



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: VI Month of publication: June 2018

DOI: <http://doi.org/10.22214/ijraset.2018.6250>

www.ijraset.com

Call:  08813907089

E-mail ID: ijraset@gmail.com

Optimization of Internal Combustion Engine Piston

Bapi Raju. V¹, Phanindra.Y.B.S²

¹Assistant Professor, Department of Mechanical Engineering, V. R. Siddhartha Engineering College, Vijayawada-520 007, India

² Student , Department of Mechanical Engineering, V. R. Siddhartha Engineering College, Vijayawada-520 007, India

Abstract: In this present work suitable material for design of I.C. engine piston is determined from Aluminium alloy and Aluminium composites. Also optimum dimensions of the Hero Karizma ZMR petrol engine piston are optimized from weight point view. For modelling and analysis CATIA V5R20 & ANSYS 14.5 softwares are used.

Keywords: FEM, Piston, Hero Karizma ZMR petrol engine, Aluminum alloys and composites.

I. INTRODUCTION

Engine pistons are one of the most complex components among all automotive and other industry field components. The engine can be called the heart of a vehicle and the piston may be considered the most important part of an engine. There are lots of research works proposing, for engine pistons, new geometries, materials and manufacturing techniques, and this evolution has undergone with a continuous improvement over the last decades and required thorough examination of the smallest details. Notwithstanding all these studies, there are a huge number of damaged pistons. Damage mechanisms have different origins and are mainly wear, temperature, and fatigue related. But more than wear and fatigue, damage of the piston is mainly due to stress development, namely- Thermal stress, Mechanical stress.

This paper describes the stress distribution on piston of internal combustion engine by using FEA. The main objectives are to determine the best material and optimum design using structural analysis. The paper describes the FEA technique to predict the higher stress and critical region on the component. Using CATIAV5 software the structural model of a piston was developed. Using ANSYS V14.5 software, simulation and stress analysis was performed.

II. OBJECTIVES OF PRESENT STUDY

Finding the most suitable material for given stress conditions from the given list of materials generally used to make the pistons. Optimizing the dimensions of the piston for achieving the lowest weight.

III. METHODOLOGY

- A. Design of piston using CATIA
- B. Meshing of designed model using ANSYS 15.
- C. Analysis of piston by stress analysis method.
- D. Comparing the performance of aluminum alloy and aluminium composite under structural analysis process.
- E. Optimization using RSM in order to decrease its weight(volume)

IV. ENGINE SPECIFICATION AND PROPERTIES OF MATERIALS USED:

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

Table 1 Specifications of the piston

| PARAMETERS | VALUES |
|---------------------|----------------------------|
| Engine type | Four stroke ,petrol engine |
| Number of cylinders | Single cylinder |
| Bore | 65.5 |
| Stroke | 66.2 |
| Maximum power | 14.9KW @ 8000rpm |
| Maximum torque | 19.7Nm @ 6500 rpm |
| Maximum speed | 129Kmph |
| Compression ratio | 96.1 |

Table 2: Properties of materials

| S.NO | PARAMETERS | Aluminium alloy | Aluminium Composite (Al-SiC10%-TiB25%) |
|------|---------------------------------------|-----------------|--|
| 1. | Density (kg/m ³) | 2684.95 | 2850.5 |
| 2. | Poisson ratio | 0.33 | 0.314 |
| 3. | Coefficient of thermal expansion(1/C) | 23×10-6 | 24×10-6 |
| 4. | Elastic modulus(Gpa) | 71 | 106.05 |
| 5. | Yield strength(Mpa) | 280 | 250 |
| 6. | Ultimate tensile strength (Mpa) | 310 | 285 |
| 7. | Thermal conductivity(W/m/0C) | 154 | 217.5 |

V. PREVIOUS STUDY

Dilip kumar sonar , Madhura Chattopadhyay studied the design of piston head[1].Tadala akhil et.al have analyzed piston head made of Aluminum alloys[2].Sundaram.K , Palanikumar.N and Kethavath Vishaldid et.al similar analysis using composites[3,4]. H.C.Anilkumar et.al, B.S.Motgi, R Patil and Arun Kumar M. B. and R. P.Swamy investigated the mechanical properties of Aluminum alloys [5,6,7].Ch.Venkata Rajam et.al ,A.R. Bhagat, Y.M. Jibhakate have done studies on Optimization of I.C. Engine Piston [8,9]

