# Design Analysis and Optimization of Hybrid Piston for 4 stroke Single Cylinder 10 HP (7.35 kW) Diesel Engine –A Review

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***Abstract*— The performance of any automobile largely depends on its size and working in dynamic conditions. The piston is a "heart" of the engine and its working condition is the worst one of the key parts of the engine in the working environment. The design of the piston optimization can lead to a mass reduction on the base of stress analysis satisfying the requirements of automobile specifications with cost and size effectiveness. Piston is the part of engine which converts heat and pressure energy liberated by fuel combustion into mechanical works. Engine piston is the most complex among automotive. This paper work describes design analysis and optimization of hybrid Piston for 4 stroke single cylinder 10 HP (7.35 kW) diesel Engine. The hybrid material, which consist of high strength (cast steel) piston crown and light alloy (aluminium alloy) for piston wall. The stress distribution of piston by using FEM and investigate and analyse of the actual engine condition during combustion process. The stresses due to combustion are considered to avoid the failure of the piston. Intensity of structural stresses should be reduced to have safe allowable limits. This paper introduces an analytical study of the structural effects on the diesel engine piston.CAD software Cre-O is used to model the piston and stress analysis is performed by using ANSYS.14 for weight optimization. The review of existing literature design analysis and optimization of hybrid Piston for 4 stroke single cylinder 10 HP (7.35 kW) diesel Engine is presented. The materials, manufacturing process, design consideration and structural and thermal analysis etc. of the piston are reviewed here.**

***Keywords*— Hybrid Piston, Diesel engine,Piston Strength Analysis, Weight Optimization.**

## I. Introduction

Combustion engines can be classified in two groups, as being follows External combustion (EC) engines and internal combustion(IC) engines. In internal combustion engine, piston is one of the important component. It reciprocates within the cylinder bore by force produced during the combustion process. as shown in fig.1.1.[10].The piston is the heart of the internal combustion engine and is subjected to loads such as thermal and structural stress. The two extremes of this motion are referred to as Top Dead Center (TDC) and Bottom Dead Center (BDC) [15]

The main functions [14] of the piston are as follows:

1-To receive the gas load and transmit it to the crankshaft through the connecting road.
2- The disperse the heat of combustion from combustion chamber to the cylinder walls.
3-To reciprocate in the cylinders as a gas tight plug causing suction, compression, expansion and exhaust stroke.

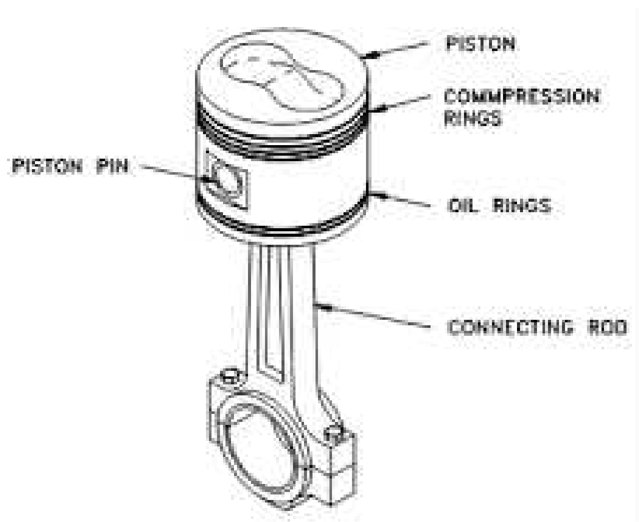


Fig. 1.1: Labeled Image of a Piston

## II. Piston Components

Main components of the piston are as follows:

A. *Piston Crown*- which carries gas pressure

B. *Skirt*-which acts as a bearing against the side thrust of connecting

C. *Piston Pin*- Piston pins are used to connect the piston to the connecting rod. These pins are made from hard steel alloy and have a finely polished surface. Most piston pins are hollow, to reduce weight

D. *Piston Rings*- which seal the annular space between cylinder wall and piston and scrap off the surplus oil on the cylinder. [13]

