© 2017 IJSRST | Volume 3 | Issue 4 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

Modeling & Analysis of Compressed Air Engine

Mohd Yousuf Ahmed[1], Durga Prasad[2], Atram Suresh[3], Mohammad Altaf[4]
[1]Assistant Professor of Mechanical Department , Lords Institute of Engineering and Technology, Hyderabad, India
[2]Professor of Mechanical Department ,Lords Institute of Engineering and Technology, Hyderabad, India
[3,4]Students of Mechanical Department, Lords Institute of Engineering and Technology, Hyderabad, India

ABSTRACT

The main objective of this project is to model, analyze, and optimization of Compressed Air Engine. To analyze the different types of load acting on the piston and to find the stress concentration on the piston and by applying the different types of materials on the piston. To reduce the piston weight and make the piston light weight thus by improving the piston efficiency and performance. The optimization of piston makes the piston light weight. Modelling, Analysis and optimization of piston which is stronger, lighter with minimum cost and with less time. Since the design and weight of the piston influence the engine performance. Analysis of the stress distribution in the various parts of the piston to know the stresses. The Piston of an engine is designed, analyzed and optimized by using graphics software. The CATIA, CAD software for performing the design phase and ANSYS for analysis and optimization phases are used. The performance of any automobile largely depends on its size and working in dynamic conditions. 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. The stress distribution of piston by using FEM and investigate and analyze of the actual engine condition during combustion process. Intensity of structural stresses should be reduced to have safe allowable limits. This project introduces an analytical study of the structural effects on the engine piston.CAD software CATIA is used to model the piston and stress analysis is performed by using ANSYS for weight optimization. The review of existing literature design analysis and optimization of hybrid Piston for 2 stroke single cylinder. The materials, manufacturing process, design consideration and structural and thermal analysis etc. of the piston are reviewed here. The impact of crown thickness, thickness of barrel and piston top land height on stress distribution and total deformation is monitored during the study of actual 2 stroke engine piston. The entire optimization is carried out based on statistical analysis..The work describes the mesh optimization with using finite element analysis technique to predict the higher stress and critical region on the component.
Keywords : Compressed Air Engine, Ansys, CATIA, Anaylsi, Optimization

I. INTRODUCTION

In a variety of applications, in a compressed air engine a piston is a mechanical element in engine it is the heart of the engine. In the engine the main part is the piston. This improves the performance and efficiency of the engine. The engine performance depends on piston. As we know that air is non polluting and freely available in nature. The utilization of this freely available air is the good idea for automobile sector. Compressed air engine operates with the compressed air and is very simple in construction and operation. In the case of a compressed air Engine, there is no combustion taking place within the engine. So it is less dangerous and non polluting. It requires lighter metal only since it does not have to withstand elevated temperatures. As there is no combustion taking place and Carburetor is eliminated because carburetor is used for mixing of fuel and air purpose. There is no need for mixing fuel and air, here compressed air is the fuel and it is directly fed into the piston cylinder arrangement. It simply expands inside the cylinder and does useful work on the piston. This work done on the piston provides sufficient power to the crankshaft.

A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and or connecting rod. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. Finite Element analysis is a simulation technique which evaluates the behavior of components, equipment and structures for various loading condition including applied forces, pressure and temperatures. A number of concept design tools that provide up front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive free form surface tools. We created model Piston using CATIA software. The results obtained for the piston made of a new material are compared with those for the current standard material. The analysis 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 so as to increase life of piston.

II. LITERATURE REVIEW

The primary object of this invention is to improve the efficiency & performance of the piston by using the optimization technique. The piston is considered as the heart of the engine. The piston undergoes many different types of working conditions of thermal, static and dynamic load conditions. But in this project we are only talking about the compressed air engine. So the pressure and temperature in the compressed air engine is less compared to the actual IC engine. So we are confirmed to only static analysis.

1. Modeling of Compressed Air Engine Parts in CATIA

CATIA is being used by designers, manufacturing facilities, assemblers, architects, industrial engineers etc. Have a Look around you. Everything and Anything you see had to be designed before manufacturing. The desk you are using, the chair you are sitting in, your daily use appliances, your car, your home etc. The list is almost endless. Nearly everything is being designed on computers. CATIA plays a major role in the design process. One object of this invention is to provide a compressed air engine assembly is that it has the less pollution and it is eco friendly .To run the engine on the natural air as fuel which does not pollute the environment and unlike the petrol & diesel engine it does not emit carbon emissions into the atmosphere.

