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# DESIGN AND ANALYSIS OF ALUMINUM ALLOY PISTON USING CAE TOOLS

**Mr. Jadhav Vishal, Dr. R.K. Jain, Mr. Yogendra S.Chauhan**
*M-Tech scholar, School Of Mechanical Engineering, ITM University, Gwalior , India.
Professor, School Of Mechanical Engineering, ITM University, Gwalior, India.
Asst.Professor, School Of Mechanical Engineering, ITM University, Gwalior, India.

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## ABSTRACT

Recent advancement of technology leads to complex decision in the Engineering field. Thus this paper entails the design and analysis of an IC engine piston using two different aluminum materials that are competitive in market. Piston plays a main role in energy conversation. Failure of piston due to various thermal and mechanical stresses is common and so expensive to replace. The specifications used for this work is related to four stroke single cylinder engine of Hero Karizma ZMR motorcycle. Design of the piston is carried out using SOLIDWORKS software, thermal and stress analysis is performed using Finite Element Analysis (FEA).The best aluminum alloy material is selected based on thermal and stress analysis results. The analysis results are used to optimize piston geometry of best aluminum alloy.

**KEYWORDS:** Piston, Solid works, thermal, stress analysis**.**

## INTRODUCTION

A piston is a component of reciprocating IC engines. It is the moving component with in a cylinder and is made of gas-tight by piston rings. In an engine, piston is used to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod. Piston endures the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of the piston, such as piston side wear, piston head cracks and so on. So there is a need to optimize the design of piston by considering various parameters in this project the parameters selected are analysis of piston by applying pressure force acting at the top of the piston and thermal analysis of piston at various temperatures at the top of the piston in various strokes. This analysis could be useful for design engineers for modification of piston at the time of design.

## PISTON DESIGN FEATURES

1. Have sufficient mechanical strength and stiffness.
2. Can effectively block the heat reached the piston head.
3. High temperature corrosion resistance.
4. Dimensions as compact as possible, in order to reduce the weight of the piston

### OBJECTIVES

1. Analytical design of piston using Hero Karizma ZMR specifications.
2. Obtaining design of piston using Solid works 2013 and then imported in ansys 15.0
3. Meshing of design model using ANSYS 15.
4. Analysis of piston by stress analysis and thermal analysis method.
5. Comparing the performance of two aluminum alloy piston under structural and thermal analysis process.
6. Identification of the suitable aluminum alloy material for manufacturing of the piston under specified conditions.

## ENGINE SPECIFICATION

The engine specifications used for this work is a four stroke single cylinder type Hero Karizma ZMR petrol engine.

***Table 1: engine specification***

| PARAMETERS | VALUES |
|---|---|
| Engine type | Four stroke, petrol engine |
| Number of cylinders | Single cylinder |
| Bore | 65.5 mm |
| Stroke | 66.2 mm |
| Maximum power | 14.9 KW @ 8000 rpm |
| Maximum torque | 19.7 Nm @ 6500 rpm |
| Maximum speed | 129 Kmph |
| Compression ratio | 9.6:1 |

## PROPERTIES OF MATERIALS

The materials considered for this work are A4032 and A2618 for an IC engine piston. The mechanical and physical properties of aluminum alloys are listed in the table

***Table 2: material properties***

| s. no | PARAMETERS | A4032 | A2618 |
|---|---|---|---|
| 1 | Density (kg/m$^3$) | 2684.95 | 2767.99 |
| 2 | Poisson's ratio | 0.33 | 0.33 |
| 3 | Coefficient of thermal expansion (1/K) | $79.2 \times 10^{-6}$ | $25.9 \times 10^{-6}$ |
| 4 | Elastic modulus (Gpa) | 79 | 73.7 |
| 5 | Yield strength (Mpa) | 315 | 420 |
| 6 | Ultimate tensile strength (Mpa) | 380 | 480 |
| 7 | Thermal conductivity (W/m/$^0$C) | 154 | 147 |

