THERMAL ANALYSIS AND MATERIAL OPTIMIZATION OF PISTON IN IC ENGINE

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ABSTRACT

The main objective of this study is to explore the analysis of a piston with design change to attain less volume and better efficiency. This has entailed performing a detailed thermal analysis. The study deals with dynamic, model and transient thermal analysis.

A proper Finite Element Model is developed using CAD software Pro/E Wildfire 5.0. In this project we are doing the material optimization in the piston. This project we are designed the 3D model of the axle by using pro-e software and the analysis taken by different materials of the bearing and the analysis taken by the ANSYS software. This project we are analyzing the pressure acting on the piston by the two materials. Presently the piston is made by the material of AL-Mg-Si, this project we are testing the same load under SILUMIN. Then the thermal analysis is done to determine the total heat flux in the existing piston for the given temperature conditions. The temperature acting on the surface of the piston is applied. The results were also used to determine the total heat flux for a particular material.

Key Words: Pro-E, ANSYS, Von misses Stress, Computer CAD, CAE

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1. INTRODUCTION

Automobile components are in great demand these days because of increased use of automobiles. The increased demand is due to improved performance and reduced cost of these components. R&D and testing engineers should develop critical components in shortest possible time to minimize launch time for new products. This necessitates understanding of new technologies and quick absorption in the development of new products. A piston is a moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine its purpose is to transfer from expanding gas in the cylinder to the crank shaft via piston rod and or connecting rod. As an important part in an engine piston endures the cyclic gas pressure and inertia forces at work and this working condition may cause the fatigue damage of the piston. The investigations indicate that greatest stress appears on the upper end of the piston and stress concentration is one of the mainly reason for fatigue failure.

2. LITERATURE REVIEW

"Thermal analysis and Optimization of I.C. Engine" Author by A**.R.BHAGAT**, **Y.M.JIBHAKATE**, Vol2, pp2919-2921,2012,[1]A piston is a component of reciprocating IC engines. It is the moving component that is obtained by a cylinder and is made gas -tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. As an important part in an engine, piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of piston, such as piston side wear, piston head/crown cracks and so on. The investigations indicate that the greatest stress appears on the upper end of the piston and stress concentration is one of the mainly reason for fatigue failure. On the other hand piston overheating seizure can only occur when something burns or scrapes away the oil film that exists between the piston and the cylinder wall. Understanding this, it's not hard to see why oils with exceptionally high film strengths are very desirable. Good quality oils can provide a film that stands up to the most intense heat and the pressure loads of a modern high output engine. Thermal analysis is a branch of materials science where the properties of materials are studied as they change with temperature.

"Machine design" by Author by **R.S.KHURMI, J.K.GUPTA,** pp1132-1144, 2004[2]The inaugural issue of Machine Design coincided almost exactly with the 1929 stock-market crash and the beginning of the Great Depression. Although the nation was in the economic doldrums, there was significant design development taking place in almost all industrial segments including automotive, aircraft, farm equipment, home appliances, and industrial machinery.

"Mechanics and Materials in Design" Author by **P.CARVALHEIRAL,** vol 9 pp271[3], The International Journal of Mechanics and Materials in Design features recent advances and original works in mechanics and materials engineering and their impact on the design process. The journal enables mechanical, aeronautical, civil, automotive, biomedical, chemical, and nuclear engineers as well as other researchers and scientists to stay abreast of the latest developments. Moreover, it enables them to exchange ideas concerning the use of mechanics and materials in design. Among the topics readers will discover are intelligent design, advanced materials in design, design analysis and optimization, experimental mechanics in design, and design case studies. These topics and more are explored in an integrated, highly focused and coherent format.

"Finite element analysis of reverse engineered internal combustion engine" author by **GUDIMETAL P. GOPINATH.** Vol 5, pp75[5], The finite element analysis is performed using CAD software to investigate and analyze thermal stress distribution at the real engine condition during combustion process. Piston skirt may appear deformation usually causes crack on the upper end of the piston head. Due to deformation, stress concentration is caused on the upper end of the piston and ,The stress distribution on the piston mainly depends on the deformation of piston. Therefore piston crown should have enough stiffness to reduce the deformation. The preliminary analyses presented in the paper was to compare the behavior of the combustion engine piston made of different type of materials under thermal load Finite element analysis is used to analyze stresses in a piston of an internal combustion engine. The stresses due to combustion gas load only are considered so as to reduce the weight and hence to increase the power output of engine

3. TYPES OF PISTON

On this new modern century, many type of piston that have been design or already in the market. Every type of piston has their capability and also has limitation. Some of these types will now be conside red (Stratman 2010).

- Two Stoke Piston
- Casr Soild Skirt Piston
- Hydrothermik piston
- Forged Soild Skirt Piston
- Ring Carrier Piston with Pin Boss Ushes.
- Ring Carrier Pistons with Cooling Channel.

3.1 TWO-STROKE PISTON

Two stroke piston is made by casting process. These pistons are mainly used in gasoline and diesel engines for passenger cars under heavy load conditions. They have cast-in steel strips but are not slotted. As a result, they form a uniform body with extreme strength.

3.2 CAST SOLID SKIRT PISTON

Cast solid skirt pistons have a long service life. Furthermore this piston more useable that can be used in gasoline and diesel engines. Besides that, their range of applications extends from model engines to large power units. Piston top, ring belt and skirt form a robust unit.

3.3 FORGED SOLID SKIRT PISTON

They are made by forged process that gives the piston more strength. This type of piston can mainly be found in high performance series production and racing engines. Besides that, due to the manufacturing process, they are stronger and therefore allow reduced wall cross-sections and lower piston weight. Also, due to relative manufacturing procedures, forged pistons tend to be more expensive than other process.

