# FINITE ELEMENT ANALYSIS OF GASOLINE ENGINE PISTON USING REINFORCED ALUMINUM METAL MATRIX COMPOSITES

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**Abstract –**

**As the efficiency norms are becoming stringent day by day, the engine manufacturers are concentrating more on engine efficiency. For effective combustion system, various parameters like combustion pressure, compression ratio, proper fuel mixing and ignition timing etc. are very important. In this scenario, lot of research has been carried out on arriving at a piston design which can give effective fuel mixing, high compression ratio using a re-entrant combustion bowl shape. For thermal analysis of piston, basic necessary thermal boundary conditions like bulk gas temperatures and heat transfer coefficients have been obtained from literature survey. Temperature of the piston due to its working in high combustion environment will itself act as thermal load causing stress to the component. In this Project, it has been decided to study a particular piston design and its capability for various above said loads. In this work initially planning to make a piston model using solid modeling in SOLIDWORKS and Finite Element Analysis is done in ANSYS Workbench. As per internal combustion engines piston plays major role in developing the power stroke various thermal stresses acts up on the piston during combustion .suitable materials required to withstand the high combustion temperatures (20000c) reinforced metal matrix composites of aluminum with al203 and sic as reinforcement particles were taken as materials for analysis of piston and comparison was done with standard aluminum alloy piston. Metal matrix composites are light weight and can withstand high temperatures of combustion chamber .as they have high thermal conductivity and low coefficient of thermal expansion. The increase in thermal conductivity of material results in increase in heat transfer rate from piston so that thermal efficiency increases. Metal matrix composites can withstand high thermal loads takes place from engines and piston will sustain longer time**

**Key words: Combustion Systems, Piston, ANSYS, Thermal Analysis, Gas Temperature, Thermal Load, Mechanical lo ads, Structural Analysis.**

## 1. INTRODUCTION:

Perhaps the most well-known engine type in the world, the automotive four-stroke engine has become the power plant of choice for today's consumers due to its greater efficiency and cost effectiveness over alternate reciprocating engines. The story of the internal combustion engine began in 1680 with a Dutch physicist Christian Huygens, who conceptually designed an engine fueled by gun powder. However, the first internal combustion engine was actually built by a Sweetish inventor by the name of Francios Isaac de Rivaz in 1807. Through the combustion of a hydrogen and oxygen mixture, his engine, with some difficulty, powered accurately constructed automobile. As the years went on, other inventors modified the design to be fueled by anything from gasoline to coal. The next greatest leap came in 1862 when a French engineer, Alphonse Beau de Rochas, designed and patented the first four-stroke engine. In 1864 an Austrian engineer, Siegfried Marcus, build the first gasoline powered vehicle, which was comprised of a cart and a one cylinder engine. But the biggest breakthrough came in 1876 when Nikolaus August Otto invented the first successful four-stroke engine, aptly nick-naming the four-stroke cycle the "Otto Cycle." The next great milestone in the development of the four stroke engine was achieved by Gottlieb Daimler in 1885, who invented an engine with a vertical positioned cylinder, fueled by gasoline injected into a cylinder chamber through a carburetor. The innovations from these important inventors over the years culminated in Daimler's engine which is commonly referred to as the "blue print" to the modern day internal combustion engine.

The four-stroke gasoline engine is comprised of many integral parts: the induction system, the cylinder heads, the engine block, the pistons, the camshaft, the crankshaft, and the flywheel. All these parts are necessary for the four cycles of operation in the Otto cycle, illustrated in fig-1. The first stroke in the Otto cycle is the induction stroke. This process starts with the carburetor or the electronic fuel injection system flowing air into the intake manifold. While the air is passing through the carburetor or electronic fuel injection system, gasoline is added into the air creating a fuel mixture. As the fuel mixture passes through the intake manifold, it is separated from one collective port to individual ports for each of the cylinders. The fuel mixture then progresses into the cylinder heads where an intake valve opens to allow the incoming mixture to flow to the cylinder chamber, while the cylinder head's exhaust valve is closed so the mixture can not escape from the chamber. During this stroke, the piston starts at the top of the cylinder moving backwards towards the bottom of the cylinder creating a vacuum which creates a vacuum pulling in the fuel mixture.