## METHODOLOGY

Let,
IP = indicated power produced inside the cylinder (W)
N = engine speed (rpm)
L = length of stroke (mm)
A = cross-section area of cylinder (mm2)
$m_p$ = mass of the piston (Kg)
V = volume of the piston (mm3)
$t_H$ = thickness of piston head (mm)
D = cylinder bore (mm)
$P_{max}$ = maximum gas pressure or explosion pressure (Mpa)
$\sigma_t$ = allowable tensile strength (Mpa)
$\sigma_{ut}$ = ultimate tensile strength (Mpa)
K = thermal conductivity (W/m K)
Tc = temperature at the centre of the piston head (K)
Te = temperature at the edge of the piston head (K)
HCV = Higher Calorific Value of fuel (KJ/Kg) = 48000 KJ/Kg
BP = brake power of the engine per cylinder (KW)
C = ratio of heat absorbed by the piston to the total heat developed in the cylinder = 5% or 0.05

$t_1$= radial thickness of ring (mm)
Pw = allowable radial pressure on cylinder wall (N/mm2) = 0.025 Mpa
$\sigma_p$ = permissible tensile strength for ring material (N/mm2) = 110 N/mm2
$t_2$ = axial thickness of piston ring (mm)
$b_1$ = width of top lands (mm)
$b_2$ = width of ring lands (mm)
$t_3$ = thickness of piston barrel at the open end (mm)
$l_s$ = length of skirt (mm)
do = outer diameter of piston pin (mm)
Mechanical efficiency of the engine (η) = 70 %.
H = Brake power (B.P)/ Indicating power (I.P)
Therefore, I.P = B.P /η = 14.9/0.9 = 16.55 KW
Also, I.P = P x A x L x N /2
I.P = P x π $D^2$/4x L x N / 2
Substituting the values we have

$$16.55 \times 1000 = \frac{P \times \pi (0.0655)^2}{4} \times (0.0662) \times \frac{6500}{2 \times 60}$$

P = 1.3566 Mpa
Maximum Pressure = Pmax = 10 x P
= 10 x 1.356 = 13.56 Mpa

## PROCEDURE FOR DESIGN OF PISTON

$$\boldsymbol{t_H = \sqrt{\frac{3pD^2}{16\sigma_t}}}$$

Where: p is the maximum gas pressure (Mpa)
D is the bore diameter (mm)
$\sigma_t$ is the permissible stress (Mpa)

$$t_1 = D \times \sqrt{\frac{3P_w}{\sigma_p}}$$

Where $P_w$ is the Pressure of fuel on cylinder wall (0.025N/mm2-0.042N/mm2)

$t_2 = 0.7t_1$ to $t_1$

or

$$t_2 = \frac{D}{10 \times n_r}$$

Where: $n_r$ is the number of rings
$b_1 = t_H$ to $1.2\ t_H$
$b_2 = 0.7t_2$ to $t_2$
$t_3 = 0.03 \times D + t_1 + 4.9$
$l_s$= (0.6D to 0.8D)
$d_0$= (0.28D to 0.38D)

The geometric values considered for design of piston in Solidworks 2013.

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***Table 3: geometric values***

| s.no | DIMENSIONS | SIZE (mm) |
|---|---|---|
| 1 | Cylinder bore (D) | 65.5 |
| 2 | Thickness of the piston head ($t_H$) | 8.03 |
| 3 | Radial thickness of ring ($t_1$) | 1.710 |
| 4 | Axial thickness of ring ($t_2$) | 2.183 |
| 5 | Width of top land ($b_1$) | 8.03 |
| 6 | Width of other land ($b_2$) | 2.183 |
| 7 | Maximum thickness of barrel ($t_3$) | 8.575 |
| 8 | Length of the skirt ($l_s$) | 39.3 |
| 9 | Piston pin diameter ($d_0$) | 18.34 |

