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ANALYSIS ON RADIAL ENGINE PISTON AND IT'S COMPONENTS

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Abstract

The Radial Engine is a reciprocating type internal combustion engine configuration in which the cylinders point outward from a central crankshaft like the spokes on a wheel. In a Radial Engine, the pistons are connected to the crankshaft with a master-and-articulating-rod assembly. One of the pistons has a master rod with a direct attachment to the crankshaft. The remaining pistons pin their connecting rods` attachments to rings around the edge of the master rod.In this project, we will be validating a 5-cylinder MOKI-S 400 against the operating conditions and verified using FEA program. The designing of the engine is done using CATIA V5 and Factor of Safety is obtained through analysis in ANSYS with different materials.

1.INTRODUCTION

An engine is a machine designed to convert one form of energy into mechanical energy. Heat engines, like the internal combustion engine, burn a fuel to create heat which is then used to do work.

The word engine derives from Old French engin, from the Latin ingenium–the root of the word ingenious. Pre-industrial weapons of war, such as catapults, trebuchets and battering rams, were called siege engines, and knowledge of how to construct them was often treated as a military secret. The word gin, as in cotton gin, is short for engine. Most mechanical devices invented during the industrial revolution were described as engines—the steam engine being a notable example. However, the original steam engines, such as those by Thomas Savory, were not mechanical engines but pumps. In this manner, a fire engine in its original form was merely a water pump, with the engine being transported to the fire by horses.

In modern usage, the term engine typically describes devices, like steam engines and internal combustion engines, that burn or otherwise consume fuel to perform mechanical work by exerting a torque or linear force (usually in the form of thrust). Devices converting heat energy into motion are commonly referred to simply as engines. Examples of engines which exert a torque include the familiar automobile gasoline and diesel engines, as well as turbo shafts. Examples of engines which produce thrust include turbofans and rockets.

When the internal combustion engine was invented, the term motor was initially used to distinguish it from the steam engine—which was in wide use at the time, powering locomotives and other vehicles such as steam rollers. The term motor derives from the Latin verb moto which means to set in motion, or maintain motion. Thus a motor is a device that imparts motion.

A heat engine may also serve as a prime mover—a component that transforms the flow or changes in pressure of a fluid into mechanical energy. An automobile powered by an internal combustion engine may make use of various motors and pumps, but ultimately all such devices derive their power from the engine. Another way of looking at it is that a motor receives power from an external source, and then converts it into mechanical energy, while an engine creates power from pressure.

1.1 RADIAL ENGINE:

The Radial Engine as shown in fig 1 is a reciprocating type internal combustion engine configuration in which the cylinders point outward from a central crankshaft like the spokes on a wheel. This type of engine was commonly used in most of the aircrafts before they started using turbine engines. In a Radial Engine, the pistons are connected to the crankshaft with a master-and-articulating-rod assembly. One of the pistons has a master rod with a direct attachment to the crankshaft. The remaining pistons pin their connecting rods` attachments to rings around the edge of the master rod. Four-stroke radials always have an odd number of cylinders per row, so that a consistent every-other-piston firing order can be maintained, providing smooth operation. This is achieved by the engine taking two revolutions of the crankshaft to complete the four strokes. Which means the firing order for a 9-cylinder radial engine is 1,3,5,7,9,2,4,6,8 and then again back to cylinder number 1.This means that there is always a two-piston gap between the piston on its power stroke and the next piston on fire(the piston on compression). If an even number of cylinders was used the firing order would be something similar to 1,3,5,7,9,2,4,6,8,10 which leaves a three-piston gap between firing pistons on the first crank shaft revolution, and only onepiston gap on the second crankshaft revolution. This leads to an uneven firing order within the engine, and is not ideal.

The Four-stroke consequence of every engine is:
a) Intake
b) Compression
c) Power
d) Exhaust

Most radial engines use overhead poppet valves driven by pushrods and lifters on a cam plate which is concentric with the crankshaft, with a few smaller radials. A few engines utilize sleeve valves instead.

Fig 1 :radial engine

1.2 PRINCIPLE:

Since the axes of the cylinders are coplanar, the connecting rods cannot all be directly attached to the crankshaft unless mechanically complex forked connecting rods are used, none of which have been successful. Instead, the pistons are connected to the crankshaft with a master-and-articulating-rod assembly. One piston, the uppermost one in the animation, has a master rod with a direct attachment to the crankshaft. The remaining pistons pin their connecting rods' attachments to rings around the edge of the master rod. Extra "rows" of radial cylinders can be added in order to increase the capacity of the engine without adding to its diameter.

