iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: III Month of publication: March 2018

DOI: http://doi.org/10.22214/ijraset.2018.3503

Investigation and Analysis of SiC Reinforced Al7075 MMC Pistons by using ANSYS 18.0

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Abstract: Engine modification leads to improve the technology advancement in automobile industries. Piston plays a major role in engine parts. Pistons are mostly failure due to mechanical and thermal stresses that create wear and tear. This paper presents the structural and thermal analysis of three different materials. Al7075 has higher strength, Sic was reinforced by using Stir casting Techniques for reducing wear and tear. This paper explains the stress distribution for piston using specifications of a Single cylinder four-stroke engine. The geometrical model was designed as per the dimensions by using CREO 3.0 software. A Structural and Thermal analysis is performed by using ANSYS Workbench 18.0. The result has been generated and analyzed to find out the suitable material that gives the better strength and consists of lightweight.
Keywords: Piston, Structural Analysis, Thermal Analysis, CREO 3.0, ANSYS Workbench 18.0

I. INTRODUCTION

Metal matrix composites are used in various fields of engineering applications. Aluminum metal matrix composites are mostly used in automobile industries because it has low density and higher mechanical properties. In engine reduction of weight and increasing efficiency will also improve the fuel economy. The piston is a major part of the engine which is reciprocating inside the cylinder to transmit all the applied pressure forces to the crankshaft through connecting rod. Pistons may cause wear and tear at working under different mechanical and thermal stresses. The piston should have strength to resist the pressure force and temperature inside the cylinder. In here SiC was reinforced in Al7075 at different compositions by using stir casting technique. The materials were tested and the properties of the materials are used to analyze the piston by using ANSYS Workbench 18.0.In this Single cylinder four stroke engine piston was used to find the stress distribution. Engine specifications are shown in Table 1.

TABLE 1
ENGINE SPECIFICATIONS

Parameters	Values
Engine Type	Four-Stroke, Petrol engine
Number of Cylinders	Single cylinder
Induction	Air Cooled
Displacement	97.2 cc
Maximum Power	6.5 KW @ 8000 rpm
Maximum Torque	8.05 Nm @ 5500 rpm
Maximum Speed	87 kmph
Cylinder Bore	50 mm
Stroke	49.5 mm
Compression ratio	9.9: 1
Ignition	Self (with i3s) & Kick

II. PROBLEM IDENTIFICATION AND METHODOLOGY

Pistons are damaged due to pressure forces and thermal stresses applied inside the cylinder during combustion. Piston damages are mostly fatigue, wear and tear. The objective of the work is finding a suitable material to reduce the wear and tear. Also find the less weight and higher mechanical strength material to reduce the inertia force acting on the piston. The following sequences of steps are the Methodology of entire process.

A. Manufacturing SiC reinforced Al7075 Metal matrix composites by using stir casting.
B. A piston dimension of Single cylinder Petrol engine was observed.
C. Creating 3D model of Piston by Using Creo Parametric 3.0
D. Converting Creo Part file is into IGES format.
E. Importing IGES file is to ANSYS Workbench 18.0.
F. Performing Static Structural and Thermal analysis on the three materials under pressure and thermal conditions.
G. Comparing the generated results.
H. Select the Suitable material on the basis of comparison.

III. MATERIAL AND ITS PROPERTIES

The Piston is a major part of an internal combustion engine. Engines are mostly made up of cast iron, cast steel, forged steel and cast aluminium. Nowadays aluminium alloys are also used in the engine materials like piston and connecting rod. Because aluminium alloys have a great strength, better corrosion resistance and low thermal expansion compared to conventional alloys. Aluminium also a lightweight material so, it reduces the entire weight of a component. Aluminium alloys are reinforced with SiC, Graphite and aluminium oxide to improve its wear resistance and strength. Al7075 has high strength and low density. It contains Zinc, magnesium, chromium, copper and some other elements. The composition of Al7075 was shown in Table 2.

