Analysis of Composite Piston

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Abstract- In an engine the purpose of the piston is to transfer force from expanding gas in the cylinder to the crank shaft via a piston rod. Piston has to endure the cyclic gas pressure and the inertial forces at work, and this working condition may cause the fatigue damage of the piston such as piston side wear, piston head cracks and so on. Usually the pistons are made of Aluminum for lightweight, thermal conductivity. But it has poor hot strength and high coefficient of expansion makes it less appropriate for high temperature applications. In this project, Aluminum Silicon Magnesium (Al-Si-Mg), an aluminum matrix composite is used as an alternative for aluminum. A 3D model would be design using design software and structural and fatigue analysis would be analyzed on analysis software. Compared to Aluminum, Al-Si-Mg 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 Al-Si-Mg is also easier than using Aluminum.

Keywords: - Piston, Analysis of piston, Al piston

I. INTRODUCTION

An internal combustion engine is defined as an engine in which the chemical energy of the fuel is released inside the engine and used directly for mechanical work, as opposed to an external combustion engine in which a separate combustor is used to burn the fuel. The internal combustion engine was conceived and developed in the late 1800s. It has had a significant impact on society, and is considered one of the most significant inventions of the last century. The internal combustion engine has been the foundation for the successful development of many commercial technologies. For example, consider how this type of engine has transformed the transportation industry, allowing the invention and improvement of automobiles, trucks, airplanes and trains.

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.

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. R&D and testing engineers should develop critical components in shortest possible time to minimize launch time for new products. This necessitates understanding of new technologies and quick absorption in the development of new products .A piston is a moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine its purpose is to transfer from expanding gas in the cylinder to the crank shaft via piston rod and or connecting rod. As an important part in an engine piston endures the cyclic gas pressure and inertia forces at work and this working condition may cause the fatigue damage of the piston. The investigations indicate that greatest stress appears on the upper end of the piston and stress concentration is one of the mainly reason for fatigue failure.

II. LITERATURE REVIEW

As our primary objective is to study the alternative material for crankshaft for cost reduction and modifying geometry if it does not meets yield/UTS limits and hence a literature survey is carried out to understand current trends in this field.

Jung Ho Son et al. [1] has explained in the paper entitled, “Design and Application of Composite Piston for High Power Diesel Engine” that the development of composite pistons to meet an explosive increase in a worldwide energy demand and to cut down overall product cost.

Javad Falsafi et al. [2] has explained in the paper entitled, “Lower Cost Automotive Piston from 2124/SiC/25p Metal-Matrix Composite” that the results of the study of the precision forging of an automotive piston from 2124/SiC/25p metal matrix composite. The study was carried out using finite element simulations. The aim was to get a better insight into the practical aspects associated with the forging process carried out under different forging conditions; isothermal forging on a hydraulic press and hot forgin on a screw press.

Yaohui Lu et al. [3] has explained in the paper entitled, “Analysis of thermal temperature fields and thermal stress under steady temperature field of diesel engine piston” that the thermal stress field only caused by the uneven temperature distribution. To simulate the stress field, the steady-state temperature field was calculated. Comparing with the transient state temperature field, the temperature fluctuation is small according to the simulation results so the steady-state

F.S. Silva [4] has explained in the paper entitled, "Fatigue on engine pistons – A compendium of case studies" that engine pistons are one of the most complex components among all automotive or other industry field components. The engine can be called the heart of a car and the piston may be considered the most important part of an engine.

Muhammet Cerit et al. [5] has explained in the paper entitled, "Temperature and thermal stress analyses of a ceramic-coated aluminum alloy piston used in a diesel engine" that to determine both temperature and thermal stress distributions in a plasmasprayed magnesia-stabilized zirconia coating on an aluminum piston crown to improve the performance of a diesel engine. Effects of the coating thickness on temperature and thermal stress distributions are investigated, including comparisons with results from an uncoated piston by means of the finite element method. Temperature and thermal stress analyses are performed for various coating thicknesses from 0.2 to 1.6 mm excluding the bond coat layer.

