Design Analysis of Piston for Four Stroke Single Cylinder Engine

Prof.Dr.D.B. Hulwan ,Vedant Awachar, Chetan Bhagat,
Prathamesh Bhosale, Bhushan Berlikar, Om Bobade

Abstract

This study examines structural analysis on a standard piston manufactured of the Aluminium alloy A2618. A second analysis is done on a piston constructed of Aluminium alloys GHY1250 and GHS1300. The material chosen for the piston's design must be lightweight, inexpensive, and thermally and structurally stable at the extremely high pressure and temperature conditions that would be present during the combustion process. It has been determined to investigate a certain piston design and its capacity for maximum gas pressure in this project. Using the solid modeling programme, a piston model is what this project's early planning entails. It has been decided to use ANSYS to mesh the geometry analysis. There has been a significant amount of literature research done on the analysis of piston input circumstances and analysis process.

Keyword:-

Piston Design Parameters,Four-Stroke Engine Dynamics,Thermal Stress Analysis,Mechanical Stress Analysis,Finite Element Analysis (FEA), Piston Material Selection,Heat Transfer Analysis,Combustion Pressure Load,Fatigue Life Estimation,Thermal Expansion,Wear Resistance,Cylinder-Piston Interf

Introduction

One of the most crucial parts of an internal combustion engine that rotates inside the cylinder is the piston. The piston's primary job is to use the connecting rod to transmit the force of the cylinder's gas to the crankshaft. In order to control thermal stresses and deformation in working conditions, it is crucial to calculate the temperature distribution on the piston. The piston experiences periodic load effects as a result of high gas pressure and fast reciprocating inertia forces. The chemical reaction of burning the gas at high pressure creates lateral force, which causes the piston to expand and produce thermal stresses and thermal deformation. Piston cracks are caused by heat and mechanical deformation.

Piston - The most crucial part of a reciprocating internal combustion engine, the piston moves back and forth inside the cylinder. It's hot additionally, the high gas pressure's strain on the piston inside the cylinder may result in fatigue damage to the piston, such as cracks in the piston head or side wear, among other things.

Piston in an IC engine must possess the following characteristics:

• It should have strength to resist high gas pressure and inertia forces.
• It should have minimum weight.
• It should be able to reciprocate at high speed with negligible noise.
• Its construction should be rigid in order to withstand thermal and mechanical distortion.
• It must have sufficient bearing area to prevent wear.
• It should have an effective sealing the gas from top and oil from the bottom.
• It should disperse the heat generated during combustion to the cylinder walls.
• It must have good resistance to distortion under heavy forces and heavy temperature.

So to resist all the loads and stresses, proper material of the piston is selected to obtain better performance of an IC engine

Methodology

Analytical design of piston, using specification of four-stroke single-cylinder engine of Bajaj Kawasaki motorcycle created.

- Creation of 3D model of piston using Solidworks and then imported in HyperMesh.
- Mesh of 3D model using HyperMesh.
- Analysis of piston using stress analysis method.
- Comparative performance of Al alloy piston.
- Select the best Al alloy

Engine Specifications - The specifications of the engine and materials used for this type of work are shown below.

Table 1. a) Engine Specifications

Sr no	Parameters	Values
1	Engine Type	Four stroke, Petrol Engine
2	Induction	Air cooled type
3	Number of cylinders	Single cylinder
4	Bore (D)	50 mm
5	Stroke	81.25 mm
8	Compression ratio	8.4
9	Maximum power	6.03 KW at 7500 rpm
10	Maximum Torque	8.05 Nm at 5500 rpm
12	Speed	5000rpm
13	Brake Power	8BHP
14	Maximum pressure	15 N/mm^2

Piston Materials - The most commonly used material for piston of IC engines is Al alloy and cast iron. But Al alloy are more preferable in comparison of cast iron due to its light weight. The heat conductivity of Al alloy is four times that of cast iron. Aluminium pistons are made thicker which is necessary for strength in order to give proper cooling.

Table 2. Mechanical Properties of Materials

S.no	Parameters	A2618	Al-GHY 1250	Al-GHS 1300
1	Elastic / Young Modulus (GPa)	70-80	83	98
2	Ultimate tensile strength (MPa)	440	1250	1300
3	Yield Strength (MPa)	370	1190	1220
4	Poisson's Ratio	0.33	0.3	0.3
S5	Thermal Conductivity (W/m°c)	147	135	120
6	Density (kg/m^3)	2767.298	2880	2780

Properties Of Materials - The material chosen for this work are conventional Al alloy i.e. A2618, Al-GHY1250, Al-GHS1300 for an IC engine piston. The Mechanical properties of conventional Al alloy alloy i.e. A2618, Al-GHY1250, Al-GHS1300, Al-GHY1250, AlGHS1300 are listed in the following table.

