International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 582-592 www.ijaem.net ISSN: 2395-5252

# Design and Analysis of Seven Cylinder Radial Engine

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Submitted: 01-08-2021 Revised: 10-08-2021 Accepted: 13-08-2021

**ABSTRACT -** The radial engine is an internal combustion engine configuration, wherein the cylinders point outward from a central crankshaft just like the spokes on a wheel. This configuration was generally used in plane engines earlier than being outdated with the aid of using faster shaft and turbojet engines. It is a reciprocating engine. The cylinders are linked to the crankshaft with a master rod assembly. One cylinder has a master rod with a direct attachment to the crankshaft.

The foremost goal of this project is to design the radial engine in described parameters and to simulate the stress, shear, tensile loads and thermal evaluation through the usage of Solidworks Software. This process is carried out for every major component. These Analysis technique is carried out in every production industries earlier than assembling the components.

**Keywords -** Radial engine, stress, shear, tensile loads, thermal analysis, Solidworks software.

## I. INTRODUCTION

The radial engine has been the work horse of military & industrial air craft ever since 1920's and the World War-I. Radial engine was utilized in all U.S. Bombers and transports plane and with inside the maximum of the other classes of aircrafts. They have been advanced to a top of performance and dependability and even today. In the jet age, many are still in operation at some stage in the sector in all kinds of duty.

The Radial engines reached their peak during WWII (World War II). There are a few radial engines around nowadays, however they're now no longer that common. Most propeller-driven planes nowadays use more conventional engine configurations (like a flat four-cylinder) or modern gas turbine engines. Gas turbines are a lot lighter than radial engines for the energy they produce. The radial engine concept may be very simple; it takes the pistons and arranges them in a circle across the crankshaft.

The radial engine has the identical kind of pistons, valves and spark plugs that any four-stroke engine has. The big distinction is with inside the crankshaft. Instead of the lengthy shaft that's utilized in a multi-cylinder automobile engine, there is a single hub from which all of the piston's connecting rods connect with this hub. One rod is fixed, and it is commonly referred to as the Master rod. The others are known as Articulating rods. They are mounted on the pins that permit them to rotate as the crankshaft and the pistons moves.

## II. LITERATURE REVIEW

[1] The very first design of internal combustion aero engine made was that of Charles Manly, who built a five-cylinder radial engine in 1901 for use with Langley's 'aerodrome', as the latter inventor decided to call what has since become known as the aero-plane. Manly made a number of experiments, and finally decided on radial design, in which the cylinders are so rayed round a central crank-pin that the pistons act successively upon it. By this arrangement a very short and compact engine is obtained, with a minimum of weight, and a regular crankshaft rotation and perfect balance of inertia forces.

[2] When Manly designed his radial engine, high speed internal combustion engines were in their infancy, and the difficulties in construction can be partly realized when the lack of manufacturing methods for this high class engine work, and the lack of experimental data on the various materials, are taken into account. During its tests, Manly's engine developed 52.4 brake horsepower at a speed of 950 revolutions per minute, with the remarkably low weight of only 1.09 kg per horsepower, this latter was increased to 1.64 kg when the engine was

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completed by the addition of ignition system, radiator, petrol tank, and all accessories, together with the cooling water for the cylinders.

[3] In Manly's engine, the cylinders were of steel, machined outside and inside to 1.625 mm thickness. On the side of the cylinder, at the top end, the valve chamber was brazed, being machined from a solid forging. The casing which formed the water jacket was of sheet steel, 0.52 mm in thickness, and this also was brazed on the cylinder and to the valve chamber. Automatic inlet valves were fitted, and the exhaust 8 valves were operated by a cam which had two points, 180 degrees apart. The cam was rotated in the opposite direction to the engine at one -quarter engine speed. Ignition was obtained by using a one-spark coil and vibrator for all cylinders, with a distributor to select the right cylinder for each spark – this was before the days of the high-tension magneto and the almost perfect ignition systems that makers now employ. The scheme of ignition for this engine was originated by Manly himself, and he also designed the sparking plugs fitted in the tops of the cylinders. Through fear of trouble resulting if the steel pistons worked on the steel cylinders, cast iron liners were introduced in the latter 1.625 mm thick.