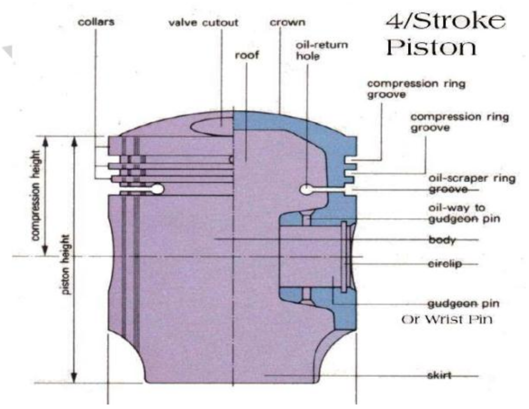


Fig.1: Engine piston

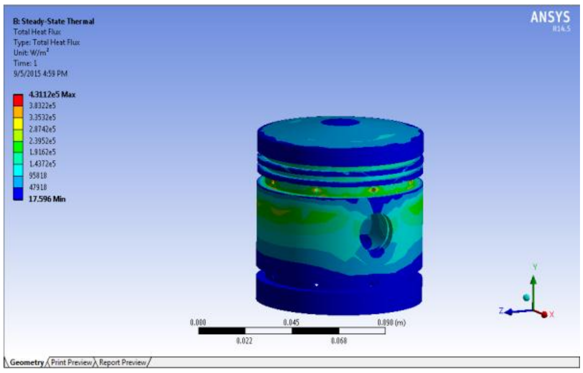
## Piston Design & Specifications:

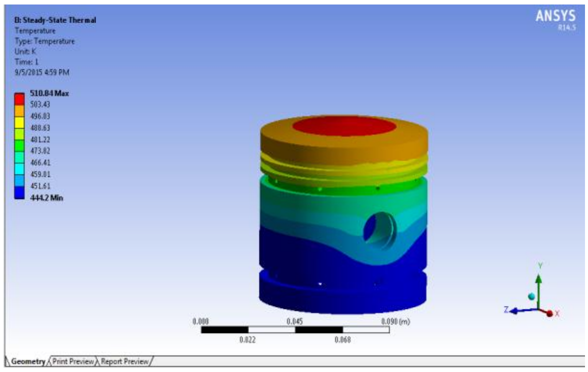
Table 1

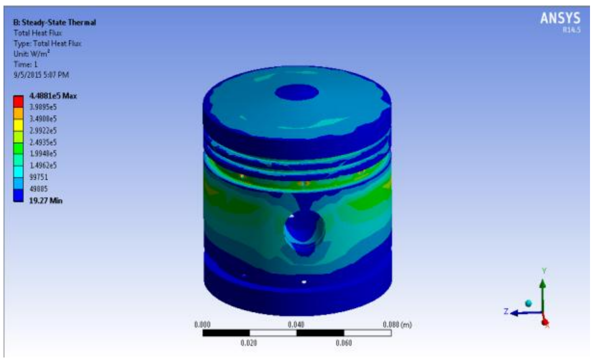
| sno | Design and dimensions | Size in cm |
|---|---|---|
| 1 | Length of piston | 15.2 |
| 2 | Cylinder bore/outside diameter of piston | 8 |
| 3 | Radial thickness of ring | 0.52 |
| 4 | Axial thickness of ring | 0.5 |
| 5 | Maximum thickness of barrel | 1.4 |
| 6 | Width of top land | 1.08 |
| 7 | Width of other ring lands | 0.4 |

| SN | PISTON REGION | TEMP (K) | HEAT TRANSFER COEFFICIENT ($W/m^2K$) |
|---|---|---|---|
| 1. | Piston Head | 623 | 300 |
| 2. | Width of top land | 603 | 160 |
| 3. | Piston Ring Area | 523 | 120 |
| 4. | Piston skirt land | 413 | 600 |

