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# 3D Modelling & Detailing of Silumin Piston With Static Analysis

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***Abstract*— Piston is the part of engine which converts heat and pressure energy liberated by fuel combustion into mechanical work. Engine piston is the most complex component among the automotives. Weight reduction has been gaining importance in automobile field because reducing in weight decreases load on the engine. As we all Know that Piston is made of Aluminium Alloy Such that its weight is less. The automobile industry has shown increased interest in replacing the Piston with the material having high strength to weight ratio.**

**Therefore the objective of this project is to present a general study on the performance comparison of Silumin Piston and Aluminium Alloy Piston. Dimensions and specifications used in modelling are collected from the actual Piston of Hero-Honda Splendor Bike. The analysis is carried out in the commercially available software Solid Works**

Keywords— ***Piston Components, Silumin, Design, Analysis.***

## I. INTRODUCTION

Engine pistons serve several purposes. They transmit the force of combustion to the crankshaft through the connecting rod. They act as a guide for the upper end of the connecting rod. And they also serve as a carrier for the piston rings used to seal the compression in the cylinder. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall

The piston must come to a complete stop at the end of each stroke before reversing its course in the cylinder. To withstand this rugged treatment and wear, it must be made of tough material, yet be light in weight. To overcome inertia and momentum at high speed, it must be carefully balanced and weighed. All the pistons used in any one engine must be of similar weight to avoid excessive vibration. Ribs are used on the underside of the piston to reinforce the hand. The ribs also help to conduct heat from the head of the piston to the piston rings and out through the cylinder walls.

The structural components of the piston are the head, skirt, ring grooves, and land. However, all pistons do not look like the typical one. Some have differently shaped heads. Diesel engine pistons usually have more ring grooves and rings than gasoline engine pistons.

Fitting pistons properly is important. Because metal expands when heated and space must be provided for lubricants between the pistons and the cylinder walls, the pistons are fitted to the engine with a specified clearance. This clearance depends upon the size or diameter of the piston and the material from which it is made. Cast iron does not expand as fast or as much as aluminium. Aluminium Pistons require more clearance to prevent binding or seizing when the engine gets hot. The skirt of bottom part of the piston runs much cooler than the top; therefore, it does not require as much clearance as the head.

The piston is kept in alignment by the skirt, which is usually cam ground (elliptical in cross section). This elliptical shape permits the piston to fit the cylinder, regardless of whether the piston is cold or at operating temperature. The narrowest diameter of the piston is at the piston pin bosses, where the piston skirt is thickest. At the widest diameter of the piston, the piston skirt is thinnest. The piston is fitted to close limits at its widest diameter so that the piston noise (slap) is prevented during the engine warm-up. As the piston is expanded by the heat generated during operation, it becomes round because the expansion is proportional to the temperature of the metal. The walls of the skirt are cut away as much as possible to reduce weight and to prevent excessive expansion during engine operation. Many aluminium pistons are made with split skirts so that when the pistons expand, the skirt diameter will not increase.

The two types of piston skirts found in most engines are the full trunk and the slipper. The full-trunk-type skirt, more widely used, has a full cylindrical shape with bearing surfaces parallel to those of the cylinder, giving more strength and better control of the oil film. The slipper- type (cutaway) skirt has considerable relief on the sides of the skirt, leaving less area for possible contact with the cylinder walls and thereby reducing friction.

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## II . DESIGNING OF PISTON

By knowing the basic engine specifications like bhp, bore , stroke, compression ratio ,maximum power and maximum torque we find the various dimensions of the piston which are sated below :-

a) Thickness of the piston head

b) Radial thickness of the ring

c) Axial thickness of the ring

d) Height of the first land

e) Thickness of the piston barrel

f) Radial thickness of ring grove

g) Length of piston skirt

h) Length of piston

i) Diameter of piston pin hole

j) Thickness of piston at open end

The various component of the piston are shown in the fig given below. Thickness of the piston head ($t_h$) can be calculated by using Grashoff's formula. The head is

assumed to be flat and fixed at the edges and the gas pressure is consider ed as uniform over the entire cross sectional area

### *A. Thickness of Piston Head ($t_h$):*

$t_h$ = (√ (3pD2)/ (16σt)) in mm

= 4.6mm

Where

P= maximum pressure in N/mm²

D= cylinder bore/outside diameter of the piston in mm.

σt=permissible tensile stress for the material of the piston.

