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STRESS ANALYSIS OF IC ENGINE PISTON FOR DIFFERENT MATERIAL AND PRESSURE LOAD USING FEA

Mr. Jadhav Vishal, Dr. R.K. Jain, Mr. Yogendra S.Chauhan
*M-Tech scholar, School Of Mechanical Engineering, ITM University, Gwalior , India.
Professor, School Of Mechanical Engineering, ITM University, Gwalior, India.
Asst.Professor, School Of Mechanical Engineering, ITM University, Gwalior, India.

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ABSTRACT
This present work describes the stress distribution of two different aluminum alloys piston by using finite element method (FEM). The piston is designed for a single cylinder petrol engine using SOLIDWORKS 2013 software. The procedure for analytical design of two different aluminum alloy piston is described. Design is imported to ANSYS 15.0 software then static stress analysis is performed at different pressure load conditions on the piston. Results are presented and a comparison is made to find the best aluminum alloy.

KEYWORDS: A4032, AL-GHY 1250, Solid works, ansys.

INTRODUCTION
The piston is an engine component which reciprocates within a cylinder. The main function of the piston of an IC Engine is to receive the impulse from the expanding gas and transmit the energy to the crank shaft through the connecting rod. Piston endures the cyclic gas pressure and the inertial forces at working condition this may cause the fatigue damage of piston.

The piston design should be rigid enough to prevent mechanical and thermal distortion and it should have sufficient bearing area to prevent undue wear. Piston is designed based on strength and thermal considerations. The Strength of piston pin should be sufficient against shear failure.

When the combustion takes place the piston is subjected to distortion and the energy stored inside the piston serves as determining factor to know the yield and failure conditions of a piston when subjected to static loading. Von misses yield Creation can be formulated in terms of the von misses stress or equivalent tensile stress; a scalar stress value can be computed from the stress tensor.

WORKING CONDITIONS OF PISTON
Moment of explosion in combustion chamber of engine, the gas temperature can reach around 2000ºC– 2200ºC,the temperature of the piston head is generally not less than 200ºC.

Top of the gas under pressure, the pressure for the maximum power stroke, in gasoline engine pressure is up to 3 ~ 5 Mpa and in diesel engine pressure is up to 6 ~ 9 Mpa (standard atmospheric pressure is 0.1 Mpa). High speed of reciprocating motion is about (8 ~ 12 m/s) and the speed is constantly changing.

PISTON FUNCTION
The piston is an element of power transmission in engine cylinder, the energy bounded up in fuel is rapidly converted into heat and pressure during combustion process. In short period of time heat and pressure valve increase greatly, the piston has a task of converting released energy in to mechanical work. The usual structure of the piston is a hallow cylinder and closed on one side with the segment piston head with ring belt, pin bas and skirt. The piston head transfers the gas forces (fuel air mixture) from combustion chamber resulting pin boss, piston pin, and connecting rod to crankshaft [9].

PISTON MATERIAL CONSIDERED FOR DESIGN

The most commonly used materials used for IC engine piston are cast iron, cast aluminum, forged aluminum, cast steel and forged steel. Therefore, mostly used alloys for manufacturing of piston are aluminum alloys having high heat conductivity, machinability. Thus materials used for this work are A4032 and AL-GHY 1250 aluminum alloys listed in table.

Table 1: Thermal and Mechanical Properties of Aluminum Alloys

S. no	PARAMETERS	A4032	AL-GHY 1250
1	Density (kg/m^3)	2684.95	2880
2	Elastic modulus (Gpa)	79	83
3	Ultimate tensile strength (Mpa)	380	1250
4	Yield strength (Mpa))	315	1190
5	Poisson's ratio	0.33	0.3
6	Coefficient of thermal expansion (1/K)	79.2×10^{-6}	20×10^{-6}
7	Thermal conductivity (W/m/^{0}C)	154	135

