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Piston Analysis using FEA Package

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Abstract:** The material in which a continuous metallic phase (the matrix) is combined with another phase (the reinforcement) to strengthen the metal and increase high-temperature stability. The reinforcement is typically a ceramic in the form of particulates, platelets, whiskers, or fibers. The metals are typically alloys of aluminum, magnesium, or titanium In general, the major advantages of Aluminium Matrix Composites (AMCs) compared to unreinforced materials, such as steel and other common metals, are as follows: Increased specific strength, increased specific stiffness, increased elevated temperature strength, improved wear resistance, lower density, improved damping capabilities. The metal matrix composite materials are used in wide range of applications and they have better variant properties like mechanical, thermal and physical properties. So went through the case study about the material and its properties .and we decided to replace the aluminum alloy piston into metal matrix composite piston. Our main objective is to increase a efficiency of automobile engine The main advantage of using MMC piston is to decrease emission upto 40%.Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. There has been an increasing interest in composites containing low density and low cost reinforcements. Now a days the particulate reinforced aluminum matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components and we have done finite element analysis. After that we designed the piston through modeling software "PRO-E " by the data we taken from the piston 180cc pulsar bike by the measurement and after some theoretical calculations were calculated for the analysis . The structural analysis and thermal analysis has done in Ansys12 software and then comparing the structural and thermal analysis results of a aluminum piston and metal matrix composite piston we got a feasible solution.

List of Figures

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I. INTRODUCTION

The most common material used for automotive pistons is aluminum alloys due to its light weight, low cost, and acceptable strength. Although other elements may be present in smaller amounts, the alloying element of concern in aluminum for pistons is silicon. The point at which silicon is fully and exactly soluble in aluminum at operating temperatures is around 12%. Either more or less silicon than this will result in two separate phases in the solidified crystal structure of the metal. This is very common. When significantly more silicon is added to the aluminum than 12%, the properties of the aluminum change in a way that is useful for the purposes of pistons for combustion engines. However, At a blend of 25% silicon there is a significant reduction of strength in the metal, so hypereutectic pistons commonly use a level of silicon between 16% and 19%. Special moulds, casting, and cooling techniques are required to obtain uniformly dispersed silicon particles throughout the piston material. These are the some applications for metal matrix composite materials. Carbide drills are often made from a tough cobalt matrix with hard tungsten carbide particles inside.`Some tank armors may be made from metal matrix composites, probably steel reinforced with boron nitride. Boron nitride is a good reinforcement for steel because it is very stiff and it does not dissolve in molten steel. Some automotive disc brakes use MMCs. Early Lotus Elise models used aluminium MMC rotors, but they have less than optimal heat properties. In general, the major advantages of Aluminium Matrix Composites (AMCs) compared to unreinforced materials, such as steel and other common metals, are as follows:

1) Increased specific strength .
2) Increased specific stiffness .
3) Increased elevated temperature strength .
4) Improved wear resistance .
5) Lower density .
6) Improved damping capabilities .

II. LITERATURE REVIEW

Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials. These materials are produced *in situ* from the conventional production and processing of metals. Here, the Dalmatian sword with its meander structure, which results from welding two types of steel by repeated forging, can be mentioned. Materials like cast iron with graphite or steel with a high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. For many researchers the term metal matrix composites is often equated with the term light metal matrix composites (MMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. In traffic engineering, especially in the automotive industry, MMCs have been used commercially in fiber reinforced pistons and aluminum crank cases with strengthened cylinder surfaces as well as particle-strengthened brake disks.Today, aluminum alloy is generally used for mass produced pistons. However, graphite has several advantages in comparison with aluminum. The density of graphite is much lower than that of aluminum alloy. Other favorable properties of graphite are the lower coefficient of thermal expansion and the higher resistance to heat. Unfavorable is that the tensile strength of graphite at room temperature is comparatively low. However, considering the tensile strength as a function of temperature. The strength of aluminum alloy drops at temperatures above 160 ^{O} C. In contrast to this the tensile strength of graphite even increases slightly with temperature.

III. FEATURES OF PISTON

The figure given below shows the detailed view of pulsor 180cc piston.

A. Nomenclature Of Piston

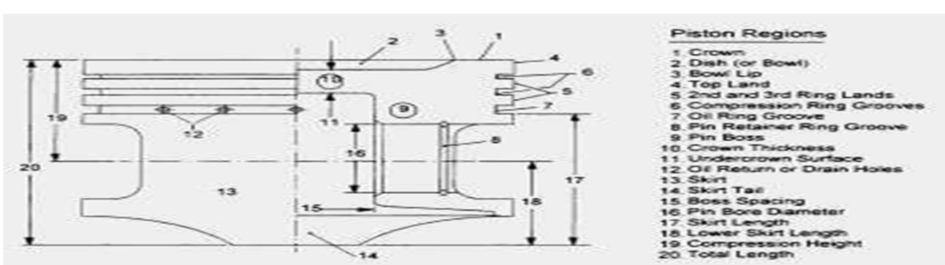

Fig 3.1

B. Nomenclature of Piston

1) *Purpose Of The Piston:* Transfer of energy of combustion gases into translation motionof the piston and eventually into rotation motion of the crank.

a) *Piston Classification*

- *Type Of Engine*
  - Diesel
  - Petrol

- *Two-Stroke Gasoline*

Four-Stroke Gasoline

- *Size Of The Engine*
  - Large
  - Medium
  - Small

- *Type Of Design*
  - Conventional
  - Articulated

b) *Modelling:* In PRO-E, modeling usually takes on the narrower meaning of generating the model, represent the special volume and connectivity of the actual system.