3.4 HYDROTHERMIK PISTON

That gives very quiet running pistons are used primarily in passenger cars. On the other hand, the pistons have cast-in steel strips and are slotted at the transition from ring belt to skirt section.

Mainly, these pistons are used in gasoline and diesel engines for passenger cars under heavy load conditions. They have cast-in steel strips but are not slotted. Besides that, they form a uniform body with extreme strength.

3.5 RING CARRIER PISTONS WITH PIN BOSS BUSHES

There have a ring carrier made from special cast iron that is connected metallically and rigidly with the piston material in order to make it more wear resistant, in particular in the first groove. Furthermore, the pin boss bushes made from a special material, the load-bearing capacity of the pin boss is increased.

3.6 RING CARRIER PISTONS WITH COOLING CHANNEL

These types of piston that ring carrier pistons with cooling channel are used in conditions with particularly high operating temperatures. Because of the high temperatures at the piston top and the ring belt, intensive cooling is provided with oil circulating through the cooling channel.

4. ALUMINIUM ALLOYS VERSUS TYPES OF STEEL

Aluminium alloys typically have an elastic modulus of about 70 GPa, which is about one-third of the elastic modulus of most kinds of steel and steel alloys. Therefore, for a given load, a component or unit made of an aluminium alloy will experience a greater elastic deformation than a steel part of the identical size and shape. Though there are aluminium alloys with somewhat-higher tensile strengths than the commonly used kinds of steel, simply replacing a steel part with an aluminium alloy might lead to problems.

With completely new metal products, the design choices are often governed by the choice of manufacturing technology. Extrusions are particularly important in this regard, owing to the ease with which aluminium alloys, particularly the Al–Mg–Si series, can be extruded to form complex profiles. In general, stiffer and lighter designs can be achieved with aluminium alloys than is feasible with steels. For instance, consider the bending of a thin-walled tube: the second moment of area is inversely related to the stress in the tube wall, i.e. stresses are lower for larger values. The second moment of area is proportional to the cube of the radius times the wall thickness, thus increasing the radius (and weight) by 26% will lead to a halving of the wall stress. For this reason, bicycle frames made of aluminium alloys make use of larger tube diameters than steel or titanium in order to yield the desired stiffness and strength. In automotive engineering, cars made of aluminium alloys employ space frames made of extruded profiles to ensure rigidity. This represents a radical change from the common approach for current steel car design, which depend on the body shells for stiffness, that is a unibody design.

Aluminium alloys are widely used in automotive engines, particularly in cylinder blocks and crankcases due to the weight savings that are possible. Since aluminium alloys are susceptible to warping at elevated temperatures, the cooling system of such engines is critical. Manufacturing techniques and metallurgical advancements have also been instrumental for the successful application in automotive engines. In the 1960s, the aluminium cylinder heads of the Corvair earned a reputation for failure and stripping of threads, which is not seen in current aluminium cylinder heads. An important structural limitation of aluminium alloys is their lower fatigue strength compared to steel. In controlled laboratory conditions, steels display a fatigue limit, which is the stress amplitude below which no failures occur – the metal does not continue to weaken with extended stress cycles.

Aluminum alloys do not have this lower fatigue limit and will continue to weaken with continued stress cycles. Aluminium alloys are therefore sparsely used in parts that require high fatigue strength in the high cycle regime (more than 107 stress cycles.

5. SILUMIN

Silumin is the name that is used in some countries for alloys based on Al–Si system. Silumin is a series of lightweight, high-strengthaluminium alloys with silicon content within range of 3–50%. Most of these alloys are casting ones, but also it would be produce by rapid solidification processes and powder metallurgy. Within the Aluminum Association designation system silumins are corresponding to alloys of two system: 3xx.x – Aluminum–silicon alloys are also containing magnesium and/or copper, and 4xx.x – Binary aluminum–silicon alloys. Among the advantages of silumin is its high resistance to corrosion, making it useful in humid environments.

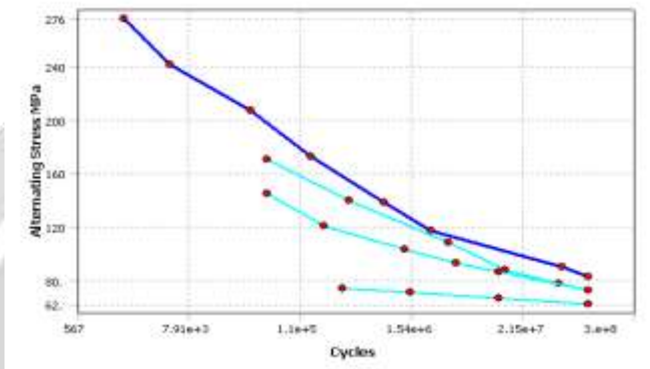
The addition of silicon to aluminium also makes it less viscous when liquid, which together with its low cost (both component elements are relatively cheap to extract), makes it a very good casting alloy and a fresher metal. It is also used on 3 phase motors to allow speed regulation. Another use is rifle scope mounts and camera mounts.

