Structural Analysis of Various Aluminium Alloy Piston

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Abstract- *In this study, Work is carried out to find out the stress distribution on different Piston Materials used. In IC engine Piston is one of the most important and complex part, so it is important to maintain Piston in good condition in order to maintain the proper functioning of the engine. Piston mainly fails due to Mechanical stress. So as to search out Mechanical stress different Piston Materials are considered.*

Keywords- IC engine ,Piston, ANSYS, Piston Materials, WB-Modeller, aluminium alloys.

I. INTRODUCTION

1. Piston function , requirement and types

Function of the piston

The piston as an element of power transmission

In the cylinder of an engine , the energy bounded up in the fuel is rapidly converted into heat and pressure during the combustion cycle. The heat and pressure values increase greatly within a very short period of time. The piston as the moving part of the combustion chamber has the task of converting this released energy into mechanical work.

The basic structure of the piston is a hallow cylinder, closed on one side, with the segments piston crown with ring belt, pin bass and skirt. The piston crown transfers the gas forces resulting from the combustion of the fuel air mixture via pin boss, the piston pin, and the connecting rod to the crankshaft.

The gas pressure against the piston crown and the oscillating initial forces, reflected to in the following as the inertia force, of the piston and connecting rod constitute the piston force. Due to the redirection of the piston force in the direction of the connecting rod (rod force) an additional component arises, following the force parallelogram namely the lateral force also known as the normal force. This force pressure the piston skirt against the cylinder bore. During a combustion cycle, the lateral force changes direction several times, which pressures the piston from one side of the cylinder bore to other, due to the existing piston clearance.

The most important tasks that the piston must full fill are

- Transmission of force form and to the working gas.
- Variable bounding of the working chamber (cylinder)
- Sealing off the working chamber
- Linear guiding of the conrod (trunk piston engines)
- Heat dissipation
- Support charge exchange by drawing and discharging (four-stroke engine)
- Support mixture formation (by means of suitable shape of the piston surface on the combustion chamber side)
- Controlling charge exchange(in two-stroke engine)
- Guiding the sealing elements (piston)
- Guiding the conrod (for top guided conrode)

As the specific engine output increase, so do the requirements on the piston at the same time. Requirement on the piston

II. MATERIAL PROPERTIES

TABLE I
AlSi MATERIAL PROPERTIES

Sl No	Properties	Value
1	Young's modulus	2.3×10^5 Mpa
2	Poisons ratio	0.24
3	Density	2937 kg/m^3
4	Thermal conductivity	197 W/m^{0}C
5	Specific heat	894 J/kg^{0}C

TABLE II
Al-Mg-SI MATERIAL PROPERTIES

Sl No	Properties	Value
1	Young's modulus	0.7×10^5 Mpa
2	Poisons ratio	0.33
3	Density	2700 kg/m^3
4	Thermal conductivity	200 W/m^{0}C
5	Specific heat	898 J/kg^{0}C

TABLE III
AlSiC-10 MATERIAL PROPERTIES

Sl No	Properties	Value
1	Young's modulus	1.67×10^5 Mpa
2	Poisons ratio	0.251
3	Density	2960 kg/m^3
4	Thermal conductivity	190 W/m^{0}C
5	Specific heat	786 J/kg^{0}C

TABLE IV
AlSiC-12 MATERIAL PROPERTIES

Sl No	Properties	Value
1	Young's modulus	1.67×10^5 Mpa
2	Poisons ratio	0.21
3	Density	2890 kg/m^3
4	Thermal conductivity	170 W/m^{0}C
5	Specific heat	808 J/kg^{0}C

III. THEORETICAL CALCULATIONS

Structural

Maximum stress at head portion of the piston is given by

$$\sigma_{max} = \frac{3pa^2}{4h^2} \text{ ------- from theory of fluxture}$$

p=Gas pressure in N/mm^2
a=Radius of the piston
h=Thickness of the piston crown.

