International Journal of Advances in Mechanical and Civil Engineering, ISSN: 2394-2827 Volume-4, Issue-2, Aprl.-2017
http://iraj.in

DESIGN AND ANALYSIS OF AN IC ENGINE PISTON AND PISTON RINGS BY USING THREE DIFFERENT MATERIALS

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Abstract - Piston plays a main role in energy conversation. Failure of piston due to various thermal and mechanical stresses. The working condition of the piston is so worst in comparison of other parts of the internal combustion engine. The main objective of this work is to investigate and analyze the stress distribution of piston. Design and analysis of an IC engine piston using three different materials that are used in this project. we are taking pulsar 220cc piston dimensions different materials (grey cast iron, aluminium alloy, AL-SIC) have been selected for structural and thermal analysis of piston and piston rings. we created pressure on piston head 13.65Mpa and 19.649N on these three materials, and we applied temperature 4000c on piston crown and 3000c on piston rings .finally we find out the which one is the suitable material on piston in these three materials. Design of the piston is carried out using CATIA software, static and thermal analysis is performed using Finite Element Analysis (FEA).

I. INTRODUCTION

We almost take our Internal Combustion Engines for granted don't we? All we do is buy our vehicles, hop in and drive around. There is, however, a history of development to know about. The compact, well-toned, powerful and surprisingly quiet engine that seems to be purr under your vehicle's hood just wasn't the tame beast it seems to be now. It was loud, it used to roar and it used to be rather bulky. In fact, one of the very first engines that had been conceived wasn't even like the engine we know so well of today. An internal combustion engine is defined as an engine in which the chemical energy of the fuel is released inside the engine and used directly for mechanical work, as opposed to an external combustion engine in which a separate combustor is used to burn the fuel. The internal combustion engine was conceived and developed in the late 1800s Internal combustion engines can deliver power in the range from 0.01 kW to 20x103 kW, depending on their displacement. The complete in the market place with electric motors, gas turbines and steam engines.
The major applications are in the vehicle (automobile and truck), railroad, marine, aircraft, home use and stationary areas. The vast majority of internal combustion engines are produced for vehicular applications, requiring a power output on the order of 102 kW. Next to that internal combustion engines have become the dominant prime mover technology in several areas. For example, in 1900 most automobiles were steam or electrically powered, but by 1900 most automobiles were powered by gasoline engines. As of year 2000, in the United States alone there internal combustion engines. In 1900, steam engines were used to power ships and railroad locomotives; today two- and four-stoke diesel engines are used. Prior to 1950, aircraft relied almost exclusively on the pistons engines. Today gas turbines are the power plant used in large planes, and piston engines continue to dominate the market in small planes. The adoption and continued use of the internal combustion engine in different application areas has resulted from its relatively low cost, favorable power to weight ratio, high efficiency, and relatively simple and robust operating characteristics of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall.

1.1 Modelling

Piston Design The piston is designed according to the procedure and specification which are given in machine design and data hand books. The dimensions are calculated in terms of SI Units. The pressure applied on piston head, temperatures of various areas of the piston, heat flow, stresses, strains, length, diameter of piston and hole, thicknesses, etc., parameters are taken into consideration Design Considerations for a Piston.
In designing a piston for an engine, the following points should be taken into consideration: It should have enormous strength to withstand the high pressure.

- It should have minimum weight to withstand the inertia forces.
- It should form effective oil sealing in the cylinder.
- It should provide sufficient bearing area to prevent undue wear.
- It should have high speed reciprocation without noise.
- It should be of sufficient rigid construction to withstand thermal and mechanical distortions.
- It should have sufficient support for the piston pin.