TABLE 2
COMPOSITION OF AL7075

Element	Zn	Mg	Cu	Fe	Si	Cr	Mn	Ti	Al
%wt	5.60	2.40	1.40	0.42	0.40	0.26	0.13	0.01	Bal

To increase the wear resistance and strength SiC was reinforced in al7075 at different compositions. Stir Casting is a manufacturing technique most commonly used to manufacture metal matrix composite. Here 5wt.% and 10wt.% SiC was reinforced in al7075 by using Stir casting Technique. Al7075 material and Silicon Carbide powder as Shown in Fig. 1 and Fig. 2 respectively.

Fig. 1 Al7075 Rod

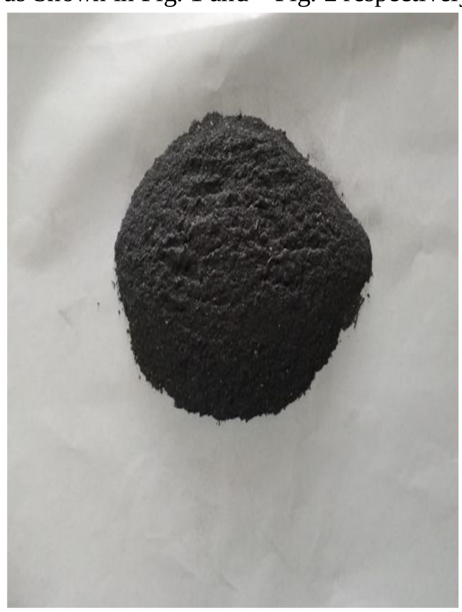

Fig. 2 Silicon Carbide Powder

In furnace Al7075 was heated at 700-750°C to obtain its liquid stage and SiC Powder was preheated in the furnace. Then the two materials are mixed with different proportions by stirring in the stir casting machine for 15-20 minutes. Then the mixed metal is poured into the die. After the process, the materials are tested and the properties used to analyze the piston by using analysis software. Properties of SiC reinforced Al7075 are shown in Table 3.

TABLE 3
PROPERTIES OF MATERIALS

Parameters	Al7075	Al7075 + 5%SiC	Al7075 + 10%SiC
Density (Kg/m^3)	2810	2825	2839
Poisson's Ratio	0.33	0.33	0.33
Elastic Modulus (GPa)	71.7	79.2	88.5
Thermal Conductivity(W/mK)	130	128	127
Specific Heat (J/KgK)	960	949	940

III. MODELING AND ANALYSIS OF PISTON

Piston has different parts like piston crown, piston skirt, etc. A piston dimension of Single cylinder four-stroke petrol engine was observed. The piston dimensions are shown in Table 4. Modeling was done by using Creo parametric 3.0.

TABLE 4
DIMENSIONS OF PISTON

Piston Part	Dimensions
Piston Length	37 mm
Piston Diameter	49.5 mm
Piston Axial Thickness	1.2 mm
Piston Radial Thickness	2 mm
Depth of the Ring Groove	2.01mm
Gap between Rings	2.6mm
Top land Thickness	5.6mm
Pin hole external Diameter	14mm
Pin hole Internal Diameter	9mm

Creo Parametric 3.0 is modeling software that is used to create a solid model. The piston was created as per the dimensions by using Creo Parametric 3.0. Initially 2D drawing was created and then it is converted into 3D model. The 3D model of piston was shown in Fig.3.

Fig. 3 Solid Model of Piston

The Creo part file is converted into IGES file. The IGES file is used to analyze the object on ANSYS Workbench 18.0. The IGES file was imported to the ANSYS Workbench 18.0. Meshing of the piston was done by automatically. The total number of nodes

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
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and elements are 17767 and 9715 respectively. Fig. 4 shows the piston after completion of meshing. After completion of meshing different boundary conditions are applied on the Piston.