$$\sigma_w = \frac{3 \times 5 \times 70^2}{4 \times 13^2}$$

=108 Mpa

Maximum Deflection of the piston due to gas pressure p is given by

$$w_{max} = (1-v^2)\frac{3}{16}\frac{pa^4}{Eh^3} \text{ ---------- from theory of fluxture}$$

p=Gas pressure in N/mm^2
a=Radius of the piston
h=Thickness of the piston crown.
v =poisons ratio of piston material
E= Young's modulus of the piston material in

Case I

Maximum Deflection of the AlSi Alloy piston due to gas pressure is

$$w_{max} = (1-0.24^2)\times\frac{3}{16}\times\frac{5\times70^4}{230000 \times 13^3}$$

= 0.9424 x 0.1875 x 0.2375
= 0.04197 mm

Case II

Maximum Deflection of the Al-Mg-Si Alloy piston due to gas pressure is

$$w_{max} = (1-0.33^2)\times\frac{3}{16}\times\frac{5\times70^4}{70000 \times 13^3}$$

= 0.8911 x 0.1875 x 0.780
= 0.1304 mm

Case III

Maximum Deflection of the AlSiC-10 Alloy piston due to gas pressure is

$$w_{max} = (1-0.251^2)\times\frac{3}{16}\times\frac{5\times70^4}{167000 \times 13^3}$$

= 0.936999 x0.1875 x 0.3272
= 0.057 mm

Case IV

Maximum Deflection of the AlSiC-10 Alloy piston due to gas pressure is

$$w_{max} = (1-0.21^2)\times\frac{3}{16}\times\frac{5\times70^4}{167000 \times 13^3}$$

= 0.05869 mm

III. PISTON DESIGN

The piston is designed according to the procedure and specification which are given in machine design and data hand books. The dimensions are calculated in terms of SI Units. length, diameter of piston and hole, thicknesses, etc., parameters are taken into consideration

TABLE V
GEOMETRICAL VALUE

S NO.	Dimensions	Size Ranges in (mm)	Preferable Size in (mm)
1	Cylinder Bore, D	---	140
2	Width of the land	7 to 14	13
3	Height of the piston, H	112 to 182	150
4	Distance from the top to the axis of piston pin, h_1	63 to 65.8	64
5	Diameter of thickness of piston pin, d	42 to 70	50
6	Distance from the front to the first channel, e	8.4 to 16.8	12
7	Wall thickness between channels, h_n	4.2 to 7	5
8	Radial thickness of the piston ring t_r	4.48 to 6.3	5
9	Axial thickness of the piston ring t_a	4.48 to 6.3	5

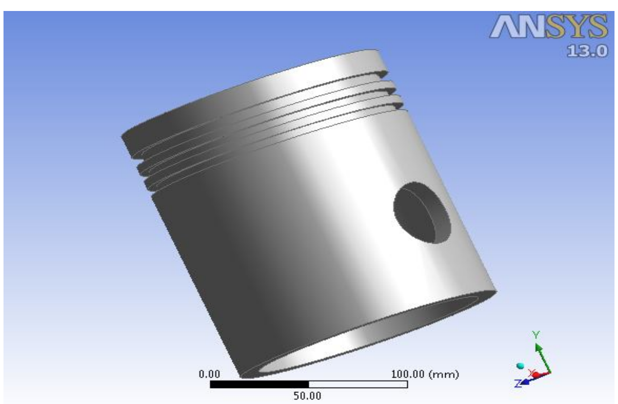


Fig. 1. 3D Piston in WB Modular

IV. MESHING OF DESIGN

The piston shape is irregular, especially in the presence of various curved surfaces of inner cavity. Firstly, Automatic meshing method is used to mesh the model. Element used is 20 node Tetrahedron named soilid90 . The element size is taken as 5, then total number elements were 11475 and nodes were 19591 found in meshed model.

The mesh grid is shown as figure below.