## BOUNDARY CONDITIONS AND LOADS

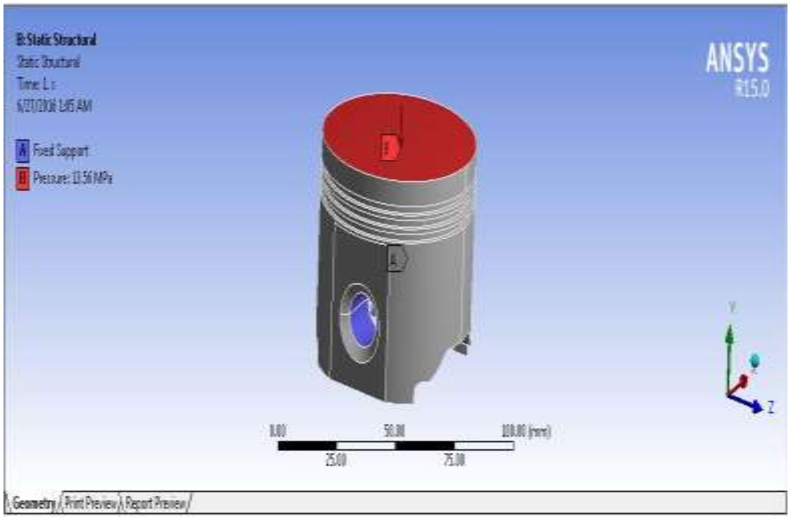


***Figure 1: Boundary conditions***

1. Maximum pressure load at the top surface of the piston crown 13.56 Mpa
2. Temperature at the top surface of the piston crown $1500^0$ C
3. Piston pin holes are fixed $D_X = D_Y = D_Z = 0$

## RESULTS AND DISCUSSIONS

The constructed piston in Solid works is analyzed using ANSYS V15.0 and the results are depicted below. Combustion of gases in the combustion chamber exerts pressure on the head of the piston during power stroke. Fixed support has given at surface of pinhole. Because the piston will move from top dead center to bottom dead center with the help of fixed support at pinhole.