PROCEDURE FOR PISTON DESIGN

Analytical design for A4032 alloy piston

Thickness of the piston head: t_H

According to Grashoff's formula the thickness of piston head is

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

where $\boldsymbol{\sigma_t} = \frac{\sigma_{ut}}{2.25} = \frac{380}{2.25} = 168.88$ Mpa

$$\boldsymbol{t_H} = 65.5 \times \sqrt{\frac{3 \times 8.77}{16 \times 168.88}}$$

$\boldsymbol{t_H} = 6.46$ mm

Radial thickness of piston rings: t_1

$$t_1 = D \times \sqrt{\frac{3P_w}{\sigma_p}}$$

$$t_1 = 65.5 \times \sqrt{\frac{3 \times 0.025}{110}}$$

$t_1 = 1.710$ mm

Axial thickness of piston rings: t_2

$$t_2 = \frac{D}{10 \times n_r}$$

$$t_2 = \frac{65.5}{10 \times 3}$$

$t_2 = 2.183$ mm

Width of the top land: b_1
$b_1 = t_H$ to $1.2\ t_H$
$b_1 = 6.46$ mm
Width of ring land: b_2
$b_2 = 0.7t_2$ to t_2
$b_2 = 0.7\times2.183 = 1.52$ mm
Maximum thickness of barrel: t_3
$t_3 = 0.03\times D + t_1 + 4.9$
$t_3 = 0.03\times65.5 + 1.710 + 4.9$
$t_3 = 8.575$ mm
Length of the skirt: l_s
$l_s = (0.6D$ to $0.8D)$
$l_s = 0.6\times65.5 = 39.30$ mm
Piton pin diameter: d_0
$d_0 = (0.28D$ to $0.38D)$
$d_0 = 0.28\times65.5 = 18.34$ mm

Analytical design for AL-GHY 1250 alloy piston

Thickness of the piston head: $t_H = 3.563$ mm
Radial thickness of piston rings: $t_1 = 1.710$ mm
Axial thickness of piston rings: $t_2 = 2.183$ mm
Width of the top land: $b_1 = 3.563$ mm
Width of ring land: $b_2 = 1.197$ mm
Maximum thickness of barrel: $t_3 = 8.575$ mm
Length of the skirt: $l_s = 39.30$ mm
Piton pin diameter: $d_0 = 18.34$ mm

MESHING OF PISTON

The piston shape is irregular, especially in the presence of various curved surfaces of inner cavity. Firstly the model is meshed. Then fine mesh is applied to the model. The total number of elements was 29836 and nodes were 52381 found in meshed model.

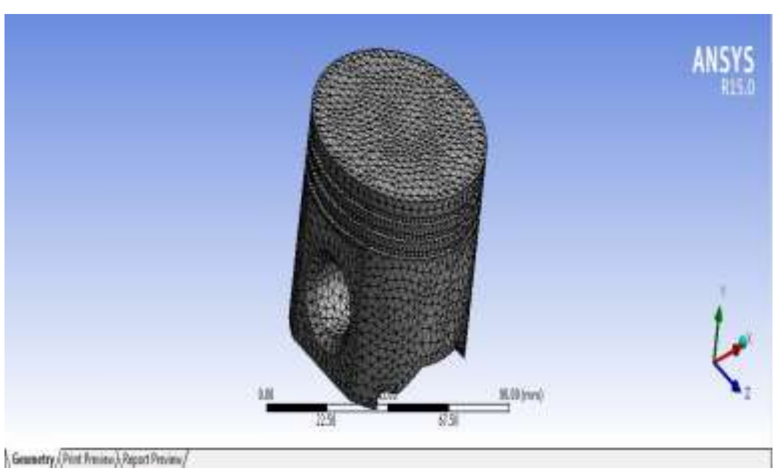

Figure 1: Meshing Of Piston

PISTON ANALYSIS USING STATIC STRESS ANALYSIS METHOD

In this analysis of piston the frictionless support is given at pin bore areas and fixed all degrees of freedom.