High castability, high fluidity, high corrosion resistance, high ductility, low specific gravity, high machinability

- Used for large castings, which are to operate under heavy load conditions

- Under the category of non-heat-treatable alloys but can be modified by the addition of Mg & Cu, which enables it to be heat treated, e.g. АП4 alloys
- Strengthened by solution treatment, e.g. adding 0.01% Na (in form NaF & NaCl) to the melt just before casting
- Disadvantage is the presence of porosity in the cast (forms foams), which can be avoided by casting under pressure in autoclaves

Examples: АП2 &АП4 alloys 15



5.1 FUNCTIONS

The functions which a piston is called to perform in an IC engine are;

- To transmit the force of explosion to the crankshaft.
- To form a seal so that the high pressure gases in the combustion chamber do not escape into the crankcase.
- To serve as a guide and a bearing for small end of the connecting rod. Apart from its capability to perform the above functions efficiently the pistons must have some other desirable characteristics.
- The design should be such that the seizure does not occur.
- It should offer sufficient resistance to corrosion due to some other products of combustion.
- It should have the shortest possible length so as to decrease overall engine size.
- It should be lighter in weight so that inertia forces created by its reciprocating motion are minimum.
- Its material should have a high thermal conductivity for efficient heat transfer so that higher compression ratios may be used without occurrence of detonation.

5.2 MATERIALS AND CONSTRUCTIONAL FEATURES

The top of the piston is called head or crown. Generally low cost low performance engines have flat head as shown. In some such pistons which come quite close to the valves, the head is provided valve relief. Pistons used in some high powered engines have a raised dome which is used to increase the compression ratio as well as to control combustion.

In some other engines the piston may be dished to form a desired shape of combustion chamber, jointly with cylinder head. In case of piston containing part of the combustion in its crown, compression ratio can be controlled very accurately but the disadvantage is that in this case much larger amount of heat has to be dissipated through the pistons and rings.

Towards the top of the piston of a few grooves are cut to house the piston rings. The bands left between the grooves are known as lands. These lands support the rings against the gas pressure and guide them so that they may flux freely in the radial direction. The supporting webs transmit the force of explosion directly from the crown to the piston pin bosses thereby relieving the groove portion of the large load and thus by preventing the deformation of the ring grooves.

The part of the piston below the rings is called skirt. Its function is to form a guide suitable for absorbing side thrust due to gas pressure. The side thrust is produced on account of the inclination of the connecting rod with the cylinder axes. The skirt is provided with the bosses on the inside of the piston pin. It must be of sufficient length to resist tilting of the piston under load. It is kept quite close fitting in the cylinder but even then it is separated from the cylinder walls by means of lubricating oil film for smooth running. The combustion pressure from the piston crown is transmitted to the connecting rod through webs inside the piston. The bosses form a bearing surface for the rocking motion of the connecting rod. The thick-sectioned webs also form heat paths from the piston crown to the pin bosses and the skirt and thus have to be designed so as to avoid expansion problems.

The distance between the axis of the piston pin and the top of the piston crown is called compression height and determines the compression ratio for a given engine. Thus the same engine a piston with lesser compression height would give lesser compression ratio and vice versa.

The material used for pistons at one time was cast iron which has good wearing qualities. As the technology developed Aluminium alloy containing silicon replaced cast iron as piston material, because of two distinct advantages. Firstly it is as much as three times lighter than the cast iron which makes it is desirable from inertia point of view.

Secondly it possesses a higher thermal conductivity which causes it to run cool. But the aluminium alloy has its own advantages. It is not as a stronger as cast iron and hence thicker sections have to be used. As a result of which the weight of piston is increased. It is seen that an aluminium alloy piston in actual practice is only about 50 percent in weight as compared to its cast iron counterpart. Further aluminium alloy is relatively soft as a result of which fine particles in the lubricating oil become embedded it. Aluminium alloy piston with fine particles embedded in it causes a sort of grinding or abrasion of the cylinder walls thus shortening cylinder life. Another important drawback of using aluminium alloy pistons for cast iron cylinders is their unequal co efficient of expansion which causes engine slaps. Because if the cold clearance is kept just sufficient there is danger of seizure at operating temperatures and if cold clearance is kept large the engine knocks or slaps when cold. This difficulty has been overcome by different methods. Some of the functions are

- Keeping the heat away from the lower part of the piston as far as possible. This is done by cutting horizontal slot in the piston on the thrust and non thrust sides just now the oil control ring. Thus the skirt does not become very hot and consequently it does not expand quit so much. In some designs the circumferential slots are made in the oil control ring groove and these slots end in inclined slots extending downwards. These elongated slots provide additional heat barriers and so reduce even more the amount of heat reaching the working faces of the skirt. Moreover the drooping end makes the skirt flexible in the upper region. Making a heat dam. It consists of a groove cut near the top of the piston. This reduces the path of heat travel from the piston crown to the skirt. The skirt therefore runs cooler and does not expand much.
- Use of vertical t slots; vertical or t slots on the non linear side of the piston were earlier used quite commonly. These slots allow the piston skirt to expand without increase of diameter. However the mechanical strength is decreased on account of slot. Moreover with the slot the skirt tends to collapse inwards without elastic recovery. As a result the diameter is reduced permanently which increases the piston slap, instead of decreasing it. for these reasons fully split skirts in which the slot goes only about halfway up with blunting holes at the ends to avoid stress concentration have been used in pistons of some light duty engines. Heavy duty pistons never use any such slots.
- Taper pistons: the piston are sometimes turned taper the crown side being smaller in diameter than the skirt end. As higher temperatures occur towards the crown than the side expands more than the skirt due to which the piston diameter becomes uniform under running conditions.
- Cam ground pistons; the pistons are cam ground such that they have elliptical section instead of the usual circular one. The minor diameter of the ellipse lies in the direction of the piston pin axis. Such pistons after expanding at operating temperatures become circular automatically the more expansion along minor axis being caused by the metal of piston bosses there. Generally tapered and ovality are combined in the same piston. The amount of ovality is kept maximum at the piston pin boss level and is reduced gradually towards the bottom of the skirt.
- use of special alloys; special alloys having low efficient of expansion or rather whose coefficient of expansion is nearly equal to that for cast iron have been used in the manufacture of pistons without split or specially shaped skirts and giving no piston slap. One such alloy is lo ex alloy. It is an alloy having 12-15% silicon 1.5-3% nickel and about 1% of magnesium and copper. However such pistons are costlier than the ordinary alloy piston.