1.2 Forces:

The major forces acting on the piston are as follows: Inertia force caused by the high frequency of reciprocating motion of piston Friction between the cylinder walls and the piston rings Forces due to expansion of gases

1.3 TYPES OF ENGINES:

There are two major cycles used in internal combustion engines: Otto and Diesel. The Otto cycle is named after Nikolaus Otto (1832 – 1891) who developed a four-stroke engine in 1876. It is also called a spark ignition (SI) engine, since a spark is needed to ignite the fuel-air mixture. The Diesel cycle engine is also called a compression ignition (CI) engine, since the fuel will auto-ignite when injected into the combustion chamber. The Otto and Diesel cycles operate on either a four- or two-stroke cycle.

- In line
- horizontally opposed
- radial
- V

Main components of the engine

1.4 Piston:

Piston is one of the main parts in the engine. Its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a connecting rod. Since the piston is the main reciprocating part of an engine, its movement creates an imbalance. This imbalance generally manifests itself as a vibration, which causes the engine to be perceivably harsh. The friction between the walls of the cylinder and the piston rings eventually results in wear, reducing the effective life of the mechanism. The sound generated by a reciprocating engine can be intolerable and as a result, many reciprocating engines rely on heavy noise suppression equipment to Pistons are commonly made of a cast aluminum alloy for excellent and lightweight thermal conductivity. Thermal conductivity is the ability of a material to conduct and transfer heat.

1.5 Piston Rings:

A ring groove is a recessed area located around the perimeter of the piston that is used to retain a piston ring. Ring lands are the two parallel surfaces of the ring.
A piston ring must provide a predictable and positive radial fit between the cylinder wall and the running surface of the piston ring for an efficient seal. The radial fit is achieved by the inherent pressure of the piston ring. The piston ring must also maintain a seal on the piston ring lands.

Figure1.5(1) : Piston Rings

In addition to inherent pressure, a piston ring seals the combustion chamber through applied pressure. Applied pressure is pressure applied from combustion gases to the piston ring, causing it to expand. Some piston rings have a chamfered edge opposite the running surface. This chamfered edge causes the piston ring to twist when not affected by combustion gas pressures. The piston acts as the movable

1.5.2 An oil ring

It is the piston ring located in the ring groove closest to the crankcase. The oil ring is used to wipe excess oil from the cylinder wall during piston movement. Excess oil is returned through ring openings to the oil reservoir in the engine block. Two-stroke cycle engines do not require oil rings because lubrication is supplied by mixing oil in the gasoline, and an oil reservoir is not required.

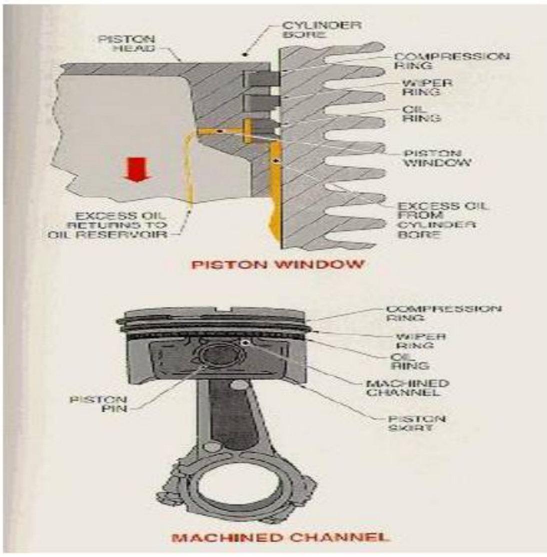


Fig: 1.5.2 an oil ring

Piston rings seal the combustion chamber, transferring heat to the cylinder wall and controlling oil consumption. A piston ring seals the combustion chamber through inherent and applied pressure.

Inherent pressure is the internal spring force that expands a piston ring based on the design and properties of the material used. Inherent pressure requires a significant force needed to compress a piston ring to a surface. This chamfered edge causes the piston ring to twist when not affected by combustion gas pressures. Another piston ring design consideration is cylinder wall contact pressure. This pressure is usually dependent on the elasticity of the piston ring material, free piston ring gap, and exposure to combustion gases. All piston rings used by Briggs Stratton engines are made of cast iron. Cast iron easily conforms to the cylinder wall. In addition, cast iron is easily coated with other materials to enhance its durability. Care must be exercised when handling piston rings, as cast iron is easily distorted.