Here the material is a particular grade of AL alloy whose permissible stress is 50 Mpa-90Mpa. Before calculating thickness of piston head, the diameter of the piston has to be specified. The piston size that has been considered here has a L*D specified as 152*140

### *B. Radial Thickness of Ring (t1):*

$t1 = (D\sqrt{3p_w}/\sigma_t)$

=(50√3∗0.035/90) =2 mm

Where D = cylinder bore in mm

Pw= pressure of fuel on cylinder wall in N/mm². Its value is limited from 0.025N/mm to 0.042N/mm². For present material, t is 90Mpa.

### *C. Axial Thickness of Ring (t2):*

The thickness of the rings may be taken as:

t2 = 0.7t1 to t1

= (0.7*2) to 2 = 1.5mm

### *D. Minimum axial thickness (t2)*

= D/( 10*nr )

Where nr = number of rings

### *E. Width of the top land (b1):*

width of the top land varies from

b1 = $t_h$ to 1.2 $t_h$ =4.6 to 1.2*4.6

= 5.6mm

### *F. Width of other lands (b2):*

Width of other ring lands varies from

b2 = 0.75t2 to t2

=1.3mm

### *G. Maximum Thickness of Barrel (t3):*

t3 = 0.03*D + b + 4.5 mm

Where

b = Radial depth of piston ring groove

$t_3$= 0.03*50+$t_1$+0.4+4..5

= 8.4mm

Piston Wall thickness towards the open end $t_4$=0.25$t_3$ to 0.35t3

=0.25*8.4 to 0.35*8.4

= 2.5mm

Total length of the piston (L) = 37mm

Piston hole External diameter ($d_0$) =12.7mm

Piston hole Internal Diameter (di) =6.6mm

We know that Max load on the piston due to gas pressure or Max gas Load= $(\pi D^2/4)$*P

=$(\pi D)^2$/4*3.15 = 6185N

Maximum bending moment at Centre of pin M=P*D/8

=38656N-mm

We also know that max bending Moment (M):

38656=π/32[$d_0^4$-$d_i^4$]/$d_0$*.σ

σ = 207N/mm$^2$

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Thus, the dimensions for the piston are calculated and these are used for modeling the piston in SOLIDWORKS. In the above procedure the ribs in the piston are not taken into consideration, so as make the piston model simple in its design. In modeling a piston considering all factors will become tedious process. Thus, a symmetric model is developed using the above dimensions.

## III . MODELLING OF PISTON

Solid Works is a 3D mechanical CAD (computer-aided design) program that runs on Microsoft Windows and is being developed by Dassault Systems Solid Works Corp. Solid Works is currently used by over 2 million engineers and designers at more than 165,000 companies worldwide. FY2011 revenue for Solid Works was 483 million dollars

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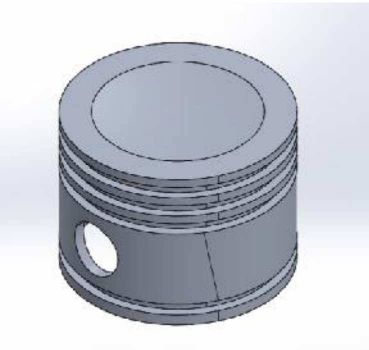


*Steps For Modelling of Piston:*

### *A. STEP1:*

First Create the half section of the piston using piston length of 37mm,piston diameter of 49.5mm,piston ring axial thickness of 0.8mm,piston ring radial thickness of 2mm,Depth of ring groove of 2.01mm,Gap between the rings is 2.6mm &Top land thickness of 5.6mm.Constrain the obtained fig by allocating suitable dimensions.

### *B. STEP2:*

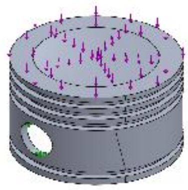
After the fig gets fully constrained, now exit the sketch and click the “Revolute” option and give the rotation angle of 360$^0$.Then the half section of piston forms the required full piston sketch.

### *C. STEP3:*

Now Select the front portion of it, then select a plane and click sketch. As we want a hole cutting through it, we select circle of 6.6mm diameter & click Extrude Cut such that we get hole through it.