5.3 COMPOSITE INSULATED PISTON

Dana engine products USA have developed a cool running piston by using stainless steel cap bonded to aluminum piston. The piston consists of a stainless steel cap on the crown of otherwise cast aluminium piston body and skirt. The insulating barrier is the air between the cap and the piston body.

The stamped steel cap has a wire mesh bonded to its underside by a sintering process. This cap is placed into a mold. As aluminium is poured into the mould it is entrapped in the wire mesh and this provides a solid mechanical lock. There is also some diffusion between the aluminium and the stainless steel cap with mesh providing a metallurgical bond as well. But the main bond is mechanical. The geometry of the cap can be formed to most of the crown shapes commonly found in aluminium pistons for current generation diesels.

A comparative idea of the temperature reductions possible can be had where in temperatures above each line are for straight aluminium pistons while the numbers below each line are for a heat shielded piston.

It is seen that piston containing low expansion steel insert at the piston pin bosses. These inserts are so moulded that their ends are anchored in the piston skirt. There is no chemical and metallurgical bond between the steel and the aluminium there is only a mechanical bond. In this case pistons are cam ground with the major diameter perpendicular to the piston pin axis. At higher temperatures during running the bimetallic action of the inserts causes them to bend outward thus causing the piston to expand along the piston pin whereas in the direction perpendicular to piston pin there is corresponding contraction of the piston due to metallic action.

Another such arrangement which provides even better expansion control enabling smaller skirt to cylinder wall clearances to be employed. In this steel inserts are employed on the thrust and non thrust sides of the piston skirt. There is clearance between the inserts on the inside and the upper piston region interrupts the heat flow to the upper piston region interrupts the heat flow to the skirt and keeps its temperature and expansion lower.

6. DESIGN CONSIDERATION

- **MODELING**
- **PISTON DESIGN**
- **DESIGN CONSIDERATIONS FOR A PISTON**
- **PROCEDURE FOR PISTON DESIGN**
- **PISTON MODEL BEFORE OPTIMIZATION**

6.1 MODELING

Range	Piston Rings for Cars, Trucks, Tractors, Marine Engine, Earth Movers, Compressors & various type of engine.
Material	Gray Cast Iron (GCI) , Spheroidal Graphite Iron (SGI) & Steel material as required
Finish	Chrome Plated, Phosphated
Type of Rings	Compression Rings, Steel Oil Control Rings, Steel Laminated Segments, Various types of Expanders and Multiple Piece Oil Control Rings.

6.2 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

6.3 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.

6.4 Procedure for Piston Design

The procedure for piston designs consists of the following steps:

- Thickness of piston head (t_H)
- Heat flows through the piston head (H)
- Radial thickness of the ring (t_1)
- Axial thickness of the ring (t_2)
- Width of the top land (b_1)
- Width of other ring lands (b_2)

The above steps are explained as below:

Thickness of Piston Head (t_h)

The piston thickness of piston head calculated using the following Grashoff's formula, $t_H = \sqrt{}\ (3pD_2)/\ (16\sigma_t)$ in mm

Where,

P= maximum pressure in N/mm²

D= cylinder bore/outside diameter of the piston in mm.

σ_t=permissible tensile stress for the material of the piston.

Here the material is a particular grade of AL-Si alloy whose permissible stress is 50 Mpa- 90Mpa.

Before calculating thickness of piston head, the diameter of the piston has to be specified. The piston size that has been considered here has a L x D specified as 152 x 140.

Heat Flow through the Piston Head (H)

The heat flow through the piston head is calculated using the formula

$H = 12.56 \times t_H \times K \times (T_c - T_e)$ Kj/sec

Where,

K=thermal conductivity of material which is 174.15W/mk

T_c = temperature at center of piston head in °C.

T_e = temperature at edges of piston head in °C.

Radial Thickness of Ring (t_1)

$t_1 = D\sqrt{3pw/\sigma_t}$

Where D = cylinder bore in mm

pw= pressure of fuel on cylinder wall in N/mm². Its value is limited from 0.025N/mm² to 0.042N/mm². For present material, σ_t is 90Mpa

Axial Thickness of Ring (t_2)

The thickness of the rings may be taken as

$$t_2 = 0.7t_1 \text{ to } t_1$$

Let assume t_2 =5mm

Minimum axial thickness (t_2)

= D/(10 x nr)

Where nr = number of rings

Width of the top land (b_1)

The width of the top land varies from

$$b_1 = t_H \text{ to } 1.2\, t_H$$

Width of other lands (b_2)

Width of other ring lands varies from $b_2 = 0.75t_2$ to t_2

Maximum Thickness of Barrel (t_3)

t_3 = 0.03xD + b + 4.5 mm

Where,

b = Radial depth of piston ring groove

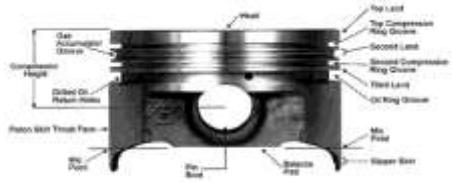
Thus, the dimensions for the piston are calculated and these are used for modeling the piston in PRO-E. In the above procedure the ribs in the piston are not taken into consideration, so as make the piston model simple in its design. In modeling a piston considering all factors will become tedious process. Thus, a symmetric model is developed using the above dimensions.