VI. NOMENCLATURE

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)

σ = allowable tensile strength (Mpa)

σ_{ut} = ultimate tensile strength (Mpa)

K = thermal conductivity (W/m K)

T_c = temperature at the centre of the piston head (K)

T_e = 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

t₁ = radial thickness of ring (mm)

P_w = allowable radial pressure on cylinder wall (N/mm²) = 0.025 Mpa

σ_p = permissible tensile strength for ring material (N/mm²) = 110 N/mm²

t₂ = axial thickness of piston ring (mm)

b₁ = width of top lands (mm)

b₂ = width of ring lands (mm)

t_3 = thickness of piston barrel at the open end (mm)

l_s = length of skirt (mm)

d_o = outer diameter of piston pin (mm)

Mechanical efficiency of the engine (η) = 70 %.

H = Brake power (B.P)/ Indicating power

n_r = the number of rings

VII. DESIGN DIMENSIONS OF PISTON

A. The parameters $t_H, t_1, t_2, b_1, b_2, t_3$, are calculated using the following steps

- 1) Thickness of Piston Head (t_H): The piston thickness of piston head calculated using the following Grashoff's formula, $t_H = \sqrt{(3pD^2) / (16\sigma)}$ in mm
- 2) Radial Thickness of Ring (t_1): $t_1 = D \times \sqrt{3Pw/\sigma p}$
- 3) Axial Thickness of Ring (t_2): The axial thickness of the rings may be taken as $t_2 = 0.7t_1$ to t_1 or $t_2 = D/10 \times n$
- 4) Width of the top land (b_1): The width of the top land varies from $b_1 = t_H$ to $1.2 t$
- 5) Width of other lands (b_2): Width of other ring lands varies from $b_2 = 0.7t_2$ to t
- 6) Maximum Thickness of Barrel at the top end (t_3): $t_3 = 0.03 \times D + t_1 + 4$.
- 7) Length of the skirt $l_s = (0.6D$ to 0.8
- 8) Piston pin diameter (d_o): $d_o = (0.28D$ to $0.38D)$
- 9) $I.P = B.P / \eta = 14.9 / 0.9 = 16.55$ KW

Also, $I.P = P \times A \times L \times N / 2$

Substituting the values we have

$$P = 13.56 \text{ Mpa}$$

The dimensions for the piston is calculated and are represented in the table given below. These are used for the modeling of piston in CATIA. In the above procedure the dimensions of the ribs are neglected, so as to make the design for the piston to be simple. The modelled piston is shown in figure 1.

Table 3 Dimensions of the piston

| S.NO | DIMENSIONS | SIZE(MM) |
|------|--------------------------------------|----------|
| 1. | Cylinder Bore | 65.5 |
| 2. | Thickness of piston head(th) | 8.03 |
| 3. | Radial thickness of ring(t_1) | 1.71 |
| 4. | Axial thickness of the ring(t_2) | 2.18 |
| 5. | Width of the top land(b_1) | 8.03 |
| 6. | Width of the other land(b_2) | 2.18 |
| 7. | Maximum thickness of barrel | 8.575 |
| 8. | Length of the skirt(l_s) | 39.3 |
| 9. | Piston pin diameter(d_o) | 18.34 |

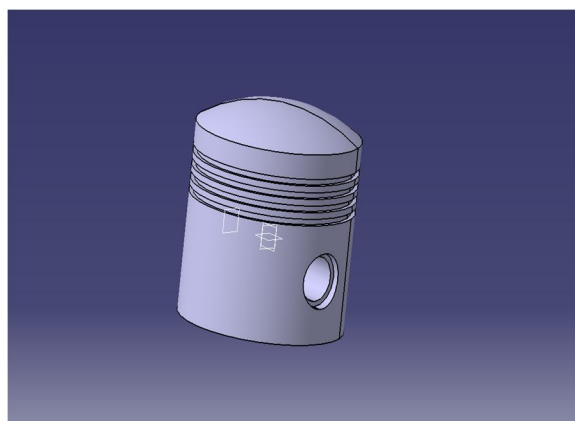


Fig 1 Model of the piston

VIII. ANSYS STIMULATION

A. ALUMINUM ALLOY

Deformation, stress and strain for Al alloy are as shown in figures 2,3,4 respectively