Piston rings commonly used on small engines include the compression ring, wiper ring, and oil ring.

II. ANSYS 6.1

2.1 Introduction to Ansys analysis

Ansys is a product analysis software it is a world leading widely distributed and popular commercial cae package, it is widely used by designers/analysis in industries such as

1. Aerospace
2. Automotive
3. Manufacturing
4. Nuclear
5. Electronic
6. Bio-medical…..,etc

Ansys provide simulation solutions that enable designers to simulate design performance directly on the desktop. In this way, it provides fast efficient and cost –effective product development from design concept stage to performance validation stage of the product development cycle

2.2 Basic Concepts of Analysis:

The software uses the Finite Element Method (FEM). FEM is a numerical technique for analyzing engineering designs. FEM is accepted as the standard analysis method due to its generality and suitability for computer implementation. FEM divides the model into many small pieces of simpleshapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously.

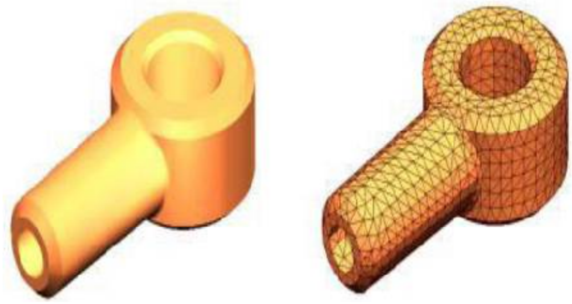


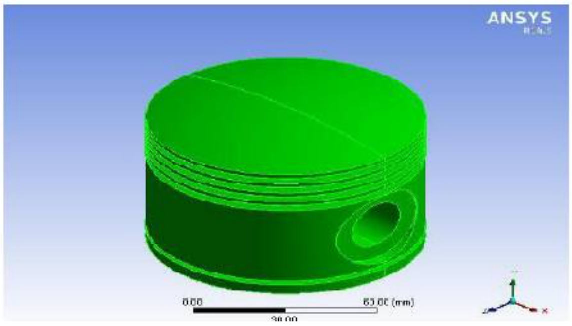
Fig 2.2 (1) CAD model of a Fig5.2 (2) Model subdivided into small pieces

III. RESULTS AND DISCUSIONS

3.1 Static Analysis

On Piston:

The static and thermal analysis for the piston was done by finite elements method using ANSYS software. For ANSYS simulation the solid works geometry is separated into elements. In this elements are interlinked to one another at a point called as Node. In present examination work we have used FEA for the Thermal and Structural analysis of piston solid works Software is used to prepare the piston. After completing solid works modelling, the model is saved in IGES file then IGES file is imported to ANSYS software for the finite element analysis.



3.1fig: Static Analys on Piston:

With the help of piston pin, piston and connecting rod are associated and no relative motion between piston pin and piston. Hence the piston pin holes are fully constrained for all degrees of freedom (DOF)

Piston ring Materials	Total deformation	Stress intensity	Temperature distribution	Heat flux
Cast iron	16.52	470.04	300	2.999
Grey cast iron	18.52	470.08	300	3.111

3.2 TYPES OF PISTONS

The pistons are classified in to two types they are 2 stroke pistons and 4 stroke pistons

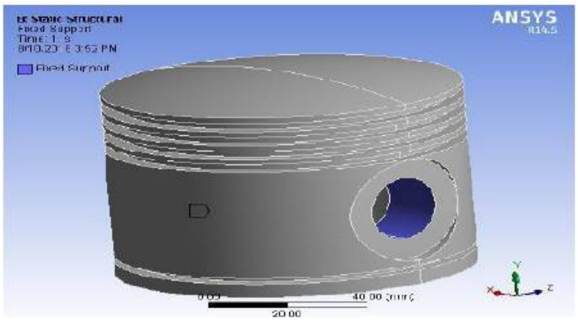


FIG 3.2 Fixed conditions:

3.3 CALCULATIONS OF HEAT TRANSFER COEFFICIENTS

The heat transfer from the combustion gases is assumed to be similar to the turbulent heat transfer of gases in a cylinder as follows:

$$Nu = C\, Re^{m}\, Pr^{n}$$

Benson mentioned that Gunter F.Hohenberg, presented a developed relationship for the equation(1) by using the cylinder volume as a function of the piston diameter

$$h_g = 226.6 * P^{0.8} * T^{-0.4} * (V+1.4)^{0.8}$$

Therefore equation (2) will be the basic equation for a heat transfer coefficient calculation at piston crown surface.

So the heat transfer coefficient will be equal to

$Nu = hD_h/k = 8.235$

where, D_h , is the

$h_r = 8.235 * k/D_h$
$D_h = 4A/P$

Calculation of Heat Transfer Coefficient at Piston Under Crown Surface The piston undercrown surface is considered a very complex geometry shape due to the existence of the ribs and the piston pin bosses, where heat transfer calculations will not be easy to evaluate the heat transfer coefficient in each area at this region

this correlation gives the Nusselt number , and hence the heat transfer coefficient can be obtained.

$$Nu = 0.023 \mathrm{Re}^{0.8} \mathrm{Pr}^{0.3}$$

By substituting above equations

$$h_{oil} = 0.023 D_h^{-0.2} k_{oil} \left(\frac{\rho_{oil} U_{oil}}{\mu_{oil}} \right)^{0.8} \mathrm{Pr}^{0.3}$$

$$Nu = \frac{h_{oil} D_h}{k_{oil}}$$

Piston ring Materials	Total deformation	Stress intensity	Temperature distribution	Heat flux
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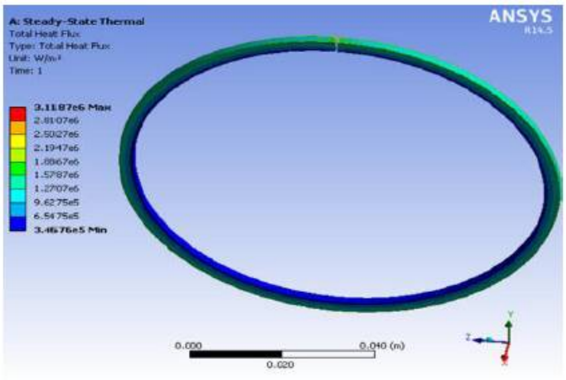
Table3.1: Static Analys on Piston:

In this research the effect of side thrust force is negligible but in reality it have some impact on deformation and stress on piston but pressure force and inertia force are taken in record and assumed that temperature is uniform. The pressure force 13.65 MPa is applied on piston crown.

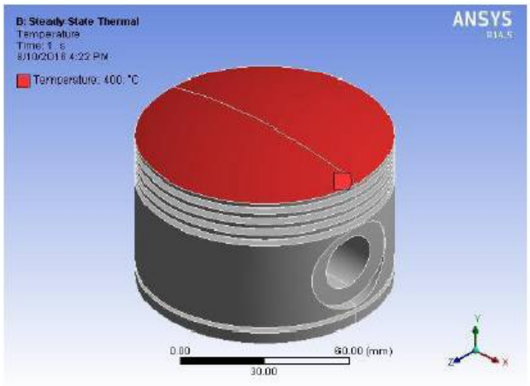
Material properties of piston:

For piston ring:

	Ductile Nodular Spheroidal cast iron	ASTM grade 50 (ISO grade 350, EN – JL 1060) Grey cast iron
Poisson ratio	0.275	0.26
Modulus of elasticity (GPa)	176	157
Thermal conductivity (w/m k)	33	46
Ultimate tensile strength MPa	414 – 827	362
Yield tensile strength (MPa)	240 – 621	228
DENSITY g/c.c	7.2	7.1