K. Venkatareddy et al. [6] has explained in the paper entitled, "Design and analysis of the piston by using composite materials" that the piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms.

Douglas M. Baker et al. [7] has explained in the paper entitled, "A methodology of couple thermodynamic and heat transfer analysis of diesel engine" that using one-dimensional (I-D) resistor heat flow models, a thermodynamic diesel engine simulation first predicts instantaneous gas temperatures and convective heat transfer coefficients throughout the engine cycle.

Ekrem Buyukkaya et al. [8] has explained in the paper entitled, "Thermal analysis of a ceramic coating diesel engine piston using 3-D finite element method" that the investigated thermal analyses on a conventional (uncoated) diesel piston, made of aluminum silicon alloy and steel. Secondly, thermal analyses were performed on pistons, coated with MgO–ZrO2 material by means of using a commercial code, namely ANSYS.

III. METHODOLOGY

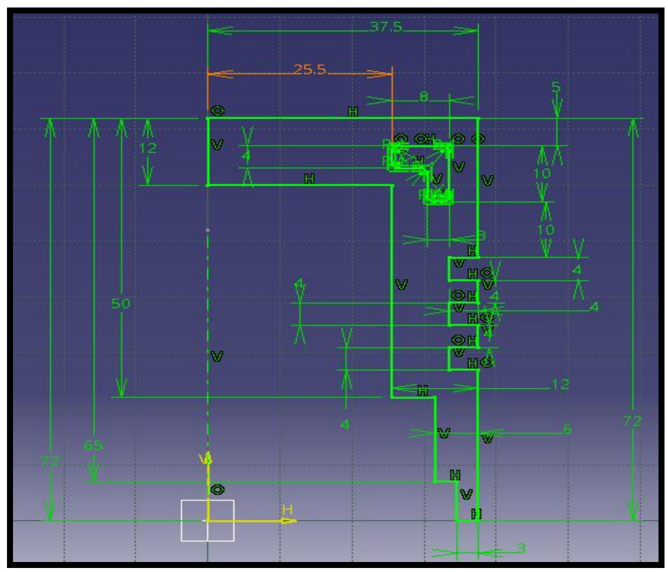
A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings.

3.1 DESIGN & ANALYSIS OF PISTON

Table 01:-Technical data for the AV1 engine

Specification	Type
Cooling	Water-Cooled Engine
Model	AV1
No. of Cylinders	1
Cubic Capacity (ltr)	0.553
Governing	Class"B1"
Power rating	5 hp
Fuel injection	Direct Injection
Rated Speed (rpm)	1500
Overall Dimensions of the standard engine	617 X 504 X 843 (L X B X H)

The piston diameter is 75 mm and depth is 72 mm while the thickness of cavity in the piston is 4 mm and the height is 10 mm.



