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"MODIFICATION IN DESIGN OF PISTON CROWN BY CHANGING THE SURFACE GEOMETRY OF CROWN "

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ABSTRACT

As we know performance of an auto motive vehicle is largely depends upon the engine of that vehicle. The engine produces power by the combustion of fuel into the cylinder. In an I.C. engine we can say that Piston is heart of engine, it is a reciprocating component which take part in the conversion of thermal energy into mechanical energy. In engine when the fuel and air mixture burn it get expand into the cylinder and this expanding gas transfer in the cylinder to crank shaft via Piston rod. When engine works, all the time the Piston crown is exposed to very high temperature. So the Piston crown is subjected to thermal residual stress and mechanical stresses, which reduces its performance and working life. My research area is to design and optimize the surface of crown by changing its surface geometry so that thermal and mechanical stresses can be minimized, by doing this we can improve the performance and life of Piston. The design of Piston is done by Pro-E, and optimization is done by the CAE software ANSYS.

KEYWORDS **:** *Piston, mechanical and thermal stress, fatigue, Elliptical voids, Piston crown.*

I. INTRODUCTION

The main objective of this review of paper is to predict the different types of thermal and mechanical fatigue failure which helps to improve the design of the piston. Piston is a cylindrical component which reciprocates into the cylinder, during the operation of engine the pressure and temperature is very high, and the entire time piston exposed to a temperature ranging from 2000^0 C to 2800^0 C. this high pressure and temperature causes thermo- mechanical fatigue stress, and which further leads to various types of failure. In appearance the piston look like very simple but in the design point of view it is very complex. The efficiency and life of piston mainly depends upon the design of piston.

For a high speed engine it is important that the weight of piston should be minimized as well as [2] it must be enough strong to resist the various loads, this requirement is fulfilled by using aluminium which is light in weight but having high thermal expansion coefficient. Also it has low resistance to wear so for preventing wear and tear aluminium alloys are used for making a piston.

Even though there are lots of changes are made but the basic function of piston not changed and basic design of piston is quite same, so the question is what has changed? – The Operating Environment. Today's engines run cleaner, without noise, work harder and run hotter than ever before. At the same time, they are expected to work last longer and with minimal maintenance.

From the reference of several papers, I found that when engine works all the time the Piston crown is exposed to very high temperature. It may be noted that the maximum temperature occurs at the center of the crown (Fig.1) and this temperature decreased with increasing distance of cylinder.

This paper describes a design method of modified piston for minimizing the effect of heat and pressure on the surface of the crown.

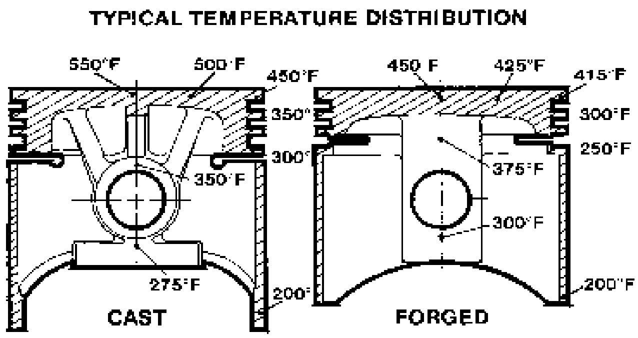

Figure 1: Distribution of temperature

II. FAILURE OF PISTON

According to my literature survey, one of the most frequently occurring engine breakdowns is the failure of the engine Piston. Piston and crown (upper part of Piston) of Piston are subjected to various mechanical failure problems which directly effect on the performance and service life of Piston. [3]When the engine of the vehicle operates the Piston and its crown are exposed to very high temperature and cyclic pressure which further leads to various serious damage problems in Piston. The common types of piston failures are listed below:

2.1 Seizures due to overheating Identification

Deep, sharp scoring on the exhaust side of Piston and cylinder (Fig. 2) from excessive (10) heat and metal to metal contact of excessive heat expanded Piston. Piston rings will be stuck in grooves.