The working condition of the piston of an internal combustion engine is so worst as compared to other parts of I.C. engine. There are high chances of failure of the piston due to wear and tear. So it is necessary to analyze the area of maximum stress concentration on the piston. The objective of the present work is to design and analyze piston made of A2618, Al-GHY1250, AlGHS 1300. In this paper, the material of piston A 2618 is replaced by Al-GHY1250 and Al-GHS 1300.

Piston Design - Design Consideration for a Piston

In the design of a piston, the following points should be taken into consideration:

I. It should have minimum mass.

II. It should have high-speed reciprocation without noise.

III. It should have high strength to withstand the high gas pressure and inertia forces.

IV. It should be rigid in construction to withstand thermal and mechanical distortion.

V. It should have sufficient bearing area to prevent wear.

Analytical design

η= Mechanical efficiency= 80% =0.8
N= Engine speed = 5000 rpm
η= Brake power (B.P) / Indicating power (I.P)
I.P = B.P / η = 8/ 0.8 = 10 KW
I.P. = PALN/120
P=(120*I.P)/ALN = 15.04 * 105 N/m2
P= 1.504 MPa
Maximum pressure= 10 * P = 15.04 MPa

a) Analytical design for A2618 alloy piston
Thickness of piston head (tH):
The thickness of piston head, according to Grashoff's formula is given by,
tH = $\sqrt{3PmaxD2/16t}$ ………………..in mm

(2)
tH = 4.4 mm
Heat flow through the piston head (H)
The heat flow through the piston head is calculated using formula
H = 12.56 *tH* k * (Tc-Te) ………………..in KJ/sec

On the basis of heat dissipation, the thickness of the piston head is given by,
tH= C * HCV * m * B.P. * 106 / 12.56 * k * (TcTe)
tH = 3.6 mm ……………m=95.45 kg/BP/s
The maximum thickness from the above formula is tH= 4.4 mm
Radial thickness of ring (t1)
$t1 = \sqrt{3Pw/\sigma t}$

(3)
t1 = 1.5 mm
The thickness of the ring may be taken as,
t2 = 0.7 t1 to t1

(4)
t2 = 1 mm
Number of rings (nr)
Minimum axial thickness (t2)
t2 = D/(10 * nr)
nr = 3rings
Width of top land and ring lands
Width of the top land (b1):
b1= tH to 1.2 tH = 4.4 mm

(5)
Width of ring land (b2):
b2=0.75 t2 to t2= 0.75 mm

(6)
Maximum thickness of the barrel at the top end (t3):
b= 0.4 + t1
t3=0.03 D + b + 4.5
t3=0.03 D + t1 + 4.9 = 7.9 mm

(7)
Thickness of piston barrel at the open end (t4):
t4= 0.25 t3 to 0.35t3 = 1.975 mm

(8)
Length of skirt
ls= 0.6 D to 0.8 D= 30 mm
Length of piston pin in the connecting rod bushing:
lp= 45% of the piston diameter= 22.5 mm
Total length of the piston(L)
Total length of the piston is given by
L=Length of skirt + Length of ring section + Top land = ls+ lr + b1= 30 +5.5 + 4.4 = 40.92 mm
Piston pin diameter (do &di)
do= 0.28 D to 0.38 D = 14 mm
di= 0.6 do= 8.4 mm
The center of the piston pin should be 0.02 D to 0.04 D above the center of the skirt = 1.5 mm

(b) Analytical design for Al-GHY1250 alloy piston
Thickness of piston head (tH) =3.919644 mm
Radial thickness of ring (t1) = 1.5mm
Axial thickness of ring (t2) = 1.05 mm
Width of the top land (b1) = 3.919644 mm
Width of ring land (b2)=0.7875 mm

Maximum thickness of the barrel at the top end (t3) =7.9mm

Thickness of piston barrel at the open end (t4) =1.975mm

Length of skirt (ls) =30mm
Length of piston pin in the connecting rod bushing (lp) =22.5mm
Total length of the piston (L) = 40.48214 mm
The Length of piston usually varies between D to 1.5 D Piston pin diameter =do= 14, di= 8.4 mm