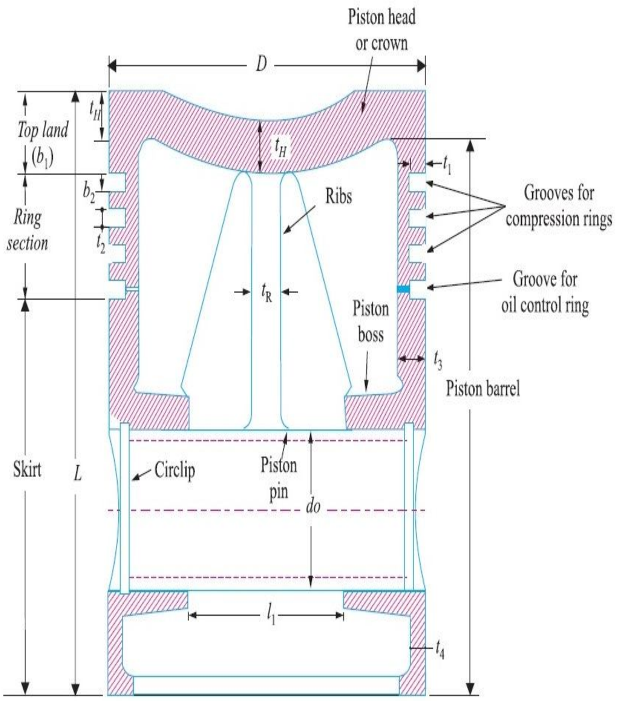


Fig. 1.2 Labelled Image of Piston Components

## III. Piston Materials And Manufacturing Process

Following materials are used for I.C. Engines pistons:

Cast iron, Cast Aluminium, cast steel and forged aluminium. The material used for piston is mainly aluminium alloy. Aluminium pistons can be either cast of forged. [11]In early years cast iron was almost universal material for pistons because it posses excellent wearing qualities, coefficient of expansion and genera suitability in manufacture. But due to reduction of weight in reciprocating parts, the use of aluminium for piston was essential. To obtain equal strength a greater thickness of metal is necessary. But some of the advantages of the light metal is lost. Aluminium is inferior to cast iron in strength and wearing qualities, and its greater coefficient of expansion necessities greater clearance in the cylinder to avoid the risk of seizure. The heat conductivity of aluminium is about thrice that of cast iron this combined with the greater thickness necessary for strength, enables and aluminium alloy piston to run at much lower temperature than a cast iron as a result carbonized oil doesn't form on the underside of the piston, and the crank case therefore keeps cleaner. This cool running property of aluminium is now recognized as being quite as valuable as its lightness. Indeed; piston are sometimes made thicker than necessary for strength in order to give improved cooling.

The allowable stresses for various materials are as under: [12]

Cast iron-35 to 40 MPa
AL alloy-50 to 90 MPa
Cast Steel- 60 to 85 MPa

An extensive literature review of Ahu Fahriye Acar et al. [2]. on Effects of Variations in Alloy Content and Machining Parameters on the Strength of the Intermetallic Bonding between a Diesel Piston and A Ring Carrier .He studied that variations in alloy content and graphite size have great influence on bonding quality.

Francis Uchenna OZIOKO [9] performed casting of motorcycle piston from aluminium piston scrap using metallic mould. The piston core prepared gave rough surface of internal cavity, this may be due to the fact that bigger sieve was used or proper percentage sand mix composition was not used. The aim to maintain the supposed composition of the LM29 when the scrap was melted could not be achieved.