[4] The connecting rods of this engine were of virtually the same type as is employed on nearly all modern radial engines. The rod for one cylinder had a bearing along the whole of the crank pin, and its end enclosed the pin. The other four rods had bearings upon the end of the firs rod, and did not touch the crank pin. The bearings of these rods did not receive any of the rubbing effect due to the rotation of the crank pin, the rubbing on them being only that of the small angular displacement of the rods during each revolution, thus there was no difficulty experienced with the lubrication.

[5] Another early example of the radial type of engine was French Anzani, of which type one was fitted to the machine with which Bleriot first crossed the English Channel— this was of 25 horse-powers. The earliest Anzani engines were of three-cylinder fan type, one cylinder being vertical, and the other two placed at an angle of 72 degreeson each side, as the possibility of over lubrication of the bottom cylinders was feared if a regular radial construction were adopted. In order to overcome the unequal dial Engine.

[6] Zhang Et. All. suggested that at low working temperatures both maximum exergy efficiency and maximum work output can be used as the design objective, however, only maximum work output can be used as the design objective for the fourstage radial turbine over the working temperature range in this work.

[7] The Top Flite Radial Engine (hereafter referred to as Radial ) is patterned after the Pratt & Whitney radial engines that powered numerous aircraft from the Golden Age of aviation.

[8] Prof. Sorathiya Arvind Et al Current four strokes single cylinder engine (bikes/moped) can be run on the compressed air with a few modifications that are the main objective of the study. Compressed air filled by electricity using a compressor. The electricity requirement for compressing air has to be considered while computing overall efficiency.

[9] Abhishek Lal. Compressed Air Engine is a better option to produce power to run automobile, generators etc. This paper contains design and dynamic analysis of a light weight single stroke compressed air engine it does not required any of the fossil fuels like petrol, diesel, CNG, LPG, hydrogen etc. to run engine and no power is required to start up engine only compressed air valve is to be opened. It works on compressed pressure air and hence is pollution free and 100% eco-friendly.

[10] Chih-Yung Huang study presents a power output examination with the pressure and temperature measurements of a piston-type compressed air engine to be installed in compact vehicles as the main or auxiliary power system.

[11] Prof. B. S. PATEL et al. To convert a conventional IC engine into an Air Powered one, few components are to be replaced. First of all replace the spark plug with a pulsed pressure control valve which can create required pressure. Now the pulsed air firing in this valve is controlled by controlling the supply of electrical signal to the plunger.

[12] Bharat Raj Singh and Onkar Singh A prototype air engine is built and tested in the laboratory. The experimental results are also seen much closer to the analytical values, and the performance efficiencies are recorded around 70% to 95%.

[13] S.K.M.Asikul Islam et al. The environmental pollution in the metropolitan cities is increasing rapidly mostly because of the increased number of fossil fuel powered vehicles.Many alternative options are now being studied through out the world. One of the alternative solutions can be a compressed

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air powered vehicle.

[14] R. Ravi, et.al Paper offers with the study ofexploring the load and price reduction but we've got taken the forged steel as the comparison for the material which is better and how to deal with substances in connecting rod. The paper has undergone detailed evaluation of joining pole through dynamic examination of linking bar considered. In the analysis of 1st part, it offers with the observe of static load analysis and materials which is chosen after which taken into account and by using maintaining the production as taken into account. Then in this paper it deals with layout of connecting rod through "CATIA" than the connecting rod is imported to ANSYS work-bench and analysis performed on this paper. Results are acquired by comparing experimental results.