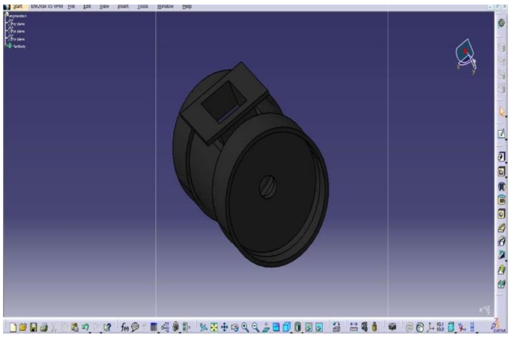

Figure 1. Model of Engine Block

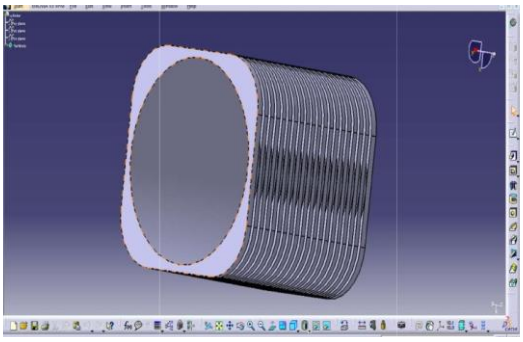

Fig. 2. Model of Cylinder

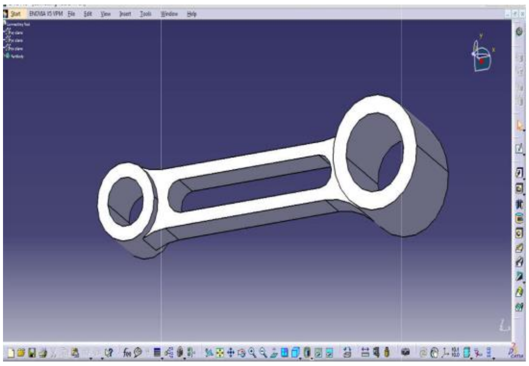

Fig. 3. Model of Connecting Rod

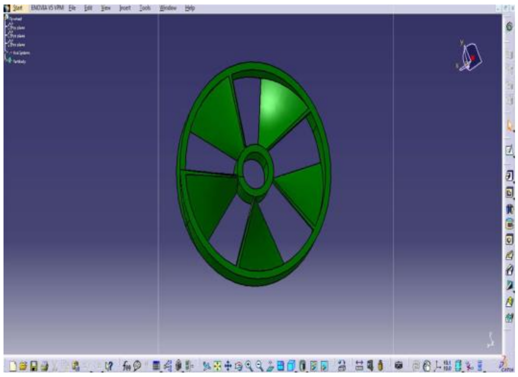

Fig. 4. Flywheel

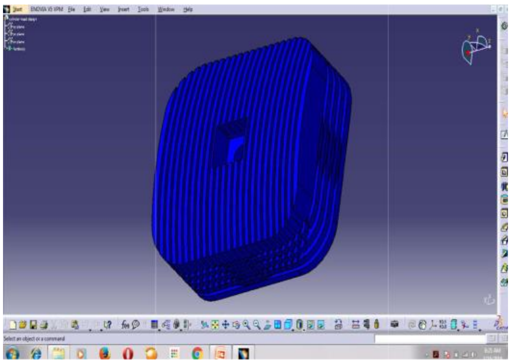

Fig. 5. Cylinder Head

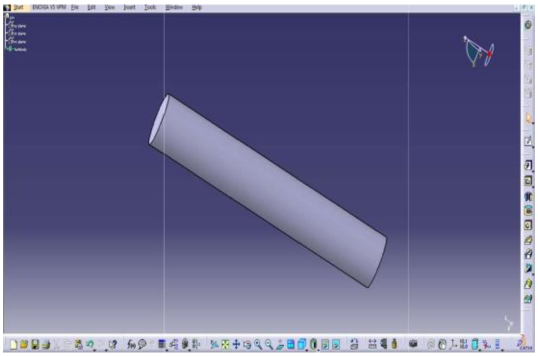

Fig. 6. Gudgeon pin

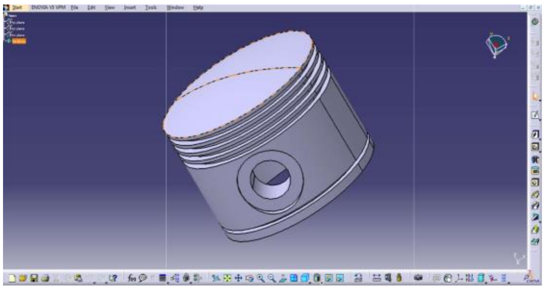

Fig. 7. Piston.