Causes

- Expansion of Piston on exhaust side from overheating.
- Lean carburetor setting
- Lean engine oil mix ratio.
- Incorrect engine oil.
- Excessive oxygenated fuel.

Figure 2: Piston Seizures

2.2 Pre- Ignition

Deep, sharp scoring on an exhaust side of Piston, Crumbling of Piston crown on the exhaust side, small, melted pieces of aluminum deposited on top of Piston (Fig. 3.2). Possible melted spark plug Electrode. Piston rings may be stuck in grooves.

Causes:

- Ignition of air/fuel mixture a millisecond prior to regular spark interval from excessive carbon build-up.
- Incorrect spark plugs heat range.
- Hot spots on top of Piston from Piston/cylinder scuffing.

Figure 3: Pre-Ignition of piston

2.3 Cracks on Piston crown

The load by combustion chamber produce deformation of crown particularly at the right angle to the direction of gudgeon pin, and this encourages the crack to progress from outside of the crown . This can cause the entire cross section of a crown to crack.

Causes

- Very high mechanical load on the engine used in racing cars.
- Heavy heating at Piston crown.
- Thermal expansion due to the temperature difference.

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Figure 4: Piston Cracks

The all discussed cases are the most common type of failure that occurs on Piston. Often, in some specific case, failure can be found, which are above not listed and they are caused by some other factors. The primary causes of failure are not responsible for the whole range of failures of Piston occurred in the engine as result of its operation in faulty condition. So by examine the first sign of failure we can make the suitable operation for reducing it.

III. METHODOLOGY

It has been discussed that the design of Piston is quite simple and it is very effective but along with all these factors there are such major problems occurs which has to be solved. In this work, main emphasis is placed on the study of thermal and fatigue behavior of Piston and then the design of Piston crown are replaced by providing elliptical voids. The design is made in the design Software (14) Pro-E and then it is analyzed in the FEM software package, before going to start let us discuss few more things like function and characteristic of the Pistons.

3.1 Selection of Piston

There are[21] many factors has been thought-about once choosing Pistons for a superior applications Choices are created by comparing value, design, material, and compression ratio, according to surface geometry of crown pistons are of three type-

Figure 5: Dome type, Dish type, and flat Type Piston

In this work a flat type piston has been considered for the analysis. For surviving at higher temperature change in Piston geometry have also been made, Piston manufacturer used to grind most of the Piston with a straight tapper profile, so from the design point of view design of Piston has been evolving since the first Piston was designed. Piston crown design depends on the type of fuel injection system.

1. In case of indirect fuel injection used in cars for silent operation, a FLAT type is used.
2. In the case of direct injection, the combustion chamber is designed in the Piston crown.

3.2 Engine specification

The engine of Hero Karizma ZMR is used for this work (21) which is single cylinder air cooled type internal combustion petrol engine. The engine specifications are given in the following table:

Table 1 Specification of Engine

Parameters	**Values**
Engine type	4 Stroke Petrol Engine
Induction	Air cooled
Number of cylinders	One
Bore	65.5 mm
Stroke	66.2 mm
Displacement volume	223 cc
Compression ratio	9.6:1
Maximum power	14.9 KW @ 8500 rpm
Maximum torque	19.7 N-m @ 6500 rpm
Number of revolution / cycle	2

3.2Selection of material

The choice of material for any [5] machine part can be said to depend on the following consideration:

- general function: structural, bearing, sealing, heat-conducting, space-filling;
- Environment: loading, temperature and temperature range exposure to corrosive condition or to abrasive wear.
- Life expectancy space and weight limitations.

These problems are addressed by victimization an Al-Si alloy i.e., Al 4032 grade alloy as the Piston material. This Piston material has a Si content of approximately 12-tone music. The composition of al 4032 grade is shown in Table 2. Mechanical properties of Al 4032 grade aluminum the fabric are also shown in Table 2.