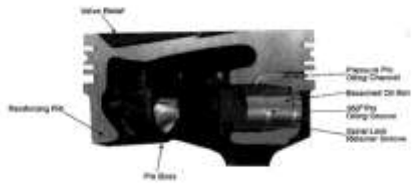
6.5 The Piston Model before optimization

The following are the sequence of steps in which the piston is modeled.

- Drawing a half portion of piston
- Exiting the sketcher
- Developing the model
- Creating a hole.

Piston was modeled using PRO-E software



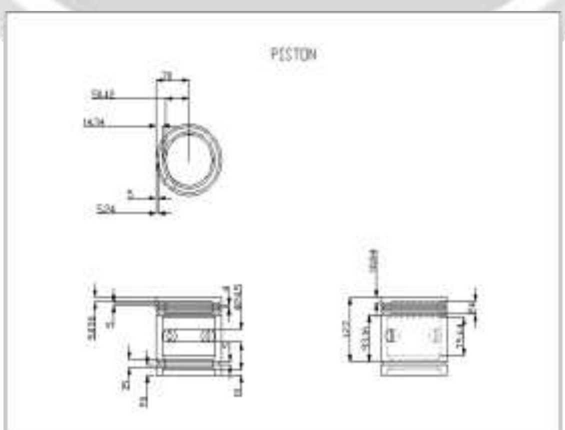


It was then imported to ANSYS 11.0. for analysis and optimization. Specifications of piston before optimization are shown in Table 3.1

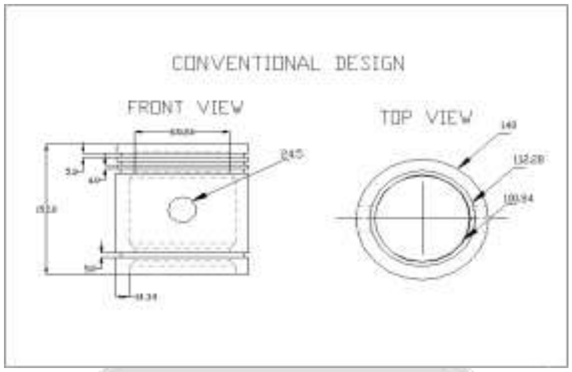
Design Specification before optimization

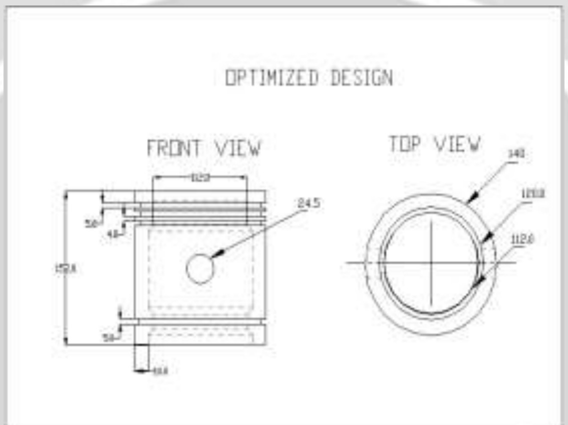
S.No.	Dimensions	Size in mm
1	Length of the Piston(L)	152
2	Cylinder bore/outside diameter of the piston(D)	140
3	Thickness of piston head (t_H)	9.036
4	Radial thickness of the ring (t_1)	5.24
5	Axial thickness of the ring (t_2)	5
6	Width of the top land (b_1)	10
7	Width of other ring lands (b_2)	4

7. CONENTIONAL PISTON SKETCH



7.1 PISTON



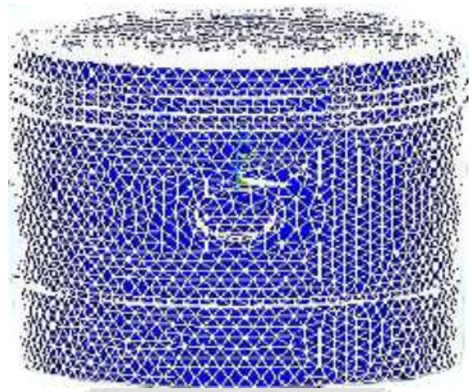


7.2 The CAD and FEA of Piston

The design of the piston starts with the definition of the piston geometry using 3D CAD software. This 3D CAD geometric model is then imported to FEA software and analysed under the predicted service conditions before anything is made. That speeds up the design and testing process, reduces the lead time to create new pistons designs, and produces a better product. The idea behind finite analysis is to divide a model piston into a fixed finite number of elements. Computer software generates and predicts the overall stiffness of the entire piston. Analyzing the data it is possible predict how the piston will behave in a real engine and allows the engineer to see where the stresses and temperatures will be the greatest and how the piston will behave . Analysis of the piston is done to optimize the stresses and minimize the weight using ANSYS. The mathematical model of optimization is established firstly, and the FEA is carried out by using the ANSYS software. Based on the analysis of optimal result, the stress concentrates on the piston has become evaluate, which provides a better reference for redesign of piston.

Meshing of piston before optimization

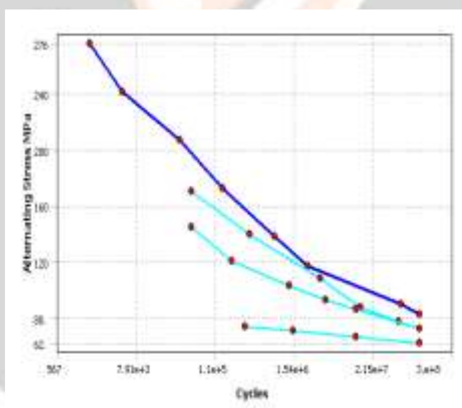
Element used is 20 node Tetrahedron named soilid90. The element size is taken as 5, then total number elements were 57630 and nodes were 91176 found in meshed model. The Figure 3.4. Shows meshed model of the piston.



