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FABRICATION AND ANALYSIS OF PISTON BY METAL CASTING

M.KHAJA GULAM HUSSAIN
ASST PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING,
RAJIV GANDHI MEMORIAL COLLEGE OF ENGINEERING & TECHNOLOGY, AFFILIATED TO J.N.T.UNIVERSITY ANANTAPUR.
NANDYAL, A.P.INDIA.
mullakhaja@gmail.com

T.JOHN BABU
ASST PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING,
RAJIV GANDHI MEMORIAL COLLEGE OF ENGINEERING & TECHNOLOGY, AFFILIATED TO J.N.T.UNIVERSITY ANANTAPUR.
NANDYAL, A.P.INDIA.
Johnbabudinesh7862012@gmail.com

U.SURESH
ASST PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING,
VNR VIGNAN JYOTHI COLLEGE OF ENGINEERING, AFFILIATED TO J.N.T.UNIVERSITY HYDERABAD.HYDERABAD.INDIA.
usuresh42@gmail.com

Abstract

The casting of automobile piston is carried out using sand mould. The prepared piston sand core was positioned in the mould to provide casting with contours and cavities. The molten metal of required composition is poured into the sand mould, allowed to solidify and take the desired shape of the cavity. Aluminium is used as the casting material. Melting of the aluminium was achieved using crucible furnace and finally pouring the molten metal into the metallic mould having the prepared piston sand core in place to obtain the piston. A 3D model was made using CATIA and Structural and thermal analysis was done on ANSYS. The comparison is performed on casted piston and modelled piston. The casted piston has lower strength when compared to modelled piston.

Index Terms *– Keywords: piston, crucible furnace, 3D model CATIA, Structural and thermal analysis on ANSYS.*

I. INTRODUCTION

The internal combustion engines are engines in which the combustion of fuel takes place inside the engine cylinder. The IC engines use either petrol or diesel as their fuel.In petrol engines (also called spark ignition engines or S.I engines), the correct proportion of air and petrol is mixed in the carburettor and fed to engine cylinder where it is ignited by means of a spark produced at the spark plug.In diesel engines (also called compression ignition engines or C.I engines), only air is supplied to the engine cylinder during suction stroke and it is compressed to a very high pressure, thereby raising its temperature from 600°C to 1000°C.The desired quantity of fuel (diesel) is injected into the engine cylinder in the form of a very fine spray and gets ignited when comes in contact with hot air.

II. BACKGROUND INFORMATION

2.1. Parts of IC engine: The principal parts of an IC engine are as follows:
1. Cylinder and cylinder liner
2. Piston, piston rings and piston pin or gudgeon pin
3. Connecting rod with big and small end bearing
4. Crank, crank shaft and crank pin,
5. Valve gear mechanism.

2.2 Piston:
The piston is a disc which reciprocates within cylinder.
It is either moved by the fluid or it moves the fluid which enters the cylinder.

2.3 Functions of piston:
The piston must also disperse a large amount of heat from the combustion chamber to the cylinder walls.
The main function of the piston of an IC engine is to receive the impulse from the expanding gas and to transmit the energy to the crankshaft through the connecting rod.

2.4 Types of piston
Trunk piston
Slipper piston
Cross head piston
Deflector piston.

a. Trunk piston
Trunk pistons are long relative to its diameter. They both act as a piston and cylindrical crosshead. As the connecting rod is angled for much of its rotation, there is also a side force that reacts along the side of the piston against the cylinder wall. A longer piston helps to support this. Trunk pistons have been a common design of piston since the early days of the reciprocating internal combustion engine. They were used for both petrol and diesel engines, although high speed engines have now adopted the lighter weight slipper piston. A characteristic of most trunk pistons, particularly for diesel engines, is that they have a groove for an oil ring below the gudgeon pin, in addition to the rings between the gudgeon pin and crown.

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Fig. 1. Trunk piston

The name 'trunk piston' derives from the 'trunk engine', an early design of marine steam engine. To make these more compact, they avoided the steam engine's usual piston rod with separate crosshead and were instead the first engine design to place the gudgeon pin directlywithin the piston. Otherwise these trunk engine pistons bore little resemblance to the trunk piston; they were extremely large diameter and double-acting. Their 'trunk'was a narrow cylinder mounted in the centre of the piston.

b. Slipper piston

A slipper piston is a piston for a petrol engine that has been reduced in size and weight as much as possible. In the extreme case, they are reduced to the piston crown, support for the piston rings, and the piston skirt remaining to leave two lands so as to stop the piston rocking in the bore. The sides of the piston skirt around the gudgeon pin are reduced away from the cylinder wall.