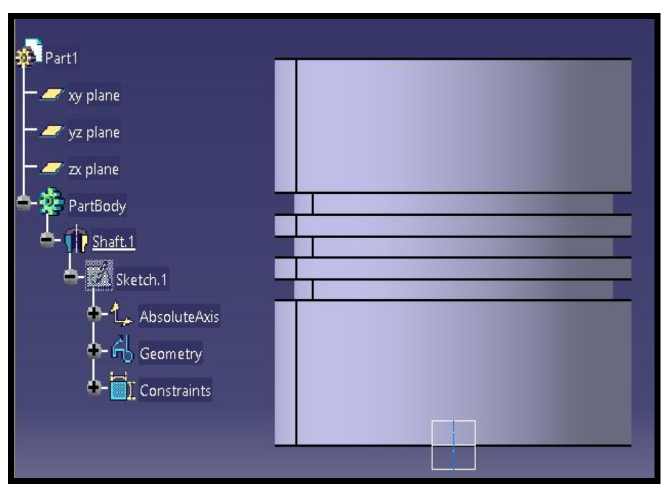


Figure 2:- Piston 3D Model

Mechanical efficiency of the engine (η) = 80 %.
η = Brake power (BP)/Indicating power (IP)
Therefore, I.P = B.P/ η, = 5/0.8= 6.25 kW
Also, Indicative power, IP = P*A*L*N/2= P*(π*D2/4)*L*(N/2)
Substituting the values, we have
6.25 x 1000 = P x (π x $(0.075)^2/4$) x 0.072 x (1500/(2x60))
6250 = P x 0.000397406
P = 6250/0.000397406
P = 15.72 x 10^5 N/m2 or 1.572 MPa
Maximum pressure, pmax= 10 x P, = 10 x 1.572 = 15.72 MPa

[A] Finite Element Analysis of Cylinder Piston

Table 02:-Boundary Conditions

Parameter	Case 4 (Full Load)
Temperature in °C	
T_g (Gas side)	1000
T_w (Water side)	120
T_a (Air side)	80
Heat transfer coefficients (Gas side, Water side, Air side) (W	
H_g (Gas side)	290.5
H_w (water side)	1859.2
H_a (Air side)	174.3