[15] Garima Chaudhary et.al Radial motor displays have long been used in aviation where the radial motor uses very less energy compared to and inadequate output in contrast with other motors. Then utter engine output was transformed in the present turbine engines. They substitute the motor and its output with this paper. A 5-cylinder MOKI-S is tested and checked through the FEA project. The engine's construction is carried out using CATIAV5 and ANSYS obtains a safety factor.

[16] Srikanth Kumar et.al this illustrates the function and use of the radial engine with respect to the master rod, while the piston is mounted with a master rod with an instant crankshaft connection. The remaining pistons are connected to the bottom of the master round by their connecting rods. 4- stroke radials have an unusual number of cylinder rowsper row, so that the order of the fire piston can be preservedin a consistent way, so as to promote activity as the differentdocuments the layout is built in PRO-E, the study in ANSYS13.0 is done.

## III. METHODOLOGY

**Modeling of Engine :**

This phase involves the modeling of various parts of the engine and assembling them to form the proposed radial engine. For this purpose Solidworks software is selected, which is modeling software being used for designing various mechanical models. Initially the crankcase of the engine is modeled then remaining parts are modeled with respect to the crankcase, keeping it as a standard reference with the help of modeling software.

Components made individually are assembled into one part. Care has been taken to keep the computer model dimensionally in accordance with the real world model. The assembled engine with all the parts in the model is shown below in figure 3.1. The design is validated by performing thermal analysis and dynamic analysis on the models using Solidworks software.

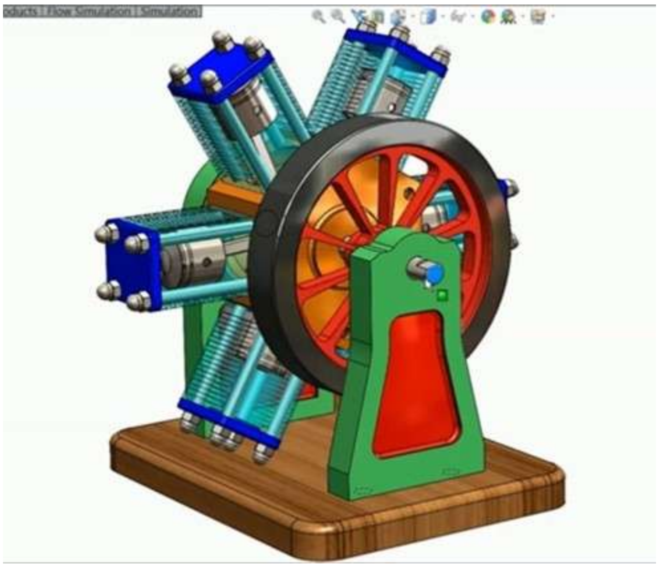

Figure 3.1: Final assembly of Radial engine

**List of Components :**
Base , Pillar support , Bearing support , Piston, Piston pin , Connecting rod , Piston ring , Cylinder body , Cylinder cover , Cylinder bolt, Valve, Valve housing, Flywheel, Crankshaft valve crank, Connecting rod hub, Counter weight, Crankshaft rod, Crankshaft pin, Crankcase, Crankcase gasket, Crankcase cover, Hub pin.

**Meshing of Model :**
The whole solid model is discretized into small elements depending upon the requirement of the accuracy of results the fineness of meshing varies. Finer is the meshing, much closer to the accurate results.

**Thermal and Dynamic analysis :**
Thermal analysis and dynamic analysis is done on the designed components of the radial engine. The components modelled in Solidworks software are imported to Solidworks simulation workbench to perform thermal and dynamic analysis. Meshing Details, Boundary condition and modelling of engine assembly are mainly focused.