## IV. Piston Design Considerations And Criterions

By knowing the basic engine specifications like bhp, bore , stroke, compression ratio ,maximum power and maximum torque we find the various design considerations and dimensions of the piston which are sated below :- [11]

a) Thickness of the piston head
b) Radial thickness of the ring
c) Axial thickness of the ring
d) Height of the first land
e) Thickness of the piston barrel
f) Radial thickness of ring grove
g) Length of piston skirt
h) Length of piston
i) Diameter of piston pin hole
j) Thickness of piston at open end

Important criterions for piston design are as follow: [14]

1. Piston should have very high heat resistance and strength
2. In order to minimise the inertia forces, it should have minimum weight.
3. It should provide sufficient bearing area to prevent wear
4. It material should wear resistance
5. It maintain its hardness at operating temperatures
6. It should have effectively prevent leakage

7. Noiseless operation

## V. DESIGN ANALYSIS AND OPTIMIZATION

The fundamental concepts and design methods concerned with single cylinders petrol engine had studied by vinod yadav et al. [8].In this paper they had found the results by the use of analytical method are nearly equal to the actual dimensions used now a days. Hence it provides a fast procedure to design a piston which can be further improved by the use of various software and methods. The most important part is that very less time is required to design the piston and only a few basic specification of the engine. This paper illustrate design procedure for a piston for 4 stroke petrol engine for hero bike and its analysis by its comparison with original piston dimensions used in bike. The design procedure involves determination of various piston dimensions using analytical method under maximum power condition. In this paper the combined effect of mechanical and thermal load is taken into consideration while determining various dimensions.

Thermal Analysis and Optimization of I.C. Engine Piston using finite element method was carried out by A. R. Bhagat et al**.** [1] and investigated and analyzed the thermal stress distribution of piston at the real engine condition during combustion process. The paper describes the mesh optimization with using finite element analysis technique to predict the higher stress and critical region on the component. The optimization is carried out to reduce the stress concentration on the upper end of the piston i.e (piston head/crown and piston skirt and sleeve). With using computer aided design (CAD), Pro/ENGINEER software the structural model of a piston will be developed. Furthermore, the finite element analysis performed with using software ANSYS. The FEA is carried out for standard piston model used in diesel engine and the result of analysis indicate that the maximum stress has changed from 228 MPa to 89 MPa. And biggest deformation has been reduced from 0.419 mm to 0.434 mm.

Thermal analyses were investigated by S. Srikanth Reddy and Dr. B. Sudheer Prem Kumar [4]. And they found that thermal analyses are investigated on a conventional (uncoated) diesel piston, made of aluminium silicon alloy for design 1 and design 2 parameters as shown in fig.1.3.Secondly, thermal analyses are performed on piston, coated with Zirconium material by means of using a commercial code, namely ANSYS. The effects of coating on the thermal behaviours of the pistons are investigated. The finite element analysis is performed by using computer aided design software. The main objective is to investigate and analyze the thermal stress distribution of piston at the real engine condition during combustion process.

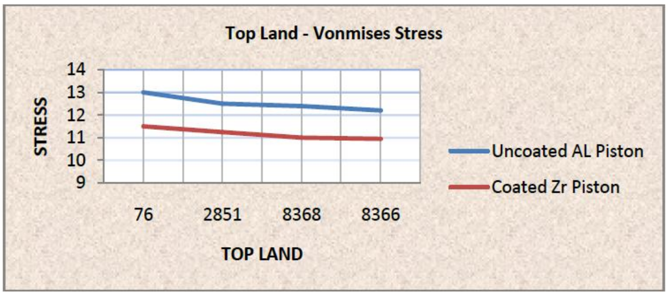


Fig. 1.3 Comparison of Uncoated Aluminium Alloy Piston and Coated Aluminium Alloy Piston

Design the Piston of Internal Combustion Engine by Pro\ENGINEER was studied by Shuoguo Zhao [6] as shown in Fig. 1.4 and Fig.1.5. He studied structural analysis and calculates the piston by pro\engineer software to gain results, which improve and optimize the structure of piston.