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Table 2 Composition of Al 4032 grade Aluminium alloy

Material	% by weight
Aluminium	85
Silicon	12.20
Copper	0.9
Magnesium	1.0
Nickel	0.9

Table 3 Mechanical Properties Al 4032 grade Aluminium alloy

Properties	Value
Density	2690 kg/m3
Poisson's ratio	0.33
Elastic modulus	79 GPa
Fatigue strength	110 MPa
Tensile strength	380 Mpa
Yieled strength	315 Mpa
Shear strength	260 Mpa
Hardness	120 BHN
Thermal expansion coefficient	19.4 x 10-6 /^{0}K
Thermal conductivity	154 W/mK

3.3 Analytical Design of Piston

The value for the modeling of piston has been taken from the research paper, in which following design specifications are considered.

Table 4: Design specification of Al 4032 Alloy Piston

Design Dimensions	Size (mm)
Outside diameter of Piston	65.8
Radial thickness of ring	1.7
Axial thickness of ring	2.18
Max. thickness of barrel at the top end	8.03
Max. thickness of barrel at the open end	2.14
Width of top land	8.03
Width of ring land	2.14
Thickness of the Piston head	8.03
Length of skirt	18.34

3.4 Modeling of Pistons

In my work, a flat crown Piston has been taken for the research. The changes in design are made by providing elliptical voids on the surface of the Piston crown.

For the analysis and validation of design 4 sets of Pistons are made with same elliptical pattern but number of patterns has been changed. The size of Piston has been taken from table 4, and the size of major and minor axis of ellipse is 4 mm and 1 mm respectively and the depth of void is 0.5mm. The design of Piston is given below.

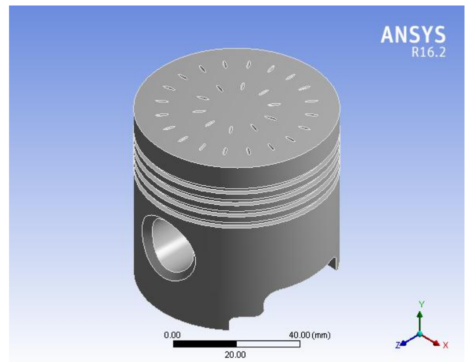

Figure 6 CAD mode of proposed Piston design

3.5Analysis of Pistons

Analysis After completing the CAD (14) geometry of Pistons it is imported in ANSYS workbench for further structural and the next step is meshing. The mesh created in this work is shown in Fig 5, in the figure there is all four set in which the number of nodes and elements are given in the table number 5, it is clear from the mesh geometry the node numbers and element numbers are almost six in digit which show that the mesh is very fine because the result accuracy depends on the mesh quality.

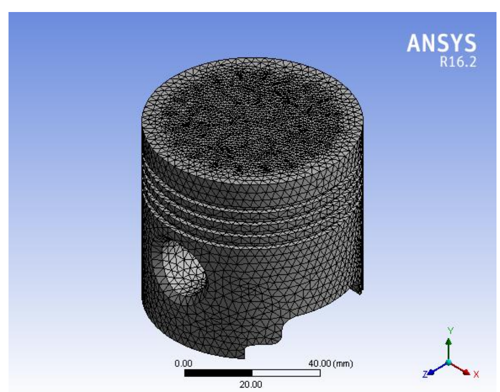

Figure 7 Meshing of proposed Piston design

3.6 Boundary condition and loading

The boundary condition for the analysis of Piston (21) is given below which is same for all four sets of design.

- Maximum pressure loads at the top surface of the Piston crown 13.56 Mpa.

- Temperature at the top surface of the Piston crown 15000 C.
- Piston pin holes are fixed DX= DY =DZ =0

IV. RESULTS AND DISCUSSION

The researcher (21) research on the standard flat crown Piston. During solution of problem same results are calculated for all four sets of the Piston. The four sets of Piston give the best value of all parameters like Von-Misses stresses, total Deformation, Total Heat Flux and mass of the modified or proposed design of Piston.