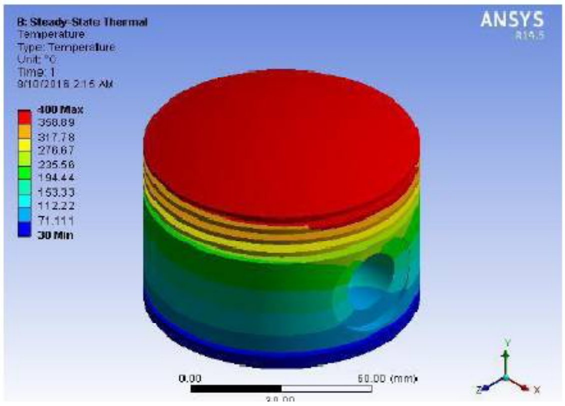


Total heat flux for grey cast iron

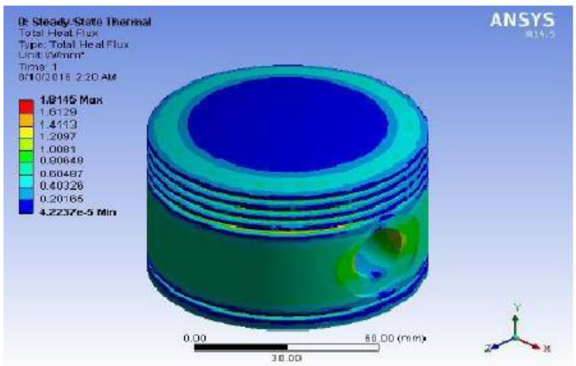


3.2 fig: Thermal analysis on piston

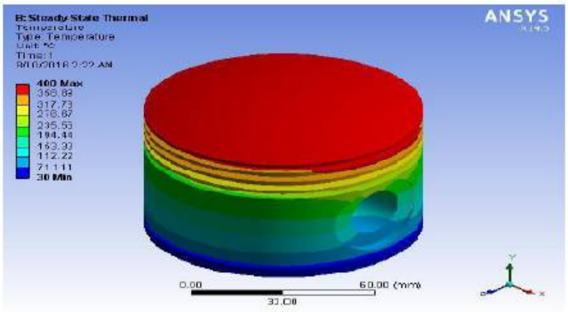
IV. RESULTS



4.1.1 For aluminum



4.1.2Fig: for grey cast iron



4.1.3 For al-sic graphite

PARAMETERS	VALUES
Engine Type	*Four Stroke, Petrol Engine*
Induction	*Air Cooled Type*
Numberof Cylinders	*Single Cylinder*
Bore	*67 Mm*
Stroke	*62.4 Mm*
Length of Connecting rod	*124.8*
Displacement Volume	*220 Cm^3*
Compression Ratio	*9.5+/-0.5:1*
Maximum Power	*15.510kw At 8500 Rpm*
Maximum Torque	*19.12 Nm At 7000 Rpm*
Number of Revolutions /Cycle	*2*

Material	Heat flux
Grey cast iron	0.55471 W/mm
Aluminum alloy	1.8145 W/mm
Al-sic graphite	1.9201 W/mm

CONCLUSION

- Modeling and analysis of piston is done
- Modeling of piston is done in catia 2016 design software by using various commands
- The catia part file is converted into IGS file and imported to ansys workbench.
- First Static structural analysis is carried out on piston at 13.65MPa pressure with three different materials, such as grey cast iron, aluminum alloy and al-sic graphite in ansys workbench.
- Maximum stress, deformation, maximum strain and maximum shear stress are noted and tabulated
- Then steady state thermal analysis is carried out at maximum temperature 400deg and minimum temperature 30deg for the above three various materials.
- Temperature distribution and heat flux are noted for three different materials and tabulated.
- From the tables it is concluded that the aluminum silicon carbide graphite (Al-SiC Graphite) is showing efficient results
- Hence Al-SiC-Graphite is preferable among the three applied materials

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