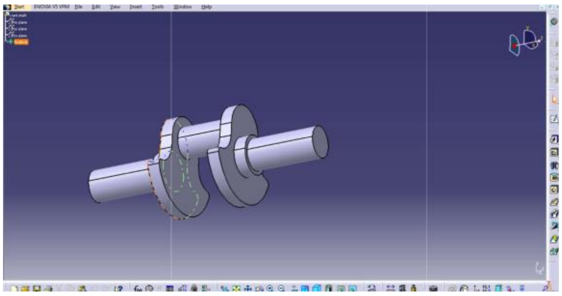

Fig. 8. Crank Shaft

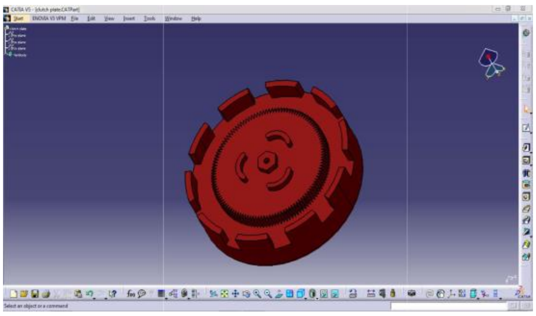

Fig. 9. Clutch Plate Housing

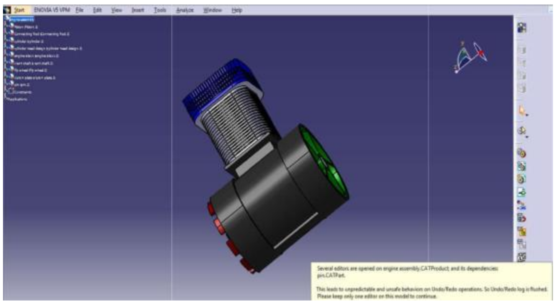

Fig. 10. Engine Assembly

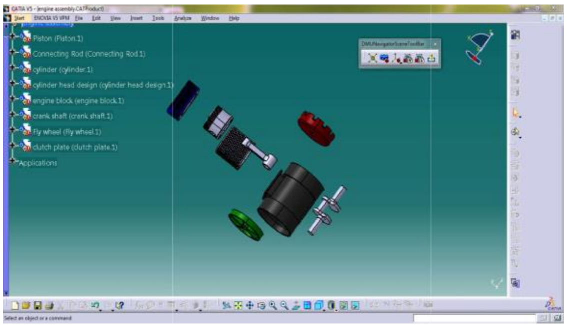

Fig. 11. Exploded view of compressed air engine

III. MATERIAL SELECTION

A. Aluminum

Aluminium is a chemical element in the boron group with symbol **Al** and atomic number 13. It is a silvery white, soft, nonmagnetic, ductile metal. Aluminium is the third most abundant element in the earth's crust after oxygen and silicon and its most abundant metal Aluminium makes up about 8% of the crust by mass though it is less common in the mantle below. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. The chief ore of aluminium is bauxite.

B. Aluminium Alloys

Aluminium alloys are alloys in which aluminium Al is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat treatable and non heat treatable.

C. Aluminium Silicon Carbide

Aluminium Silicon Carbide AlSiC an Aluminium matrix composite is used as an alternative for Aluminium. Compared to Aluminium, AlSiC has better abrasion resistance, creep resistance, dimensional stability, exceptionally good stiffness to weight and strength to weight ratios and better high temperature performance. Fabrication of piston using AlSiC is also easier than using Aluminium.

D. Aluminium Alloy7075

Aluminium alloy 7075 is an aluminium alloy with zinc as the primary alloying element. It is strong, with strength comparable to many steels, and has good fatigue strength and average machinability, but has less resistance to corrosion than many other Al alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable.

E. Material Data

Table 1. Material Properties of AlSiC

Density	$2.937e^{006}$ kg mm^{3}
Thermal conductivity	0.197 W mm^{1} C^{1}
Young's Moduluds MPa	2.3e
Poisson's Ratio	0.24
Bulk modulus MPa	1.4744
Shear modulus MPa	92742

Table 2. Mechanical Properties of Aluminium

Young's modulus	70 GPa
Poison's ratio	0.35
Density	2700 kg/m3
Thermal conductivity	237 W/m c
Specific gravity	910 j/kg c

Table 3. Mechanical properties of AlSiC

Young's Modulus	230 GPa
Poison's Ratio	0.24
Density	2937 kg/ m^3
Thermal Conductivity	194 W/m c
Specific Gravity	894 j/kg c

Table 3. Shows AlSiC Constants such as Young's modulus, Poisson's ratio ,thermal conductivity and Table 2. Aluminium Material Properties such as Young's modulus, Poisson's ratio ,thermal conductivity and Table AlSiC material properties such as Young's modulus, Poisson's ratio, thermal conductivity. And we compared material properties and found that AlSiC has superior properties.

F. Material Composition

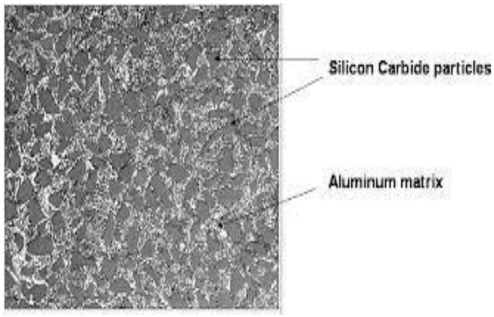

Fig. 12. Micro structure of AlSiC

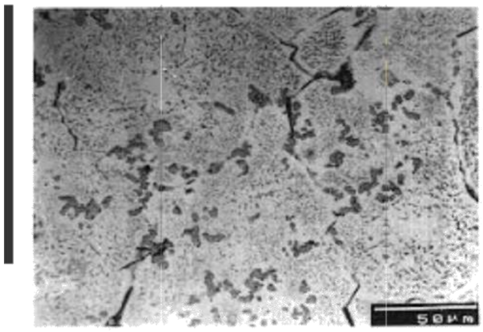

Fig. 13. Micro structure of Aluminium

G. The ANSYS Workbench Interface

The ANSYS Workbench interface consists primarily of a Tool box region, the Project Schematic, the Toolbar, and the Menu bar. Depending on the analysis type and or application or workspace, you may also see other windows, tables, charts, etc. One way to work in ANSYS Workbench is to drag an item such as a component or analysis system from the Tool box to the Project Schematic or to double click on an item to initiate the default action. Design Modeler is designed to be used as a geometry editor of existing CAD models. Design Modeler is parametric features based solid modelers designed so that you can intuitively and quickly begin drawing 2D sketches, modeling 3D parts, or uploading 3D CAD models for engineering analysis preprocessing. Use the Workbench Simulation module to define your model's environmental loading conditions, solve the simulation, and review results in various formats depending on the type of simulation.