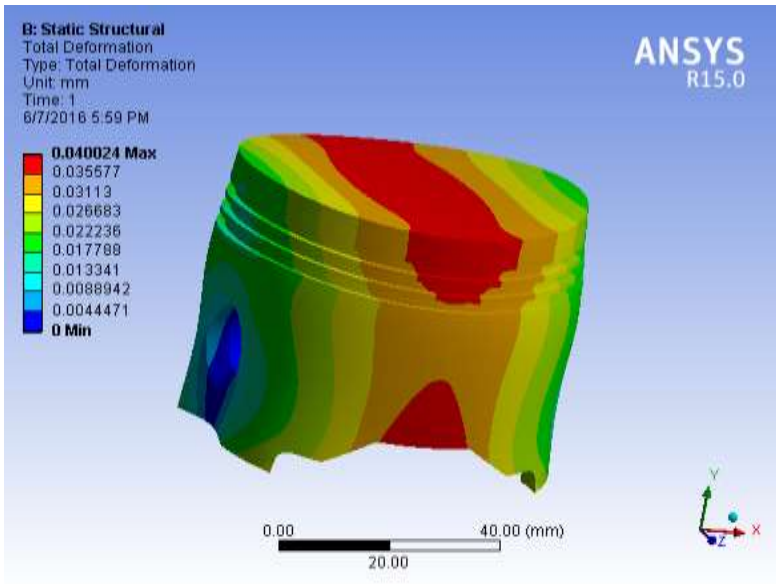

Figure 3: (a) A4032

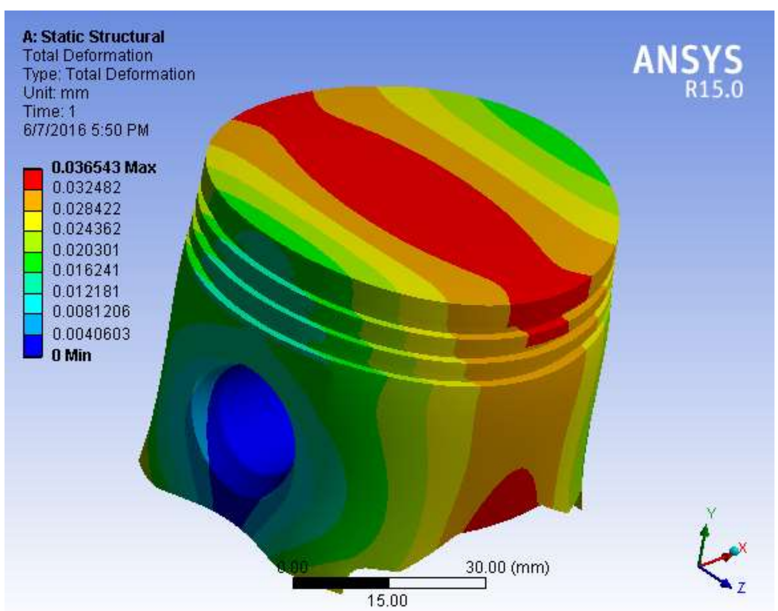

Figure 4: (b) AL-GHY-1250

Total deformation at 6.83 Mpa pressure load on (a) A4032 (B) AL-GHY-1250

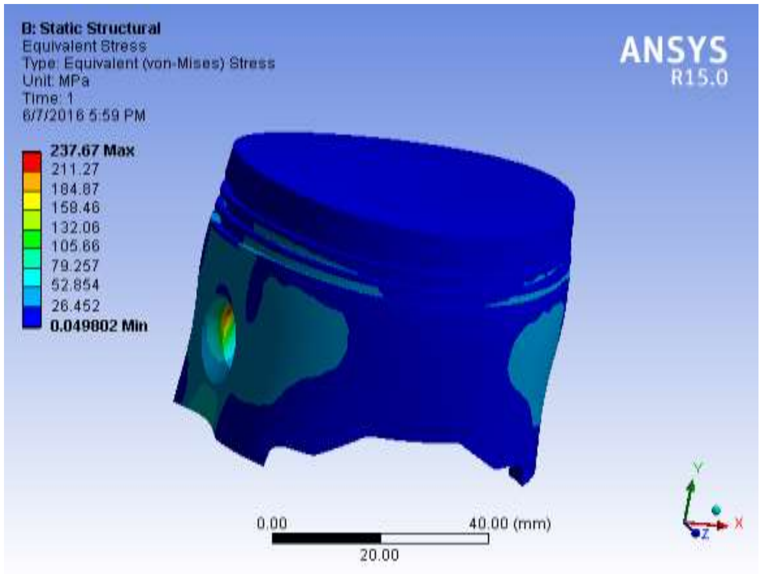

Figure 5: (a) A4032

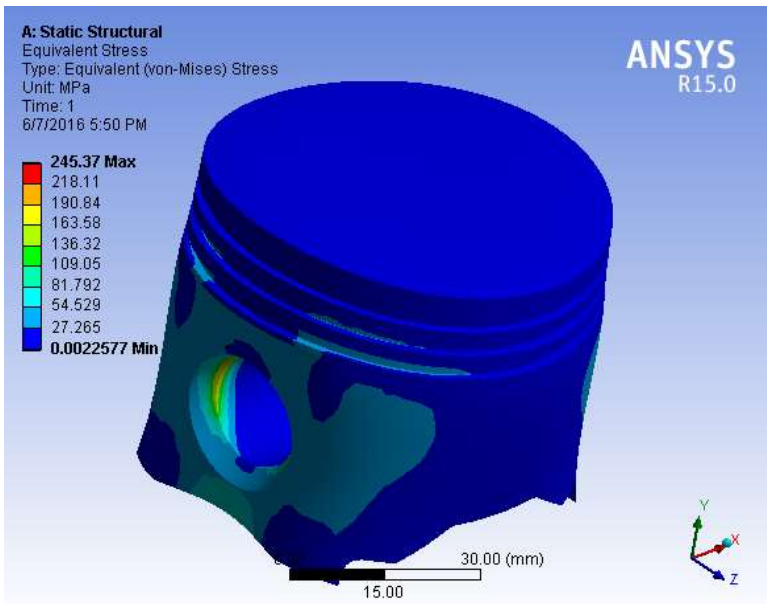

Figure 6: (b) AL-GHY-1250

Von mises stress at 6.83 Mpa pressure load on (a) A4032 (b) AL-GHY-1250

The values of von-mises stress and total deformation at 6.83 Mpa pressure load applied on the piston head is listed in table 3.