Fig. 2 Slipper piston

The purpose is to reduce the reciprocating mass, thus making it easier to balance the engine and so permit high speeds. A secondary benefit may be some reduction in friction with the cylinder wall, since the area of the skirt, which slides up and down in the cylinder is reduced by half. However most friction is due to the piston rings, which are the parts which actually fit the tightest in the bore and the bearing surfaces of the wrist pin, the benefit is reduced.

c. Cross head piston

Fig..3 Cross head piston

Large slow-speed Diesel engines may require additional support for the side forces on the piston. These engines typically use crosshead pistons. The main piston has a large piston rod extending downwards from the piston to what is effectively a second smaller-diameter piston. The main piston is responsible for gas sealing and carries the piston rings. The smaller piston is purely a mechanical guide. It runs within a small cylinder as a trunk guide and also carries the gudgeon pin. Because of the additional weight of these pistons, they are not used for high-speed engines.

d. Deflector piston

Fig. 4 Deflector piston

Deflector pistons are used in two-stroke engines with crankcase compression, where the gas flow within the cylinder must be carefully directed in order to provide efficient scavenging. With cross scavenging, the transfer (inlet to the cylinder) and exhaust ports are on directly facing sides of the cylinder wall. To prevent the incoming mixture passing straight across from one port to the other, the piston has a raised rib on its crown. This is intended to deflect the incoming mixture upwards, around the combustion chamber. Much effort, and many different designs of piston crown, went into developing improved scavenging. The crowns developed from a simple rib to a large asymmetric bulge, usually with a steep face on the inlet side and a gentle curve on the exhaust. Despite this, cross scavenging was never as effective as hoped. Most engines today use Schnuerle porting instead. This places a pair of transfer ports in the sides of the cylinder and encourages gas flow to rotate around a vertical axis, rather than a horizontal axis. **1.6 Trunk piston parts**

Trunk piston is most commonly used piston in IC engines. It consists open end and following parts:

1. Head or Crown:The piston head or crown may be flat, convex or concave depending upon the design of combustion chamber. It withstands the pressure of gas in the cylinder.
2. Piston rings:The piston rings are used to seal the cylinder to prevent leakage of gas past the piston.

The piston rings are used to import the necessary radial pressure to maintain the seal between the piston and the cylinder bore. The piston rings are two types, they are

1. Compression rings or Pressure rings
2. Oil control rings or Oil scraper.

The compression rings transfer heat from the piston to the cylinder liner and absorb part of the piston fluctuation due to the side thrust.

The oil rings provide proper lubrication to the liner by allowing sufficient oil to move up during upward strokeand at the same time scraps the lubricating oilfrom the surface ofthe linerinorder to minimise the flow of the oil to the combustion chamber.

3. Piston skirt:The portion of the piston below the ring section is known as piston skirt. The skirt acts as a bearing for the side thrust of the connecting rod on the walls of cylinder.

4. Piston pin:It is also called gudgeon pin or wrist pin. It is used to connect the piston to the connecting rod.

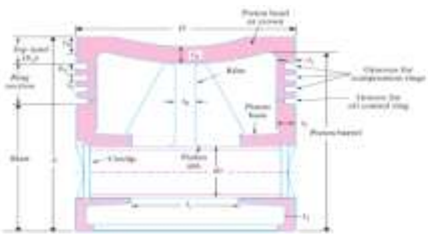

Fig. 5 Sectional view of piston

2.5 Materials used for piston:

The most commonly used materials for pistons of I.C. engines are cast iron, cast aluminium, forged aluminium, cast steel and forged steel. The cast iron pistons are used for moderately rated engines with piston speeds below 6 m / s and aluminium alloy pistons are used for highly rated engines running at higher piston speeds.

2.6 Casting:

Casting is a manufacturing process in which a liquid material is poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mould to complete the process.