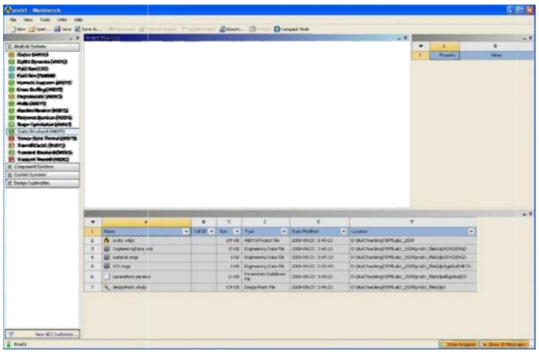

Fig. 14. Software outfit

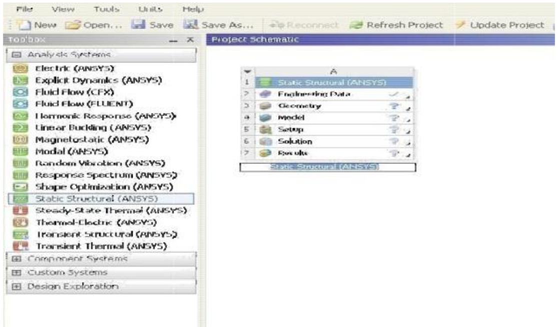

Fig. 15. Workbench Project Mode

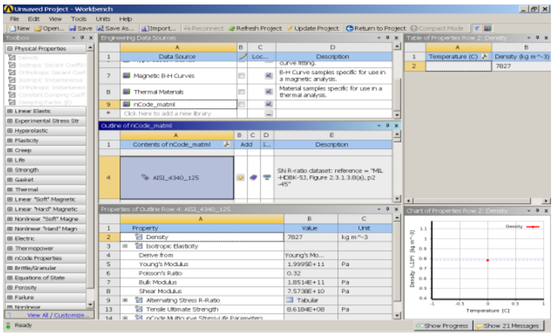

Fig. 16. Engineering Data Mode

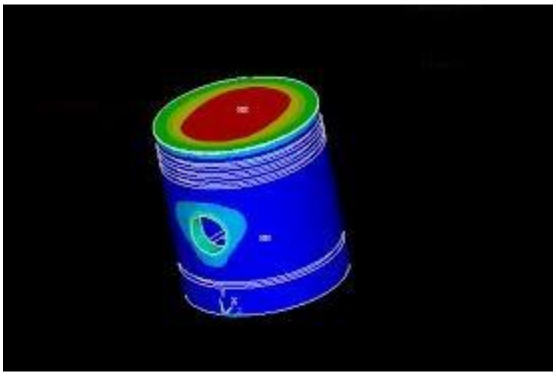

Fig. 17. Analysis of Piston

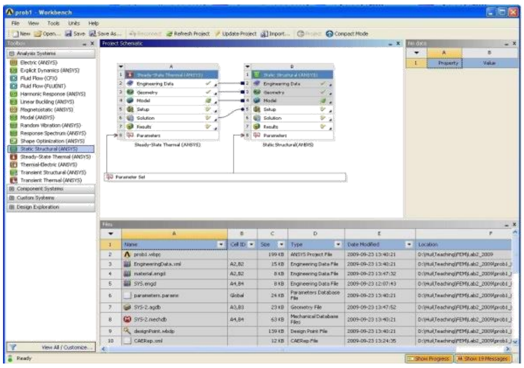

Fig. 18. Thermal Analysis

V. Results & Optimization

A. Results

Procedure for Analysis

- STEP 1 Preferences Structural and Thermal
- STEP 2 Material Properties
- STEP 3 Meshing Mesh Tool
- STEP 4 Loads Define Load Apply Structural Displacements on Areas
- STEP 5 Structural Pressure on Areas
- STEP 6 Solution Solve Current Ls
- STEP 7 General Post Process Plot Results

B. Aluminium

Table 4. Material Properties of Aluminium

Material	Aluminium
Young s modulus	$7x10^5$N/mm^2
Poisson ratio	0.3
Yield strength	310N/sq.mm