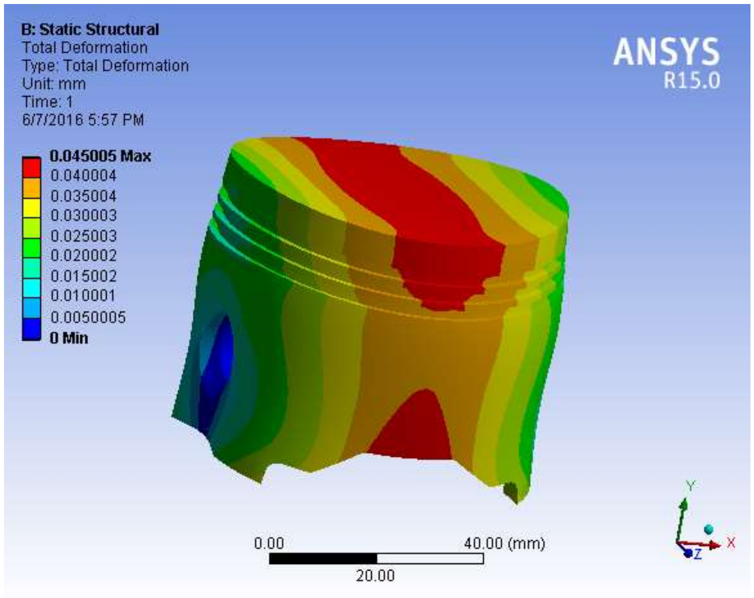

Figure 7: (A) A4032

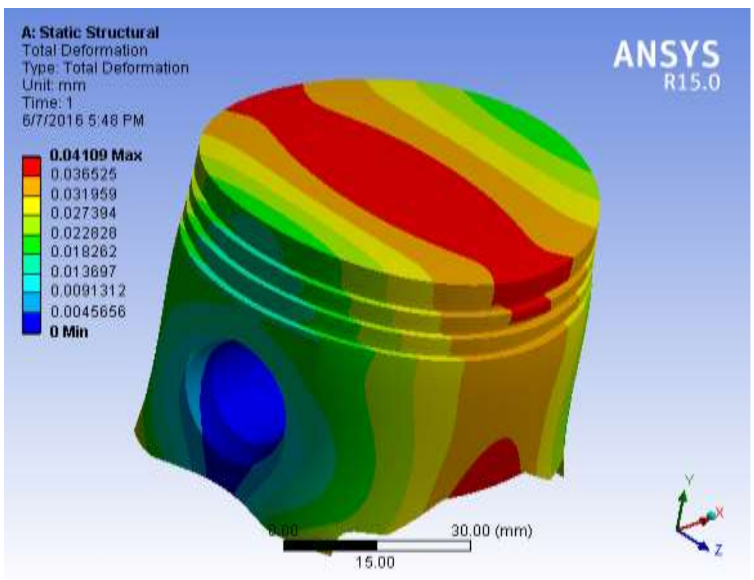

Figure 8: (b)AL-GHY-1250

Total deformation at 7.68 Mpa pressure load on (a) A4032 (b) AL-GHY-1250

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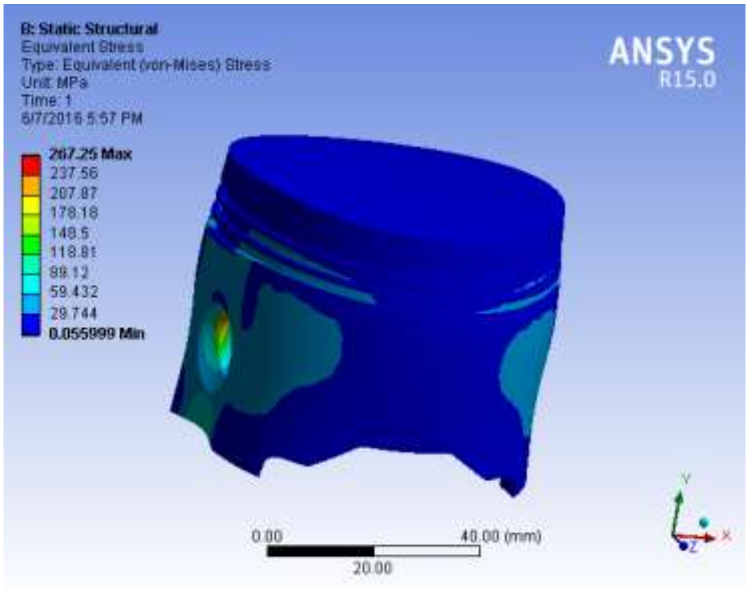