## IV. RESULTS AND DISCUSSION

**Analysis of Piston :**

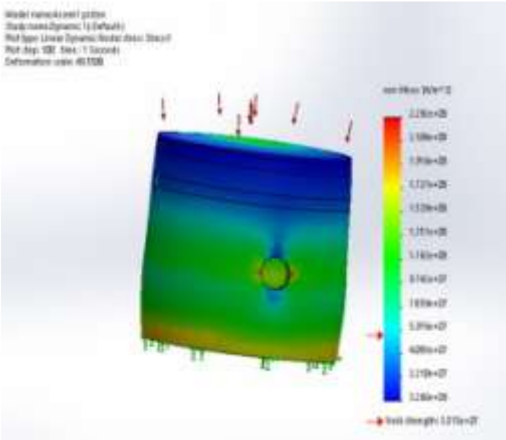

Figure 4.1: Stress Distribution in the Piston

From the Fig 4.1, the maximum stress occurs at the hole provided for gudgeon pin in the piston and it is 2.292*108 N/m$^2$ and minimum stress occurs at outer surface of the piston and it is 3.266*106 N/m$^2$.

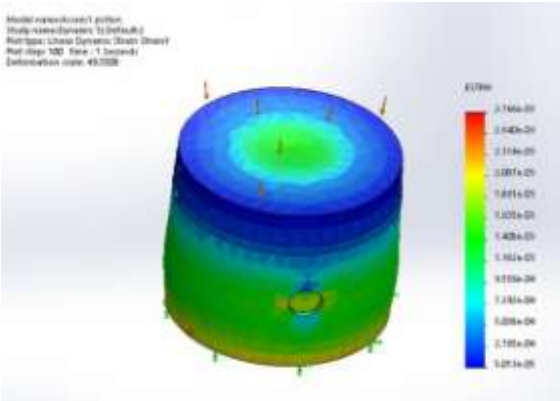

Figure 4.2: Strain Distribution in the Piston

From the Fig 4.2, the maximum strain occurs at the hole provided for gudgeon pin in the piston and it is 5.013*105 and minimum strain occurs at outer surface of the piston and it is 2.766*10$^{-3.}$

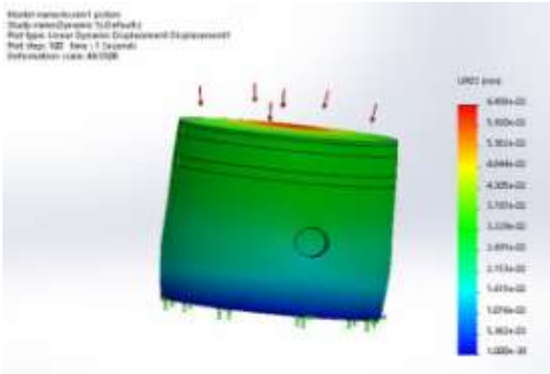

Figure 4.3: Total Deformation of the Piston

From the Fig 4.3, the maximum deformation occurs at the top and bottom part of the piston and it is $6.458*10^{-1}$ mm and minimum deformation occurs at the hole provided for gudgeon pin.

**Analysis of Crankshaft :**

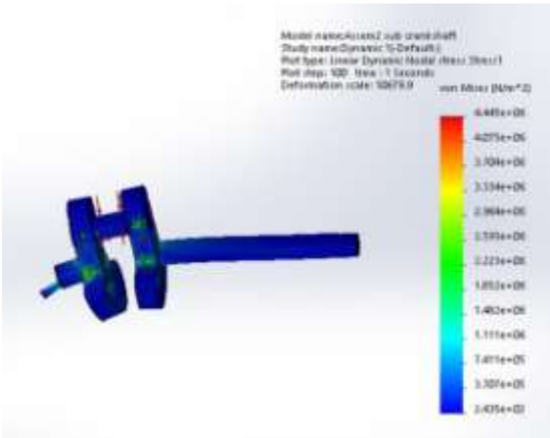

Figure 4.4: Stress distribution in the crankshaft

From the Fig 4.4, the maximum stress is 4.445*106 N/mm$^2$ and minimum stress is 2.435*102 N/mm$^2$.