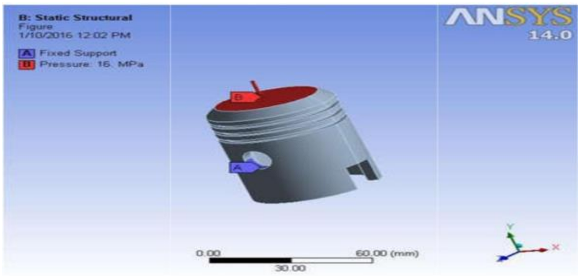

Fig. 19. Shows the Fixed Support Model of Aluminium Piston

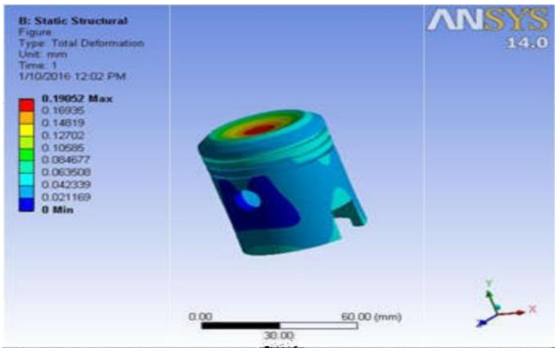

Fig. 20. Total deformation on Aluminium Piston

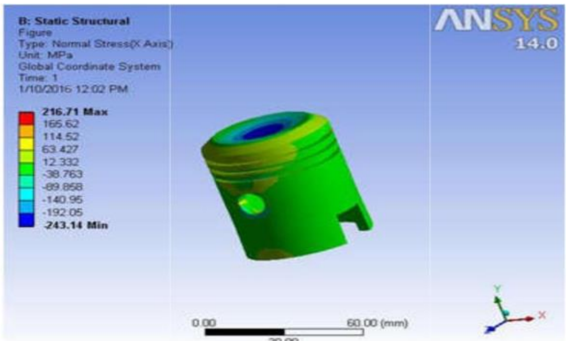

Fig. 21. Normal Stress distribution on Aluminium Piston

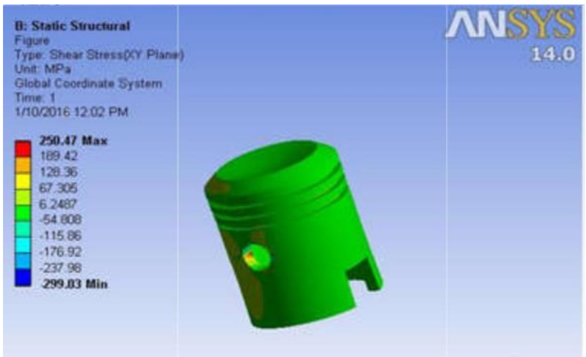

Fig. 22. Shear Stress distribution on Aluminium Piston

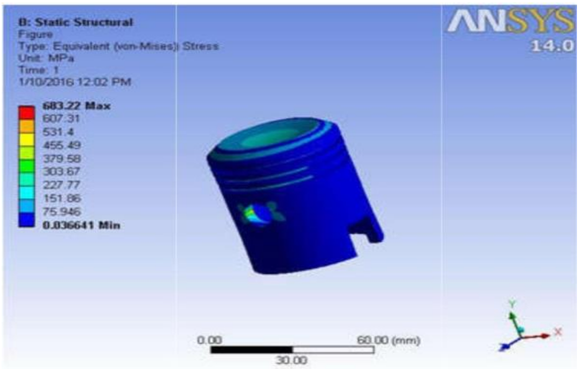

Fig. 23. von Misses distribution on Aluminium Piston

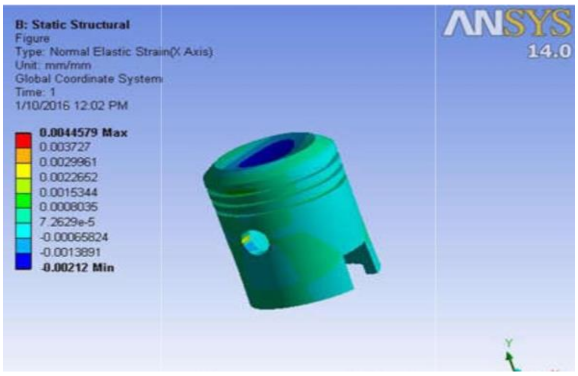

Fig. 24. Normal Elastic Strain distribution on Aluminium Piston

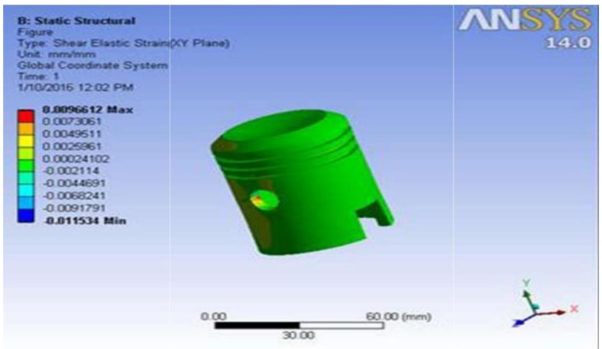

Fig. 25. Shear Elastic Strain distribution on Aluminium Piston

C. Aluminium Silicon Carbide

Table 5. Material Properties of Aluminium Silicon Carbide

Material	Aluminium Silicon Carbide
Young s modulus	$23x10^4 N/mm^2$
Poisson ratio	0.24
Yield strength	390N/sq.mm