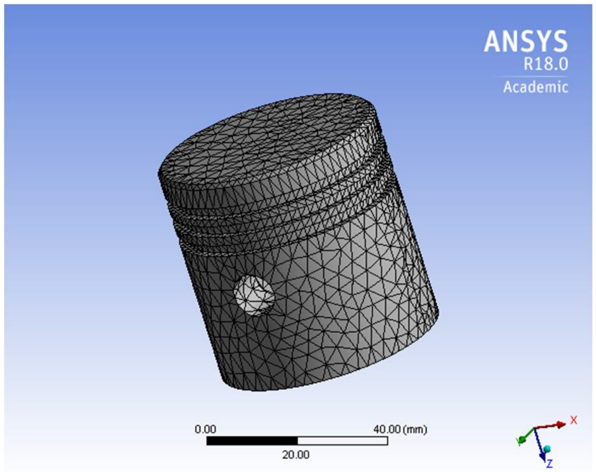

Fig. 4 Meshed model of Piston

A. Structural Analysis Boundary Conditions

In engine pressure force was acting on the piston head during combustion process. Then the piston moves downwards from TDC to BDC. In piston both mechanical and thermal stress were applied. Here, the Structural and Thermal distribution was analyzed. Structural analysis is used to find the maximum principal stress, equivalent stress, Shear stress and also the deformation of a piston. In here static structural analysis was done by using analysis software. Pin hole of the piston was arrested in all degrees of freedom. In a petrol engine 3 to 5 MPa was acted on the piston. In this analysis we used 5MPa pressure force on the Piston head.

B. Thermal Analysis Boundary Conditions

In engine more amount of heat was generated inside the piston during combustion takes place. If the piston material should not resist the heat generated inside the piston it causes failure or damage to the piston. Thermal analysis was used to find the temperature distribution and total heat flux in the piston. Piston head reaches up to 450°C during combustion stage. In here 450°C was applied to piston head and also convection loads are applied to the entire piston.

IV. RESULT AND DISCUSSION

Static structural and thermal analysis was performed for the internal combustion engine piston with using properties of three different materials. The results were generated for both structural and thermal analysis.

A. Static structural Analysis of Al7075

Here, 5 MPa pressure load is applied to the piston head. Maximum Principal Stress, Total deformation and von-mises stress are shown in fig. 5, fig. 6 and fig. 7 respectively.

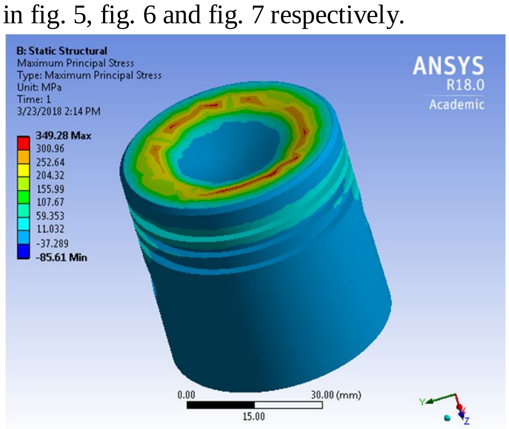

Fig. 5 Maximum Principal Stress

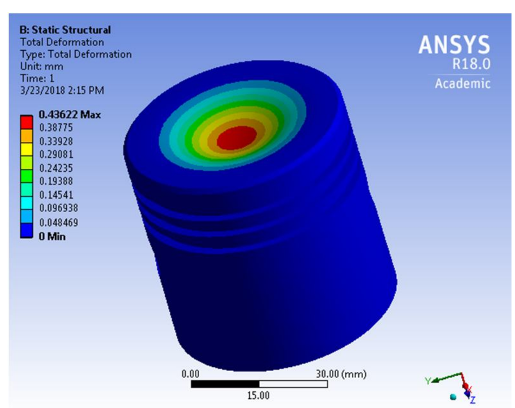

Fig. 6 Total Deformation

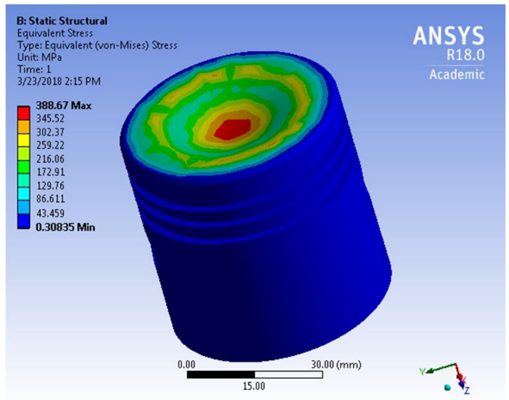

Fig. 7 Von-mises Stress

B. Static Structural Analysis of Al7075+ 5% SiC

Here, 5 MPa pressure load is applied to the piston head. Maximum Principal Stress, Total deformation and von-mises stress are shown in fig. 8, fig. 9 and fig. 10 respectively.