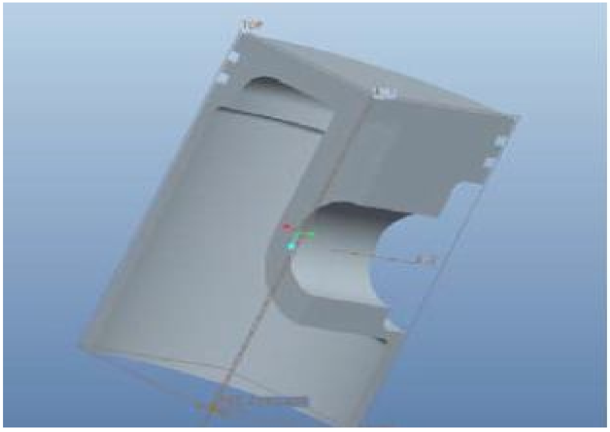

Fig. 1.4 Part of the piston model

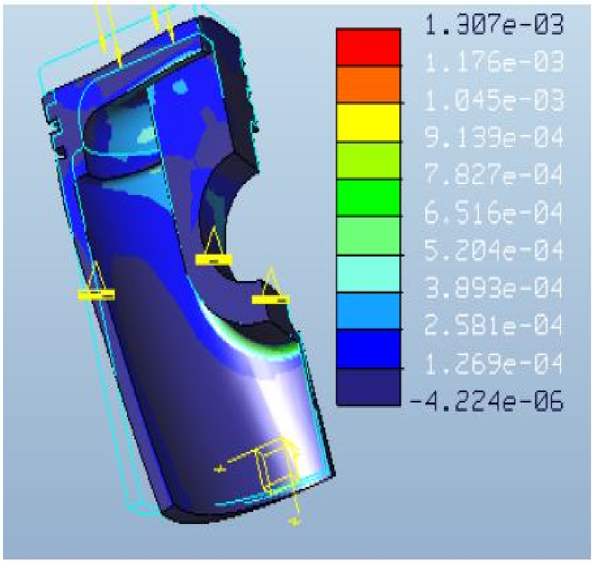


Fig. 1.5 optimal design of piston

Piston Strength Analysis Using FEM was studied by Swati S Chougule and Vinayak H Khatawate [5] .FEM had performed by using computer aided engineering (CAE) software. The main objective of this paper is to investigate and analyse the stress distribution of piston at the actual engine condition during combustion process. The parameter used for the simulation was operating gas pressure and material properties of piston. The piston under study belongs to the two stroke single cylinder engine of SUZUKI Max100 motorcycle. Aluminium was selected as piston material. Computer aided design (CAD) software PRO-E Wildfire 4.0 used to model the piston. And static stress analysis and dynamic analysis had performed by using ANSYS 14.

Thermal Analysis of IC Engine Piston using FEA studied by Praful R. Sakharkar et al. [7]. And presented proposed model as shown in fig. 1.6 to improve quality of piston to withstand high thermal and structural stresses and at the same time reduce stress concentration the upper end of the piston. The FEA was carried out for standard diesel engine piston and the results of analysis were compared for maximum stress. Different alloys of aluminium are tested for maximum stiffness at operating thermal and structural stress using FEA.

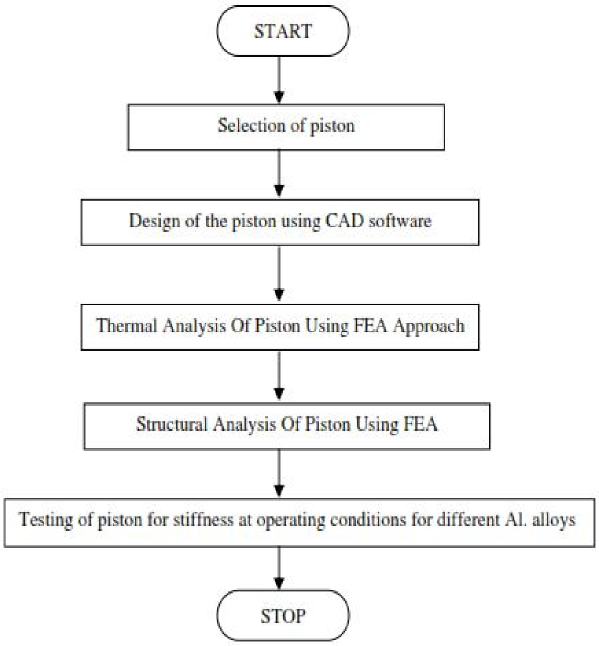


Fig. 1.6 Proposed Model of structural analysis of piston

The structural analysis of the piston for the various pressure on the piston for different position of the piston in the cylinder moving between TDC to BDC have been studied by S N Kurbet et al. [3]The following conclusions were made.

