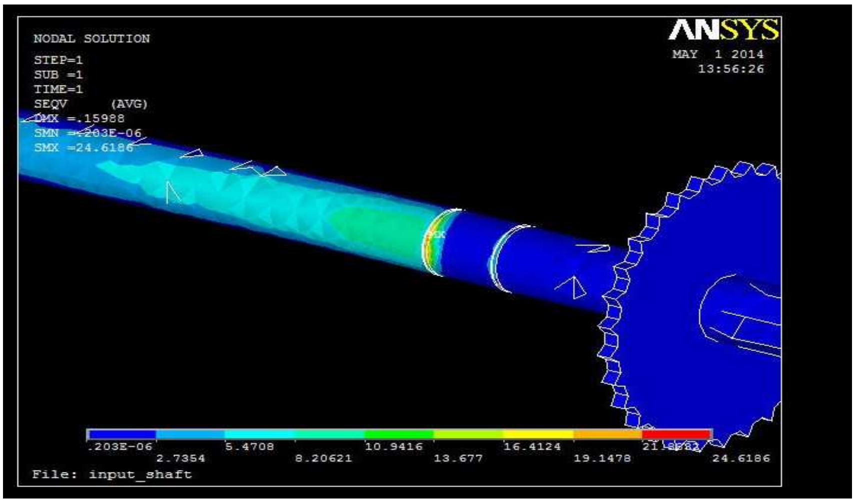


Figure 15: Von Mises Stress Gear Box Input Shaft

Gear Box Output Shaft or Flywheel Shaft

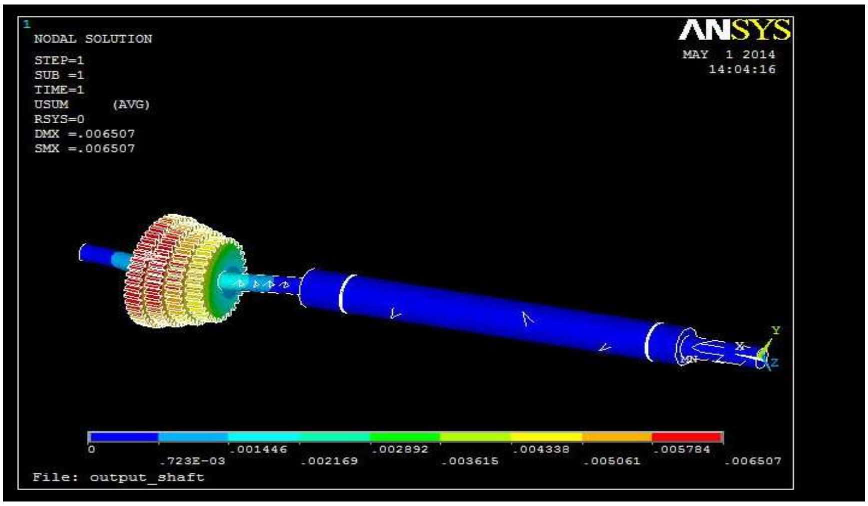


Figure 16: Deflection in Flywheel Shaft

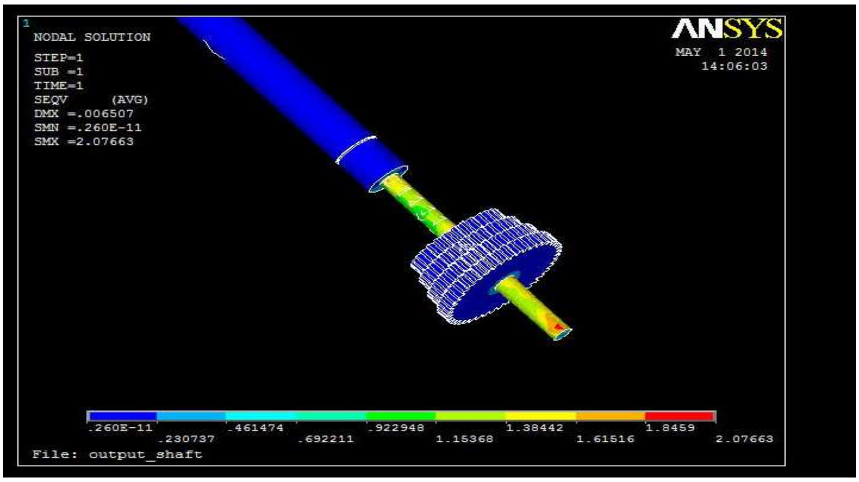


Figure 17: Von Mises Stresses in Flywheel Shaft

CONCLUSIONS

From prepared CAD model of set up in Pro-E, structural analysis is carried out for all the mechanical components. The maximum value of input force was find out on thr basis of the RPM of the flywheel which is noted down during observation and accordingly the maximum values of input force is taken as 59.32 N. and results of analysis are plotted.

From the figures of the analysis of the flywheel figure no 8 indicates the meshing of the flywheel. From the stress analysis it is observed that the maximum deflection is 0.03346mm (figure no 7) for the load 59.32 N with considering material of the flywheel as cast iron.

Due to loading the stresses developed in flywheel are as shown in figure no 10. From the figure the maximum value of stress is found to be 1.11978 N/mm^2. This value of maximum stress is at the point of maximum deflection and shown by the point Mx in the figure no 10.

The component will fail when the stress is at maximum limit and at the deflection point when the maximum stress intensity will be 1.22461 N/mm^2. (figure no 9).

Similarly the values of the maximum deflection, maximum stress and safe stress for each of the components are tabulated below.

Sr. No	Name of Component	Max Deflection (Mm)	Max Stress (N/Mm^2)	Safe Stress (N/Mm^2)
1	Flywheel	0.03346	1.11978	1.22461
2	Circular sprocket	0.1315	1.43261	1.79162
4	Gear box input shaft	0.15988	0.71004	2.111
5	Gearbox output shaft	0.06507	0.876336	2.6245

Conclusion Table: Results of stress analysis

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