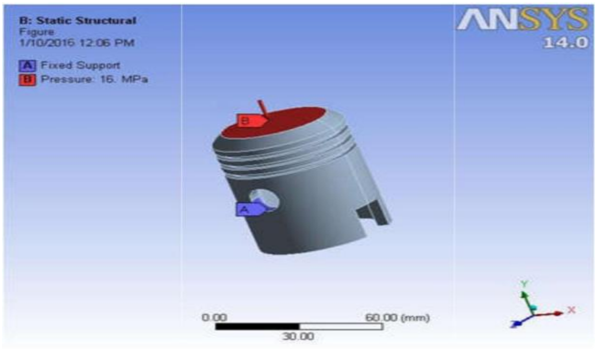

Fig. 26. Shows the Fixed Support Model of AlSiC Piston

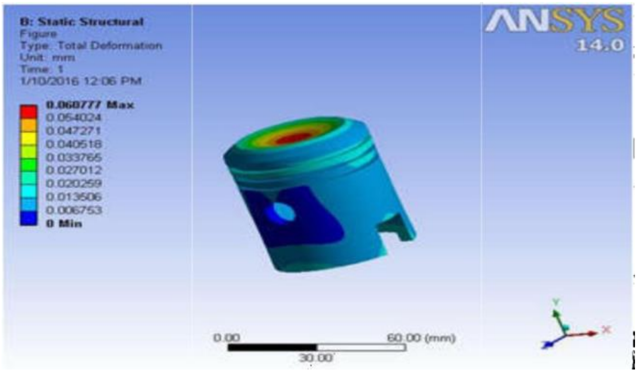

Fig. 27. Total Deformation on AlSiC Piston

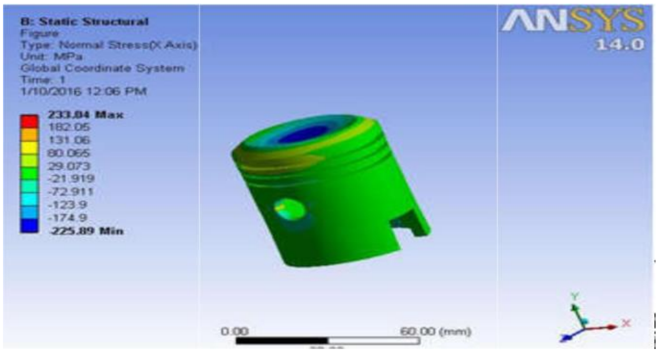

Fig. 28. Normal stress distribution on AlSiC Piston

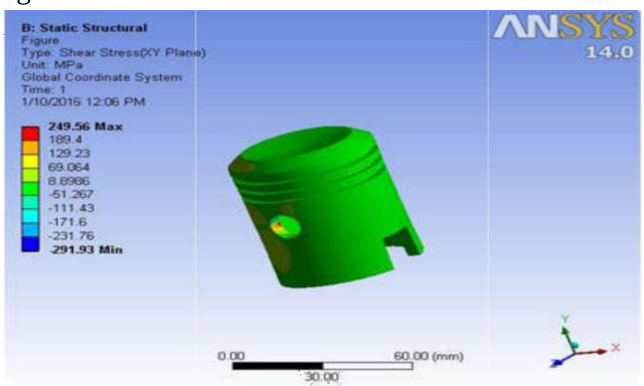

Fig. 29. Shear stress distribution on AlSiC Piston

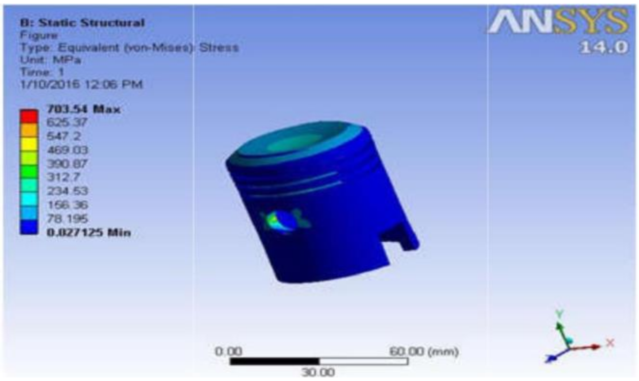

Fig. 35. von Missses stress distribution on AlSiC Piston

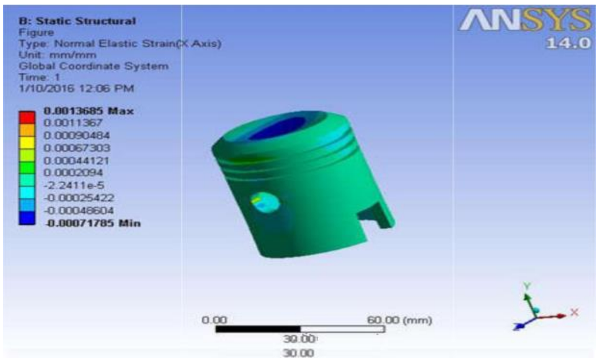

Fig. 36. Normal elastic stress distribution on AlSiC Piston

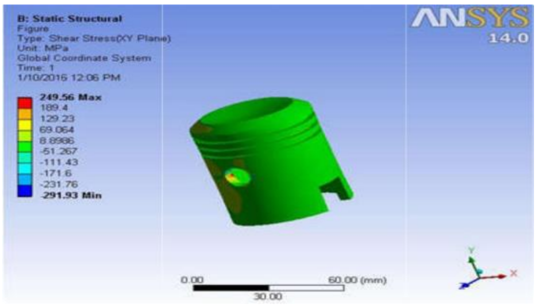

Fig. 37. Shear elastic strain distribution on AlSiC Piston

D. Optimization

Design, Analysis and optimization of piston which is stronger, lighter with minimum cost and with less time. Since the design and weight of the piston influence the engine performance Analysis of the stress distribution in the various parts of the piston to know the stresses due to the gas pressure and thermal variations using with Ansys. The Piston of an engine is designed, analyzed and optimized by using graphics software. The CATIA, CAD software for performing the design phase and ANSYS for analysis and optimization.