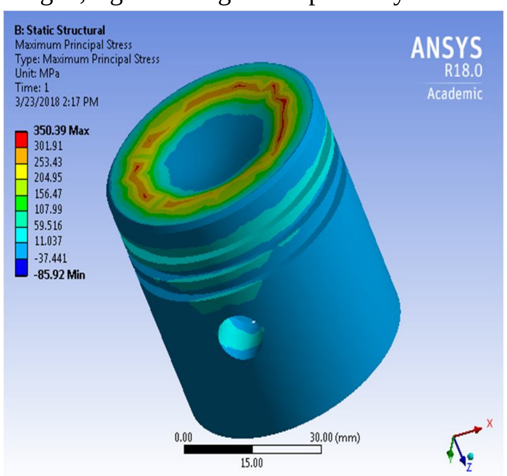

Fig. 8 Maximum Principal Stress

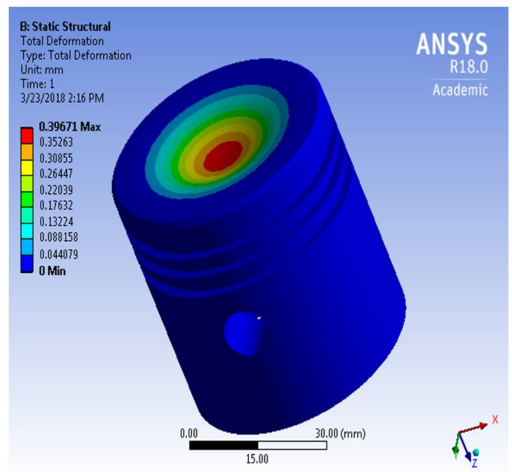

Fig. 9 Total Deformation

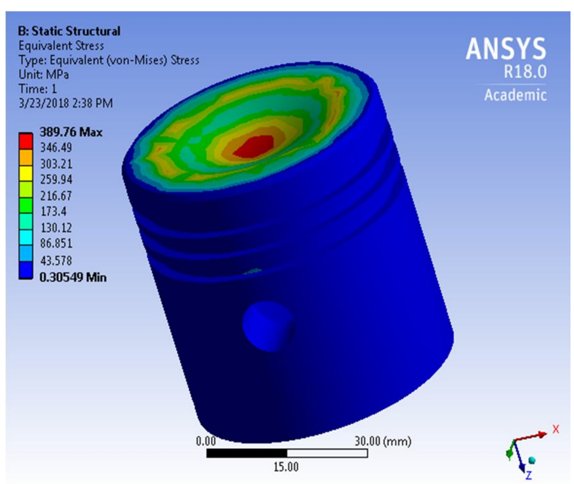

Fig. 10 Von-mises Stress

C. Static Structural Analysis of Al7075 + 10% SiC

Maximum Principal Stress, Total deformation and von-mises stress are shown in fig.11, fig.12 and fig.13 respectively.

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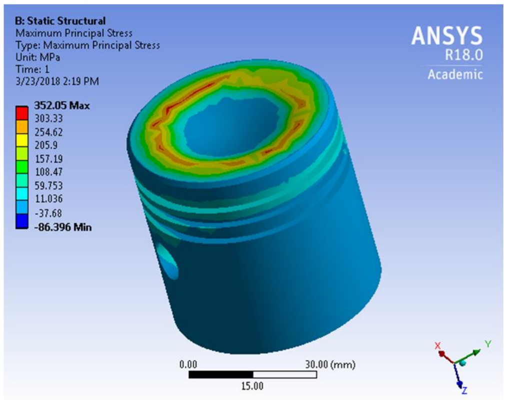