## IV ANALYSIS OF PISTON

### *A. Model of Piston*



### *B. Model Information*

| *Piston* | *Treated as* | *Volumetric Properties* |
|---|---|---|
|  | Solid Body | Mass:0.0373557 kg<br>Volume:1.33413e-005m^3<br>Density:2800 kg/m^3<br>Weight:0.366086 N |

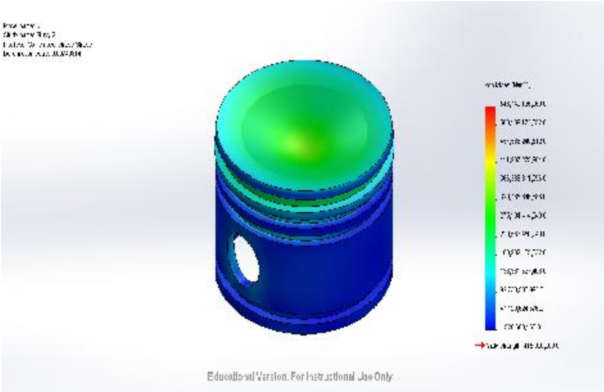
### *C. Aluminum Alloy Properties*

| *Piston* | *Properties* | |
|---|---|---|
|  | Name: | **Al-2024-T6** |
| | Model type: | **Linear Elastic Isotropic** |
| | Default failure criterion: | **Max von Mises Stress** |
| | Yield strength: | **4.15e+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** |

### *D. Study Results*

*i) Stress Analysis*

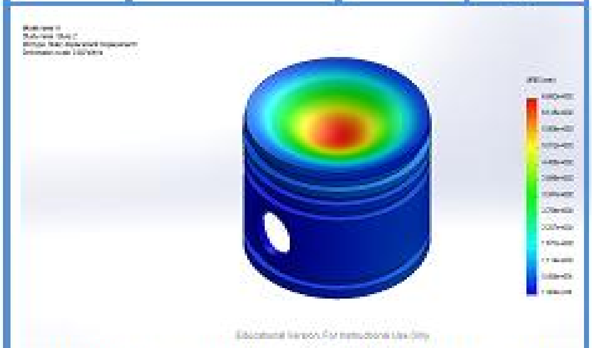
| Name | Type | Min | Max |
|---|---|---|---|
| *Stress1* | *VON: von Mises Stress* | *1.52867e+009 N/m^2 Node: 5125* | *5.4874e+011 N/m^2 Node: 5913* |




*Stress Diagram*

*ii) Displacement Analysis*

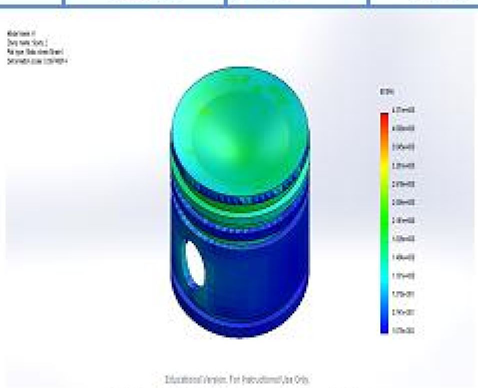
| Name | Type | Min | Max |
|---|---|---|---|
| Displacement1 | URES: Resultant Displacement | 0 mm Node: 126 | 668.2 mm Node: 23 |



**K-Study 2-Displacement-Displacement1**

*iii) Strain Analysis*

| Name | Type | Min | Max |
|---|---|---|---|
| *Strain1* | *ESTRN: Equivalent Strain* | *0.0107476 Element: 7814* | *4.37136 Element: 4655* |



**K-Study 2-Strain-Strain1**

## V .SILUMIN PISTON

Al-Si-Mg alloys, known as silumins, have good castability and a good combination of properties, which makes them a good choice in many automotive applications.

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 silumins are corresponding to alloys of two systems: 3xx.x – Aluminum–silicon alloys are also containing magnesium and/or copper, and 4xx.x – Binary aluminum–silicon alloys. Among the advantages of silumin is its high resistance to corrosion, making it useful in humid environments. The addition of silicon to aluminium also makes it less viscous when liquid, which together with its low cost (both component elements are relatively cheap to extract), makes it a very good casting alloy and a fresher metal. It is also used on 3 phase motors to allow speed regulation. Another use is rifle scope mounts and camera mounts.

The group is alloyed with Cu, Mn, and Mg and sometimes with Zn, Ti, Be, and other metals, depending on the desired combination of fabricating characteristics and operational performance. Silumin alloys have good casting properties, but their mechanical properties are inferior to those of casting alloys based on the Al-Cu system.

