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DESIGN AND ANALYSIS OF DIESEL ENGINE PISTON BY FEA FOR DIFFERENT PISTON HEAD GEOMETRY

GURURAJ DESHPANDE
Professor, Department of Mechanical Engineering, A.G. Patil Institute of Technology, Solapur, India.

ROHIT GAIKWAD,
Student of Mechanical Engineering, A.G. Patil Institute of Technology, Solapur, India.

VISHAL OTARI
Student of Mechanical Engineering, A.G. Patil Institute of Technology, Solapur, India.

VASIM PATEL,
Student of Mechanical Engineering, A.G. Patil Institute of Technology, Solapur, India.

CHANDRAKANT TOLNUR
Student of Mechanical Engineering, A.G. Patil Institute of Technology, Solapur, India.

ABSTRACT

Piston is an important part of engine, which reciprocates inside the engine cylinder by application of pressure causes due to combustion of fuel inside engine cylinder. As engine have evolved over the years, piston have evolved with them. They are getting shorter and lighter, and use smaller skirts cylindrical "body" of the piston. Never pistons are obtained made of aluminum alloy, which increases strength of piston.

One of the biggest advancement in piston technology is use of piston "tops" or "crowns", the part that enters the combustion chamber and is subjected to combustion. While older piston tops mainly flat, many now features bowls on top that have different effect on combustion process

In this project, we design the four models of pistons "cylindrical head, Hemi-spherical head, toroidal head & straight-sided" using ANSYS-Design Modeler and then analysis in ANSYS 15.0 workbench and find out the equivalent stresses, total deformation, heat distribution, and heat flux. By comparing the results, we can say among these which one of the piston had better results.

KEYWORDS: - Diesel Engine, Piston, Piston Head Geometries, FEA, ANSYS 15.0 Workbench

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. [1]

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 occur. [2]

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 minimizes launch time for new products. This necessitates understanding of new technologies and quick absorption in the development of new products. [3]

The main requirement of piston design is to measure the prediction of temperature distribution on the surface of piston which enables us to optimize the thermal aspects for design of piston at lower cost. Most of the pistons are made of an aluminum alloy which has 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 behavior is extremely crucial in designing more efficient engines. Good sealing of the piston with the cylinder is the basic criteria in design of the piston. Also to improve the mechanical efficiency and reduce the inertia force in high speed machines the weight of the piston also plays a major role. To allow for thermal expansion, the diameter of the piston must be smaller than that of the cylinder. The necessary clearance is calculated by estimating the temperature difference between piston and cylinder and considering the coefficient of thermal expansion of piston. [4]

METHODOLOGY

PHYSICAL AND THERMAL PROPERTIES OF ALUMINUM ALLOY

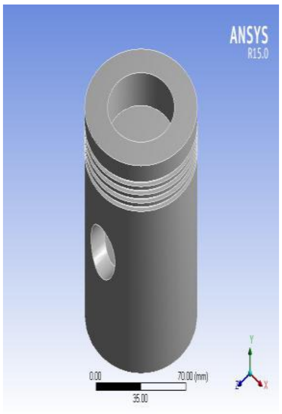
Density – 2770 (Kg/m3)
Poisson Ratio – 0.33
Young Modulus – 71000 (MPa)
Tensile Ultimate Strength – 310 (MPa)
Tensile Yield Strength – 280 (MPa)
Compressive Yield strength – 280 (MPa)
Thermal conductivity =174.15 (W/m ^{0}C)

Table 1 Engine specification

PARAMETERS	SPECIFICATION
Type of Engine	Kirloskar make Single cylinder 4 stroke diesel engine
Rated Power	5.2 kw (7HP) @ 1500 RPM
Cylinder Diameter	87.5 mm
Stroke length	110 mm
Compression ratio	17.5:1

MODELING & MESHING OF PISTON

Model of piston is created in ANSYS workbench as shown in fig.1 and finite element mesh is generated using Tetrahedron method with mesh refinement applied all faces & mesh generated as shown in fig.2.