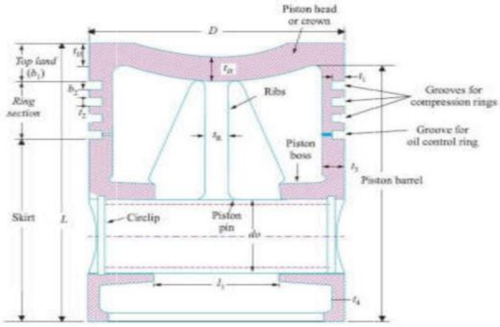

Fig. 38. Labeled Image of Piston Components

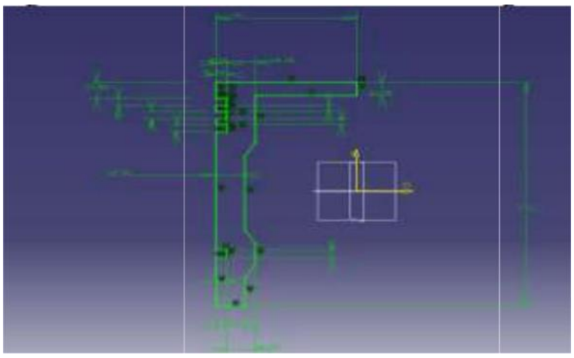

Fig. 39. Sketch of the Piston before optimization

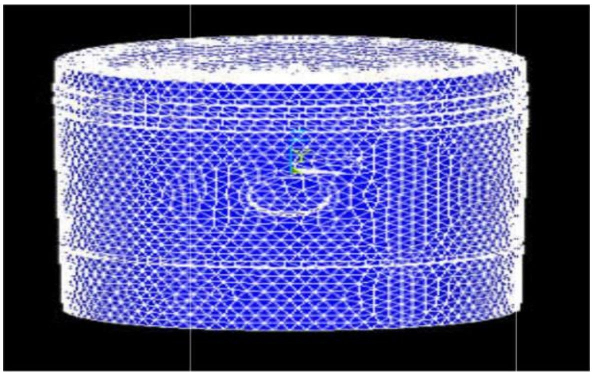

Fig. 40. Meshing of the Piston before optimization

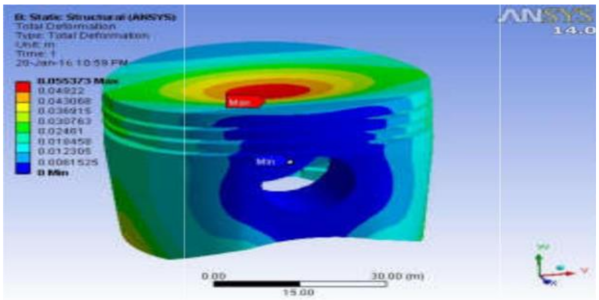

Fig. 41. Total deformation of the Piston before optimization

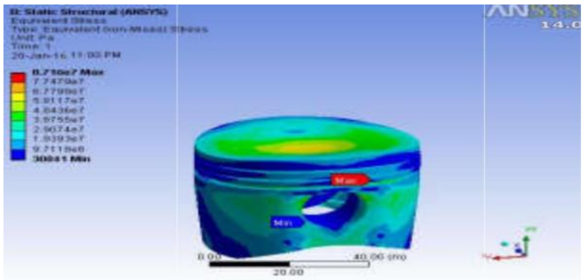

Fig. 42. Equivalent Stress of the Piston before optimization

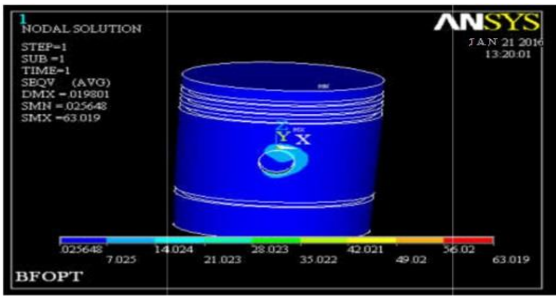

Fig. 43. von Misses Stress of the Piston before optimization

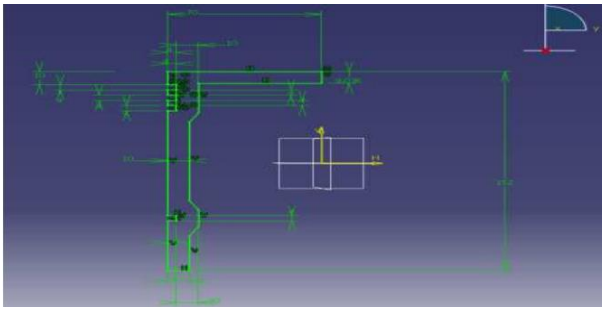
Fig. 44. Sketch of the Piston after optimization

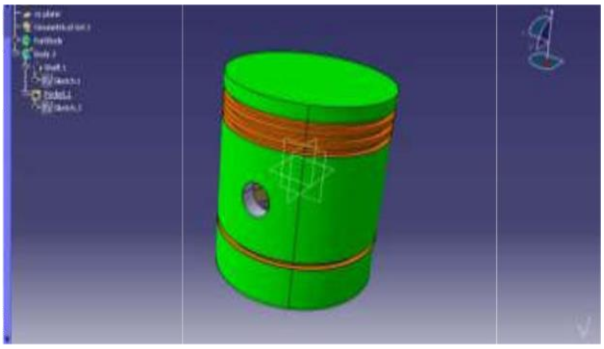
Fig. 45. Model of the Piston after optimization

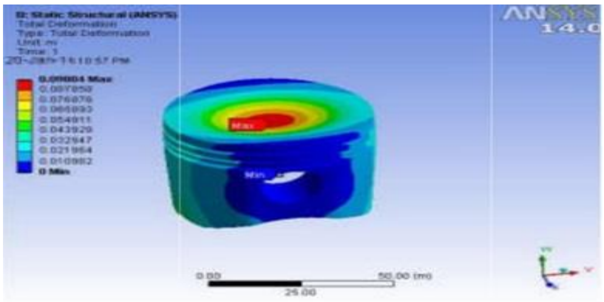
Fig. 46. Total deformation of the Piston after optimization