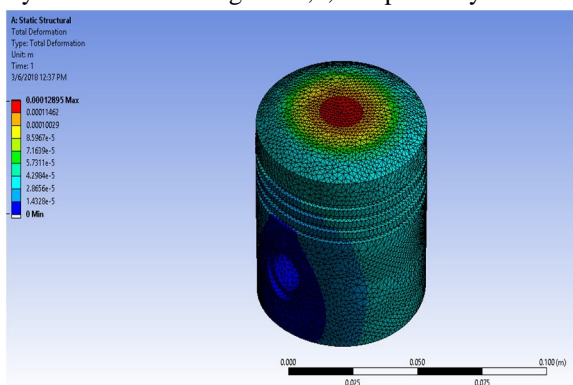


Fig 2 Deformation of Al alloy piston

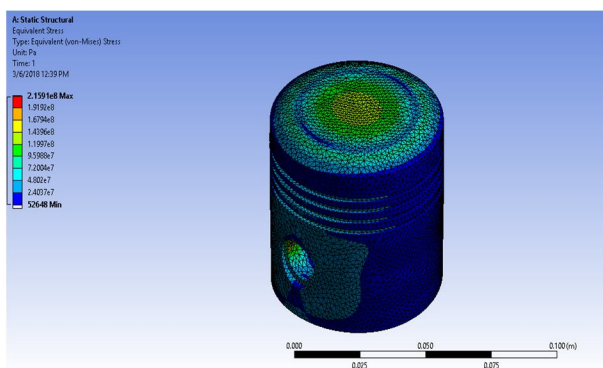


Fig 3 Stress of Al alloy piston

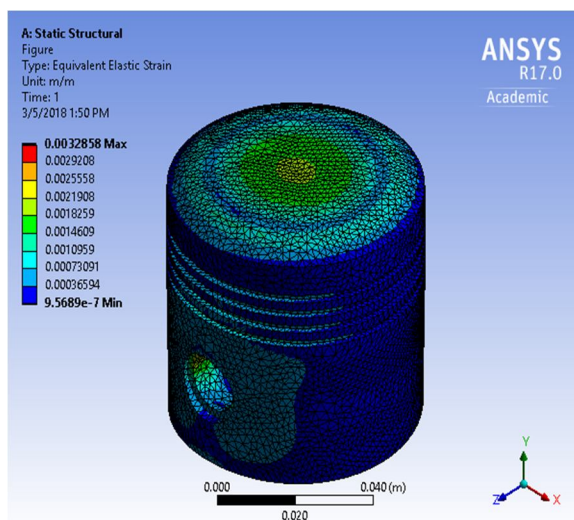


Fig 4 Elastic Strain of Al alloy piston

B. ALUMINUM COMPOSITES

Deformation, stress and strain for Al composites are as shown in figures 5, 6,7 respectively