Table 5. Validation of result

Type	Von-Misses stress (N/mm2)	Total deformation (mm)	Heat Flux (W/mm2)
Flat Piston	304.83	0.051334	1.0787
Set-1	300.84	0.049409	0.96761
Set-2	298.45	0.049173	0.96516
Set-3	297.04	0.047782	0.95947
Set-4	301.33	0.049222	1.0245

4.1 Results for Von-Misses Stresses

The figure shows result outcome from the analysis which is carried out in ANSYS workbench 16.2 and static structural work tool has been chosen for analysis.

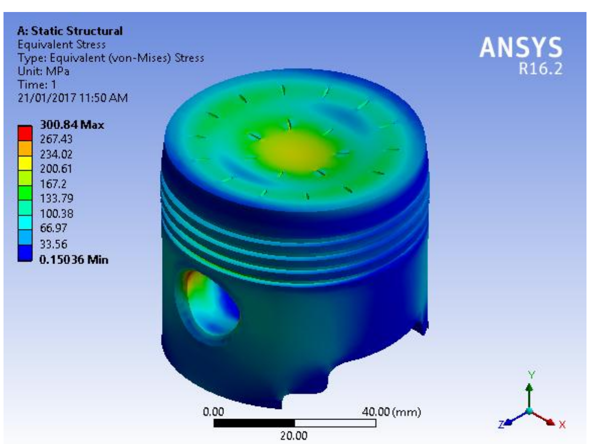

Figure 8 Von- Misses Stress for Set- 1

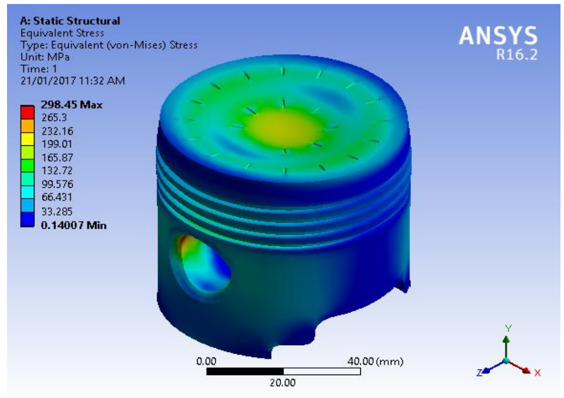

Figure 9 Von-Misses Stress for Set- 2

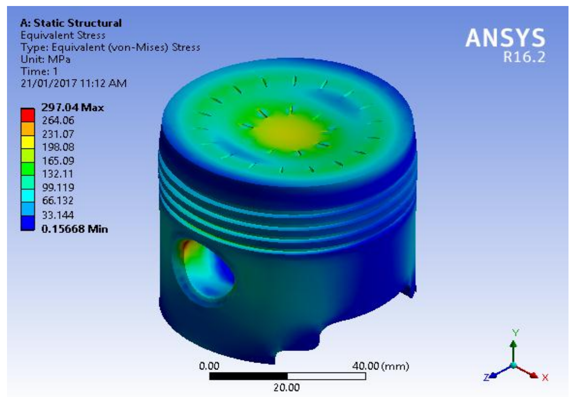

Figure 10 Von- Misses Stress for Set- 3

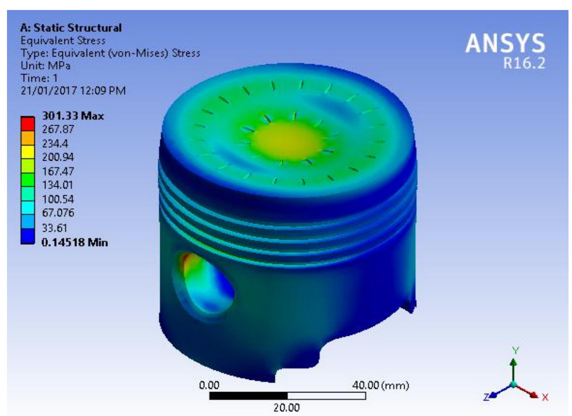

Figure 11 Von- Misses Stress for Set- 4

From the above figures the Von-Misses stress for a standard flat crown Piston is given by 304.83 N/mm2 as per as Jain et. al. (14), by providing the elliptical voids on the Piston crown, by changing this surface geometry the stresses are reduced.