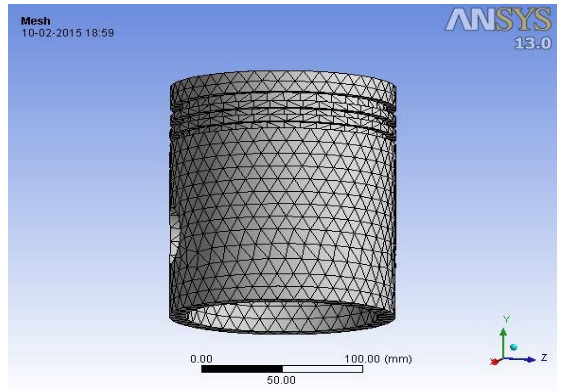


Fig. 2.Meshing of Piston

AlSi

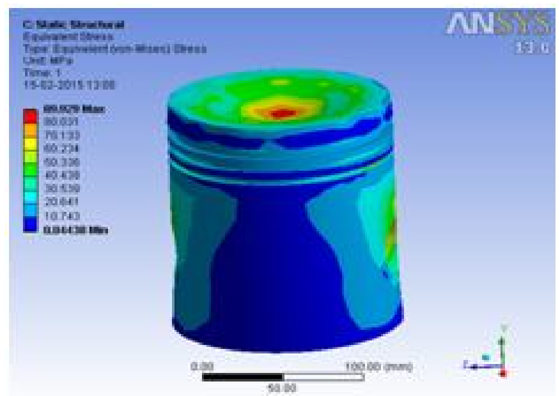


Fig. 2. Vonmises Stress of AlSi Piston

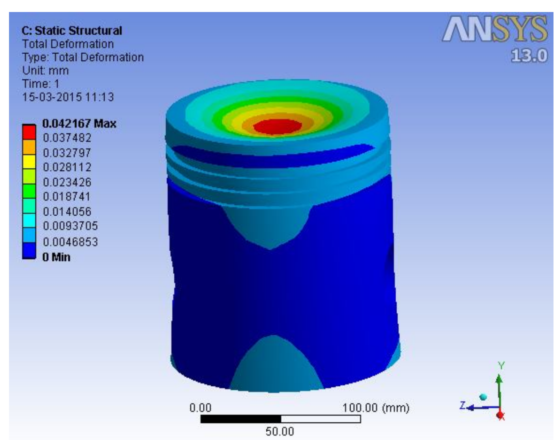


Fig. 3. Total deformation of AlSi piston

Fig (3) and Fig (4) show the structural results of Aluminum silicon Alloy piston influenced by gas pressure.

Fig (3) show the distribution of Vonmises stresses induced within the piston body. The maximum values of equivalent stresses observed at centre portion of the piston crown is 89.929 Mpa.

Fig (4) show the maximum deflection in the piston geometry due to the application of gas pressure is 0.042167 mm, which is observed at the central portion of the piston crown.