2.7 Advantages of casting

Molten metal flows into small section in the molten cavity, hence any complex shape can be easily produced.
Practically any type of material can be casted.
Ideal method is by producing small quantities
Due to small cooling rate from all directions, the properties of casting are same in all directions.
Any size of casting can be produced like up to 200 tons.
Casting is the often cheapest and most direct way of producing a shape with certain desired mechanical properties.
Certain metals and alloys such as highly creep resistant metal-based alloys for gas turbines cannot be worked mechanically and can be cast only.
Heavy equipment like machine leads, ship's propeller etc. can be cast easily in the required size rather than fabricating them by joining several small pieces.

2.8 Limitations of casting

With normal sand casting process, the dimensional accuracies and surface finish is less.
Defects are unavoidable.
Sand casting is labour intensive.

2.9 Terms in casting

Moulding sand:Moulding sand is the refractory material used for making the mould. It is mixture of silica, clay and moisture to get required properties.
Baking sand:Baking sand consists of refractory material and it is made of used sand or burnt sand.
Facing sand: Facing sand is the carboneous material sprinkled on the inner surfaces of the moulding cavity for obtaining better surface finish.
Loam sand: Green or dry sand with at least 50% clay and dries hard is called loam sand. It also contains fire clay. It has 18 to 20% moisture and produces a good surface finish.
Parting sand: For separating the moulds from adhering to each other by separating a fine sharp dry sand called parting sand. It also can be used to keep green sand from sticking to the pattern. It is the clean clay free silica sand.

Flask: Flask is the moulding box used for holding the sand. Based on the situation it can be named as cope, drag, cheek etc.
Drag: Lower moulding flask is called drag.

Cope: Upper moulding flask is called cope.
Cheek: The middle moulding flask used in three piece pattern.
Pattern: The pattern is the replica of the casting to be produced.
Parting line: The parting line is the dividing line between the two flasks.
Sprue: Sprue is the connecting passage between the pouring basin and runner. It controls the flow of molten metal.
Runner: The runner is the passage used for regulating the flow of molten liquid.
Ingate: Ingate is the last point of gating from where the molten metal enters the cavity.
Riser: The riser is the reservoir of molten metal provided in the casting process to compensate the liquid shrinkage's taking place during solidification.
Chill: Chill is the metallic piece used for obtaining directional solidification.
Chaplets: Chaplets are used for supporting the cores inside the mould cavity to take care of its own weight and mould cavity to take care of its own weight and overcome the buoyancy forces.

III. PISTON DESIGN

3.1 Design considerations of piston

In designing a piston for I.C. engine, the following points should be taken into considerations:

1. It should have enormous strength to withstand the high gas pressure and inertia forces.
2. It should have minimum mass to minimize the inertia forces.
3. It should form an effective gas and oil sealing of the cylinder.
4. It should provide sufficient bearing area to prevent due wear.
5. It should disperse the heat of combustion quickly to the cylinder walls.
6. It should have high speed reciprocation without noise.
7. It should be of sufficient rigid construction to withstand thermal and mechanical distortion.
8. It should have sufficient support for the piston pin.

3.2 Design of piston parameters

1. Piston head:

The piston head or crown is designed keeping in view the following two main considerations,

a. It should have adequate strength to withstand the straining action due to pressure of explosion inside the engine cylinder, and
b. It should dissipate the heat of combustion to the cylinder walls as quickly as possible.

On basis of strength

The thickness of the piston head (t_h), according to Grashoff's formula is given by

$t_h = \sqrt{3PD^2/16\sigma_t}$

P = Maximum gas pressure or explosion pressure N/mm²

D = Cylinder bore or outside diameter of the piston in mm

σ_t = Permissible bending (tensile) stress for the material of the piston in MPa or N/m

On the basis of heat transfer $t_h = H/12.56k(T_C-T_E)$

Where

H = Heat flowing through piston in KJ/S or Watts $H = C \times HCV \times m \times B.P$

K = Heat conductivity factor in w/m/°C

T_C = Temperature at the centre of the piston head in °C
T_E= Temperature at the edges of piston head in °C
HCV = Higher calorific of the fuel in KJ/Kg
C = Constant and generally its value taken as 0.05
m = Mass of fuel used in Kg per B.P per second
B.P = Brake power of engine per cylinder in kW
The thickness of the piston head (t_h) is calculated by using above equations and larger of two values obtained should be adopted.