Figure 9: (a) A4032

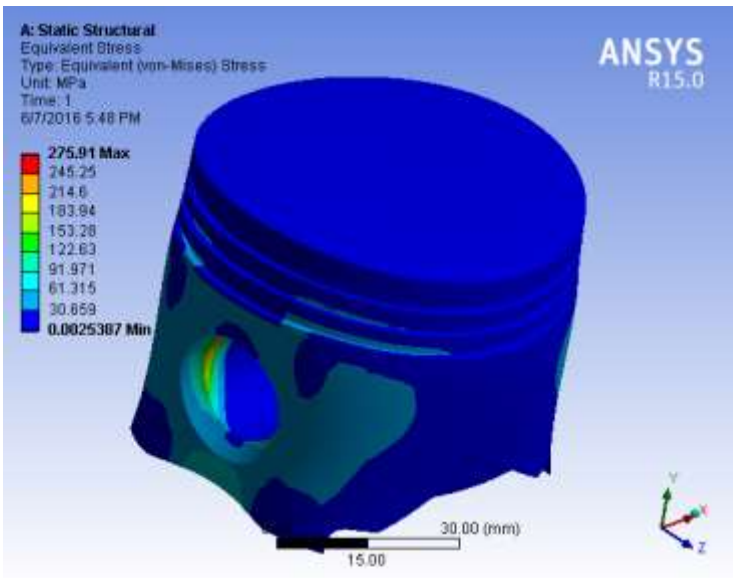

Figure 10: (b) AL-GHY-1250

Von mises stress at 7.86 Mpa pressure load on (a) A4032 (b) AL-GHY-1250

The values of von-mises stress and total deformation at 7.86 Mpa pressure load applied on the piston head is listed in table 3.