Meshed Model of the Piston

Thermal and Geometric Properties

It is important to calculate the piston temperature distribution in order to control the thermal stresses and deformations within acceptable levels. The temperature distribution enables us to optimize the thermal aspects of the piston design at lower cost, before the first prototype is constructed. As much as 60% of the total engine mechanical power lost is generated by piston ring assembly. The piston skirt surface slides on the cylinder bore. A lubricant film fills the clearance between the surfaces. The small values of the clearance increase the frictional losses and the high values increase the secondary motion of the piston. Most of the Internal Combustion (IC) engine pistons are made of an aluminum alloy which has a thermal expansion coefficient, 80% higher than the cylinder bore material made of cast iron. This leads to some differences between running and the design clearances. Therefore, analysis of the piston thermal behaviour is extremely crucial in designing more efficient engine[. The thermal and geometric properties are as shown in below table 3.2



Thermal and Geometric Properties:

S.No.	Name of the Property	Value
1	Thermal conductivity	174.15 W/Mk
2	Specific Heat	0.13 J/kgK
3	Young's Modulus	$71x10^3$ Mpa
4	Poisson's Ratio	0.33
5	Density, Dens	$2.77x10^{-6}$ kg/mm³

Applying Temperatures, Convections and Loads

The piston is divided into the areas defined by a series of grooves for sealing rings. E. The boundary conditions for mechanical simulation were defined as the pressure acting on the entire piston head surface (maximum pressure in the engine cylinder). It is necessary to load certain data on material that refer to both its mechanical and thermal properties to do the coupled thermo-mechanical calculations.

The temperature load is applied on different areas and pressure applied on piston head. The regions like piston head and piston ring regions are applied with large amount of heat (160°C- 200°C). The convection values on the piston wall ranges from 232W/mK to 1570W/mK. The working pressure is 2Mpa.

8. INTRODUCTION TO FEA

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modeling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modeling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

8.1 HISTORY OF FEA

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures".

By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters

8.2 NODES AND ELEMENTS

- Red dots represent the element's nodes.
- Elements can have straight or curved edges.
- Each node has three unknowns, namely, the translations in the three global directions.
- The process of subdividing the part into small pieces (elements) is called meshing. In general, smaller elements give more accurate results but require more computer resources and time.
- Ansys suggests a global element size and tolerance for meshing. The size is only an average value, actual element sizes may vary from one location to another depending on geometry.
- It is recommended to use the default settings of meshing for the initial run. For a more accurate solution, use a smaller element size.

8.3 ANALYZING THE BEARING – STEP BY STEP PROCEDURE

- The 3D model of the crank shaft is designed by using pro-e software and it is converted as **IGES** format.
- The **IGES** (Initial Graphic Exchange Specification) format is suitable to import in the ANSYS Workbench for analyzing
- Open the ANSYS workbench
- Choose static structural

- Go to engineering data
- Provide the required materials.
- Go to geometry
- File – import external geometry file – generate
- Close the window
- Go to model
- Click mesh
- Under mesh details, choose sizing – relevant center – fine
- Right click the mesh in tree view – generate mesh
- Click static structural
- Static structural – right click – insert – fixed support
- Select the inner circular face of the pin hole
- Geometry – apply
- Static structural – right click - insert – load - pressure – select the top face.
- Geometry – apply
- Then define the solution
- Solution – right click - insert the total deformation, equivalent elastic strain, and equivalent stress.
- Right click the solution icon in the tree – solve
- To capture the figure use the option new figure in tool bar. The all results are taken in a picture – and save it to the required folder in the system

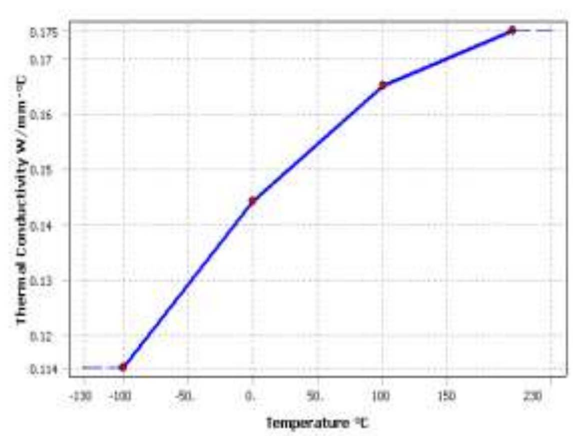
9. RESULTS AND DISCUSSION

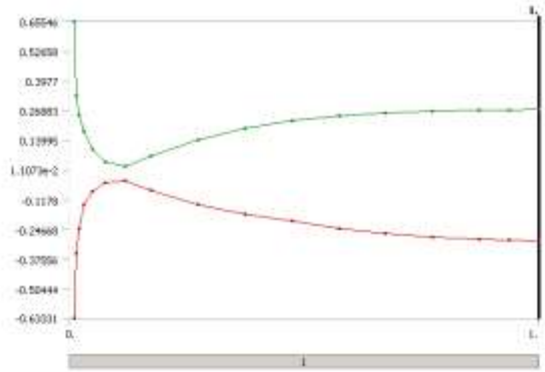
The following images are shown for resulted von-mises stresses before and after optimization

i). Vonmisses Stress before Optimization

(ii). Von misses Stress after Optimization

The optimized values after optimization using ANSYS





Design values after optimization:

S.No.	PARAMETER	BEFORE OPTIMIZATION
1	Volume	997021 mm³
2	Radial thickness of the ring (t_1)	5.24 mm
3	Axial thickness of the ring (t_2)	5 mm
4	Maximum Thickness of Barrel (t_3)	14.34 mm
5	Width of the top land (b_1)	10.84 mm
6	Width of other ring lands (b_2)	4 mm
7	Von misses stress	63.019Mpa
8	Deflection	0.0198 mm

	TOTAL DEFORMATION (mm)	STRAIN (mm/mm)	STRESS (MPa)
ALUMINIUM	0.82165	5.63e-4	39.968
SILUMIN	0.01887	1.20e-4	39.214

The length 152mm of the piston obtained is same as before and after optimization process. The value after optimization is taken into consideration. It is not considerable that the variations in piston length. Applying the temperature and pressure loads on different areas of the piston and heat flow has not affected the length.

The diameter also same even after optimization process i.e., 140mm and is taken into consideration for design purposes. The heat flow in the piston material and pressure on the head has not affected in length and diameter as these are larger than other parameters. So the piston can withstand easily on sizes of these parameters.

The volume has varied after applying temperature and pressure loads over the piston as volume is depends on not only on length and diameter and also on thicknesses. The volumetric size after optimization is taken into consideration. The volume of piston before optimization is 997021 mm³ and for the same after optimization is 752994mm³

The radial thickness of the piston has affected more as it is very small in size and the temperature and heat flow are very high to this size of thickness. Before optimization value is given as 5.24mm and obtained after optimization is 3.46mm. This is rounded to next highest value i.e., 4mm and is taken into consideration for design. The axial thickness of the piston ring before optimization is 5mm, it is changed to 3.52mm after optimization, since the more and more heat and stress applied through groves as it is very near to the head of the piston. This is rounded to next highest value i.e., 4mm is taken into consideration for design.

The maximum thickness of the barrel before optimization is 14.34mm has much affected in variation of size after applying pressure and temperature loads and is changed to 9.08mm and rounded to next highest value i.e., 10mm taken into consideration.

The width of the top land has not much affected while comparing with the maximum thickness of the barrel. The initial value i.e., before optimization is 10.84mm and is changed after applying pressure which is directly applied on the head i.e., top of the piston as a result the shape of the piston on top will become just like a bowl. The value after optimization is obtained as 9.36mm and it is rounded to 10mm. This value is considerable for design.

The width of the other lands i.e., near piston rings are 4mm in size and is changed due to pressure and heat applied on rings through groves. The value after optimization is 3.24mm and is rounded to 3mm.

The von misses stress initially was 63.019Mpa, after optimization it is obtained as 75.95Mpa and it is permissible up to 90Mpa. So the piston with these considerations can withstand easily.

The deflection due to pressure applied is more than that of temperature applied. In this analysis the pressure as well as temperature loads are taken into consideration for applying on the piston. The deflection before optimization is given as 0.0198mm and after optimization it is obtained that 0.120mm, this value is taken into consideration for design purpose.

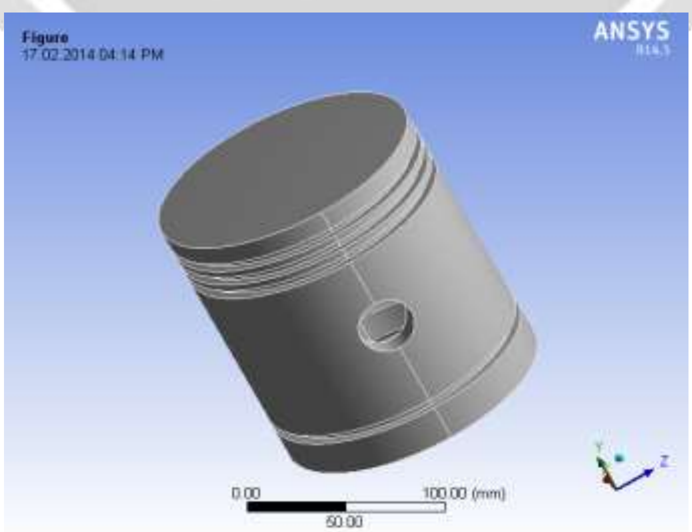
10. COMPARISION TABLE

For Existing design and Optimized design

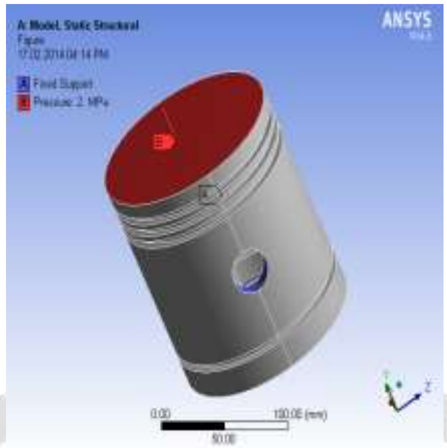
	TOTAL DEFORMATION (mm)	STRAIN (mm/mm)	STRESS (MPa)
ALUMINIUM	0.13325	7.**48e**-4	52.522
SILUMIN	0.03059	1.79e-4	50.181

Because of less deformation, strain and stress values silumin as a best material for piston.