2. Piston ribs:
The thickness of the ribs may be taken as $t_h/3$ to $t_h/2$.

3. Piston rings:
The radial thickness (t_1) of the ring may be obtained by considering the radial pressure between cylinder wall and the ring. From bending stress consideration in the ring, the radial thickness given by $t_1 = D \times \sqrt{\frac{3Pw}{\sigma t}}$
The axial thickness (t_2) of the rings may be taken as 0.7 t_1 to t_1.
D = Cylinder bore in mm, P_w = pressure of the gas on the cylinder wall in N/mm^2
σ_t =Allowable bending (tensile) stress in MPa
The width of the top land (i.e. the distance from top of the piston to the first ring groove)
$b_1 = t_h$ to $1.2t_h$
The width of other ring lands (i.e. the distance between the ring grooves) in the piston maybe given as b_2= 0.75 t_h to t_h

4. Piston barrel:
The maximum thickness (h) of the piston barrel may be obtained from the following empirical relation
h= 0.03D+b+4.5 mm
Where
b = Radial depth of the piston ring groove = t_1+0.4 mm
The piston wall thickness (t_4) towards open end is decreased and should be taken as 0.25 t_3 to 0.35 t_3.

5. Piston skirt:
Length of the piston skirt is given by $l_s = \frac{\mu\left[\frac{\pi\times D^2\times pmax}{4}\right]}{ps\times D}$
The total length of piston (L) is given by
L= Length of skirt + Length of ring section + Top land
Maximum bending moment at the centre of pin is given by $M= \frac{p\times D}{8}$
Bending stress of the material of the piston is given by $_b$ = M/Z
Where section modulus, $Z = \frac{\pi}{32}\left(\frac{do^2-di^2}{do}\right)$
M = Maximum bending moment at the centre of piston in N-m

d_o = Outer diameter of the pin in mm
d_i= Inner diameter of the pin in mm

IV. MAIN RESULT

MATERIALS USED FOR IC ENGINE PISTON

4.1 Aluminium

After iron, aluminium is now the second most widely used metal used metal in the world. The properties of aluminium include low density and therefore low weight, high strength, superior malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity are amongst aluminium's most important properties. Aluminium is also very easy to recycle. Compared with other materials, aluminium has larger coefficient of thermal expansion. Aluminium is a non-magnetic (actually paramagnetic) material. To avoid interference of magnetic fields aluminium is often used in magnet X-ray devices. After oxygen and silicon, aluminium is the most common element in the Earth's crust. Aluminium compounds also occurs naturally in our food.

4.2 Aluminium-silicon alloy

The composition of Al-Si alloy is as follows
Aluminium-70-75%, Copper 4-5%, ferrous -1.3% silicon-16 to 18%, magnesium-0.45-0.65%, zinc-1.5% and nickel-0.1%. Silicon is the main alloying element; it imparts high fluidity and low shrinkage, which result in good castability and weldability. The low thermal expansion coefficient is exploited for pistons, the high hardness of the silicon particles for wear resistance. The important properties of the Al-Si alloy includes good wear resistance, corrosion resistance, increase in creep resistance, lower thermal coefficient of expansion, etc.

4.3 Grey Cast Iron

Microscopically, all grey irons contain flake graphite dispersed in a silicon-iron matrix. Graphite is present, the length of the flakes and how they are distributed in the matrix directly influence the properties of the iron. The basic strength and hardness of the iron is provided by the metallic matrix in which the graphite occurs. The properties of the metallic matrix can range from those of a soft, low carbon steel to those of hardened, high carbon steel. The matrix can be entirely for maximum machinability but the iron will have reduced wear resistance and strength. An entirely pearlitic matrix is characteristic of high strength grey irons, and many castings are produced with a matrix microstructure of both ferrite and pearlite to scobtain intermediate hardness and strength. Alloy additions and/or heat treatment can be used to produce grey iron with very fine pearlite or with an acicular matrix structure.
Graphite has little strength or hardness. It decreases these properties of the metallic matrix; however, the presence of the graphite provides several valuable characteristics to cast iron. These include:
The ability to produce sound castings economically in complex shapes suchn as water cooled engine blocks.
God machinability even at wear resisting hardness levels and without burring.
Dimensional stability under differential heating such as in brake drums and disks.
High vibration damping as in power transmission cases.