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4.2 Results for Total Deformation

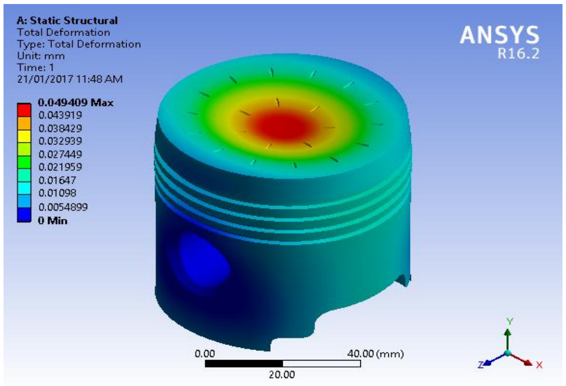

Figure 12 Total Deformations for Set- 1

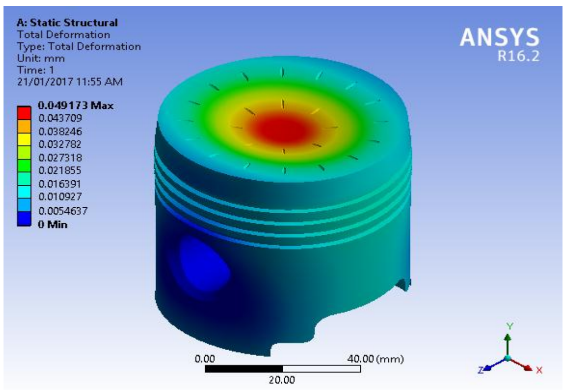

Figure 13 Total Deformations for Set- 2

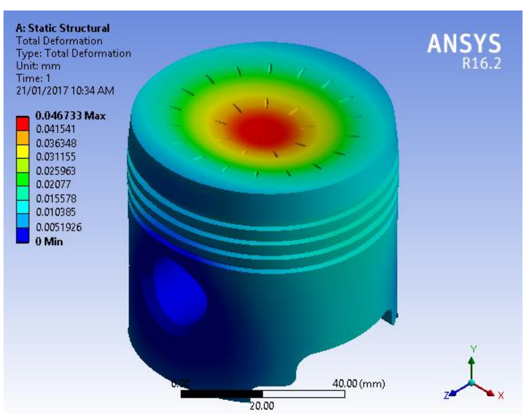

Figure 14 Total Deformations for Set- 3

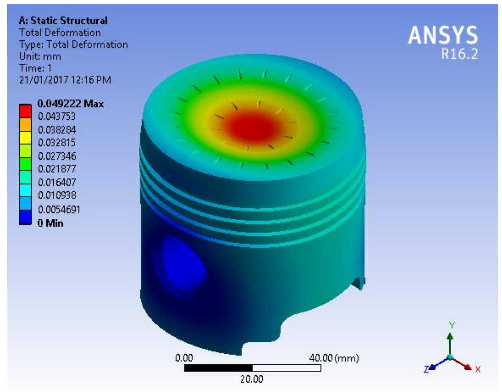

Figure 15 Total Deformations for Set- 4

From the figures the Total Deformation for a standard flat crown Piston is given by 0.051334 mm, the above figures show the resulting outcome from the analysis. For Set-1 total deformation is 0.04909 mm, for Set-2 total deformation is 0.049173 mm, for Set-3 total deformation is 0.04733 mm, & for Set-1 total deformation is 0.049222 mm.