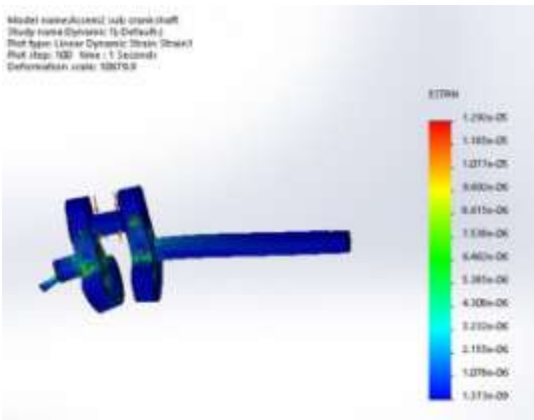

Figure 4.5: Strain distribution in the crankshaft

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From the Fig 4.5, the maximum strain developed is $1.292*10^{-5}$ and the minimum strain developed is $1.373*10^{-9}$.

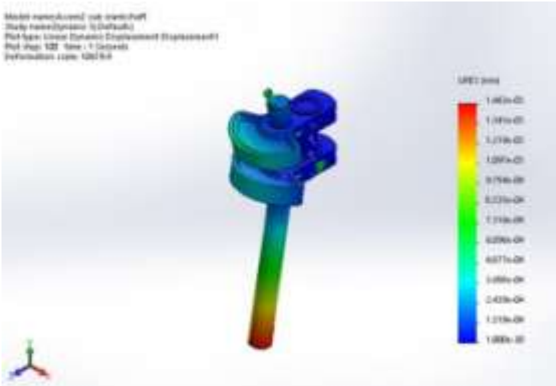

Figure 4.6: Total deformation of the crankshaft

From the Fig 4.6, the maximum deformation occurs at the bottom part of the crankshaft and it is $1.463*10^{-3}$ mm and minimum deformation occurs at the top of the crankshaft.

**Analysis of Connecting Rod :**

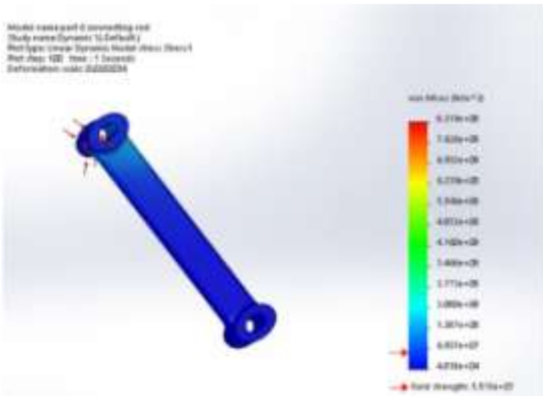

Figure 4.7: Stress distribution in the connecting rod

From the Fig 4.7, the maximum stress occurs at the piston end of the connecting rod and it is $8.319*10^{8}$ N/mm$^2$ and minimum stress occurs at the crank end of the connecting rod and it is $4.818*10^{4}$ N/mm$^2$.

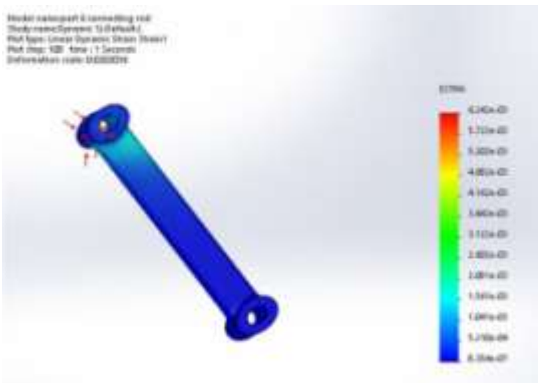

Figure 4.8: Strain distribution in the connecting rod

From the Fig 4.8 the maximum strain occurs at the piston end of the connecting rod and it is $6.243*10^{-3}$ and the minimum strain occurs at the crank end of the connecting rod and it is $8.354*10^{-7}$.