Borderline lubrication retention as in internal combustion engine cylinders.
The following table shows the different mechanical properties of various materials.
Table-1 Mechanical properties of various materials

S.no	Property	Al-Si alloy	Aluminium	Grey cast iron
1	Density Kg/m3	2770	2700	7200
2	Poisson's ratio	0.33	0.35	0.27
3	Young's modulus (GPa)	71	70	100
4	Tensile yield strength (MPa)	280	276	98
5	Tensile ultimate strength (MPa)	310	310	140
6	Shear modulus (GPa)	26	26	45
7	Thermal Conductivity (W/mk)	174.75	175	46.6

4.4 Design parameters of piston (Al)

1. Thickness of piston head a/c Grass Hoof's formula

Based on strength $t_h = \sqrt{3PD^2/16\sigma_t}$

For Al σ_t= 38 N/mm^2.

D =46.48 mm, P =8 N/mm^2.

$t_h = \sqrt{3 \times 8 \times 80^2 / 16(38)}$ t_h = 9.23 mm

Thermal basis = H/12.56k (T_C-T_E)

Here k = 175 $\left(W/m/_s \right)$ for Al

(T_C-T_E) = 111 °C

H = $C \times HCV \times m \times B.P$

HCV = 48×10^3 KJ/Kg (Petrol)

B.P =8.51 KW

C =0.05

m = $1/8.51 \times 3600$=3.26×10^{-5} Kg/KW sec

H = $0.05 \times 48 \times 10^3 \times 3.26 \times 10^{-5} \times 8.51$

H = 0.665 KJ/S

$t_h = \frac{0.665\times10^3}{12.5\times111\times175}$ t_h =2.73 mm

Max t_h = 9.23 mm

2. Thickness of ribs = $t_h/3$ to $t_h/2$

Thickness of ribs = $\frac{9.23}{3}$ = 3.07 mm

3. Piston rings

Radial thickness of piston rings

$t_1 = D \times \sqrt{\frac{3Pw}{\sigma t}}$

P_w = 0.024 to 0.031 MPa

P_w = 0.031 MPa

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$t_1 = 46.48 \times \sqrt{\frac{3\times0.031}{38}} = 2.29$ mm
Axial thickness or depth of piston rings
$t_2 = 0.7\ t_1$ to t_1.
$t_2 = 0.7\ t_1 = 0.7\times2.29 = 1.603$ mm
Thickness of top land
$b_1 = t_h$ to $1.2t_h$
$b_1 = 1.2 \times 9.23 = 11.076$ mm
Minimum depth of piston rings
$h = \frac{D}{10i} = \frac{46.48}{10\times3} = 1.54$ mm
Thickness of ring land $t_{land} = h = 1.54$ mm
Radial depth of ring grooves $b = t_1 + 0.4$ mm
$b = 2.29+0.4$
$b = 2.69$ mm
4. Piston barrel
$t_3 = 0.03D+b+4.5$ mm
$= 0.03(46.48) +2.69+4.5$
$t_3=8.58$mm
Wall thickness toward open end $t_4 = 0.35\ t_3 = 0.35\times8.58 = 3.003$ mm
5. Diameter of piston pin
$d_o = \frac{\pi}{4}D^2\times Pmax/l_1p_b = \frac{\pi}{4}46.48^2 \times \frac{8}{1.5\times15.7} = 24.00$ mm
$d_i = 0.6\times d_o = 0.6\times24 = 14.4$ mm
$M = p*D/8 \quad p = \frac{\pi}{4}D^2\times Pmax = \frac{\pi}{4}\times 46.48^2 \times 8 = 13.57$ KN
$M = \frac{13.57\times46.48}{8} = 78.84$ KN- mm
$\sigma = \frac{M}{Z}$
$Z = \frac{\pi}{32}\left(\frac{do^2-di^2}{do}\right)$
$Z = \frac{\pi}{32}\left(\frac{24^2-14.4^2}{24}\right)$
$Z = 1.50$
$\sigma = \frac{78.84}{1.50} = 52.56$ N/mm^2

V. MODELLING OF PISTON

5.1 **Modelling :**
For modelling of piston we have chosen DISCOVER 110 c.c engine of 4- Stroke single cylinder.
Specifications taken from modelling of piston:
Bore : 48 mm
Stroke : 111.63 mm
Rpm : 7500
Brake power : 8.51 KW
Fuel : Petrol
Sp. Gravity : 0.713