Four-stroke radials have an odd number of cylinders per row, so that a consistent every-other-piston firing order can be maintained, providing smooth operation. For example, on a five-cylinder engine the firing order is 1, 3, 5, 2, 4, and back to cylinder 1. Moreover, this always leaves a one-piston gap between the piston on its combustion stroke and the piston on compression. The active stroke directly helps compress the next cylinder to fire, making the motion more uniform. If an even number of cylinders were used, an equally timed firing cycle would not be feasible. The prototype radial Zoche aero-diesels (below) have an even number of cylinders, either four or eight; but this is not problematic, because they are two-stroke engines, with twice the number of power strokes as a four-stroke engine per crankshaft rotation.

2. LITERATURE REVIEW

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.

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

In Manly`s engine, the cylinders were of steel, machined outside and inside to 1.625 of a 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 of a 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 1.625of a mm thick.

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.

3.MODELLING AND ANALYSIS

CATIA is among the very few software which has its application in about every industrial sector. It is mostly used by the designer team. The designer team of any organization needs to create a digital copy of any object which has to be manufactured. This digital copy can be created as shown fig 2,3 and 4with much ease by using CATIA. It is mostly found in companies who are associated with design and manufacturing of products.

3D CATIA MODELFOR RADIAL ENGINE

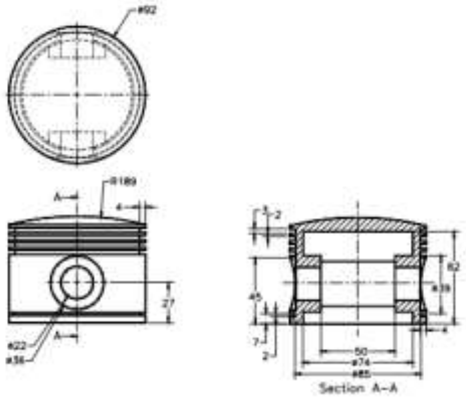

Fig :2 Views and dimensions of the Piston

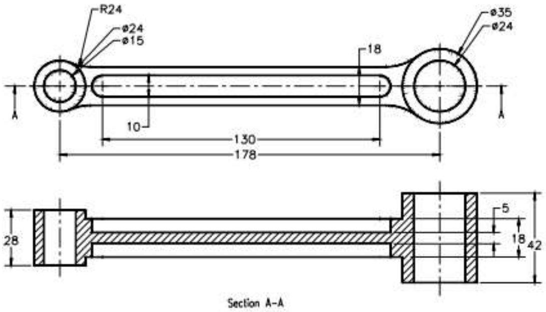

Fig :3 Views and dimensions of the Articulated Rod

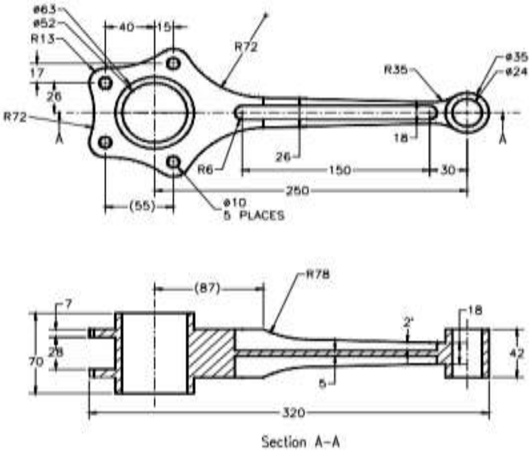

Fig :4 Views and dimensions of the master Rod

PISTON

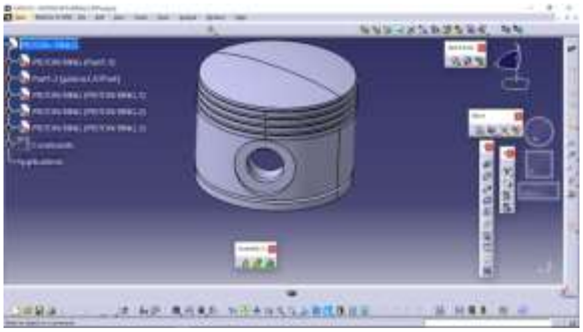

Fig :5 Piston

According to the above fig 5,piston developed in CATIA parametric software with help of features like shaft.