(c) Analytical design for Al-GHS1300 alloy piston

Thickness of piston head (tH) =4.409599 mm
Radial thickness of ring (t1) = 1.5mmAxial thickness of ring (t2) = 1.05mm
Width of the top land (b1) = 4.409599mm
Width of ring land (b2) =0.7875 mm

Maximum thickness of the barrel at the top end (t3) =7.9 mm

Thickness of piston barrel at the open end (t4) =1.975mm

Length of skirt (ls) =30mm

Length of piston pin in the connecting rod bushing (lp) =22.5mm

Total length of the piston(L) =40.9721mm

The Length of piston usually varies between D to 1.5 D Piston pin diameter do= 14 mm di= 8.4 mm

Static Structural Analysis

a) For A2168 Alloy

The figure illustrates the total deformation of the piston. The value of maximum deformation is 0.10001mm .The value of minimum deformation 0.011112 mm, which is occurred at the center of piston head as shown in figure

Table 3. Output parameters for different materials

Properties	A2618	Al-GHY1 250 alloy piston	Al-GHS 1300 alloy piston
Thickness of piston head (t_H)	4.4mm	3.9196 44 mm	4.40mm.
Radial thickness of ring (t_1)	1.5mm	1.5mm	1.5 mm
Axial thickness of ring (t_2)	1mm	1.05 mm	1.05mm.
Width of the top land (b_1)	4.4mm	3.9196 44 mm	4.40mm
Width of ring land (b_2)	0.75m m	0.7875 mm	0.7875 mm
Maximum thickness of the barrel at the top end (t_3)	7.9mm	7.9mm	7.9 mm
Thickness of piston barrel at the open end (t_4)	1.975m m	1.9475 mm	1.975 mm
Length of skirt (l_s)	30mm	30mm	30mm
Length of piston pin in the connecting rod bushing (l_p)	22.5	22.5m m	22.5mm
Total piston length (L)	40.92m m	40.482 14 mm	40.97214 mm
Piston pin diameter (d_o & d_i)	14&8.4 mm	14&8.4 mm	14&8.4

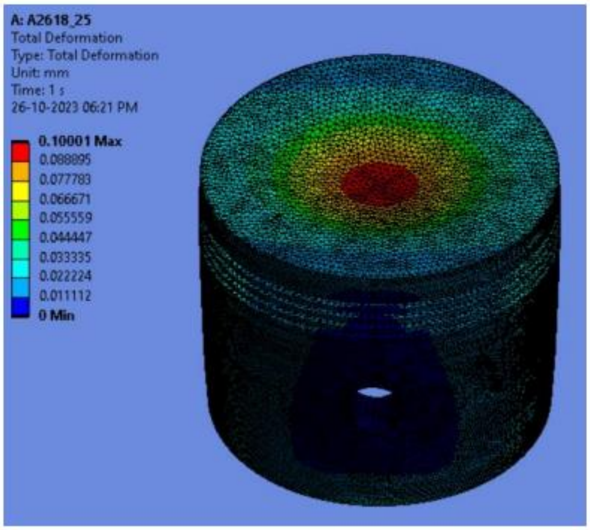

Fig. 1 Total Deformation

b) For A2618 Alloy

Figure 2 illustrates the variation of von-mises strain in the piston. The value of maximum strain was found to be 0.00578 MPa. The value of minimum strain is found to be 0.00064387 MPa.

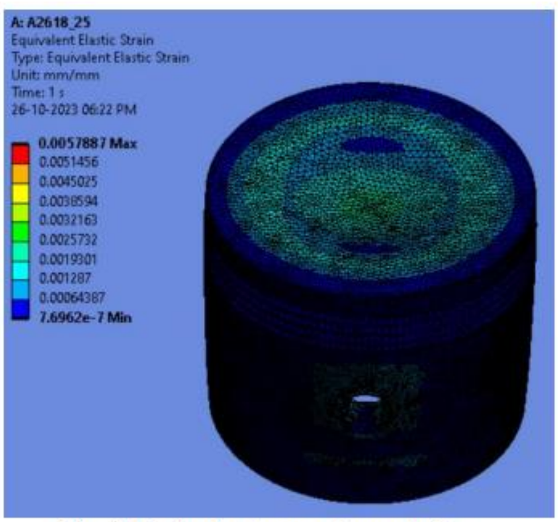

Fig. 2 Equivalent von-misses strain

c)For A2618 Alloy

The figure 3 illustrates the variation of von-mises stress in the piston. The value of maximum stress found to be 361 MPa. The value of minimum stress is found to be 0.042609 MPa.