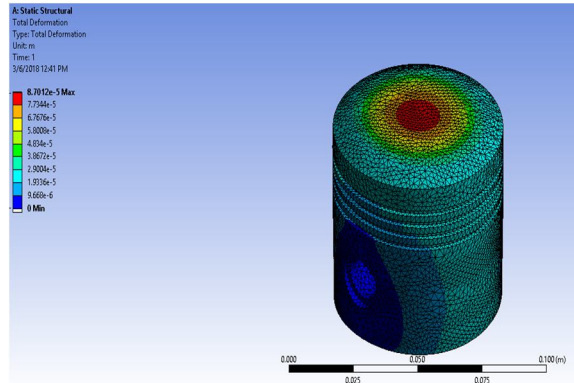


Fig 5 Deformation of Al-SiC10%-TiB₂5% composite

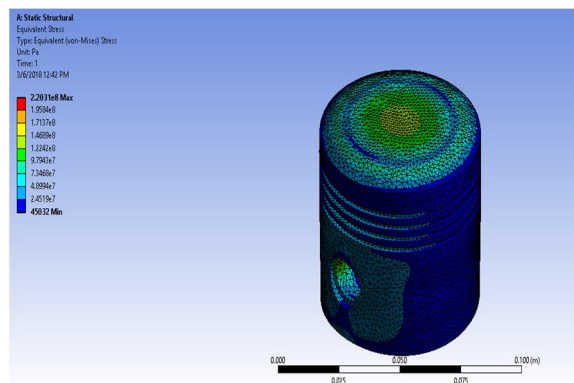


Fig 6 Stresses in Al-SiC10%-TiB₂5% composite

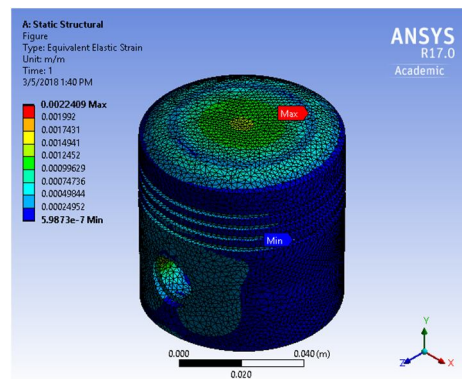


Fig 7 Elastic Strain in Al-SiC10%-TiB₂5% composite

As can be seen the composite is better than the alloy, because the deformation produced in aluminum composite is 40% less than the deformation produced in aluminum alloy. Although the stresses in composite are 5MPa more than that produced in alloy we can use composite for the design of piston.

IX. OPTIMIZATION

Optimization is done in order to achieve the objective of Minimization of the volume (weight) without crossing the stress and deflection limits. Following input parameters taken for optimization

P1= width of the top land (b1)

P2= radial thickness of the ring (t1)

P3= axial thickness of the ring (t2)

P4= length of the skirt (ls)

P5= maximum thickness of the barrel

P6= width of the other land (b2)

The Design of Experiments is used to find the optimum points the bounds of the input parameters are taken as follows.

Table 4 Lower and Upper limits of parameters

| ID | Name | Classification | Lower Bound | Upper Bound |
|----|-------------|----------------|-------------|-------------|
| P1 | XYPlane.L13 | Continuous | 7.227 [mm] | 8.833 [mm] |
| P2 | XYPlane.L14 | Continuous | 1.539 [mm] | 1.881 [mm] |
| P3 | XYPlane.L15 | Continuous | 1.962 [mm] | 2.398 [mm] |
| P4 | XYPlane.L18 | Continuous | 35.37 [mm] | 43.23 [mm] |
| P5 | XYPlane.L19 | Continuous | 7.7175 [mm] | 9.4325 [mm] |
| P6 | XYPlane.L22 | Continuous | 1.962 [mm] | 2.398 [mm] |

The Response Surface chart is drawn in ANSYS and is as shown in figure 8

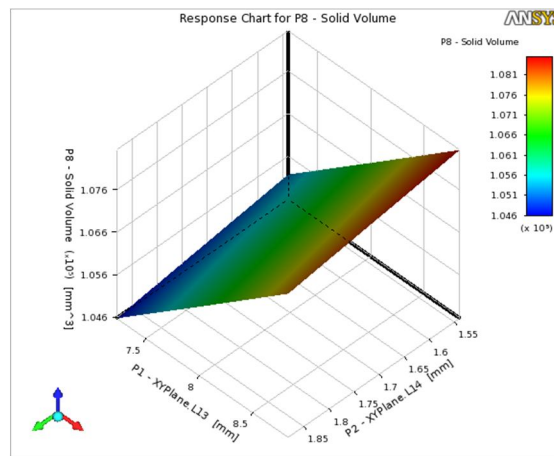


Fig 8 Response surface of Solid Volume

Best candidates of the optimization study using Response Surface Optimization are as shown in table 4. Table 5 shows the ratings used.