Al-Mg-Si

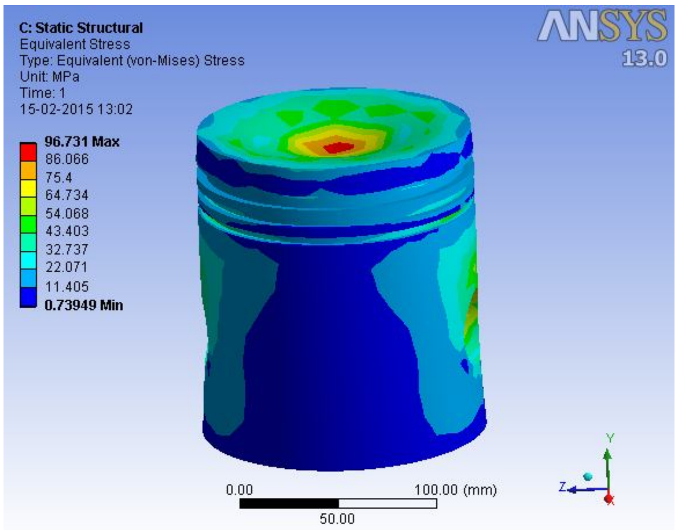


Fig. 5. Vonmises stress of Al-Mg-Si piston

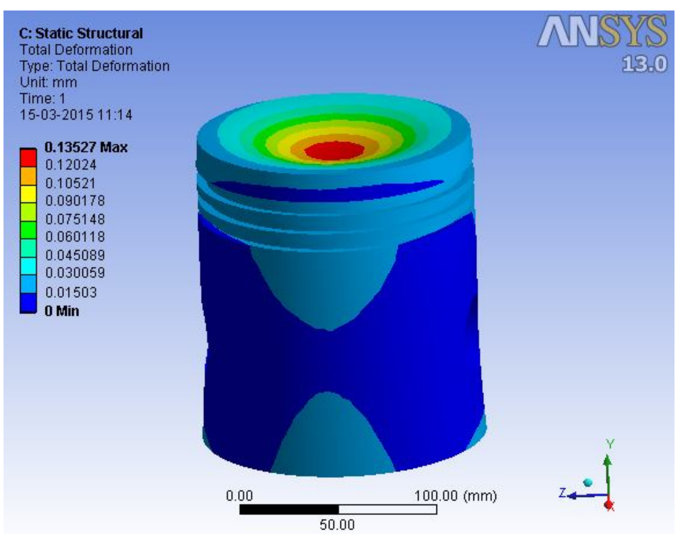


Fig. 6. Total deformation of Al-Mg-Si piston

Fig (5) and Fig (6) show the structural results of Al-Mg-Si Alloy piston influenced by gas pressure.

Fig (5) show the distribution of Vonmises stresses induced within the piston body. The maximum values of equivalent stresses observed at centre portion of the piston crown is 96.739 Mpa.

Fig (6) show the maximum deflection in the piston geometry due to the application of gas pressure is 0.13527 mm, which is observed at the central portion of the piston crown.

AlSic-10

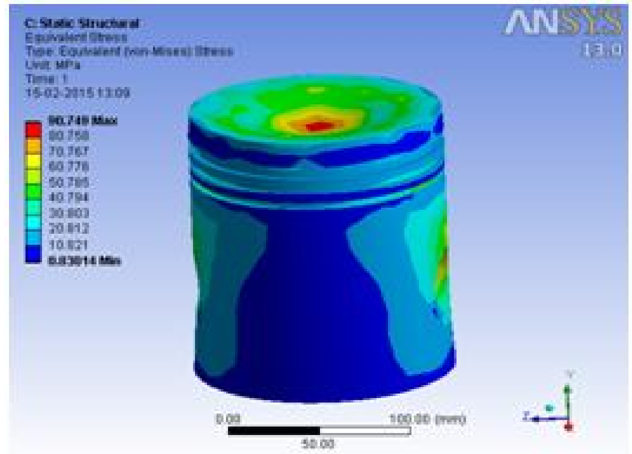


Fig. 7. Vonmises stress of AlSiC -10piston

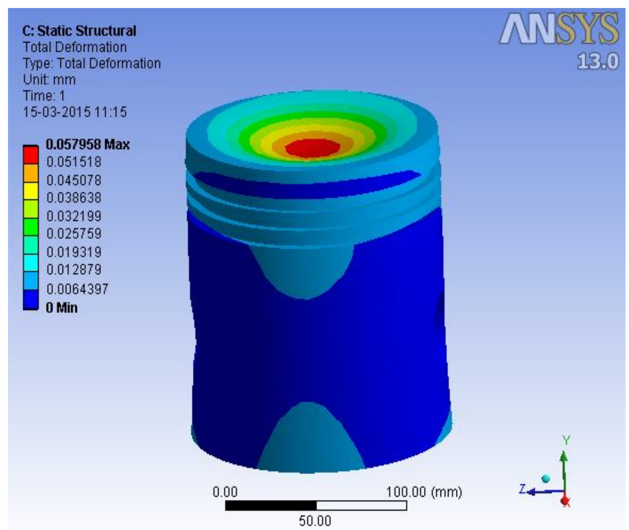


Fig. 8. Total deformation of AlSiC-10 piston

Fig (7) and Fig (8) show the structural results of AlSiC-10 Alloy piston influenced by gas pressure.

Fig (7) show the distribution of Vonmises stresses induced within the piston body. The maximum values of equivalent stresses observed at centre portion of the piston crown is 90.749 Mpa.

Fig (8) show the maximum deflection in the piston geometry due to the application of gas pressure is 0.057958 mm, which is observed at the central portion of the piston crown.