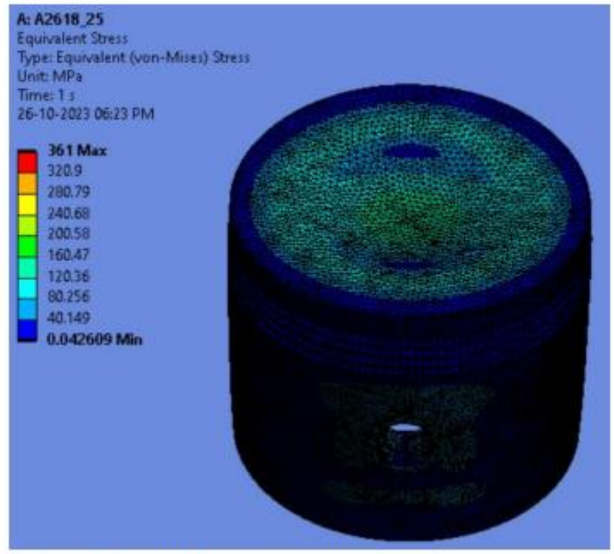

Fig. 3 Equivalent von-misses stress

Heat Flux Analysis for Al-GHS1300

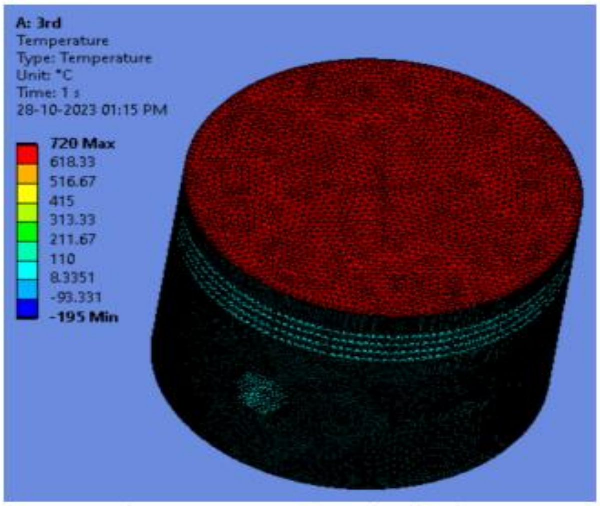

Fig. 12 Temperature distribution

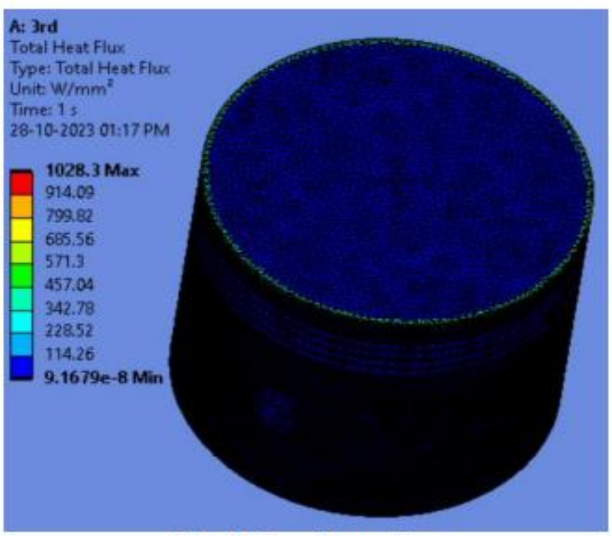

Fig. 12 Total heat flux

Comparative Analysis

S no	Parameters	Al alloy A2618 Max Min	AlGHY1 250 Max Min	AlGHS1300 Max Min
1	Total Deformati on (mm)	0.1000 0.011112	0.08549 0.009499	0.072464 0.0080516
2	Equivalent von-misses stress (MPa)	361 0.042609	366.56 0.22049	336.87 0.036998
3	Equivalent von-misses strain (MPa)	0.00578 0.000643 87	0.004950 0.000553 7	0.0038322 0.00042617

Conclusion

After doing a comparative analysis of various types of Al alloy i.e.in between A2618, AlGHY1250, and Al-GHS1300. for total deformation, equivalent von Mises stress, and equivalent von- mises strain.

From the analyzed result through this work, it is concluded that stress that occurred by using this material is lower than the permissible stress value, soAl-GHS1300 is the best material for piston

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