Silumin alloys are noted for their high resistance to corrosion in humid and marine atmospheres. They are used in the manufacture of components with complex shapes, mainly in automotive vehicle and aircraft manufacture. The USSR produces silumin alloys under such trade names as AL2, AL4, and AL9

## VI. SILUMIN PISTON ANALYSIS

### *A. Model Information*

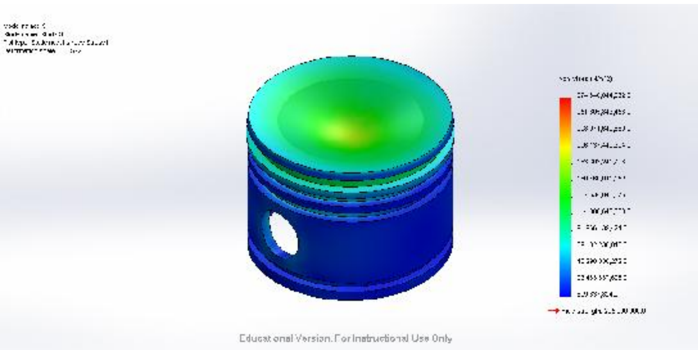
| *Piston* | *Treated as* | *Volumetric Properties* |
|---|---|---|
|  | Solid Body | Mass:0.0354746 kg<br>Volume:1.33413e-005 m^3<br>Density:2659 kg/m^3<br>Weight:0.347651 N |

### *B. Silumin Properties*

| *Piston* | *Properties* | |
|---|---|---|
|  | Name: | **Silumin** |
| | Model type: | **Linear Elastic Isotropic** |
| | Default failure criterion: | **Max von Mises Stress** |
| | Yield strength: | **2.25e+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** |

### *C. Stress Analysis*

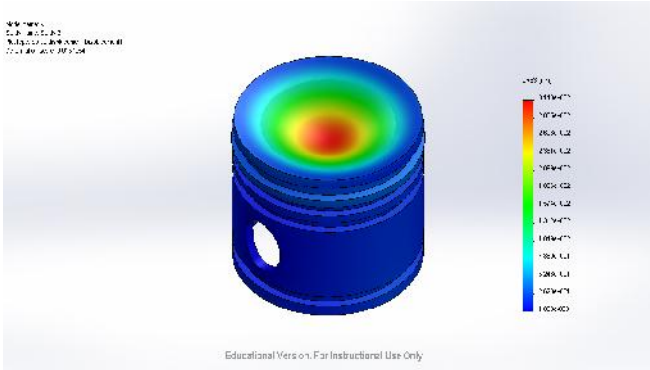
| Name | Type | Min | Max |
|---|---|---|---|
| Stress1 | VON: von Mises Stress | 6.29638e+008N/m^2 Node: 11075 | 2.7464e+011N/m^2 Node: 5913 |




*Stress Diagram*

### *D. Displacement Analysis*

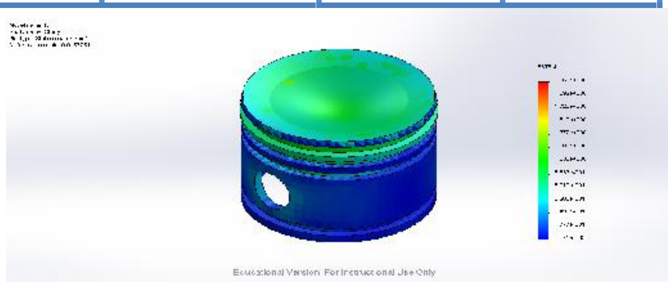
| Name | Type | Min | Max |
|---|---|---|---|
| Displacement1 | URES: Resultant Displacement | 0 mm Node: 123 | 314.777 mm Node: 23 |




*Displacement Diagram*

### *E. Strain Analysis*

| Name | Type | Min | Max |
|---|---|---|---|
| Strain1 | ESTRN: Equivalent Strain | 0.00637123 Element: 323 | 2.06289 Element: 4655 |




## VI. RESULTS

COMPARISION TABLE

| **Material Used** | ***Weight (N)*** | ***Max Stress (N/m^2)*** | ***Max Displacement (mm)*** | ***Max Strain*** |
|---|---|---|---|---|
| Al 2024-T6 | 0.366086 | *5.4874 e+011* | 668.2 | 4.37136 |
| SILUMIN | 0.347651 | 2.7464 e+011 | 314.777 | 2.06289 |

## VII. CONCLUSION

In this project, a piston is modeled in 3D modeling software SOLIDWORKS. Present used material for piston is Cast Aluminum. The Cast aluminum is replaced with SILUMIN. The weight of the piston is less since its density is less.

Static analysis is done on the piston by applying the pressure to verify the strength of the piston using 2 materials. The Max Strain, Displacement, and Max Stress for the SILUMIN-Alloy piston are less than that of Al-Alloy Piston. so in future SILUMIN Alloy can be adopted in the commercial automobiles to enhance the performance range of the engine from piston's side. The analysis is carried out in the commercially available software Solid Works.

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