**A. A4032 aluminum alloy piston**

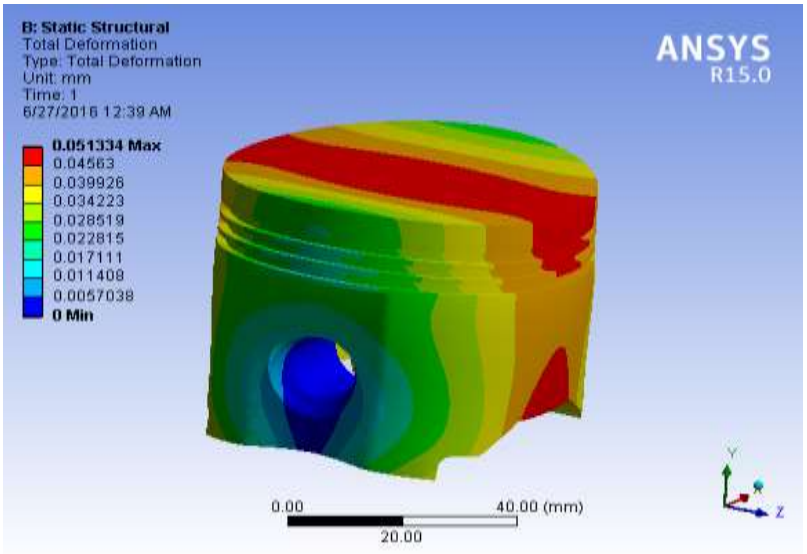


***Figure 2: Total deformation***

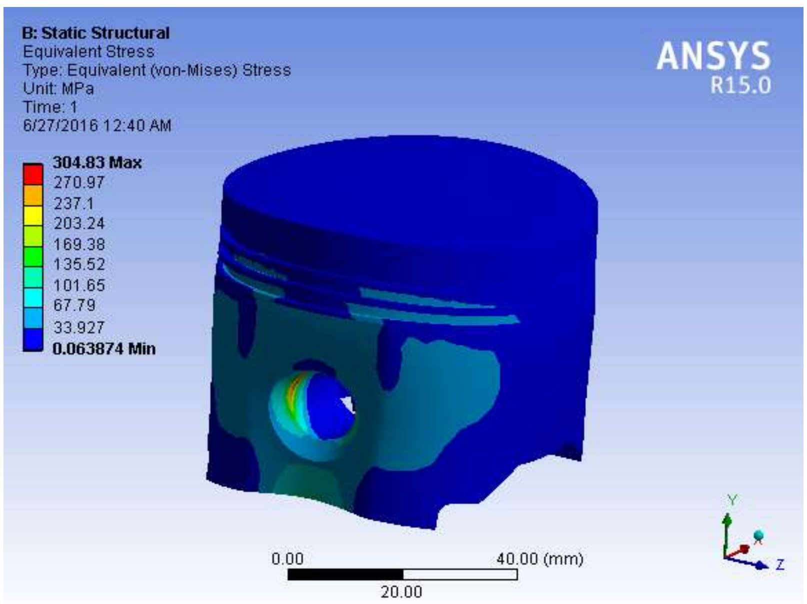


***Figure 3: von misses stress***

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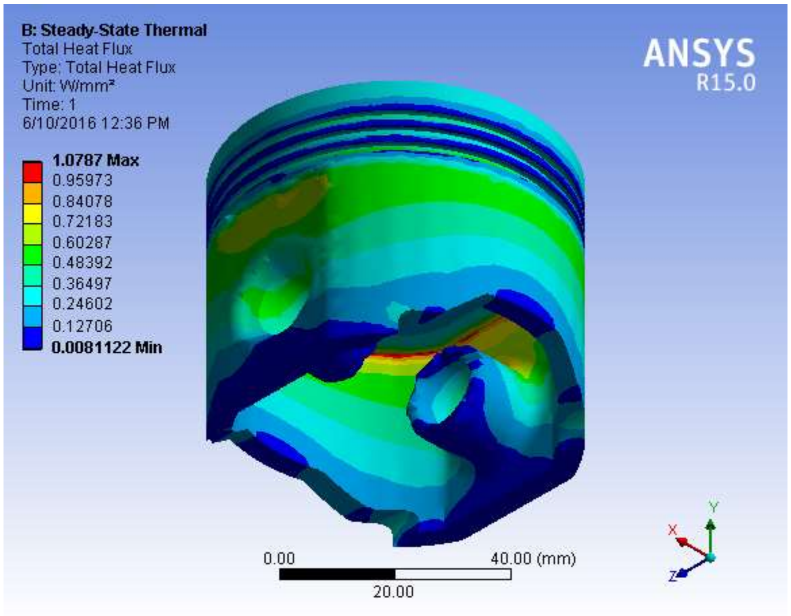