Calorific value : 47300 KJ/Kg

Table-2 Parameters of piston (for Al)

S.NO	PARAMETER	CALCULATED VALUE	MEASURED VALUE
1.	Thickness of piston head	9.23 mm	11.16 mm
2.	Thickness of ribs	3.07 mm	3 mm
3.	Radial thickness of piston ring	2.29 mm	2 mm
4.	Axial thickness of piston ring	1.603 mm	1.5 mm
5.	Thickness of ring land	1.54 mm	1.2 mm
6.	Thickness of top land	11.076 mm	11 mm
7.	Thickness of piston barrel	8.58 mm	10 mm
8.	Radial depth of ring grooves	2.69 mm	2 mm
9.	Outer diameter of piston pin	24 mm	18.74 mm
10.	Inner diameter of piston pin	14.4 mm	14 mm

5.2 CATIA (V5 R20)

Introduction to CATIA

This is an Introduction to CATIA V5 Release 20 is a collection of tutorials meant to familiarize the reader with the mechanical design workbenches that are available in CATIA Release 20.The reader is not required to have any previous CATIA knowledge.

The workbenches covered in this book are; Sketcher, Part Design, Wireframe and Surface Design, Assembly Design, and Drafting. Preceding each tutorial is a description of the workbench, toolbars, and commands to be used and focused on within the tutorial. This book is not meant to be strictly a reference book. It is meant to enable the reader to get right into CATIA and start drawing. The author directs the reader to CATIA s Companion for in depth reference material and a more detailed description of the commands.

PART DESIGN

The part design application makes it possible to design precise 3D mechanical parts with an intuitive and flexible user interface from sketching in an assembly context to iterative detailed design. Part design application will enable us to accommodate design requirements for parts of various complexities from simple to advance. Now we will see the procedure for modelling the piston using CATIA.

5.3 Procedure used for modelling in CATIA

Open the CATIA V5 R20 software by double clicking on the Catia icon.

Click on Start → Mechanical design → Part design → Enter part name → Ok.

Select Shaft tool → Click on Sketcher → select X-Y plane → Draw the complete closed profile → Then draw the axis → exit work bench → enter angle → preview → ok.

Select Pocket tool → create the cutting surface using Sketcher → exit work bench → enter the depth → preview → ok.

Save the model by clicking save on the Standard tool bar.

For modelling the piston, we have taken the standard dimensions of ASME.

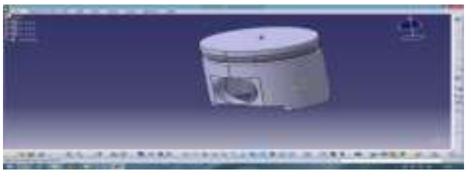

Fig 6. Piston modelled in CATIA

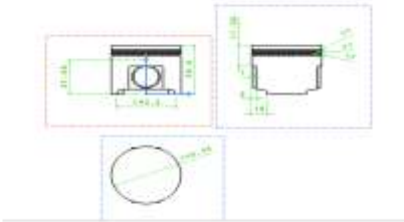

Fig 7.Views of piston

VI. **ANALYSIS OF IC ENGINE PISTON**

6.1 Introduction of ANSYS

ANSYS finite element analysis (FEA) is a computer based numerical technique for calculating the strength and behaviour of engineering structures. It can be used to calculate deflection, stress, vibration, buckling behaviour and many other phenomena. It can be used to analyse either small or large-scale deflection under loading or applied displacement. It can analyse elastic deformation, or permanently bent out of shape plastic deformation. The computer is required because of the astronomical number of calculations needed to analyse a large structure. The power and low cost of modern computers has made Finite Element Analysis available to many disciplines and companies. Useful for problems with complicated geometries, loadings, and material properties where analytical solutions cannot be obtained.

In the finite element method, a structure is broken down into many small simple blocks or elements. The behaviour of an individual element can be described just as the set of elements would be joined together to build the whole structure, the equations describing the behaviours of the individual elements are joined into an extremely large set of equations that describe the behaviour the of the whole structure .the computer can solve this large set of simultaneous equation. From the solution, the computer extracts the behaviour of the individual elements. From this, it can get the stress and deflection of all the parts of the structure. The stresses will be compared to allowed values of stress for the materials to be used, to see if the structure is strong enough.