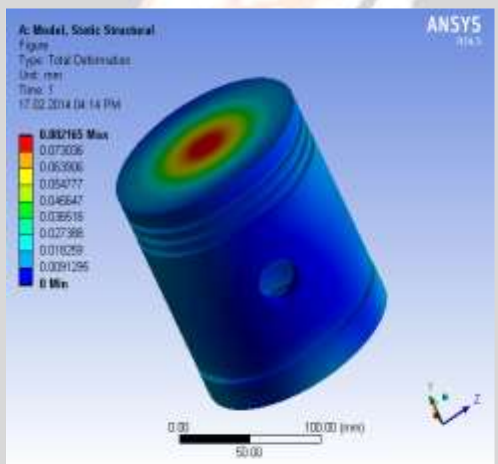
INPUT AND RESULTS IMPORTED



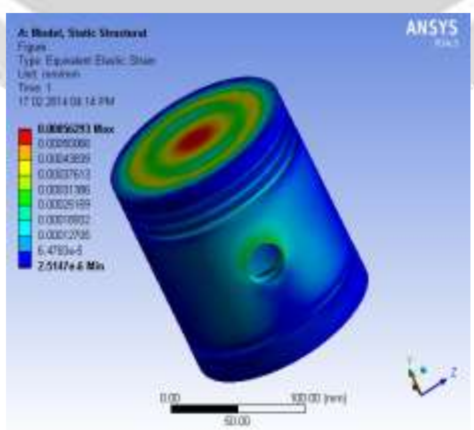
BOUNDARY CONDITIONS



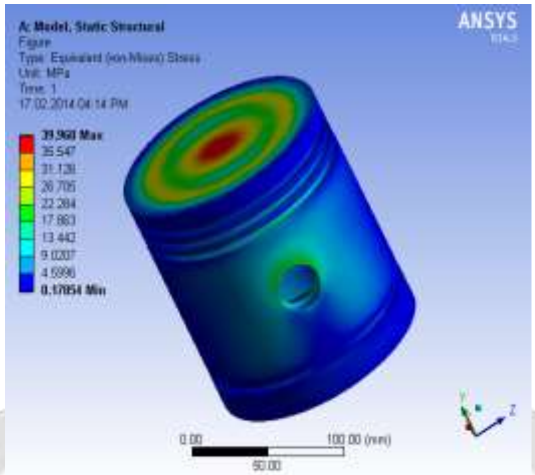
ALUMINIUM DEFORMATION



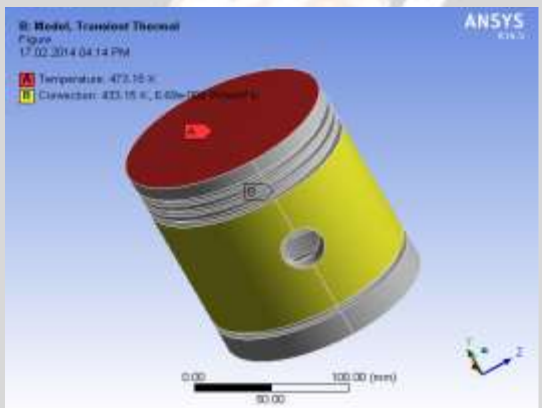
STRAIN



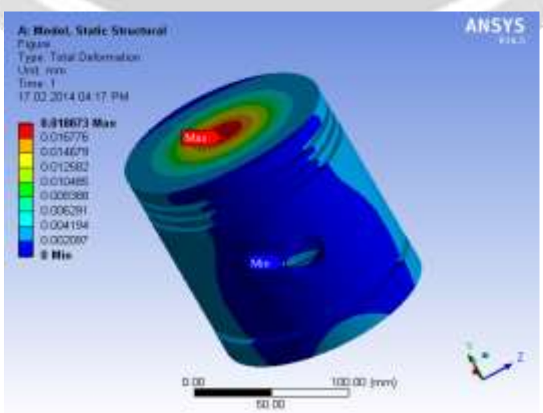
STRESS



THERMAL INPUT



SILUMIN DEFORMATION



11. CONCLUSION

From the above analysis, the weight reduction have be achieved by both design and material optimization. The weight reduction that is been achieved by 26.59 %. From this analysis, we conclude that the best material for piston is silumin as it has low values of deformation

12. REFERENCES

1. A. R. Bhagat, Y. M. Jibhakate, Thermal Analysis and Optimization of I.C. Engine Piston Using Finite Element Method, International Journal of Modern Engineering Research (IJMER), Vol.2, Issue.4, pp.2919-2921, 2012.
2. R.S.Khurmi,J.K.Gupta, A Text Book of Machine Design, S.Chand& Co., pp. 1132- 1144, 2004.
3. P. Carvalheira1, and P. Gonçalves, FEA of Two Engine Pistons Made of Aluminium Cast Alloy A390 and Ductile Iron 65-45-12 Under Service Conditions, 5th International Conference on Mechanics and Materials in Design Porto-Portugal, vol 9, pp271,2006.
4. ANSYS'S Element Reference http://www1.ansys.com /customer /content / documentation/121/ ans_elem.pdf pp 1-1688.
5. Gudimetal P. Gopinath C.V. Finite Element Analysis of Reverse Engineered Internal Combustion Engine Piston, King Mongkut's University of Technology North Bangkok Press, Bangkok, Thailand AIJSTPME, Vol.5(4), pp 75-92, 2003.
6. MirosáawWendeker, PaweáMagryta Adam Majczak, MichaáBiaáy, "Modeling The Thermal Loads in the Subaru EJ25 Engine" Journal of KONES Powertrain and Transport, Vol. 18, No. 1, pp. 683-688, 2011.
7. D.Janko , Jovanovi," Finite Element Evaluation and Optimization of Geometry with DOE", International Journal for Quality research UDK- 005. Vol.5, No. 1, pp. 39-45, 2011.
8. A.Atish Gawale, A. Shaikh and Vinay Patil, "Nonlinear Static Finite Element
9. Analysis and Optimization of connecting rod World Journal of Science and Technology, Vol. 2(4), pp .01-04, 2012.