*Figure 4: Total heat flux*

## B. A2618 ALUMINUM ALLOY PISTON

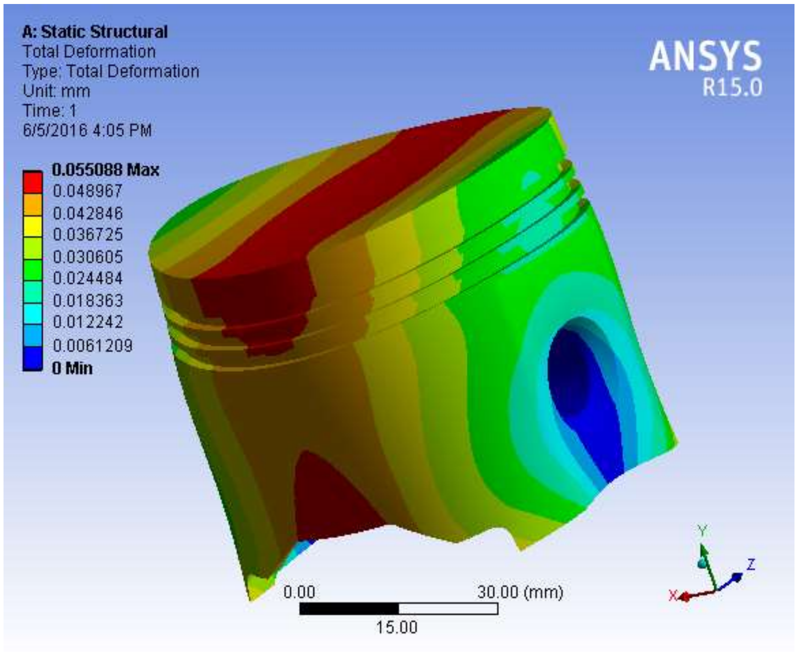


*Figure5: Total deformation*

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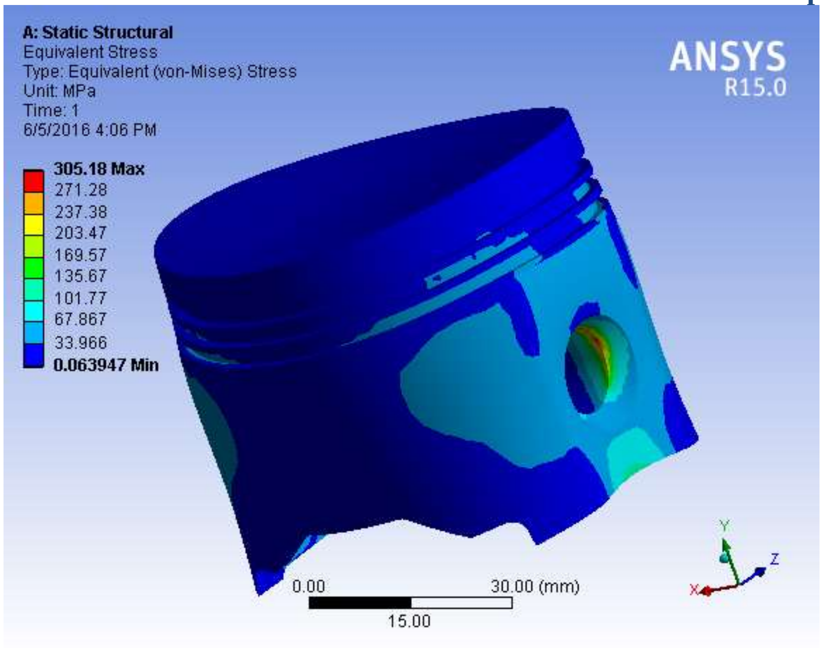


*Figure 6: von-misses stress*

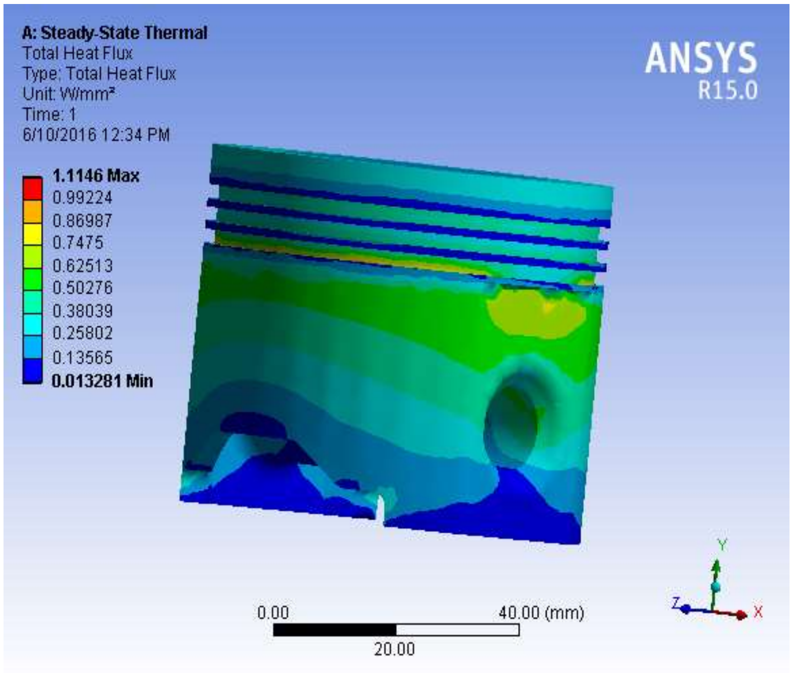


*Figure 7: Total heat flux*

***Table 4: Results of aluminum alloy material***

| s. no | PARAMETERS | A4032 | A2618 |
|---|---|---|---|
| 1 | Total deformation (mm) | 0.051334 | 0.055088 |
| 2 | Von-misses stress (Mpa) | 304.83 | 305.18 |
| 3 | Total heat flux (W/mm$^2$) | 1.0787 | 1.1146 |
| 4 | Mass (kg) | 0.2209 | 0.2277 |

## CONCLUSION

The piston plays a major role in the performance of the engine performance, materials of the piston is made up of impacts the strength of the piston. The maximum stress intensity is on the bottom surface of the piston crown in both the materials, as it is expected. The maximum displacement is absorbed at the top of the piston of 4032 and A2618. The highest value of maximum temperature found in piston is due to thermal conductivity of the materials and the total maximum heat flux is absorbed in both the piston materials. Results comparison between two alloys is found approximately same. Thus further research can be carried with the advance materials and different designing, analysis tools.

## ACKNOWLEDGEMENTS

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