4.3 Results for Total Heat Flux

The results are obtained from the analysis which has been carried out in ANSYS workbench 16.2 & steady-state-thermal work tool has been chosen the outcome of results are shown in figure below.

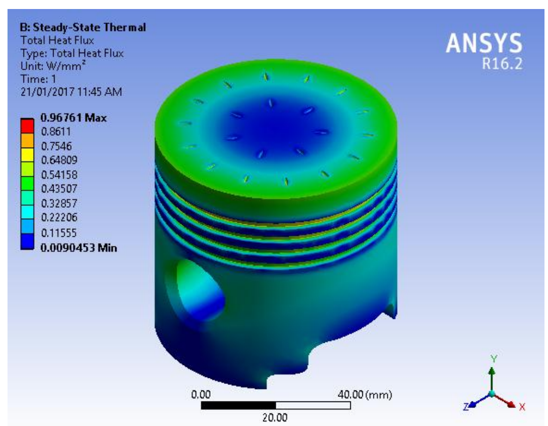

Figure 16 Total Heat Flux for Set- 1

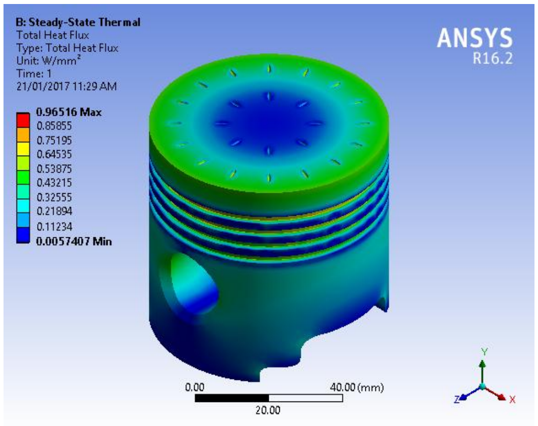

Figure 17 Total Heat Flux for Set- 2

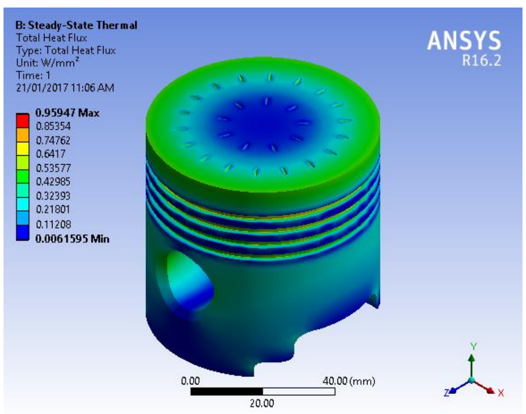

Figure 18 Total Heat Flux for Set- 4

From Figure the total heat flux obtained in the previous analysis is given by 1.0787 W/mm2 and after providing elliptical voids to the Piston crown the total heat flux is reduced which is clearly can be seen in the above figures.
So from above all three results of Von-Misses stress, Total Heat Flux and Total deformation have been evaluated for all the four sets of the Piston. From all the perspective it is clear that all the parameters are minimized by providing the elliptical voids on the surface of the Piston crown.
So from all the above graph we can say that the Von-Misses stress, total deformation and the total heat flux are minimized by providing 27 elliptical voids on the surface of Piston crown, which is comparatively less than to the previous analysis made by Jain et.al

V. CONCLUSION

Internal Combustion engine is one of the most important inventions of the last century. It has been developed in the late 1800s and from there on it has had a significant impact on our society. It has been and will remain for foreseeable future a vital and active area of engineer research.
The aim of this project is to design a piston with improved geometry of piston crown which helps to reduce the failures occurs in piston Another goal is to make drawings on CAD software that clearly display the proposed design that what I want to draw. And last but not least, to chose a pattern from various geometries like spherical, triangular, circular, and elliptical, So that the desired outcome can be found. After a number of patterns analyzed a elliptical voids has been chosen which gives desired output.

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