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ANALYSIS AND COMPARISON OF ALUMINIUM ALLOY [Al 2024-T6] AND SILUMIN PISTON BY USING FEA

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ABSTRACT

A piston is a component of reciprocating engines. Its purpose is to transfer force form expanding gas in the cylinder to the crank shaft via piston rod and a connecting rod. It is one of the most complex components of an automobile. The main objective of this paper is to compare the two different materials [ALUMINIUM ALLOY Al 2024-T6 AND SILUMIN] made of piston with design change to attain less volume, less weight, minimum deformation, minimum strain, and better efficiency on the basis of coupled field analysis. A proper finite element model is developed using cad software pro/E wildfire 5.0. Complete design is imported ANSYS 14.5 software then analysis is performed. Result are shown and a comparison is made to find the best suited material for design and reduced cost for mass production.

Keywords- ANSYS 14.5, ALUMINIUM ALLOY [Al2024-T6], SILUMIN, pro/E wildfire 5.0,

I. INTRODUCTION

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.

An Internal Combustion Engine is that kind of prime mover that converts chemical energy to mechanical energy. The fuel on burning changes into gas which impinges on the piston and pushes it to cause reciprocating motion. The reciprocating motion of the piston is then converted into rotary motion of the crankshaft with the help of connecting rod. IC engines are used in marine, locomotives, aircrafts, automobiles and other industrial applications. A piston is a component of reciprocating IC-engines. 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.

1.2 Objective of the Thesis

Comparison of two material [ALUMINIUM ALLOY [Al 2024-T6] and [SILUMIN] for the manufacturing of piston of automobile application based on minimum weight , less volume , better efficiency and minimum deformation for safe design using structural and coupled field analysis.

1.3 Project Requirements

Software's are main requirement for this project. For software requirement, I have chosen PRO E and ANSYS WORKBENCH Software. PRO E is a software tool suite used primarily for design. By using this software we can create only 3D design. The next software is ansys workbench which is widely used for analyzing purpose. By using this software we can get the values of maximum deformation, strain and stress values of piston.

1.4 Selection of Material

1.4.1 ALUMINIUM ALLOYS [AL2024-T6]

Aluminium alloys typically have an elastic modulus of about 70 GPa, which is about one-third of the elastic modulus of most kinds of steel and steel alloys. Therefore, for a given load, a component or unit made of an aluminium alloy will experience a greater elastic deformation than a steel part of the identical size and shape. Though there are aluminium alloys with somewhat-higher tensile strengths than the commonly used kinds of steel, simply replacing a steel part with an aluminium alloy might lead to problems.

Model type:	Linear Elastic Isotropic
Default failure criterion:	Deformation and strain
Yield strength:	4.05e+008 N/m^2
Tensile strength:	4.7e+008 N/m^2
Compressive strength:	4.7e+008 N/m^2
Elastic modulus:	7.24e+010 N/m^2
Poisson's ratio:	0.33
Mass density:	2800 kg/m^3
Shear modulus:	2.8e+010 N/m^2
Thermal expansion coefficient:	2.3e-005 /Kelvin

Table 1.1: mechanical properties of Al 2024-T6 material

1.4.2 SILUMIN

Silumin is the name that is used in some countries for alloys based on Al–Si system. Silumin is a series of lightweight, high-strength aluminium alloys with silicon content within range of 3–50%. Most of these alloys are casting ones, but also it would be produce by rapid solidification processes and powder metallurgy.

Within the Aluminum Association designation system silumin are corresponding to alloys of two systems: 3xx.x – Aluminum–silicon alloys, and 4xx.x – Binary aluminum–silicon alloys. Among the advantages of silumin is its high resistance to corrosion, making it useful in humid environments.

Model type:	Linear Elastic Isotropic
Default failure criterion:	deformation and strain
Yield strength:	4.11e+008 N/m^2
Tensile strength:	1.823e+008 N/m^2
Elastic modulus:	7.74e+010 N/m^2
Poisson's ratio:	0.37
Mass density:	2659 kg/m^3
Shear modulus:	916.256 N/m^2

Table 1.2: mechanical properties of silumin material

II. EXPERIMENTAL PROCEDURE

2.1 LOAD CALCULATION

Mechanical efficiency of the engine (η) = 80 %.

