



## Material Optimization of Internal Combustion Engine Piston using ANSYS

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### ABSTRACT

The IC engine pistons are one of the most important components of an automobile which is subjected to high thermal and structural stresses. The material of piston should have high strength to density ratio and high thermal conductivity so as to dissipate heat and prevent piston wear and engine damage. The current research investigates the application of MMC (Metal Matrix Material) composite material for IC engine piston subjected to structural loading conditions. The CAD model of piston is developed using Creo 2.0 software and analysis is conducted using ANSYS FEA software. The MMC taken for analysis is 124/SiC/25p and compared with conventional Eutectic alloy type ATC12CuMgNi.

**Keywords:** IC Engine piston, Finite Element Analysis, MMC

### 1 Introduction

During the early days of automobile manufacturing, IC engine pistons were made from cast iron. Due to increased inertia effect caused by high weight the cast iron was substituted with low weight Aluminium alloy with silicon which had reduced expansion and higher strength as compared to cast iron. On the basis of concentration of silicon, the alloy can be regarded as eutectic (12% silicon) or hypereutectic (22% silicon). Further increase in silicon would make the piston brittle and unsuitable for structural or thermal application. As IC engines are subjected to high temperatures, the piston materials should be able to withstand it without causing any failures. The vulnerable areas of piston are top ring groove and bowl rim and has to be protected from premature failure.

In IC engines, about 6 to 8 percent of fuel energy is transferred to piston and in uncooled piston 60 percent of heat is passed through piston ring area. Additional heat is passed through the skirt into the coolant jacket and from the underside of the piston via oil splash/mist to the crankcase oil [1][2]. For an oil cooled piston, a major amount of heat is carried by oil thus reducing the relative amount that passes through the ring region. Different temperature zones of piston is shown in figure 1 above. MMC material offers advantages as compared to conventional eutectic alloy material used for pistons. MMC materials have high thermal conductivity and strength. The coefficient of thermal expansion is also low. All these characteristics make MMC superior than Eutectic alloys.

### 2 Proposed Work

The objective of this research is to optimize material of I.C. engine piston using metal matrix composites popularly known as MMC's and analyze its effect on structural and thermal stresses induced. The analysis is performed using techniques of Finite Element Method and software used is ANSYS. The analysis is conducted using Eutectic alloy type ATC12CuMgNi and with 124/SiC/25p metal matrix composite material. The mechanical and physical properties are taken from literature [3],[4].

### 3 Methodology

In this stage the CAD model is developed using Creo 2.0 design software using extrude, revolve and pattern tools. The Creo is 3d modelling parametric software developed by PTC which is best known tool for designing complex 3d models. Schematic of I.C. engine piston is shown in figure 2 below. Based on the initial data and recommendations from literature, we established the main dimensions of the piston, after which we built the 3D model.

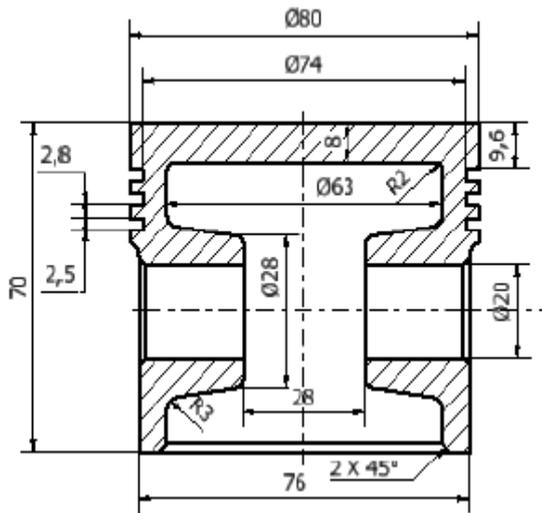


Figure 2: Schematic of I.C. Engine piston [3]

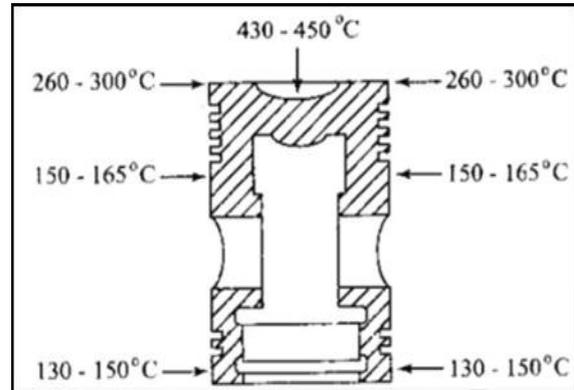


Figure 1: Temperature ranges

The CAD model of IC engine piston is developed in Creo 2.0 software with dimensions as shown in figure 2 above. The tools used for modelling are revolve by creating a center axis and cross-section revolved about this axis. After revolving, fillet, chamfer and other dress up tools are used to create CAD model of piston as shown in figure 3 below.