AlSiC-12

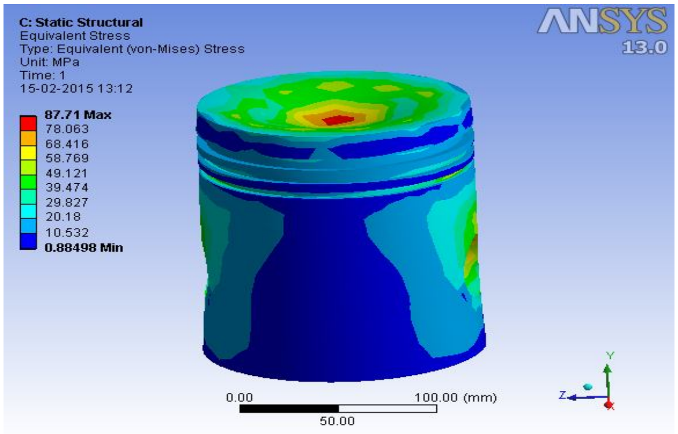


Fig. 9. Vonmises stress of AlSiC -12piston

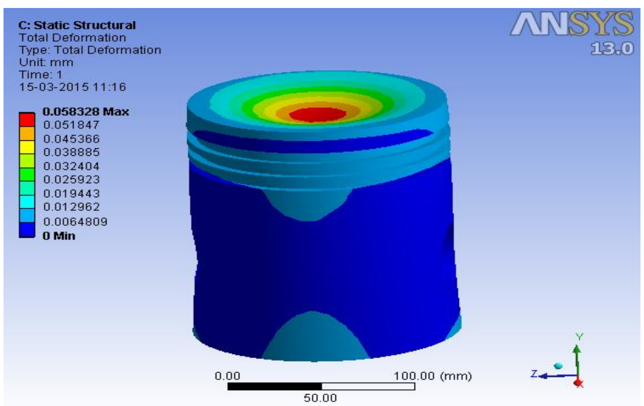


Fig. 10. Total deformation of AlSiC-12 piston

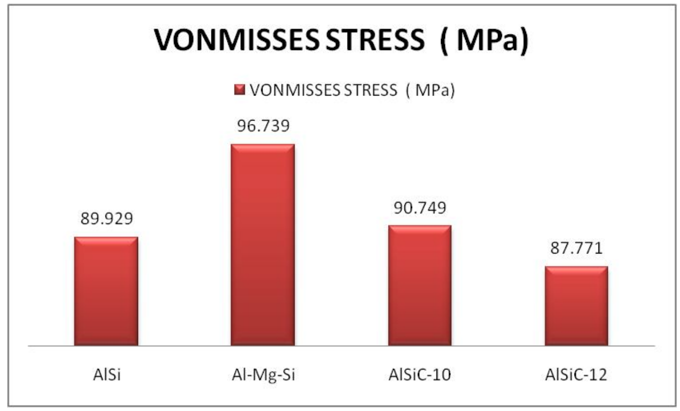
Fig (9) and Fig (10) show the structural results of AlSiC-12 Alloy piston influenced by gas pressure.

Fig (9) show the distribution of Vonmises stresses induced within the piston body. The maximum values of equivalent stresses observed at centre portion of the piston crown is 87.771 Mpa.

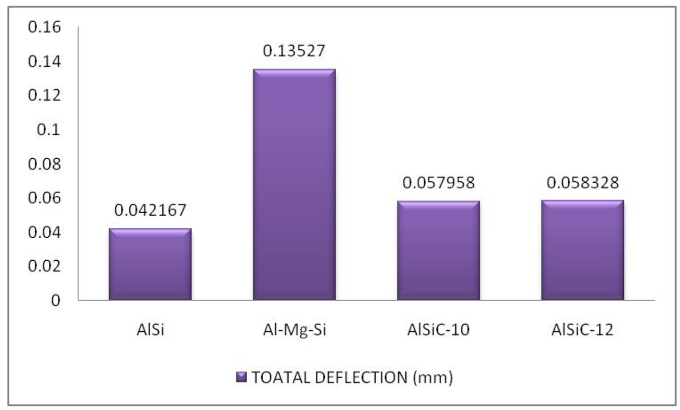
Fig (10) show the maximum deflection in the piston geometry due to the application of gas pressure is 0.058328 mm, which is observed at the central portion of the piston crown.