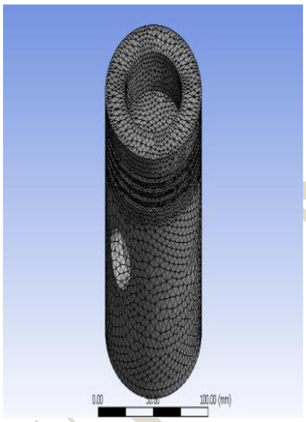


Figure 1 Piston Model
Figure 2 Meshed piston Model

PISTON DESIGN PROCEDURE

(1) Thickness of Piston Head (t_H)

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

Where: -
p = Max. Gas pressure (MPa)
D = Bore diameter (MM)
σ_t = Permissible Stress (MPa)

(2) Radial Thickness of Ring(t_1)

$$t_1 = D\sqrt{\frac{3P_w}{\sigma_t}}$$

Where: -
P_w = Pressure of gas on cylinder wall (o. o25 MPa to 0.042 MPa)
D = Bore diameter (MM)
σ_t = Permissible tensile Stress (MPa)

(3) Axial Thickness of the Ring (t_2): - may be taken as $0.7t_1$ to t_1

The minimum axial thickness (t_2) may also be obtained from the following empirical relation:

$$t_2 = \frac{D}{10n_R}$$

Where: - n_R = No. of rings

(4) Width of top land (b_1): - may be taken as t_H to 1.2 t_H (MM)

(5) Width of the other ring land (b_2): - may be taken as 0.75 t_2 to t_2 (MM)
(6) Thickness of piston Barrel (t_3): - 0.03D + t_1 +4.9 (MM)

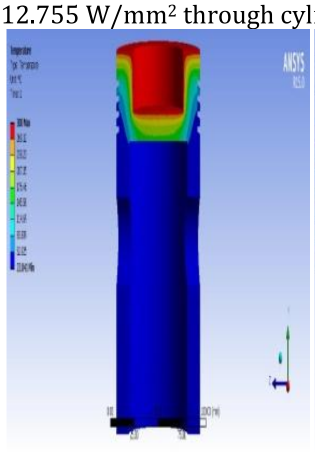
(7) Piston wall thickness towards open end (t_4): - may be taken as 0.25 t_3 to 0.35 t_3

Table 2 Geometric values

Sr. No.	Dimensions	Size(MM)
1	Thickness of Piston Head (t_H)	8.5
2	Radial Thickness of Ring(t_1)	2.8
3	Axial Thickness of the Ring (t_2)	2.4
4	Width of top land (b_1)	8.6
5	Width of the other ring land (b_2)	2
6	Thickness of piston Barrel (t_3)	10.3
7	Piston wall thickness towards open end (t_4)	3.1

TRANSIENT THERMAL ANALYSIS RESULTS

Cylindrical head Piston: - Fig. 3 shows temperature distribution on cylindrical head piston & max temp is 300 ^{0}C and min temp is 22 ^{0}C. In Fig. 4 max heat flux is 12.755 W/mm^2 through cylindrical head piston.



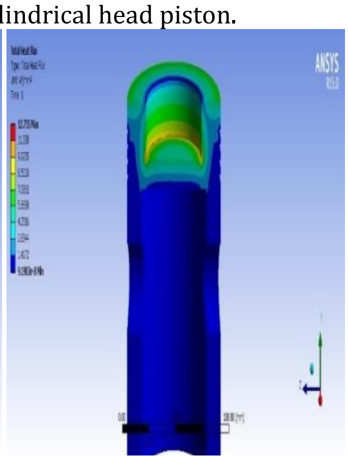


Figure 3 Temperature Distribution
Figure 4 Total Heat Flux

Hemispherical Head Piston: - Fig. 5 shows temperature distribution on hemispherical head piston & max temp is 300 ^{0}C and min temp is 22 ^{0}C. In Fig. 6 max heat flux is 7.3554 W/mm^2 through hemispherical head piston.