ARTICULATED ROD

Fig :6 Articulated Rod

According to the above fig 6, Articulated Rod developed in CATIA parametric software with help of features like Pad and pocket.

MASTER ROD

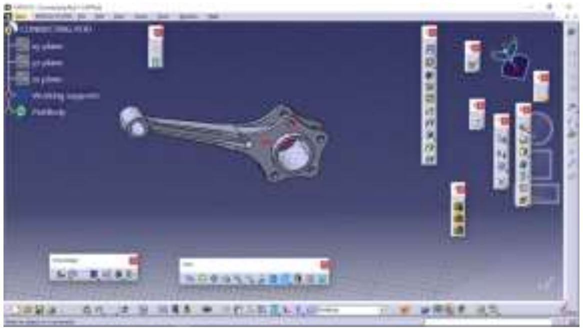

Fig :7 Master Rod

According to the above fig 7, Master Rod developed in CATIA parametric software with help of features like Pad and pocket.

PISTON CONNECTING ROD ASSEMBLY

Fig :8 Piston Connecting Rod Assembly

According to the above fig 8 Master Rod developed in CATIA parametric software with help of assembly features like coincidence and contact constraint .

ASSEMBLE PRODUCT OF RADIAL ENGINE

Fig :9 Assemble Product Of Radial Engine Assembly

According to the above fig 9, Master Rod developed in CATIA parametric software with help of assembly features like coincidence and contact constraint .

Structural Analysis

ANSYS Autodyn is computer simulation tool for simulating the response of materials to short duration severe loadings from impact, high pressure or explosions.

ANSYS Mechanical

ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior, and supports material models and equation solvers for a wide range of mechanical design problems. ANSYS Mechanical also includes thermal analysis and coupled-physics capabilities involving acoustics, piezoelectric, thermal–structural and thermo-electric analysis.

4.STATIC ANALYSIS OF PISTON

Deformation

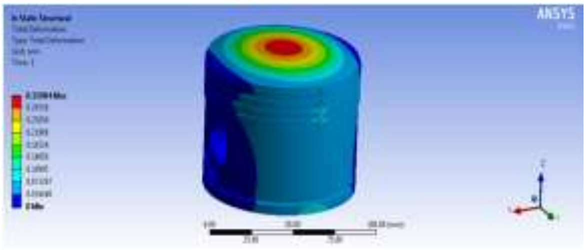

Fig :10 deformation of the piston

According fig 10 to the counter plot, the maximum deformation at piston head and minimum deformation at gudegent pin place

Stress

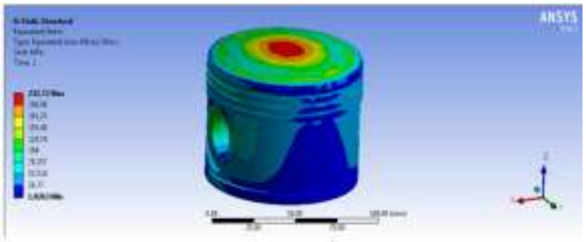

Fig :11 stress

According fig 11 to the counter plot, the maximum stress at piston head and minimum stress at gudegent pin place

Strain

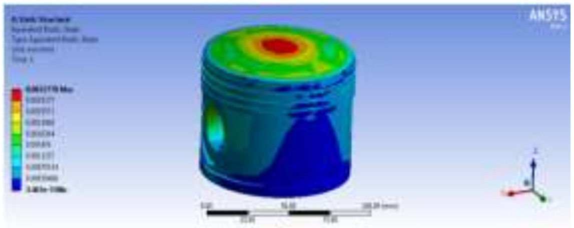

Fig :12 strain

According fig 12 to the counter plot, the maximum strain at piston head and minimum strain at gudegent pin place

STATIC ANALYSIS OF MASTER ROD

Deformation

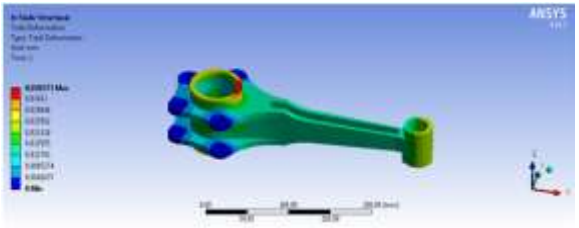

Fig :13 deformation of the master rod

According to fig 13 the counter plot, the maximum deformation at master rod pin and minimum deformation at fixed place