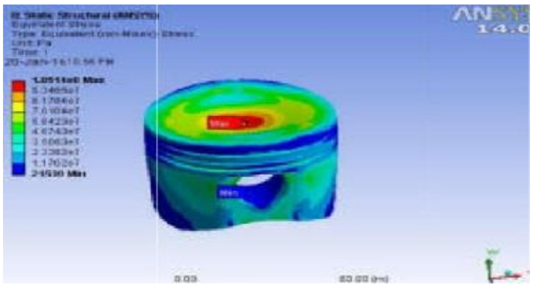
Fig. 47. Equivalent Stress of the Piston after optimization

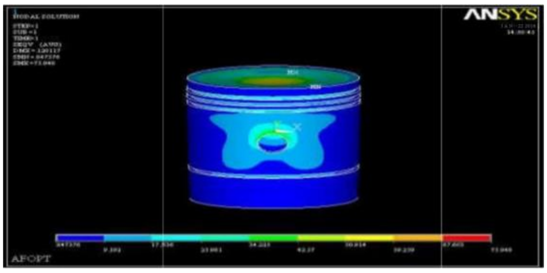

Fig. 48. von Misses Stress of the Piston after optimization

IV. CONCLUSION

It has been conclude that from the below given values Aluminium silicon carbide composite is more efficient and improved properties when compare to Aluminium. As Aluminium SiC has more durability and strength compared to Al Alloys 2024 & 7075.But when compare to cost, Alloys is less expensive and easily available.

The deflection due to pressure applied after optimization is more than before optimization and this value is taken into consideration for design purpose. The stress distribution on the piston mainly depends on the deformation of piston. Therefore, in order to reduce the stress concentration, the piston crown should have enough stiffness to reduce the deformation. All the phases in this project given can be extended to the piston design with reduction of material at bottom. The material is removed to reduce the weight of the piston so as to improve the efficiency. It is essential to obtain the optimized results for new piston with reduced material. The deflection due to pressure applied after optimization is more than before optimization and this value is taken into consideration for design purpose. The stress distribution on the piston mainly depends on the deformation of piston. Therefore, in order to reduce the stress concentration, the piston crown should have enough stiffness to reduce the deformation. All the phases in this project given can be extended to the piston design with reduction of material at bottom. The material is removed to reduce the weight of the piston so as to improve the efficiency. It is essential to obtain the optimized results for new piston with reduced material. Aluminum SiC are the preferred material for pistons both in gasoline and diesel engines due to their specific characteristics low density, high thermal conductivity, easy machinability, high reliability and very good recycling characteristics. Proper control of the chemical composition, processing conditions and final heat treatment results in a micro structure which ensures the required mechanical and thermal performance, in particular the high thermal fatigue resistance.

Table 6. Design values after optimization

Parameter	Before optimization	After optimization	Design consideration
Radial thickness(t1)	5.24mm before	3.46mm after	4mm consider
Axial thickness(t2)	5mm	3.52mm	4mm
Max thickness of barrel(t3)	14.34mm	9.08mm	10mm
Width of topo land (b1)	10.84mm	9.36mm	10mm
Width of other land(b2)	4mm	3.24mm	3mm
Volume	997021mm^3	752994mm^3	752994mm^3
von-Misses	63.019 MPa	75.95 MPa	63-76MPa
Deflection	0.0198mm	0.120mm	0.120mm

Table 7. Mechanical properties of AlSiC & Aluminium

MATERIAL	TOTAL DEFORMATION	EQUIVALENT ELASTIC STRAIN	von-MISSES
ALUMINIUM	0.19052	0.0097603	683.22
AlSiC	0.06077	0.0030589	703.54

Table 8. Mechanical properties of Aluminium

Young's modulus	70 GPa
Poison's ratio	0.35
Density	2700 kg/m3
Thermal conductivity	237 W/m c
Specific gravity	910 j/kg c

Table 9. Material Properties of AlSiC

Young's modulus	230 GPa
Poison's ratio	0.24
Density	2937 kg/m^3
Thermal conductivity	194 W/m c
Specific gravity	894 j/kg c

V. REFERENCES

[1]. Sunday Aribo, Joseph Ajibade Omotoyinbo, Davies Oladayo Folorunso, High temperature mechanical properties of silicon carbide particulate reinforced cast aluminum alloy composite,

[2]. International journal of applied engineering research, Volume 1, pp. 4-9, 2007. Khurmi

[3]. Pandya and Shah, Design of machine Elements‖, S Chand, 14th edition, 2006.

[4]. A. R. Bhagat, Y. M. Jibhakate, Thermal Analysis and Optimization of I.C. Engine Piston Using FEM Research (IJMER), Vol.2, Issue.4, pp. R.S.Khurmi,J.K.Gupta, A Text Book of Machine Design, S.Chand & Co.

[5]. Haisheng Chen et al. "Air fuelled zero emission road transportation: A comparative study", Applied Energy 88 (2011), 24 June 2010, pp: 337–342

[6]. Amir Fazeli et al. "A novel compression strategy for air hybrid engines" Applied Energy 88 (2011) ,8 March 2011, pp: 295–2966