η = Brake power (B.P)/ Indicating power (I.P)

Therefore,

I.P = B.P/ η = 6.2/0.8 = 7.75 KW

Also, I.P = P x A x L x N/ 2

I.P = P x (π D^2/4) x L x (N/2)

Substituting the values

7.75 x 1000 = P x (π $(0.14)^2$/4) x 0.152 x (5000/ (2x60))

P = 0.7949 MPa

Maximum Pressure

p_{max} = 10 x P = 10 x 0.7949 = 7.949 MPa

2.2 ANALYTICAL DESIGN FOR ALLUMINIUM ALLOY [AL2024-T6] PISTON

- THICKNESS OF PISTON HEAD (t_H)

The piston thickness of piston head calculated using the following Grashoff's formula

$$t_H = D\sqrt{3Pmax/16\sigma t}$$

$$t_H = 140\sqrt{3\times7.921/16\times307}$$

$$t_H = 9.738 \text{ mm}$$

Where,

D = Cylinder bore / outside diameter of the piston in mm

σt = allowable tensile strength (Mpa)

- RADIAL THICKNESS OF RING (t_1)

$$t_1 = D\sqrt{3\,Pw/\,\sigma t}$$

$$t_1 = 140\sqrt{3\times0.115/307}$$

$$t_1 = 5.244 \text{ mm}$$

P_w = pressure of fuel on cylinder wall in N/mm^2. Its value is limited from 0.115 N/mm^2 to 0.142 N/mm^2

- AXIAL THICKNESS OF THE RING (t_2)

Sl.NO	**Dimensions**	**Size in mm**
1	Length of the Piston (L)	152
2	Cylinder bore/outside diameter of the piston(D)	140
3	Thickness of piston head (t_H)	8.036
4	Radial thickness of the ring (t_1)	5.04
5	Axial thickness of the ring (t_2)	5
6	Width of the top land (b_1)	10
7	Width of other ring lands (b_2)	3.5
8	Thickness of barrel (t_3)	14.34

$t_2 = 0.7\ t_1$ to t_1

$t_2 = 5$ mm

- WIDTH OF THE TOP LAND (b_1)

$b_1 = t_H$ to $1.2\ t_H$

$b_1 = 10$ mm

- WIDTH OF THE OTHER RING LANDS (b_2)

$b_2 = 0.75\ t_2$ to t_2

$b_2 = 4$ mm

- MAXIMUM THICKESS OF BARREL [t_3]

$t_3 = 0.03*D+b+4.5$mm

$t_3 = 14.34$ mm

2.3 Analytical Design For Silumin Piston

2.4 MODELLING OF PISTON

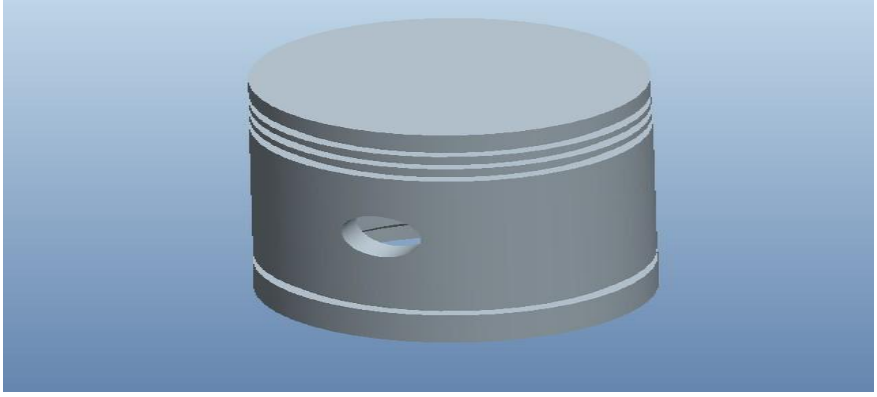

Fig 2.1: 3D view ofAl 2024-T6 piston in proe

2.4.1 Meshing of piston

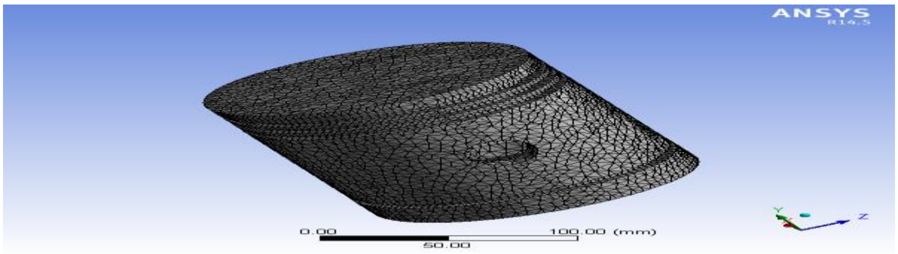

Fig 2.2: meshing diagram of Al 2024-T6 piston

III. ANALYSIS OF PISTON UNDER THERMAL AND MECHANICAL LOADS [COUPLED FIELD]

- Frictionless support at pin bore areas
- Downwards pressure [7.949MPa] to gas load acting on piston head
- Temperature and heat transfer coefficient applied to the piston