Fig. 11 Maximum Principal Stress

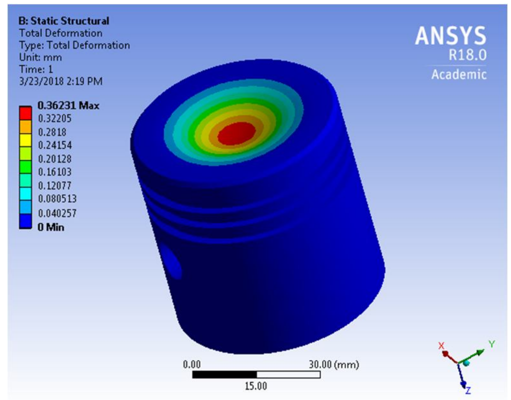

Fig. 12 Total Deformation

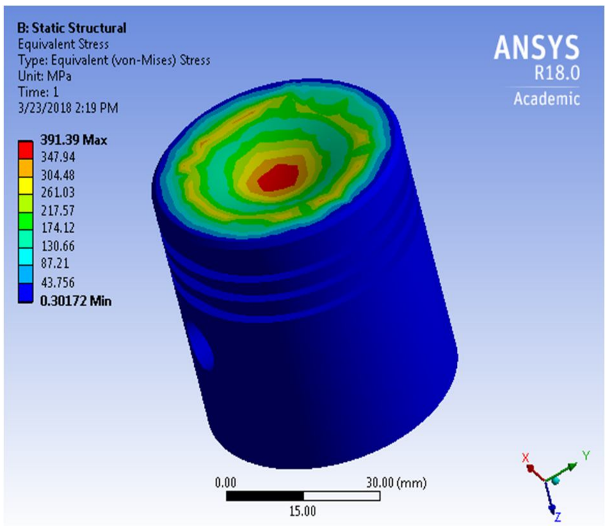

Fig. 13 Von-mises Stress

The static structural analysis was done and the results were generated. Table 5 shows the comparative results of three different materials.

TABLE 5
COMPARISION OF RESULT FOR STATIC STRUCTURAL ANALYSIS

Material	Von-mises Stress (MPa)	Maximum Principal Stress (MPa)	Total Deformation (mm)
Al7075	388.67	349.28	0.43622
Al7075 + 5% SiC	389.76	350.39	0.39671
Al7075 + 10% SiC	391.39	352.05	0.36231

The above table shows the variation of stresses and total deformation of the three materials. From table, Al7075 + 10% SiC material is deformed lower than the other two materials. And also it has higher strength compared to the other two materials. Addition of SiC will improve the mechanical strength of the material. Addition of SiC will improve the mechanical strength of the material.

D. Static Thermal Analysis of Al7075

Temperature distribution and Total heat flux are shown in fig. 14 and fig. 15 respectively.

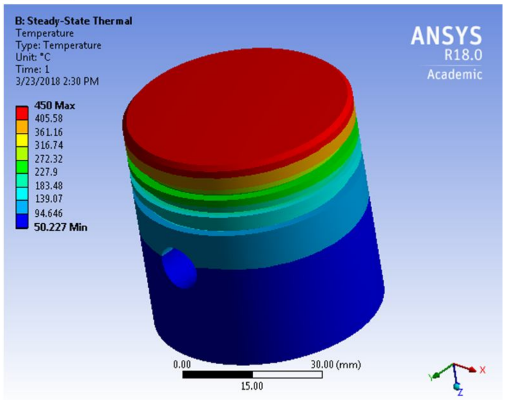

Fig. 14 Temperature Distribution

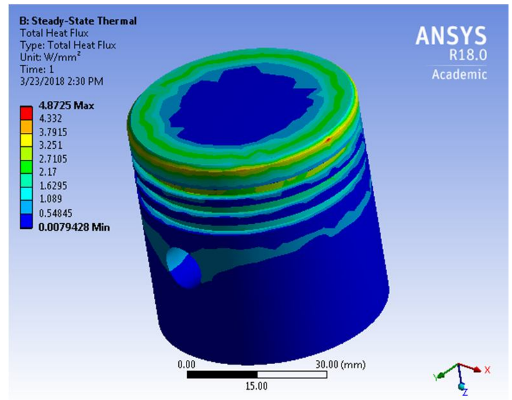

Fig. 15 Total Heat Flux

E. Static Thermal Analysis of Al7075 + 5% SiC

Temperature distribution and Total heat flux are shown in fig. 16 and fig. 17 respectively.