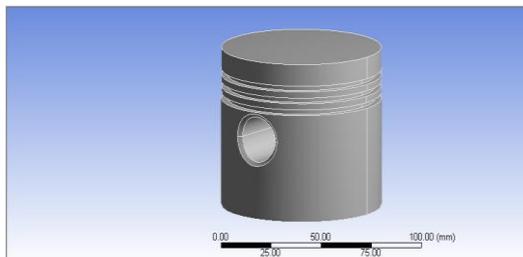


Figure 3: CAD model of I.C. Engine piston

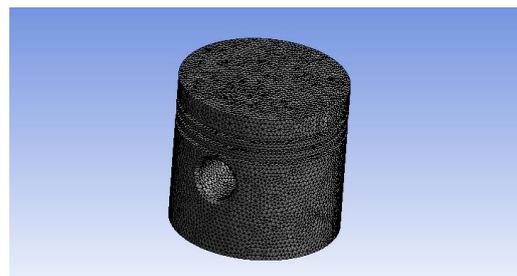


Figure 4: Meshed model of helical coil suspension

The CAD model is meshed using tetrahedral elements and fine sizing with curvature effects on. The number of elements generated is 146685 and number of nodes generated is 223600 as shown in figure 4 above. The element shape of tetrahedral element is shown in figure 3 below. It consists of 4 nodes connected to each other by tetrahedral shape. CAD model of suspension after being meshed is applied with appropriate loads and boundary conditions.

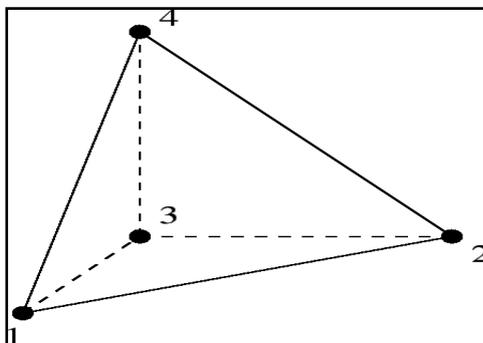


Figure 4: Tetrahedral element

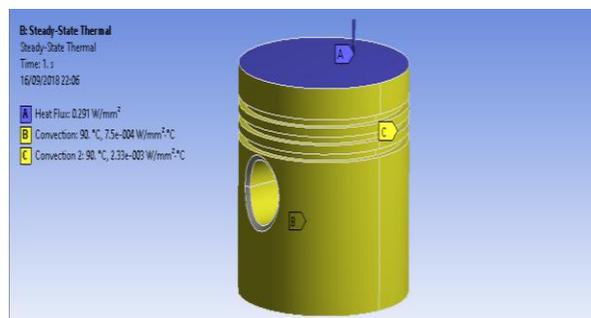


Figure 5: Thermal Loads and Boundary conditions

The bottom face of suspension is kept fixed and top face is applied with force of 1356.4N in downward direction. Constant heat flux of

.291W/mm<sup>2</sup> is applied on top face of cylinder and side surfaces are applied with convection of .00075 W/mm<sup>2</sup> K and ambient temperature is set to 90oC. The inner surface is also applied with convection of .000233 W/mm<sup>2</sup> K and ambient temperature is set to 90oC. After applying loads and boundary conditions the software formulates element stiffness matrices, assemble global stiffness matrix. The next stage is computing results at nodes by matrix inversions, multiplications etc. The results generated at nodes are interpolated to entire element edge length using linear or quadratic interpolation function.

#### 4 Results and Discussion

The static structural analysis is performed using techniques of Finite Element Method used by ANSYS software. The material used for analysis is Eutectic alloy type ATC12CuMgNi.