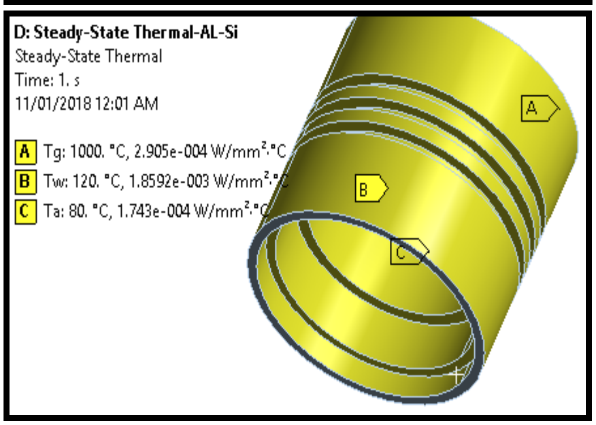


Figure 3 :-Steady State Thermal AL-Si

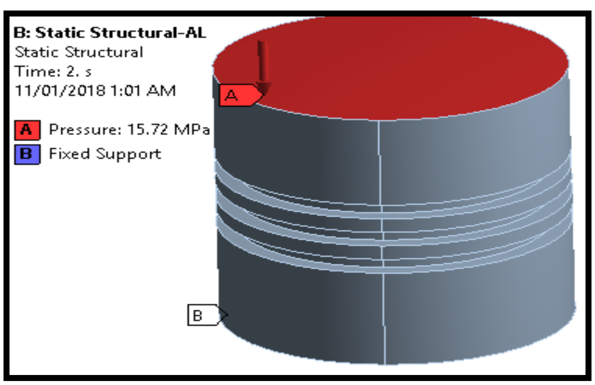


Figure 4:- Static Structural AL

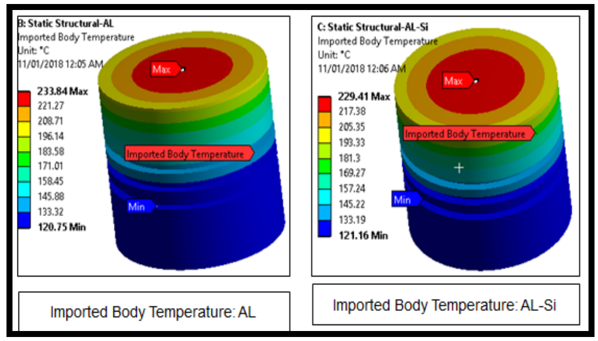


Figure 5:- Imported Body Temp for Static Analysis

III. RESULTS

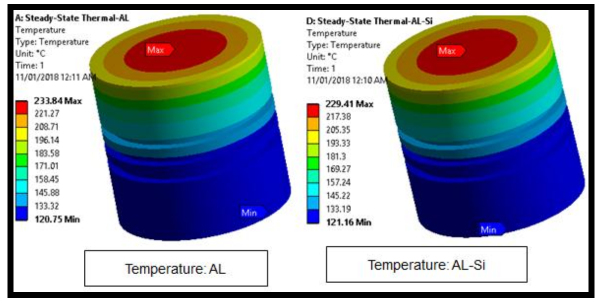


Figure 6:- Piston Temperature Plot

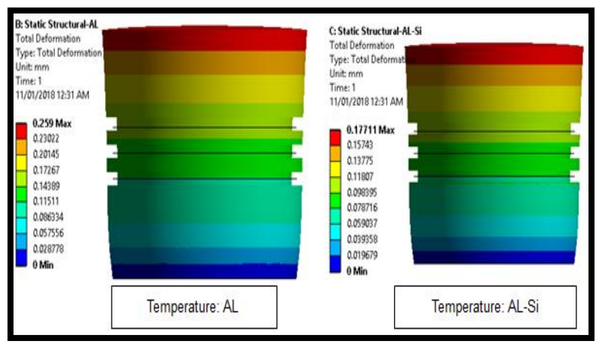


Figure 7:- Deformation Plot for Temperature Only

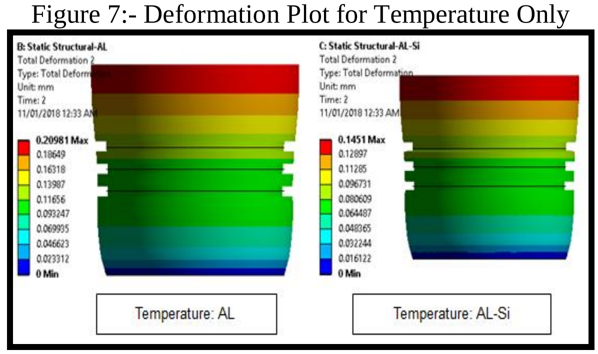


Figure 8:- Deformation Plot for Cylinder Pressure + Temperature

[B] Fatigue analysis of piston:

Stress Life based on empirical S-N curves is considered here to calculate fatigue life of piston. Constant amplitude with fully reverse loading were considered with Goodman theory for the mean stress.

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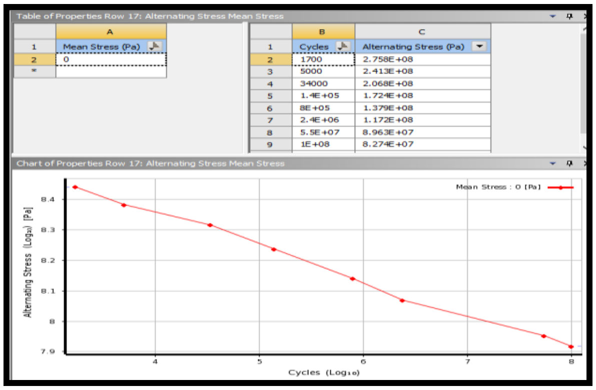

Figure 9:- S-N Curve for AL/AL-Si

The AL material of piston have min life of 3004 cycles whereas AL-Si gives 5094 no of cycles.

IV. CONCLUSIONS

Composite AL-Si material has been successfully used to calculate temperature and Stresses. Kirloskar AV1 Agricultural single cylinder engine piston used here. Max temperature of 233˚C at piston crown was observed with AL and 229˚C with AL-Si material due to negligible difference in thermal conductivity.

Deformation and stresses of piston with AL-Si material is observed on lower side compared to AL piston. AL piston have FOS of 1.65 whereas AL-SI have FOS of 6.86. AL-SI has observed lower deformation compared to AL piston due to lower thermal expiation of composite. The AL material of piston has min life of 3004 cycles whereas AL-Si gives 5094 no of cycles. Based on all above observations, with AL-Si piston gives best performance compared to conventional AL piston.

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