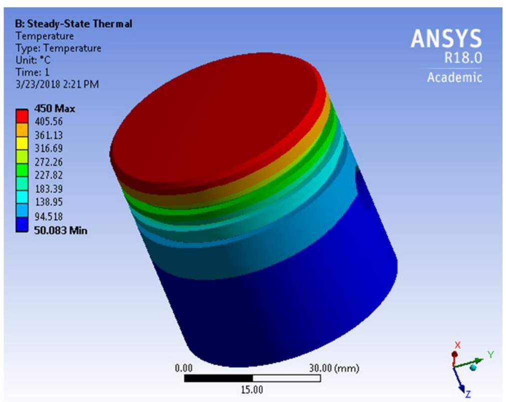

Fig. 16 Temperature Distribution

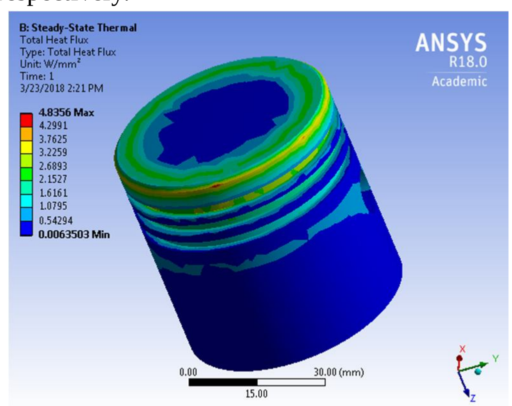

Fig. 17 Total Heat Flux

F. Static Thermal Analysis of Al7075 + 10% SiC

Temperature distribution and Total heat flux are shown in fig. 18 and fig. 19 respectively.

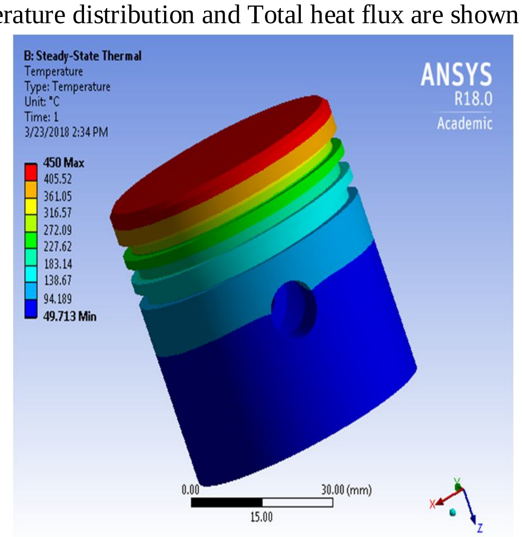

Fig. 18 Temperature Distribution

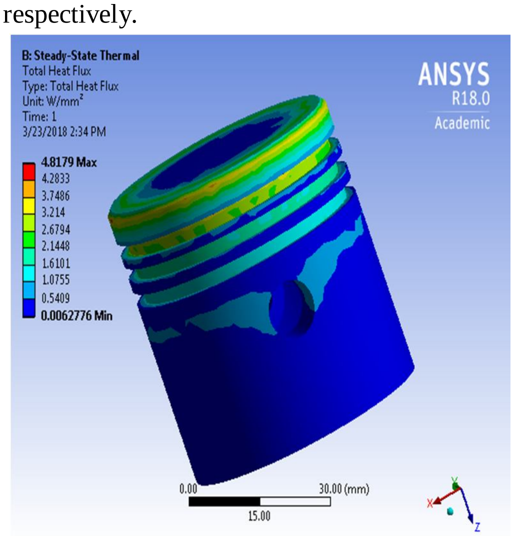

Fig. 19 Total Heat Flux

The static thermal analysis was done and the results were generated. Table 6 shows the comparative results of three different materials.

Table 6
Comparision of result for static thermal analysis

Materials	Total Heat Flux (W/mm^2)
Al7075	4.8725
Al7075 + 5% SiC	4.8356
Al7075 + 10 % SiC	4.8179

The table shows Al7075 + 10% has low heat flux compared to other two materials. Increasing the SiC material in aluminium alloys should decrease the total heat flux of the material.

V. CONCLUSION

Al7075 was reinforced by SiC with different compositions and the material was manufactured by using stir casting technique. The reinforced material was performed under different tests to find its properties. Piston 3D model was analyzed for three different material under pressure forces and temperature conditions. From analyzing results Al7075+10% SiC has low deformation and low heat flux compared to other two materials. SiC reinforced material have a good wear resistance. We concluded that increasing % of SiC will improve the Mechanical and Thermal properties of a material. From three compositions, Al7075 + 10% SiC was a suitable material for the piston.