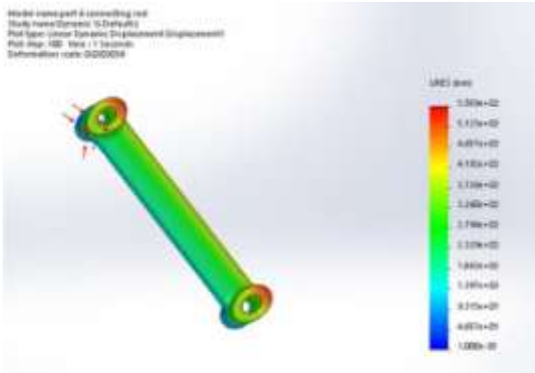

Figure 4.9: Total deformation of the connecting rod

From the Fig 4.9, the maximum displacement occurs in the connecting rod is $5.589*10^2$ mm. It is clear that the load imparts a compressive stress to Connecting Rod and causes bending.

**Analysis of Flywheel :**

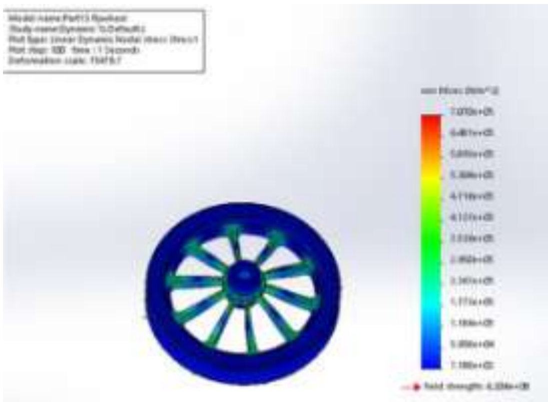

Figure 4.10: Stress distribution in the Flywheel

From the Fig 4.10, the maximum stress occurred in the flywheel is $7.070*10^5$ $N/mm^2$ and the minimum stress occurred is$7.188*10^2$ N/mm.

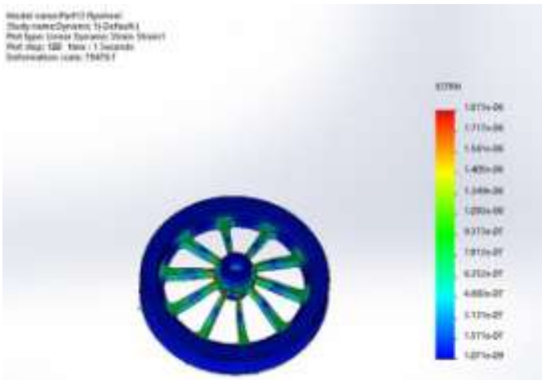

Figure 4.11: Strain distribution in the Flywheel

From the Fig 4.11 the maximum strain developed is $1.873*10^{-6}$ and the minimum strain developed is $1.071*10^{-9}$.

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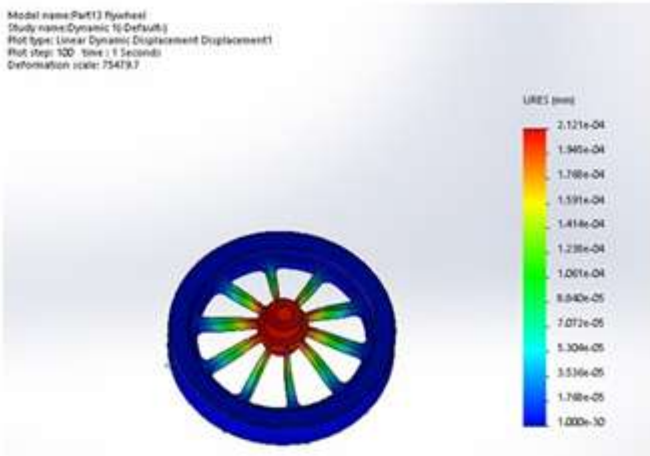


Figure 4.12: Total deformation in the Flywheel

From the Fig 4.12, the maximum displacement occurs in the flywheel is $2.121*10^{-4}$ mm. It is clear that the load imparts a compressive stress to flywheel and causes bending.