SL.NO	PISTON REGION	TEMPERATURE [^{0}c]	HEAT TRANSFER COEFFICIENT[W/m^{2}k]
1	Piston head	623	3200
2	Width of top land	603	2400
3	Piston ring area	523	1600
4	Piston skirt area	413	1000

Table 3.1: Temperature and heat transfer coefficient applied to the piston

3.1 Al2024-T6 PISTON UNDER COUPLED FIELD ANALYSIS

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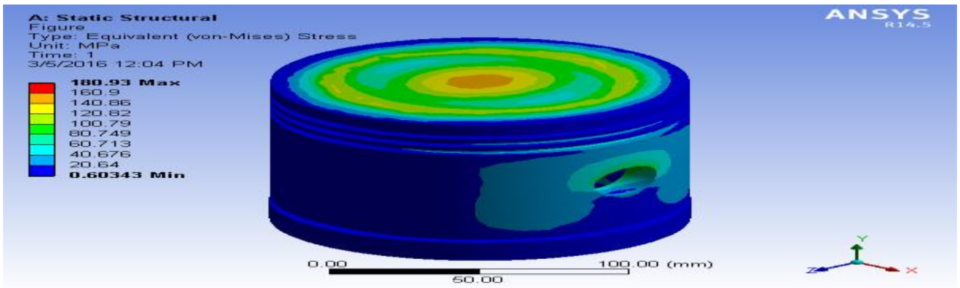