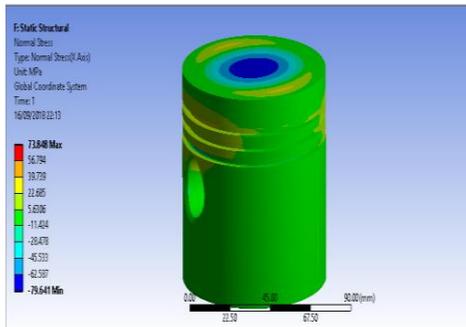


Figure 6: Radial stress generated by Eutectic alloy type ATC12CuMgNi

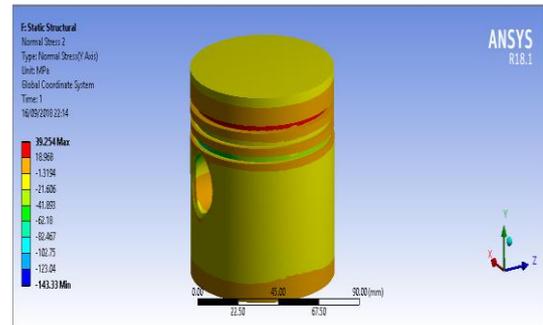


Figure 7: Tangential stress generated by Eutectic alloy type ATC12CuMgNi

The radial stress generated from FEA structural analysis is shown in figure 6 above. The maximum radial stress observed from analysis is 73.84MPa on inner cylindrical portion of cylinder. Stress decreases as we move away from cylindrical support as shown by green contour and magnitude of 5.63MPa.

The tangential stress generated from FEA structural analysis is shown in figure 7 above. The maximum tangential stress observed from analysis is 39.254MPa on piston ring area as shown by red contour. Stress decreases as we move away from piston ring as shown by orange and green contour and magnitude of 18.96MPa.

The deformation generated from FEA structural analysis is shown in figure 8 above. The maximum deformation observed from analysis is .087mm on piston top area as shown by red contour. Deformation decreases as we move away from piston top as shown by orange and green contour and magnitude of .039mm. Further static structural analysis is performed using 124/SiC/25p metal matrix composite material and results obtained are discussed below.

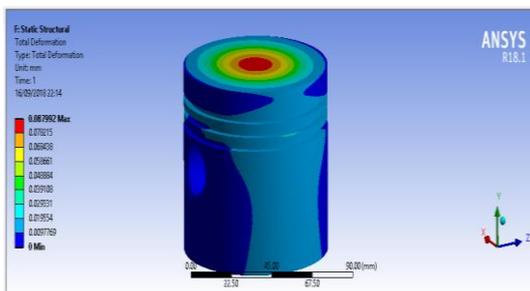


Figure 8: Deformation generated by Eutectic alloy type ATC12CuMgNi

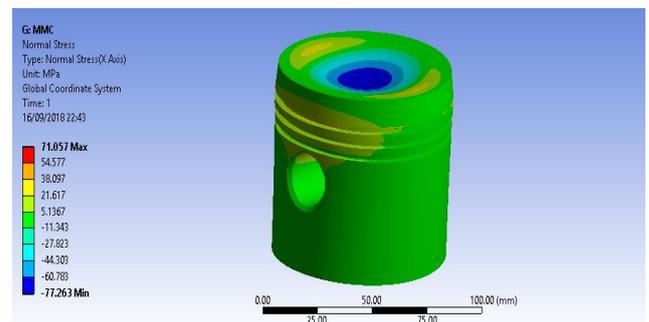
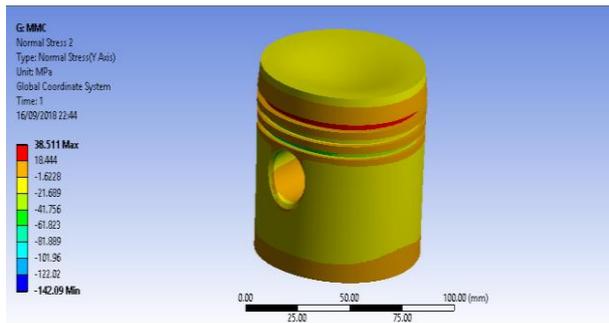
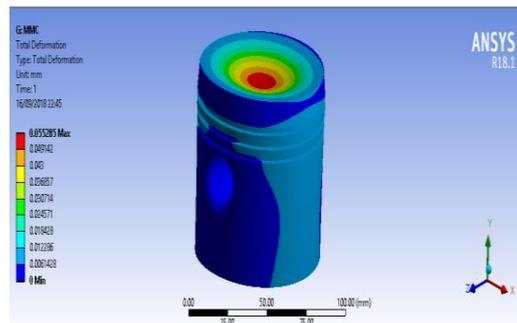


Figure 9: Radial stress generated by 124/SiC/25p metal matrix composite material

The radial stress generated from FEA structural analysis is shown in figure 9 above. The maximum radial stress observed from analysis is 71.05MPa on inner cylindrical portion of cylinder. Stress decreases as we move away from cylindrical support as shown by green contour and magnitude of 5.13MPa.