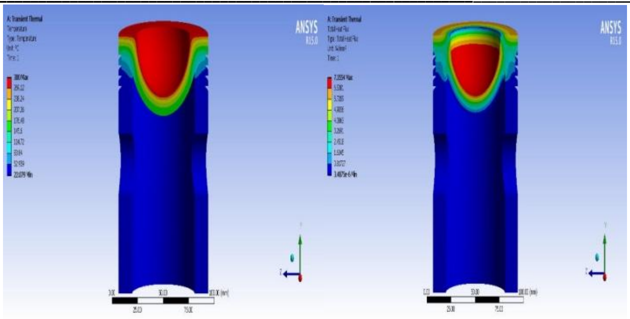


Figure 5 Temperature Distribution
Figure 6 Total Heat Flux

Straight-sided Head Piston: - Fig. 7 shows temperature distribution on hemispherical head piston & max temp is 300 ^{0}C and min temp is 22 ^{0}C. In Fig. 8 max heat flux is 8.3721 W/mm^2 through hemispherical head piston.

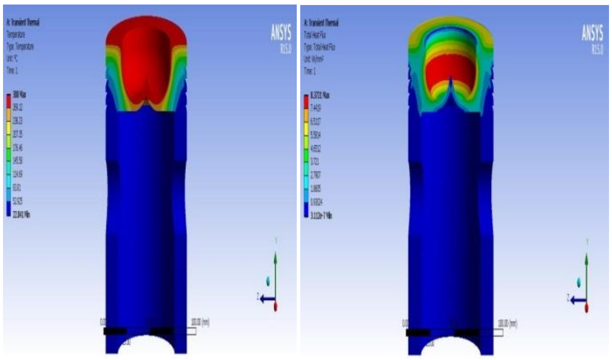


Figure 7 Temperature Distribution
Figure 8 Total Heat Flux

Toroidal Head Piston: - Fig. 9 shows temperature distribution on toroidal head piston & max temp is 300 ^{0}C and min temp is 22 ^{0}C. In Fig. 10 max heat flux is 9.759 W/mm^2 through toroidal head piston.

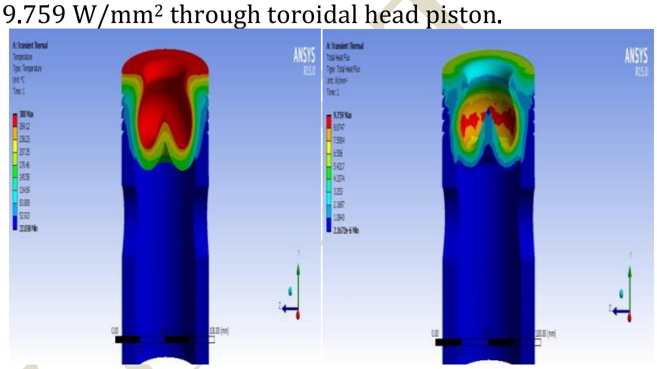


Figure 9 Temperature Distribution
Figure 10 Total Heat Flux

STATIC ANALYSIS RESULTS

Cylindrical Head piston: - Fig. 11 Shows total deformation of cylindrical head piston, max deformation is 0.035094mm. & Fig. 12 shows equivalent stress on piston, max stress value is 88.417MPa.

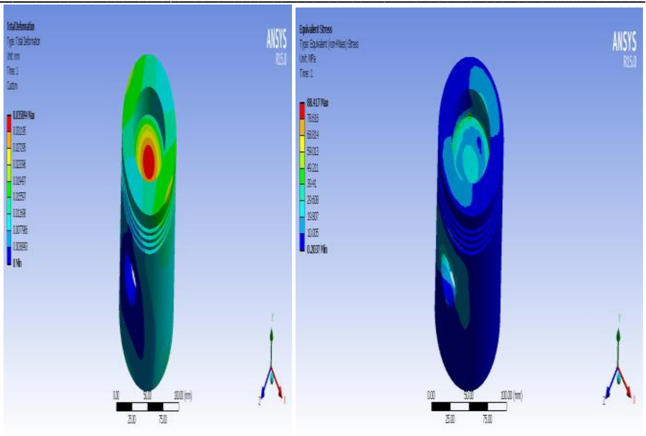


Figure 11 Total Deformation
Figure 12 Equivalent Stress

Hemispherical Head piston: - Fig. 13 Shows total deformation of hemispherical head piston, max deformation is 0.018808mm. & Fig. 14 shows equivalent stress on piston, max stress value is 75.508MPa.