Fig 3.1: Von misses stress analysis diagram

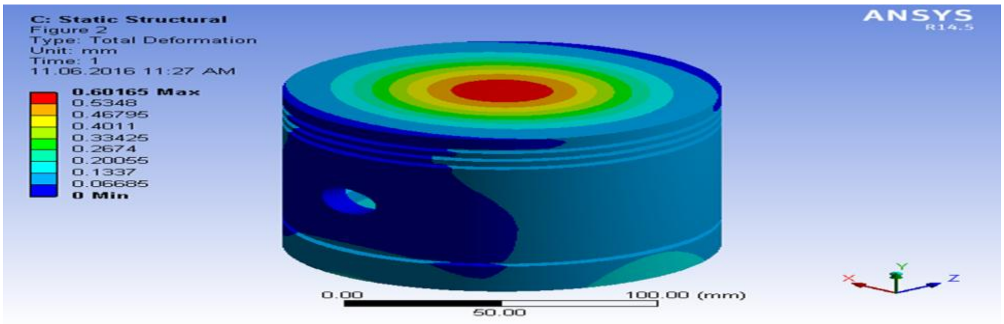

Fig 3.2: Deformation analysis diagram

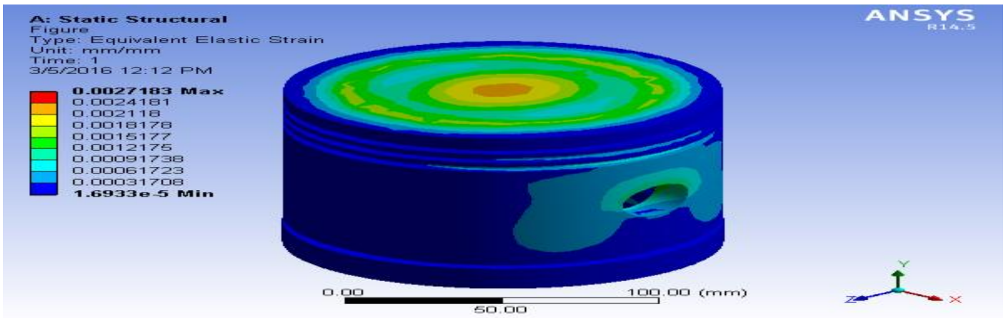

Fig 3.3Strain analysis diagram

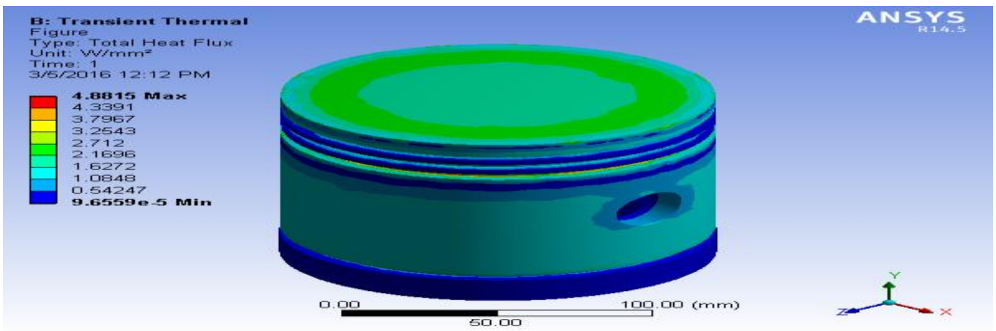

Fig 3.4: Total heat flux diagram

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4.2 **Silumin Piston Under Coupled Field Analysis**