Table 5 Candidate points of Solid Volume

| | P1 – XYPlane.L13 (mm) | P2 - XYPlane.L14 (mm) | P3 - XYPlane.L15 (mm) | P4 - XYPlane.L18 (mm) | P5 - XYPlane.L19 (mm) | P6 - XYPlane.L22 (mm) | P8 - Solid Volume (mm ³) |
|-------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|--------------------------------------|
| Candidate Point 1 | 7.227 | 1.881 | 1.962 | 35.37 | 7.7175 | 1.962 | ★★★ 87875 |
| Candidate Point 2 | 7.7899 | 1.7028 | 2.3845 | 35.651 | 7.7541 | 2.352 | ★★★ 91733 |
| Candidate Point 3 | 7.3177 | 1.5766 | 2.2637 | 37.386 | 7.7584 | 2.0199 | ★★★ 93757 |

Table 6 Rating Values (Response Surface Optimization system)

| | P8 - Solid Volume (mm ³) |
|-----------|--------------------------------------|
| Objective | Range |
| ★★★ | [87875 ; 91006] |
| ★★ | [91006 ; 97267] |
| ★ | [97267 ; 1.0353E+05] |
| — | [1.0353E+05 ; 1.0979E+05] |
| × | [1.0979E+05 ; 1.1605E+05] |
| × | [1.1605E+05 ; 1.2231E+05] |
| × | [1.2231E+05 ; 1.2544E+05] |

X. RESULT ANALYSIS OF OPTIMIZATION

From minimization of surface volume it can be seen that candidate point 1 has got three stars, so for design of the piston the dimensions of the candidate point 1 must be taken into consideration.

XI. CONCLUSION

A comparison is made between piston made of Al alloy and Al composite. It is found that Al composite performs better than Al alloy. Optimization is done with an objective decreasing volume. It is observed for the objective of having minimum volume is met by choosing candidate point 1 as shown in table 5.

REFERENCES

- [1] Dilip kumar sonar , Madhura Chattopadhyay “theoretical analysis of stress and design of piston head using catia & ansys International Journal of Engineering Science Invention Volume 4 Issue 6, June 2015 ,PP.52-61”
- [2] Tadala akhil, K.Naresh, Abdul khurshid, Purushotham anil kumar "Analysis on Four Stroke Single Cylinder Engine Piston by using Aluminum Alloys (Al-GHS 1300, Al-Sic- Graphite, A6061, Pure Aluminum)", SSRG International Journal of Mechanical Engineering (SSRG - IJME), V3(1),4-12 January 2016.
- [3] Sundaram.K , Palanikumar.N “Investigation And Analysis Of Piston By Using Composite Material” Vol-2 Issue-6 2016”
- [4] Kethavath Vishal, Dinesh Bajaj, A.Sai Kumar, " Design and Structural Analysis of Composite Piston ", International Journal & Magazine of Engineering, Technology, Management, and Research, ISSN No:23484845
- [5] H.C.Anilkumar, H.S.Hebbar and K.S.Ravishankar, “Mechanical properties Of SiC Reinforced Aluminum Alloy Composites”, IJMME, 2011, Vol.6, Issue.1, pp. 41-45.
- [6] B.S.Motgi, R Patil, “A Study on Mechanical Properties of SiC and Tib2 Reinforced Aluminum Alloy Composites”, IOSR,Vol. 7, Issue 6, 2013, pp.41-46.
- [7] Arun Kumar M. B. and R. P.Swamy, “Evaluation of Mechanical Properties of al6061, SiC and e-glass Fiber Reinforced Hybrid Metal Matrix Composites”, ARPN, 2011, Vol.6, Issue.5
- [8] Ch.Venkata Rajam, M.V.S.Murali Krishna, P.V.K.Murthy, G.M.Prasada Rao, "Design Analysis and Optimization of Piston using CATIA and ANSYS," International Journal of Innovative Research in Engineering & Science, vol. 1st, no. 2, pp. 41-51, 2013.
- [9] A.R. Bhagat, Y.M. Jibhakate, Thermal Analysis and Optimization of I.C. Engine Piston Using Finite Element Method, IJMER, Vol.2, July 2012, 2919-2921.
- [10] B.Tech project by , Y.B.S.Phanindra, Y.Vijay lesley, B.Jaya Prakash, C.Vinod Kumar, M. Jayadeep VRSEC, Mechanical Engineering Department, 2018



10.22214/IJRASET



45.98



IMPACT FACTOR:
7.129



IMPACT FACTOR:
7.429



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24*7 Support on Whatsapp)