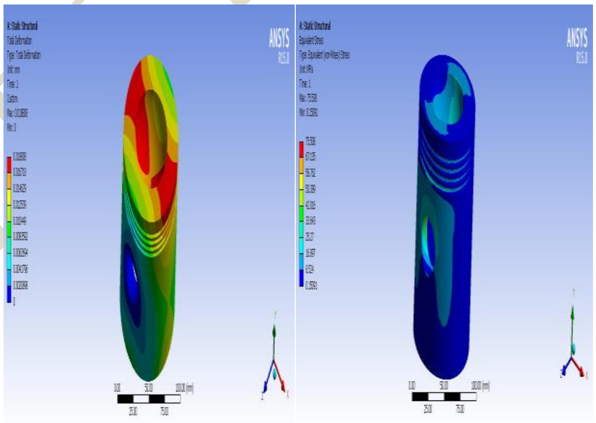


Figure 13 Total deformation
Figure 14 Equivalent stress

Straight-sided Head piston: - Fig. 15 Shows total deformation of straight-sided head piston, max deformation is 0.05243mm. & Fig. 16 shows equivalent stress on piston, max stress value is 73.143MPa.

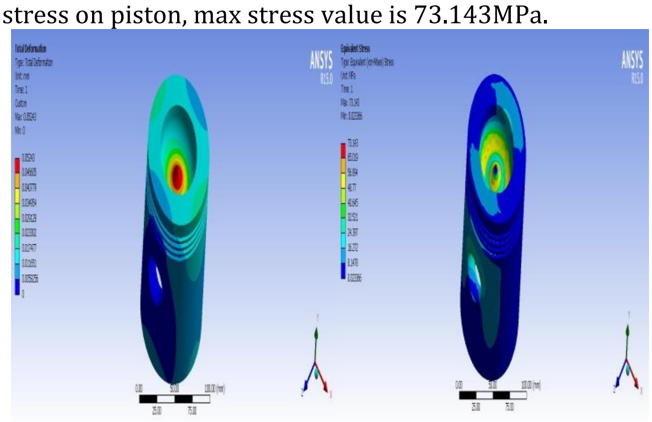


Figure 15 Equivalent stress
Figure 16 Total deformation

Toroidal Head piston: - Fig. 17 Shows total deformation of Toroidal head piston, max deformation is

0.029256mm. & Fig. 18 shows equivalent stress on piston, max stress value is 65.905MPa.

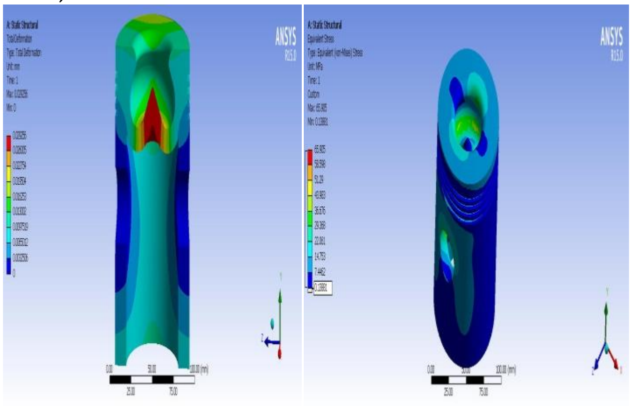


Figure 17 equivalent Stress
Figure 18 Total Deformation

Table 3 Results of different piston head

Piston / Geometries Parameters	Cylindrical	Hemispherical	Straight-sided	Toroidal
Temperature (^{0}C) (Max)	300	300	300	300
Total Heat Flux(W/mm^2) (Max)	12.755	7.3554	8.3721	9.759
Total Deformation(mm) (Max)	0.035094	0.018808	0.05243	0.029256
Equivalent stress (MPa) (Max)	88.417	75.508	73.143	65.905
Mass (Kg)	0.98349	0.98762	0.96962	1.03

CONCLUSION

By comparing result obtained by analysis with different piston heads, it shows that

-Cylindrical head piston has max heat flux (12.755W/mm^2) which is better one as compared to other.