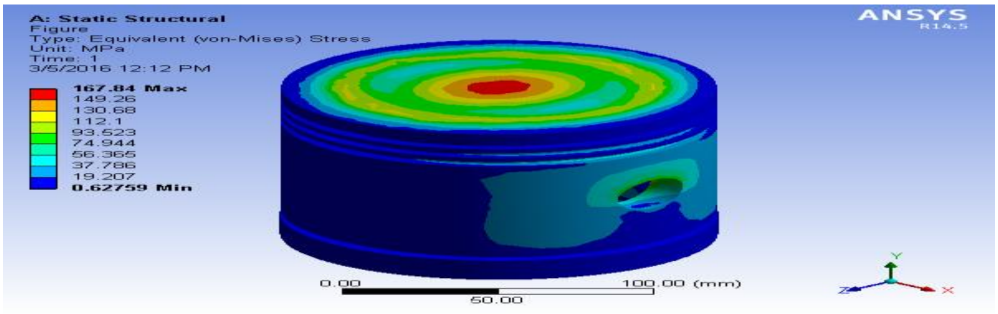

Fig 3.5: Von misses analysis diagram

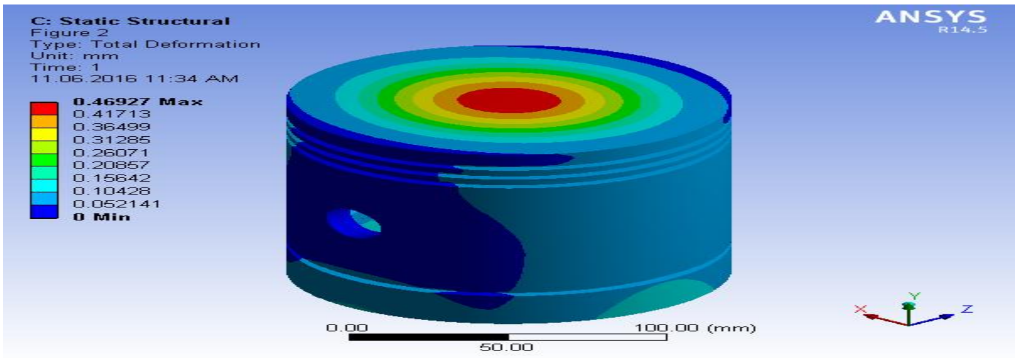

Fig 3.6: Deformation analysis diagram

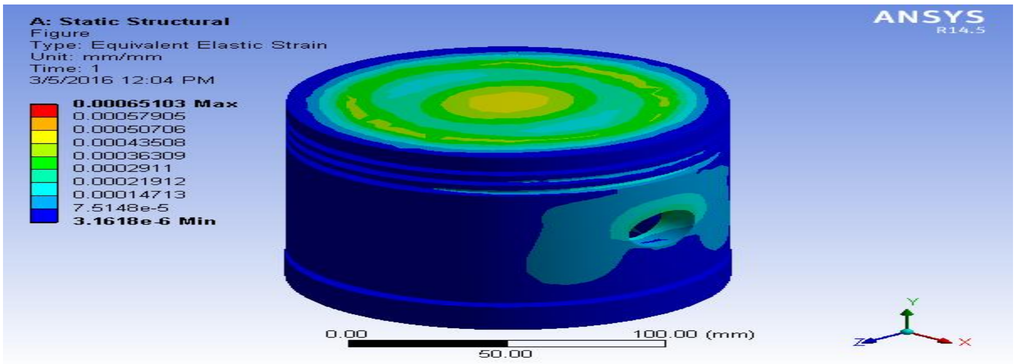

Fig 3.7: strain analysis diagram

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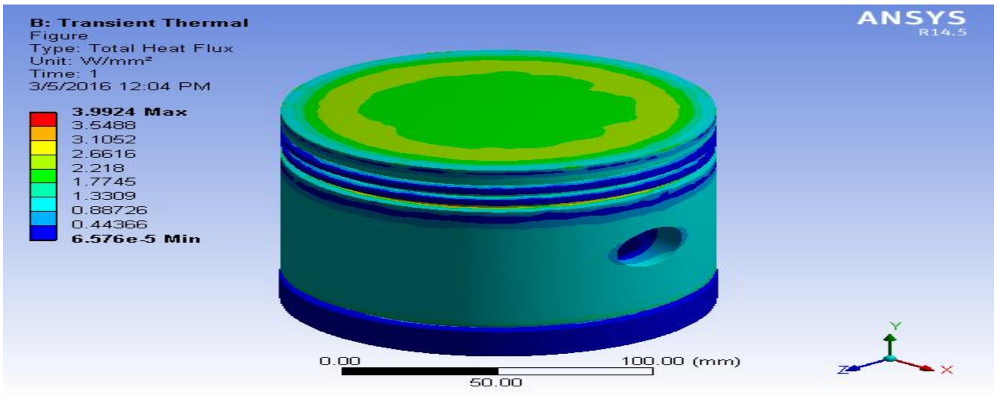

Fig 3.8: total heat flux diagram

V. RESULT AND DISCUSSION

- Based on the result obtained by analysis using ansys software maximum induced von misses stress is less than the yield stress at the material
- For ALUMINIUM ALLOY [Al 2024-T6] piston the maximum von misses stress is 180.9 Mpa is less than the yield stress[401 Mpa]
- For SILUMIN piston the maximum von misses stress is 167.86 is less than the yield stress[411 Mpa]
- In this coupled field analysis result SILUMIN is lesser thickness to compare ALUMINIUM ALLOY [Al 2024-T6] but the design is safe
- Next we observed from the coupled field analysis the deformation and strain for SILUMIN and ALUMINIUM ALLOY [Al 2024-T6]
- In SILUMIN piston the maximum deformation value is 0.472 it is much less than the maximum deformation value of ALUMINIUM ALLOY [Al 2024-T6] that is 0.620
- In SILUMIN piston the maximum strain value is 0.00061 it is much less than the maximum strain value of ALUMINIUM ALLOY [Al 2024-T6] that is 0.0021

SL.NO	PRESSURE OR LOAD [Mpa]	MATERIALS	VON MISSES STRESS [Mpa]	DEFORMATION [mm]	STRAIN [mm/mm]	TOTAL HEAT FLUX [W/m2k]
1	[7.94]	Al 2024-T6	180.93	0.602	0.00274	4.88
		SILUMIN	167.87	0.412	0.00061	3.99

Table 4.1: von misses stress, strain, deformation, and total heat flux

5.1 PARAMETER FOR SELECTION OF MATERIAL

SL.NO	PARAMETERS	Al 2024-T6	SILUMIN
1	Weight [N]	26.224	21.176
2	Volume[mm^3]	966350	906340
3	Strain [mm/mm]	0.00274	0.00061
4	Total deformation [mm]	0.602	0.412

Table 4.2 selection of materialS of Al 2024-T6 and SILUMIN

VI. CONCLUSION

The following conclusion can be drawn from analysis conducted in this study:

- It was found that the maximum Von misses stress is 167 MPa which is less than the maximum tensile stress (182 MPa) and yield strength (411 MPa) of the material
- Based on the coupled field analysis the maximum deformation of the SILUMIN piston is 32% is less than the ALUMINIUM ALLOY [Al2024-T6]
- 17% weight reduction and 10% volume reduction was to be found in SILUMIN piston to compare with ALUMINIUM ALLOY [Al 2024-T6] piston it indicate that reduced cost for mass production.

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