Stress

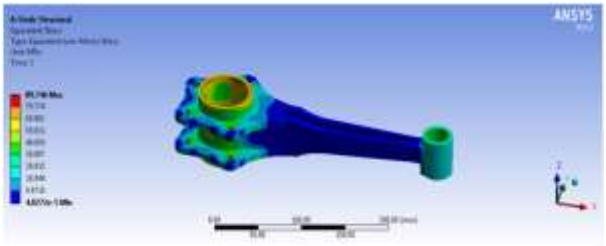

Fig :14 stress of the master rod

According to fig 14 the counter plot, the maximum stress at master rod pin and minimum stress at fixed place

Strain

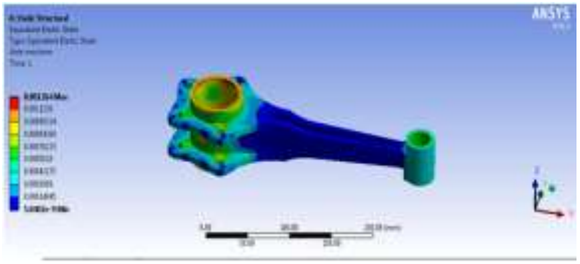

Fig :15 strain of the master rod

According to fig 15 the counter plot, the maximum strain at master rod pin and minimum strain at fixed place

STATIC ANALYSIS OF PISTON AND MASTER ROD ASSEMBLY

Deformation

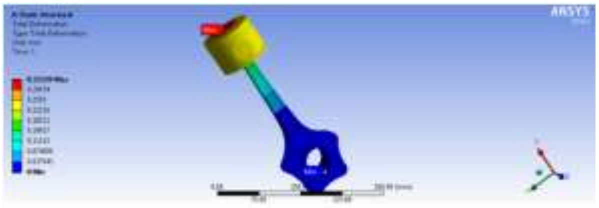

Fig :16 deformation of the master rod assembly

According to fig 16 the counter plot, the maximum deformation at master rod assembly and minimum deformation at fixed place

Stress

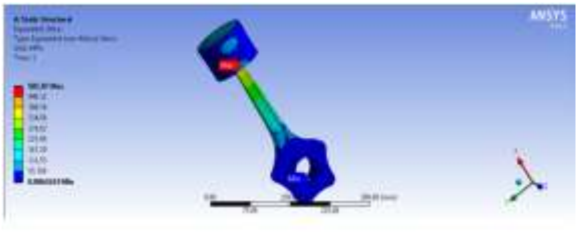

Fig :17 stress of the master rod assembly

According to fig 17 counter plot, the maximum stress at master rod assembly and minimum stress at fixed place

Strain

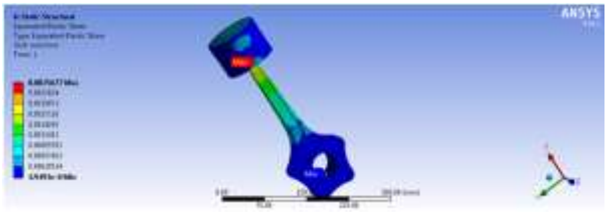

Fig :18 strain of the master rod assembly

According to fig 18 the counter plot, the maximum stress at master rod assembly and minimum stress at fixed place