**Graphs :**

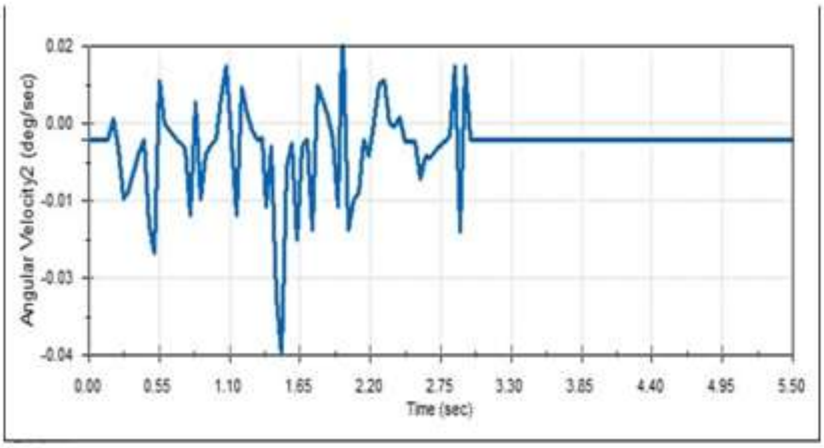


Figure 4.13: Angular velocity Vs Time

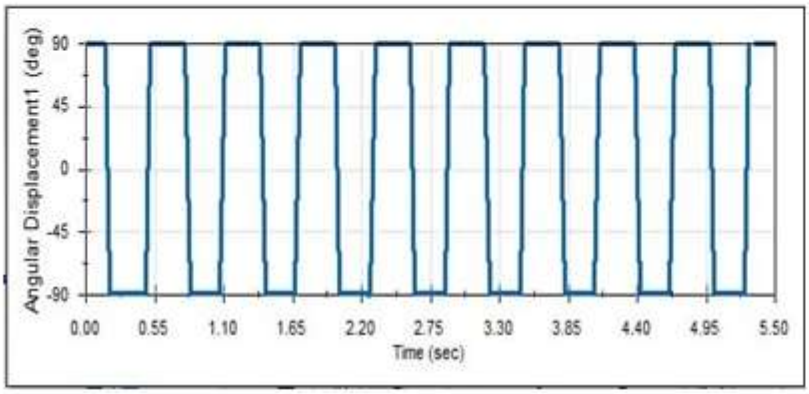


Figure 4.14: Angular acceleration Vs Time

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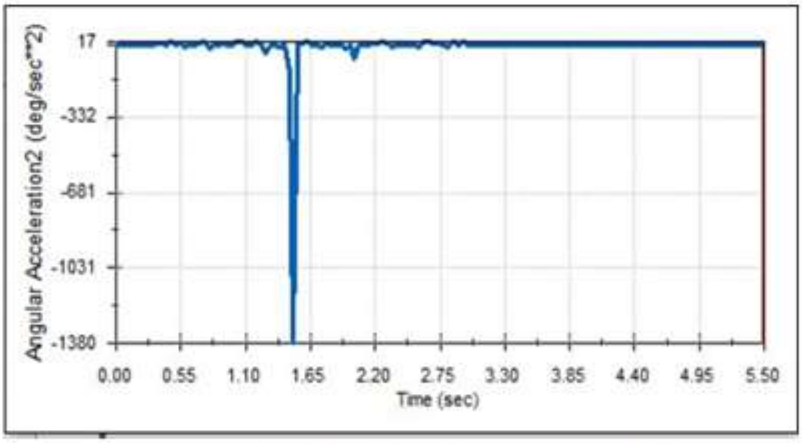