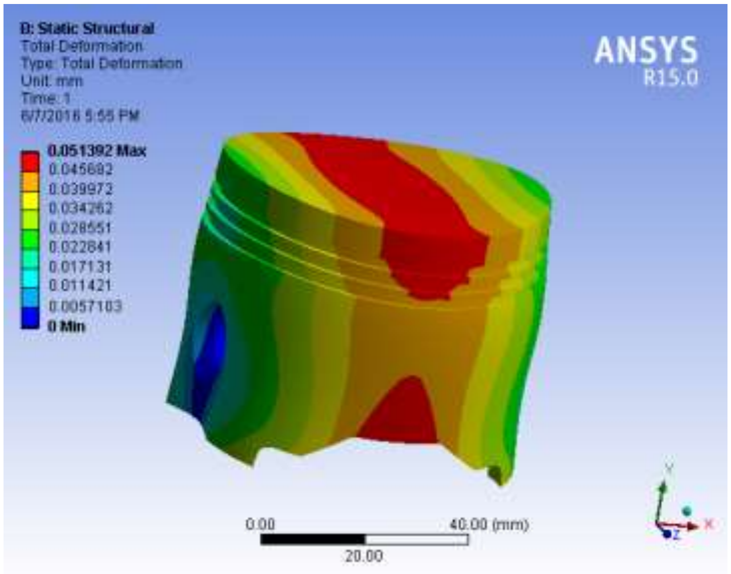

Figure 11: (a)A4032

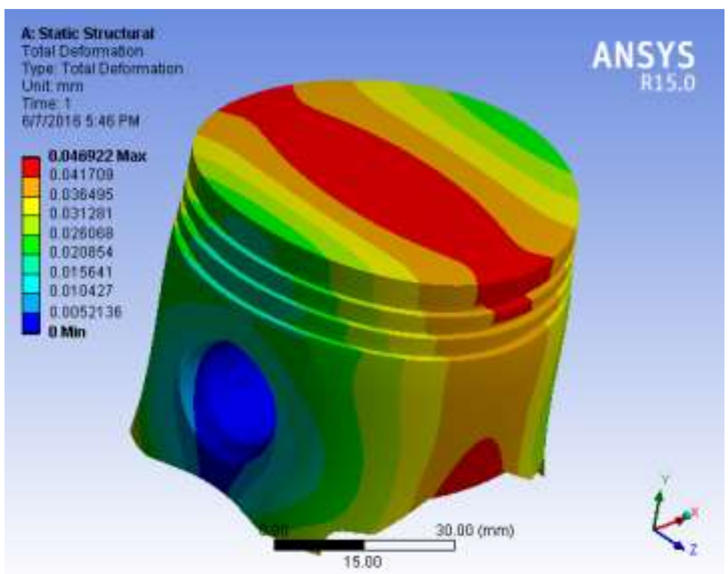

Figure 12: (b)AL-GHY-1250

Total deformation at 8.77 Mpa pressure load on (a) A4032 (b) AL-GHY-1250

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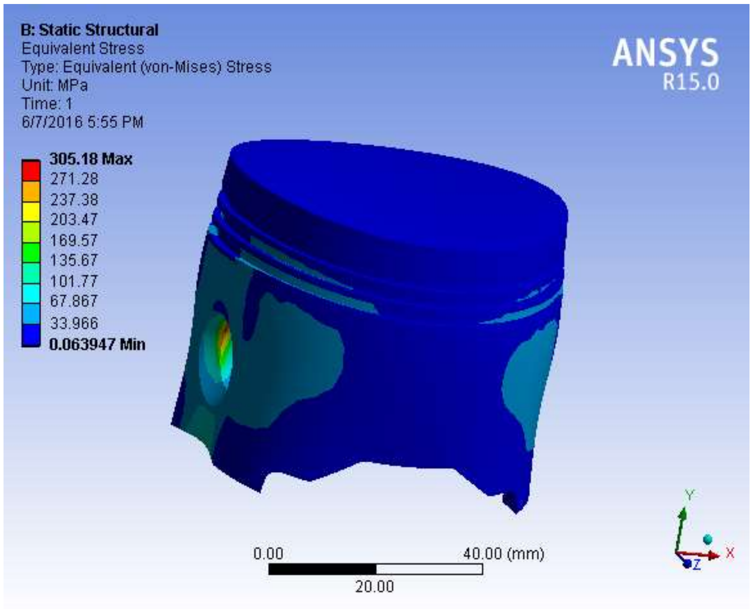

Figure 13: (a) A4032

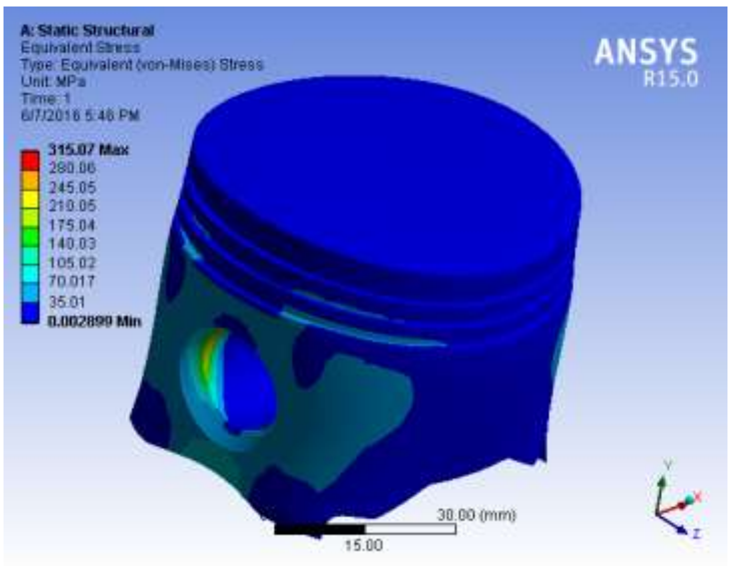

Figure 14: (b) AL-GHY-1250

Von mises stress at 8.77 Mpa pressure load on (a) A4032 (b) AL-GHY-1250

The values of von-mises stress and total deformation at 8.77 Mpa pressure load applied on the piston head is listed in table 3.

RESULTS AND DISCUSSION

The values of total deformation and von-mises stress of two aluminum alloys at different pressure load conditions are listed in table.

Table 3: Deformation and Stress Values under Different Pressure Load Conditions

S. N O	PRESSURE LOAD (Mpa)	MATERIAL	ANSYS RESULT	
			DEFORMATION (mm)	VON-MISES STRESS (Mpa)
1	6.83	A4032	0.040024	237.67
		AL-GHY-1250	0.036543	245.37
2	7.68	A4032	0.045005	267.25
		AL-GHY-1250	0.04109	275.91
3	8.77	A4032	0.051392	305
		AL-GHY-1250	0.0469	315.07

CONCLUSION

The result comparison is made on aluminum alloy materials of piston at different load conditions. Total Deformation is low in AL-GHY-1250 aluminum alloy material at different efficiency pressure load applied on the piston head. AL-GHY-1250 alloy has high strength compared to A4032. From the above result we can conclude that AL-GHY-1250 aluminum alloy material for piston is better than standard alloy material. So, further development of high power engine is possible by using this material.

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