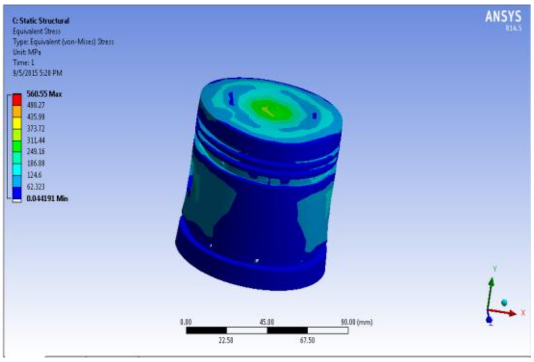
## 2. Results of thermal analysis:

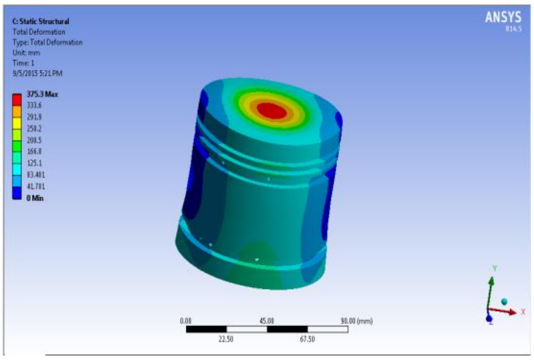


2.1 Results of structural analysis:




**2.2 Calculations:**

Total amount of heat flow from the piston head was calculated with the help of equation -2

| Material type | Heat flow (kj/sec) |
|---|---|
| **Al356t6** | **1.46** |
| **F3S10ST6** | **1.7** |
| **F3K20ST6** | **1.6** |

**3. ANALYSIS RESULTS:**

**Thermal analysis:**

| MATERIAL | MAXIMUM TEMP(K) | MINIMUM TEMP(K) | TOTAL HEAT FLUX |
|---|---|---|---|
| **AL356T6** | 510.84 | 444.2 | 4.3112E5 |
| **F3S10ST6** | 504.72 | 447.41 | 4.481E5 |
| **F3K20ST6** | 512.1 | 443.56 | 4.2747E5 |

**4. Structural analysis**

| MATERIAL | MAXIMUM STRESS(mpa) | DEFORMATION(mm) |
|---|---|---|
| **AL356T6** | 560.55 | 375.3 |
| **F3S10ST6** | 557.2 | 283.78 |
| **F3K20ST6** | 560.55 | 279.43 |

5. CONCLUSION: From the analysis it can be concluded that total amount of heat flow from piston head is more in f3s10st6 so that temperature drop will be maximum, more will be heat transfer rate from the piston and can sustain the thermal load for longer life. that can be seen in static analysis that maximum stress acting on the material f3s10st6 is 557.2 which is lesser than other materials and maximum deformation occur in this material is lesser that general material from aluminum. the total amount of heat flux is also more in case of f3s10st6 than other material .the final statement is metal matrix component of aluminum that reinforcement with 20%sic is suitable material to with stand maximum thermal loads and deformation due to combustion pressure and the material is economic .this can improve the heat transfer rate of engine piston and thus increase the thermal efficiency. The general material AL356t6 has maximum stress and subject to more amount of deformation

**6. FUTURE SCOPE**

We may enhance the piston dimensions and material properties to analyze how it behaves in different loading conditions, moreover the simulation work can be made using some other software. More amount of stress acting on piston head and major amount of deformation acting on piston head. Thermal and stress barrier analysis is to be done on piston head by coating with ceramic materials.

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