TABLE VII
THEORETICAL VALUES

S NO	MATERIAL	VONMISSES STRESS (MPa)	TOATAL DIFLECTION (mm)
1	AlSi	89.929	0.042167
2	Al-MgSi	96.739	0.13527
3	AlSiC-10	90.749	0.057958
4	AlSic-12	87.771	0.058328



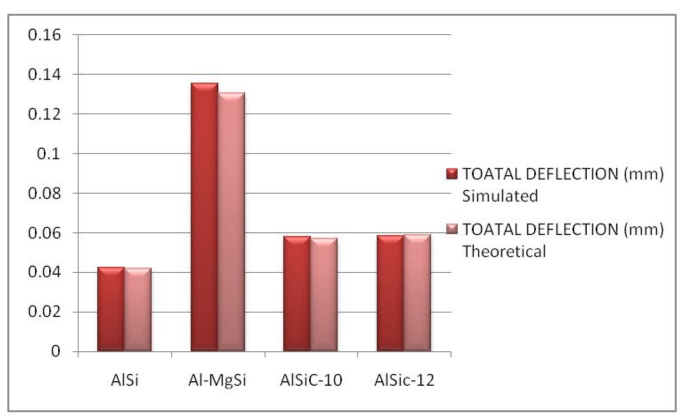
Graph. 1. Vonmisses Stress



Graph. 2. Total Deflection

TABLE VII
COMPARISON BETWEEN SIMULATED & THEORETICAL

S.NO	MATERIAL	TOATAL DEFLECTION	
		Ansys	Theoretical
1	AlSi	0.042167	0.04197
2	Al-MgSi	0.13527	0.1304
3	AlSiC-10	0.057958	0.057
4	AlSic-12	0.058328	0.05869



Graph. 3. Comparison between Simulated & Theoretical

V. CONCLUSION

1. From the analysis results of different material on piston is observed that deformation, Vonmises stress in AlSiC composite compared to Al-Si, Al-Mg-Si, Alloy.
2. Theoretical calculation of the piston have been done to get the influence of mechanical load.
3. Results comparison between theoretical and analysis simulated done and found approximately same.

REFERENCES

[1] "Structural Analysis of a Ceramic Coated Diesel Engine Piston Using Finite Element Method".Narsaiyolla Naresh, (M.Tech), 2P.Sampath Rao, M.Tech; (PhD).SSRG International Journal of Mechanical Engineering (SSRG-IJME) – volume1 issue 5 September2014.

[2] "Piston Design and Analysis by CAE Tools" Ghodake A. P.*, Patil K.N. IOSR Journal of Engineering (IOSRJEN) ISSN: 2250-3021 ISBN: 2878-8719 PP 33-36

[3] "Structural Analysis of a Ceramic Coated Diesel Engine Piston Using Finite Element Method".Narsaiyolla Naresh, (M.Tech), 2P.Sampath Rao, M.Tech; (PhD).SSRG International Journal of Mechanical Engineering (SSRG-IJME) – volume1 issue 5 September2014.

[4] "Experimental Investigation and Analysis of Piston by using Composite Materials" R. RAVI RAJA MALARVANNAN1, P. VIGNESH.International Journal of Mechanical Engineering applications Research.Vol 04, Article-K100; November 2013.

[5] "Piston Strength Analysis Using FEM" by Swati S Chougule*, Vinayak H Khatawate**International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622.

[6] " Design, Analysis and Optimization of Three Aluminium Piston Alloys Using FEA" by Ajay Raj Singh*, Dr. Pushpendra Kumar Sharma. Journal of Engineering Research and Applications ,ISSN : 2248-9622, Vol. 4, Issue 1(Version 3, January 2014, pp.94-102.

[7] "Thermal Analysis And Optimization Of I.C. Engine Piston Using finite Element Method" by A. R. Bhagat1, Y. M. Jibhakate 2. International Journal of Modern Engineering Research (IJMER), Vol.2, Issue.4, July-Aug 2012 pp-2919-2921.