FATIGUE ANALYSIS OF PISTON AND MASTER ROD ASSEMBLY

LIFE

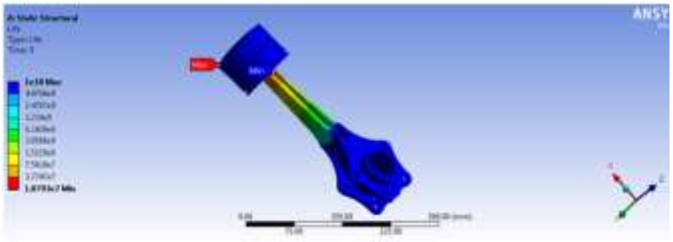

Fig :19 life of the master rod assembly

DAMAGE

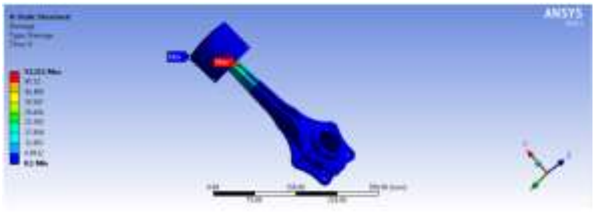

Fig :20 damage of the master rod assembly

SAFTEY FACTOR

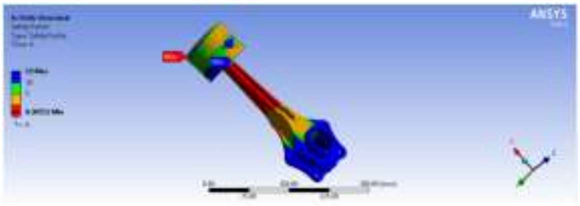

Fig :21 safety factor of the master rod assembly

RESULTS TABLES

Table :1 Static analysis piston results

Materials	Deformation (mm)	Stress (N/mm^2)	Strain
Cast iron	0.25023	260.34	0.0023668
Aluminum alloy	0.35427	249.96	0.0035206
Carbon fiber	0.32984	233.72	0.0032778

According to the above Table 1 results, by observing the static analysis results the stress value minnum at carbon fiber when compared to the other materials

Table :2 Static analysis master rod results

Materials	Deformation (mm)	Stress (N/mm^2)	Strain
Cast iron	0.014974	99.42	0.00049711
Aluminum alloy	0.40566	94.874	0.0013363
Carbon fiber	0.038373	89.746	0.001264

According to the above table 2 results, by observing the static analysis results the stress value minnum at carbon fiber when compared to the other materials

Table :3 Static analysis piston and master rod assembly results

Materials	Deformation (mm)	Stress (N/mm^2)	Strain

Cast iron	0.40006	602.24	0.0030812
Aluminum alloy	0.36673	552.06	0.0028244
Carbon fiber	0.3339	501.87	0.0025677

According to the above table 3 results, by observing the static analysis results the stress value minnum at carbon fiber when compared to the other materials

Table :4Fatigue analysis piston and master rod assembly results

Materials	**Life**	**Damage**	**Safety factor**	
			Min	**Max**
Cast iron	$1e^{10}$	42.44	0.2291	15
Aluminum alloy	$1e^{10}$	69.983	0.27497	15
Carbon fiber	$1e^{10}$	53.211	0.30512	15

According to the above table 4s results, by observing the fatigue analysis results the damage value minnum at carbon fiber when compared to the other materials

5.CONCLUSION

We designed this engine in two stages, first of which was gathering the information about the orientation and working of the engine and detailed process of its designing which was done on CATIA V5. The next stage was the stress analysis of the engine so as to know the behaviour of its various parts under desired performance conditions.

By observing the static analysis results, the stress values are less than the respective yield stress values for both the materials. The stress values are less for carbon fibre.

By observing the fatigue analysis, the safety factor is more for carbon fibre.

So it can be concluded that using carbon fibre for piston and connecting rod is better considering weight and analysis results.

REFERENCES

1. W.D. Callister, Jr.,(2010), “Materials Science and Engineering”: An Introduction, 8th edition, Wiley & Sons
2. Reciprocating Compressor Performance and Sizing Fundamentals, a Practical Guide to Compressor Technology, Second Edition, By Heinz P. Bloch Copyright 2006 John Wiley & Sons, Inc.
3. Sasa Trajkovic, The Pneumatic Hybrid Vehicle, A New Concept for Fuel Consumption Reduction, Doctoral ,thesis, Division of Combustion Engines, Department of Energy Sciences, Faculty of Engineering, Lund university.
4.Abhishek lal, 2013- international journal of renewable energy research, New York, 1966. (Recent, authoritative. Includes theory, materials design, and manufacturing). International Journal of Management, Technology And Engineering Volume 8, Issue VII, JULY/2018 ISSN NO : 2249-7455 Page No:1028
5. Mr F. A. Pathan, Static Analysis of connecting Rod for weight Optimization.
6. Kuldeep B, “Analysis and optimization of connecting rod using Alfasic composites”.
7. Prof. N.P.Doshi, “Analysis of Connecting Rod Using Analytical and Finite Element Method”. 8. Zhang, “New Continental Aircraft Engines” Automotive and Aviation Industries 93, Dec. 15,1945. (Post war series of horizontal opposed air- cooled engines).
9. B.S.Patel "A Study of parts of radial engine, Eng.J.3, March-Apri 1956,12. (Review of G.M. methods and techniques).
10. S.K.M.Asikul Islam"Compressed air vehicles" Trans.SAE 46,243(1940).(c0ntinentalopposed cylinder air-cooled lin.)