-Hemispherical head piston has less deformation & straight sided piston has max deformation.

-Equivalent stress values of all pistons are within allowable limit.

-Straight-sided head piston has less mass (0.96962kg) & Toroidal has max mass (1.03kg).

-From the above we conclude that cylindrical crown Piston is better piston comparing to other piston.

REFERENCES

1) Dilip Kumar Sonar, Madhura Chattopadhyay "Theoretical Analysis of Stress and Design of Piston Head CATIA & ANSYS," International Journal of Engineering Science Invention, ISSN (online): 2319 – 6734| ISSN (Print): 2319 – 6726, Volume 4 Issue 6, PP.52-61, June 2015.
2) Velivela Lakshminath, Dr. Amar Nageswara Rao "Modeling and Analysis of I.C. Engine Piston Crown Using FEM Package Ansys," IJRMET, ISSN: 2249-5762(online)| ISSN: 2249-5770(Print), Volume 5,Issue 1, PP 51-59, Nov2014-April 2015.
3) Ch. Venkata Rajam, P.V.K. Murthy, M.V.S. Murali Krishna, G.M. Prasada Rao "Design Analysis and Optimization of Piston using CATIA and ANSYS," International Journal of innovative Research in Engineering & Science, ISSN 2319-5665, volume1, issue2, PP 41-51, January 2013.
4) Lanka Tata Rao, Katakam Satyanarayana, M.S.S.Srinivasa Rao, T.V. Hanumanta Rao, S.V. UmamaheswaraRao, "Stress Analysis of 4Stroke Diesel Engine Piston", 3rd International conference on Progress In Production, Mechanical and Automobile engineering (ICPMAE 2015) ,ISBN 978-93-85225-05-4,PP 46-50, Feb.,2015
5) Sangeetham Sivkumar, Guru Murthy, P. Satish reddy, "Modeling and thermal conduction and static analysis of an I.C. Engine Piston using CATIA V5 Tool and ANSYS", International journal of svience engineering and advance technology,ISSN 2321-6905, volume 3, Issue 12,PP 1231-1238,Dec-2015.
6) Mr. Jadhav Vishal, Dr. R.K. Jain, Mr. Yogendra S.Chauhan, "Design and Analysis of alumimum alloy Piston using CAE tools", Internation Journal of Engineering Sciences & Research technology, ISSN: 2277-9655,PP 332-339, Vishal*et al., 5(7): July, 2016
7) S. Srikanth reddy, Dr. B. Sudheer Prem Kumar, "Thermal Analysis and optimization of I.C. Engine Piston using Finite Element method",International Journal of Innovative in science, Engineering and technology, ISSN: 2319-8753, Vol. 2, Issue 12, PP 7834-7843, Dec 2013
8) Amit Patil, "Analysis of Single Cylinder Diesel Engine Piston Using Finite Element Method", Imperical Journal of Interdisciplinary Research, ISSN: 2454-1362, Vol. 2, Issue 11, PP 1385-1388, 2016
9) Lokesh Singh, Suneer Singh Rawat, Taufeeque hasan, Upendra Kumar, "Finite Element Analysis of Piston In Ansys", IJMTER, ISSN (online):2349-9745|ISSN (Print):2392-8161, vol. 2, Issue 4,pp 619-626, April 2015.
10) Deovrat Vibandik, Ameya Pradhan, Sampada Mhaskar, Nikita Sukthankar, Atul Dhale , "Design Analysis and optimization of piston and determination of its Thermal Stress using CAE Tools", IJESRT, ISSN: 2277-9655, PP375-381, Vibhandik et al., 3(5): May, 2014