*Figure 4.15: Angular displacement Vs Time*

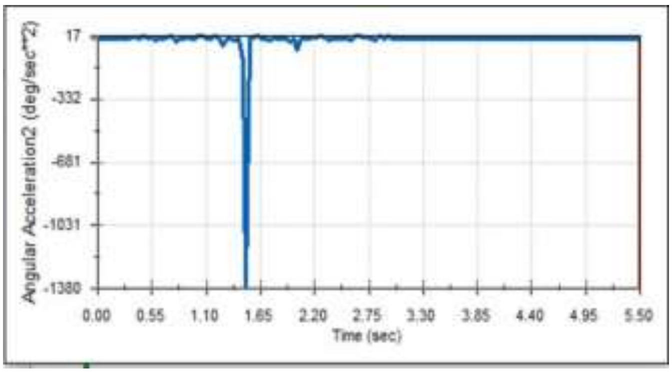


Figure 4.15: Angular displacement Vs Time

## 1. MOTION SIMULATION

### 5.1 Stress :

From the Fig 4.12, the maximum displacement occurs in the flywheel is $2.121*10^{-4}$ mm. It is clear that the load imparts a compressive stress to flywheel and causes bending.

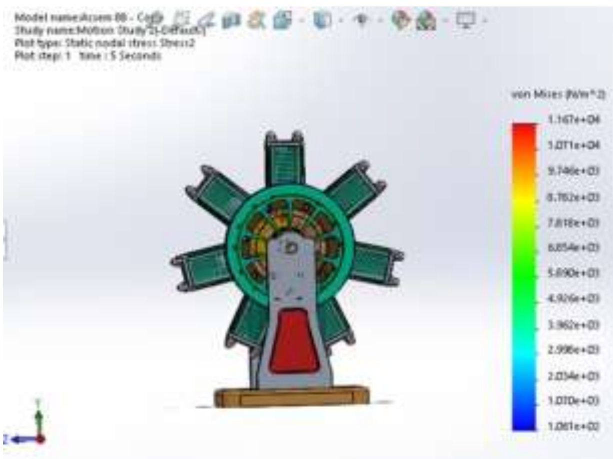

Figure 5.1: Static nodal stress analysis of the assembly

Maximum = $1.67*10^{4}$ Minimum = $1.061*10^{2}$

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**Displacement :**

Figure 5.2: Static displacement analysis of the assembly

Maximum = $2.463*10^{-1}$ Minimum = $1.055*10^{-3}$

**FOS :**

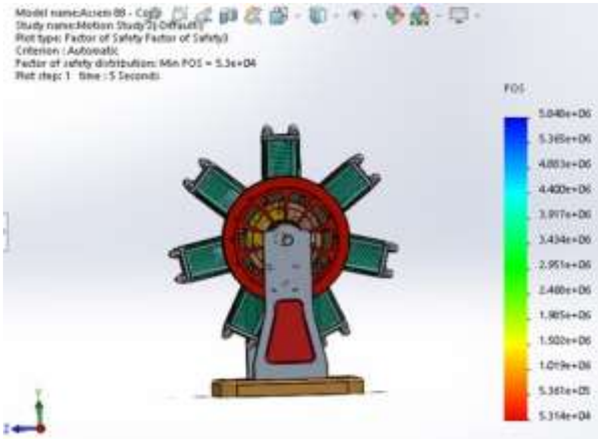

Figure 5.3: FOS distribution of the assembly

Maximum = $5.845*10^{6}$ Minimum = $5.314*10^{4}$

## V. CONCLUSION

In this project it is focused on the design and analysis of the seven cylinder radial engine. Design and analysis of the engine is done based on the literature work with the help of Solidworks software. Analysis is done for the main components like piston, connecting rod, crank shaft, flywheel, etc. because these are the most important components of the engine and most of the engine's load is taken up by these components. During the study of result the material properties are considered into account along with the factor of safety to decide whether the designed engine is safe or not. Based on analysis it is observed that the analyzed components are found safe.

It is proposed to calculate engine performance parameters for the final design of the engine that is obtained based on the trial and error error done by analysis (design obtained after optimizing the dimensions for the compactness). Also engine can be fabricated for the further testing to check engine capabilities.

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