**Figure 10: Tangential stress generated by 124/SiC/25p metal matrix composite material**



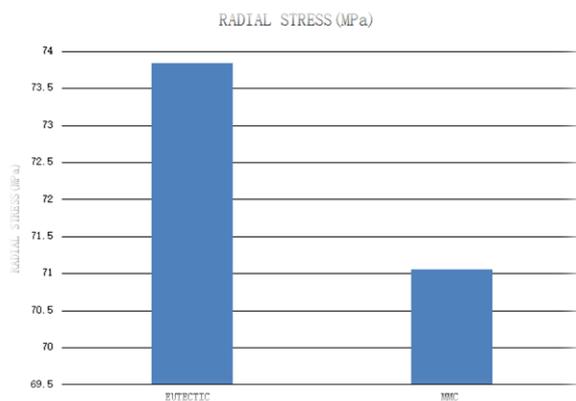
**Figure 11: Deformation generated by 124/SiC/25p metal matrix composite material**

The tangential stress generated from FEA structural analysis is shown in figure 10 above. The maximum tangential stress observed from analysis is 38.511MPa on piston ring area as shown by red contour. Stress decreases as we move away from piston ring as shown by orange and green contour and magnitude of 18.44MPa.

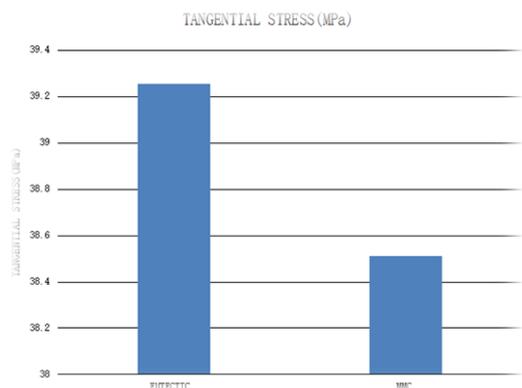
The deformation generated from FEA structural analysis is shown in figure 8 above. The maximum deformation observed from analysis is .0552mm on piston top area as shown by red contour. Deformation decreases as we move away from piston top as shown by orange and green contour and magnitude of .036mm.

**Table 1: Structural Analysis results comparison**

MATERIAL	RADIAL STRESS(MPa)	TANGENTIAL STRESS(MPa)	DEFORMATION(mm)
EUTECTIC	73.84	39.254	0.0879
MMC	71.05	38.51	0.0552

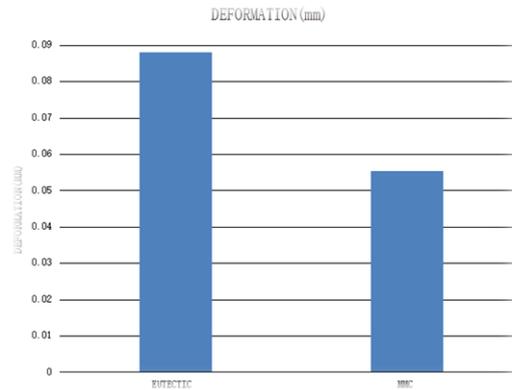


**Figure 12: Radial stress comparison between Eutectic and MMC piston**



**Figure 13: Tangential stress comparison between Eutectic and MMC piston**

From the structural analysis of IC engine piston, the comparison of radial stress shows higher value for eutectic alloy and MMC piston has lower value.



**Figure 14: Tangential stress comparison between Eutectic and MMC piston**

From the structural analysis of IC engine piston, the comparison of tangential stress shows higher value for eutectic alloy and MMC piston has lower value as shown in figure 13 above. Similarly deformation value obtained for eutectic alloy is higher with magnitude of .0879mm while deformation value obtained for MMC piston is .0552mm as shown in figure 14 below.

## 5 Conclusion

The FEA analysis is conducted to determine structural load bearing characteristics of IC engine piston using conventional Eutectic alloy and advanced MMC material. The stresses and deformation obtained are lower for MMC piston as compared to Eutectic alloy. Besides this the weight of MMC pistons are lighter than eutectic alloy pistons. Therefore MMC pistons due to good strength to density ratio are better than Eutectic alloys.

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