FEM can be broadly can classified in to:
Pre-processing.
Processing (Solution).
Post-processing.
Pre-processing
Model generation is conducted in this processor, which involves material definition, creation of a solid model, and, finally, meshing. Important tasks within this pre-processing are:
Specify element type.

Define real constants (if required by the element type).
Define material properties.
Create the material geometry.
Generate the mesh.

The finite element mesh subdivides the geometry into elements, upon which are found nodes. For a two-dimensional (2D) analysis, or a three-dimensional (3D) thin shell analysis, the elements are essentially 2D, but may be "warped" slightly to conform to a 3D surface. An example is the thin shell linear quadrilateral; thin shell implies essentially classical shell theory, linear defines the interpolation of mathematical quantities across the element, and quadrilateral describes the geometry. For a 3D analysis, the elements have physical thickness in all three dimensions. Common examples include solid linear brick and solid parabolic tetrahedral elements. In addition, there are many special elements, such as axisymmetric elements for situations in which the geometry, material and boundary conditions are all symmetric about an axis.
Material properties required vary within the type of solution .A linear statics analysis, for example, will require an elastic modulus, Poisson's ratio and perhaps a density for each material. Thermal properties are required for a thermal analysis.
Free mesh
Free-meshing automatically subdivides meshing regions into elements, with the advantages of fast meeting, easy mesh-size transitioning (for a denser mesh in regions of larger gradient), and adaptive capabilities.

Loads include forces, pressures and heat flux. It is preferable to apply boundary conditions to the CAD geometry, with the FEA package transferring them to the underlying model, to allow for simpler application of adaptive and optimization algorithms.
Processing (Solution)
Solution is often a batch process, and is demanding of computer resource. The governing equations are assembled into matrix form and are solved numerically. The assembly process depends not only on the type of analysis (e.g. static or dynamic), but also on the model's element types and properties, material properties and boundary conditions.
Post processing
After a finite element model has been prepared and checked, boundary conditions have been applied, and the model has been solved, it is time to investigate the results of the analysis. This activity is known as the post-processing phase of the finite element method.

6.2 Static Structural Analysis
A static structural analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes). If the stress values obtained in the analysis crosses the allowable values it result in the failure of the structure in the static condition itself. To avoid such a failure, this analysis is necessary.

Static analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; the loads and the structure's response are assumed to vary slowly with respect to time.

6.3 Thermal Analysis

A Thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities in a system or component. Typical thermal quantities interested are:

Temperature distribution

The amount of heat loss or gained.

Thermal fluxes

Thermal gradients

Thermal simulations play an important role in design of many engineering application including internal combustion engines, turbines, heat exchangers, piping systems and electronic components. In many cases engineers follow a thermal analysis with stress analysis to calculate thermal stresses.

Types of thermal analysis

ANSYS supports two types of thermal analysis:

A steady state thermal analysis determines the temperature distribution and other thermal quantities under steady state loading conditions. A steady state loading condition is a situation where heat storage effects varying over a period of time are ignored.

A transient thermal analysis determines the and other thermal quantities under conditions that vary over a period of time.

6.4 Procedure for analysis of piston in ANSYS (17.0)

(Structural analysis)

Open the ANSYS (Work bench) software → Select structural analysis → Go to Geometry → Import geometry → Go to model → Right click on model → Select edit option (new window will be open).

Go to geometry → Click on part body → Go to material assignment → Right click on it → Select Engineering data sources → Select general material or we can add material at the last row → Click on edit option → Enter the various values such as click on " +" symbol to add the material → now refresh all data by using function key F5. Now enter in to the project then go to file → refresh the data → Go to materials → Right click → select the material which has been added.

Go to mesh → Right click → Generate mesh.

Go to structural analysis → Right click → Insert → Select fixed support as piston pin centre → Select geometry → Apply.

Go to structural analysis → Right click → Insert → Select pressure → Select required faces → Enter magnitude → Apply.

Go to solution → Right click → Select total deformation and equivalent stresses → Generate solution.