1. The piston experiences maximum stress in the region where the combustion of the fuel takes place, i.e., at the piston head and skirt.
2. This high stress region in the piston deforms more than the other region of the piston.
3. The maximum x-displacement of the piston as shown in Fig.1.7 [3] for structural analysis resembles the maximum displacement of the piston in MBD (Multi body dynamic) analysis as shown in Fig.1.8 and Table I.[3]

TABLE I

COMPARISONS BETWEEN MBD AND STRUCTURAL ANALYSIS

| | MBD Analysis | Structural analysis |
|---|---|---|
| **Displacement along x-axes in mm** | 1.741 | 1.710 |
| **Stress in n/mm2** | 159 | 157 |

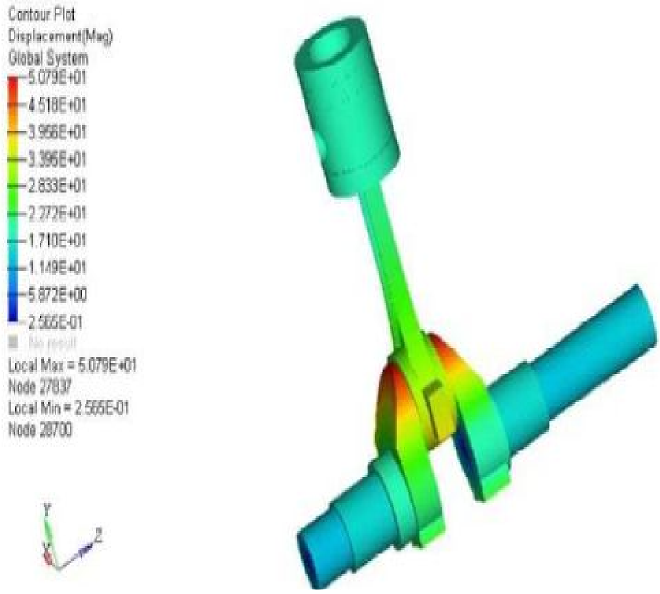


Fig. 1.7 Displacement of MBD Analysis of Engine

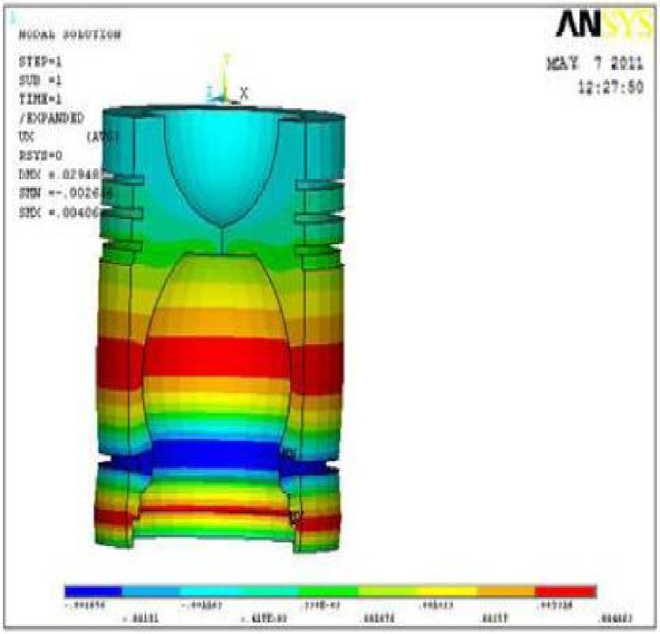


Fig. 1.8 Displacement zone of piston at TDC

## VI. Conclusions

For a piston following are the major consideration.