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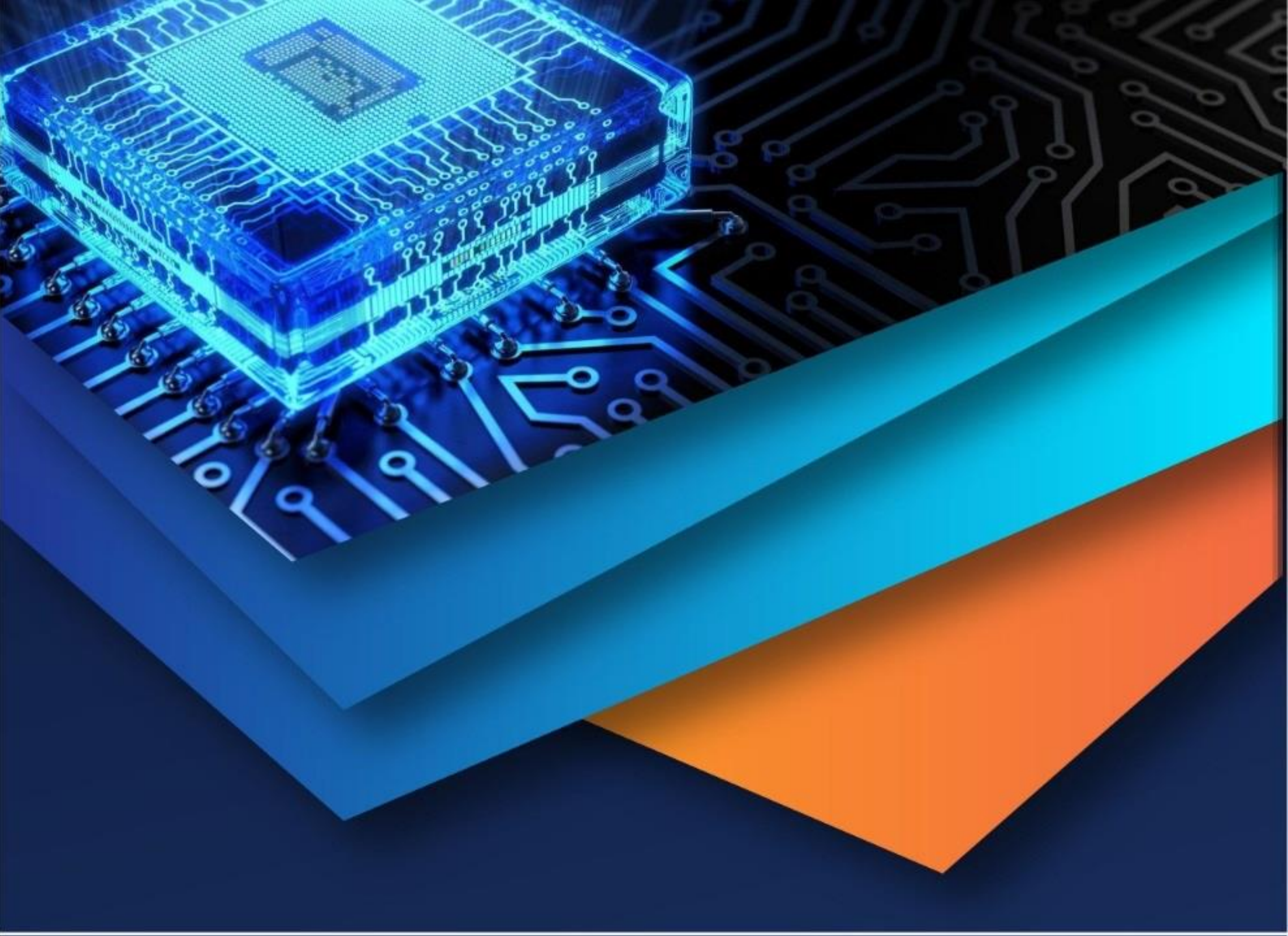

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