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6.5 Procedure for Analysis of piston in ANSYS (R 17.0)
(Thermal analysis)
Open the ANSYS (Workbench) software → Select thermal analysis → Go to geometry → Import geometry → Go to model → Right click on model → select edit option (new window will be open).
Go to geometry → Click on part body → Go to material assignment → Right click on it → Select new material or we can add material at the last row → click on edit option → Enter the various values such as Thermal conductivity, Density, Tensile strength, Young's modulus, Poisson's ratio, etc. → Click on "+" symbol to add material → Now refresh all data by using function key F5. Now enter in to project then go to file → Refresh data → Go to materials → Right click → Select material which has been added.
Go to mesh → Right click → Generate mesh.
Go to thermal analysis → Right click → Insert → Select temperature and convection → Select geometry i.e. , surface of piston head → Enter magnitude → Apply. Then generate solution by right clicking.

VII. RESULTS
This chapter deals with the results of Static and Thermal analysis of Al model of IC engine piston. The model is made to be symmetric about two axes, where the actual rod is symmetric about one. Also, some miner features such as fillets and bolts are neglected. These simplifications made modelling quick and easy. Patterned features and feature symmetry also help in importing the model into ANSYS. The less complex the model, shorter the import time and the more likely it is that import will be successful.
Static and thermal analysis of piston is performed using ANSYS 17.1 analysis software, by considering the pre-determined conditions (necessary boundary conditions and loads) to achieve the results within the allowable limits.
From the static structure analysis, total deformation, Von- misses stress and Von- misses strain of piston has been determined by using necessary boundary conditions and fixed Support. The obtained results are within the allowable limits.
Static structural analysis of Aluminium piston is performed using ANSYS 17.1 analysis software, by considering of the pressure load 8MPa.
From the results of static structural analysis of Aluminium piston, we got the total deformation, equivalent stress are 3.2978e-0.04m, 363.77MPa.
The following figure shows the variation of deformation, stresses that analytically through ANSYS software.

7.1 Results of structural analysis of Aluminium

Fig.8 Meshing of piston

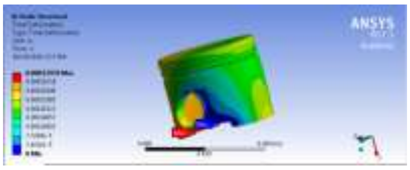

Fig.9. Total deformation of piston

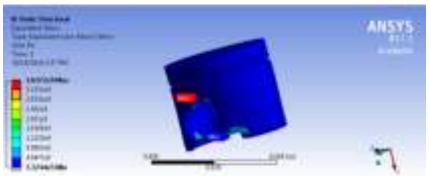

Fig.10.Equivalent stress

Thermal analysis of piston using Aluminium material has been done using necessary boundary conditions. The results obtained are in allowable limits and satisfactory

Steady state thermal analysis of Aluminium piston has been performed using ANSYS 17.1 analysis software, by considering temperature of 275°c and film coefficient of 22W/m²k.

The following figures show the results obtained using ANSYS software.

7.2 Results of Thermal analysis of Al

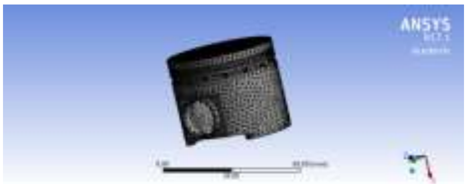

Fig.11 Meshing of piston

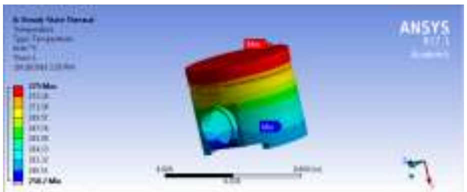

Fig.12 Temperature distribution (AL)

Fig.13 Heat flux (Aluminium)

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7.3 Analytical Results

Analytical results obtained for Aluminium piston using ANSYS 17.1. Analytical results are shown in following tables.

Structural analysis

Table-3.Structure analysis

	Total deformation (m)	Equivalent stress (Pa)
Minimum	0	7.2244e+005
Maximum	3.2978e-004	3.6372e+009

Thermal analysis

Table-4 Thermal analysis

SL.NO	Material	Temperature(K)		Heat flux(w/m²)	
		Max	Min	Max	Min
1	Al	275	252	5.7865e+005	690.8

VIII. CONCLUSION

BY using CATIA, the piston has been modelled successfully which made easier in lesser time.

By using ANSYS software analysis (structural and thermal) of piston has been carried out successfully.

The structure analysis shows the safe design of piston as the stress developed are lesser than yield strength of the material.

By using piston material as Al can reduce the weight of the engine there by increasing the mechanical efficiency of the engine.

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