1. Comparative study needs to be applied for the selection of material and manufacturing process so as to have cost effectiveness and weight optimization.
2. The weight optimization is carried out to reduce the stress concentration on the upper end of the piston i.e (piston head/crown and piston skirt and sleeve.
3. Fatigue is the dominant mechanism of failure of the piston.
4. Dynamic analysis must be conducted due to the nature of the loading applied to the component such as piston.
5. Accurate stresses are critical input to fatigue analysis and optimization of the piston.

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## References

[1] A. R. Bhagat and Y. M. Jibhakate,2012 “Thermal Analysis and Optimization of I.C. Engine Piston using finite element method” International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.4, July-Aug 2012, pp-2919-2921 ISSN: 2249-6645 www.ijmer.com

[2] Ahu Fahriye Acar, Fahrettin Ozturk, and Mustafa Bayrak “Effects of Variations in Alloy Content and Machining Parameters on the Strength of the Intermetallic Bonding Between A Diesel Piston and A Ring Carrier” Original scientific article/Izvirni znanstveni ~lanek, ISSN 1580-2949, MTAEC9, 44(6)391(2010).

[3] S N Kurbet, Vinay V Kuppast and Vijaykumar N Chalwa “Finite Element and MBD Analysis of Piston to Predict the Engine Noise “international journal of mechanical engineering and robotic research, Vol. 2, No. 1, January 2013, ISSN 2278 – 0149 www.ijmerr.com

[4] 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 research in science, engineering and technology. (IJRISET) Vol. 2, Issue 12, December 2013, PP-7834-7843 ,ISSN: 2319-8753,www.ijriset.com

[5] Swati S Chougule, Vinayak H Khatawate “Piston Strength Analysis Using FEM” International Journal of Engineering Research and Applications (IJERA) Vol. 3, Issue 2, March -April 2013, pp.1724-1731, ISSN: 2248-9622 www.ijera.com

[6] Shuoguo Zhao” Design the Piston of Internal Combustion Engine by Pro\ENGEER” 2nd International Conference on Electronic & Mechanical Engineering and Information Technology (EMEIT-2012), Published by Atlantis Press, Paris, France. pp. 2163-2166.

[7] Praful R. Sakharkar , Avinash M. Wankhade “Thermal Analysis of IC Engine Piston Using FEA” International Journal of Engineering Science and Technology (IJEST), Vol. 5 No.05S May 2013, ISSN : 0975-5462 Vol. 5,PP-75-77.

[8] Vinod Yadav and Dr.D.N.Mittal “Design and Analysis of Piston Design for 4 Stroke Hero Bike Engine” International Journal of Engineering Innovation & Research ,Volume 2, Issue 2, ISSN: 2277 – 5668,PP.148-150

[9] Francis Uchenna OZIOKO” Casting of Motorcycle Piston from Aluminium Piston Scrap using Metallic Mould” Leonardo Electronic Journal of Practices and Technologies, Issue 21, July-December 2012, ISSN 1583-1078, p. 82-92

[10] Kolchin A. and Demidov V. *Design of Automotive Engines*, Translated from the Russian by P. Zabolotnyi, MIR Publishers Moscow, First published *1984,* Revised from the second 1980 Russian edition, ©English translation, Mir Publishers, 1984

[11] Shigley, Joseph E. *Mechanical Engineering Design*, 3rd edition, 1977 McGraw-Hill.

[12] *Design Data, Databook of Engineers*, Compiled by PSG college of Technology Coimbatore, Published by Kalaikathir Achchagam Coimbatore ©1968, Revised edition 1970, Reprinted in January 2010

[13] Dr. P.C. Sharma, Aggarwal, R.D.K, , A Text Book of Machine Design, S. K. Kataraia and sons, New Delhi. 2004

[14] Prof.J.S.Soni ,Design of machine elements part-II ,Nirav and Roopal Prakashan, Educational Publishers,Ahmedabad.

[15] Mathur M.L., Sharma, A Course in Internal Combustion Engine R.P. Dhanpat Rai Publication 1997 (i, ii, iii).