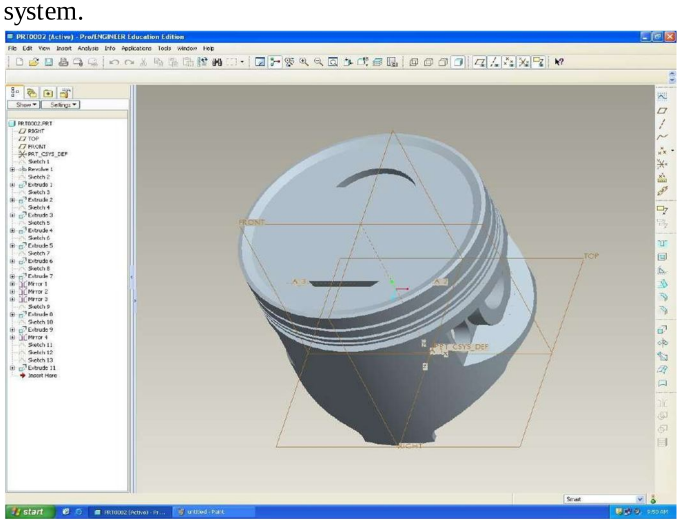

FIG – 3.1 Solid Modeling of Piston

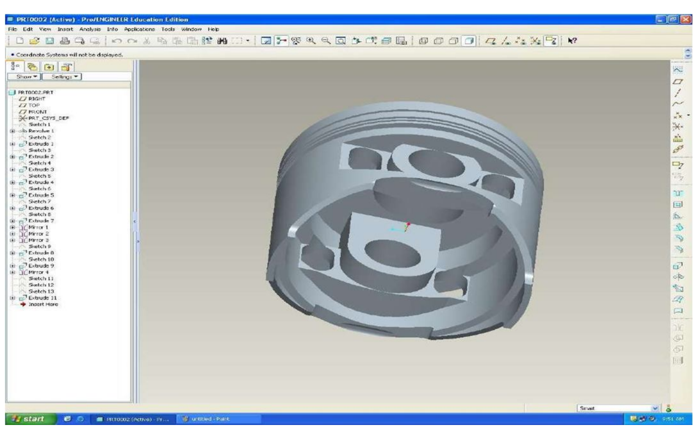

Fig-3.2. A view of pin holes

C. *Technical Details Of The Piston*

1) *Specifications of pulsar 180cc four Stroke petrol Engine Piston*

Bore DIAMETER : 56mm Stroke Length : 78.4mm Gas pressure : 5 Mpa BMEP : 1.34Mpa
Speed : 8000rpm

2) *Material of the piston*

Aluminium alloy.

3) *Mechanical Properties of the Piston Made of Aluminum*

Young's modulus: 0.645×10^{5}N/mm^2 Poisons ratio : 0.345
Density : 2707Kg/m^3

Thermal diffusivity : 84.18×10^{-6} m^2 /s Specific heat : 896J/kgK
Thermal conductivity : 204.2W/mK

D. *Theoretical Calculation to Find Out The Maximum Load On The Piston*

1) Step1: Calculation of Power

Brake power = BP
Mean pressure = P
Stroke length = L
Area of piston = A
Speed = N

$$BP = \frac{PLAN}{1000\times60}\ \text{KW}$$

$$= \frac{1.34\times78\times\prod\times(56\times56)\times8000}{1000\times4\times60}$$

$$= 17.162\text{KW}$$

2) *Step2:* Length of the piston(L)

L=D, =56mm

3) *Step3:* Calculation of thickness based on heat dissipation

$$q = \frac{K2\times C\times W\times BP}{A}$$

$$= \frac{0.177\times(48000\times1000)\times \frac{0.121}{3600}\times17.162}{2.463\times10^{-3}}$$

$$= 200344\text{J/S-m}^2$$

$$t1 = \frac{D^2q}{1600\times K\times(T_C - T_E)}$$

$$= \frac{56^2\times200344}{1600\times460\times222} = 3.8\text{mm}$$

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4) *Step4:* Then thickness head based on the empirical formula

$$t = 0.032D+1.5mm = 0.032\times56 + 1.5$$
$$= 3.1mm$$

5) *Step5:* The thickness of piston head based on stress

$$\sqrt{\frac{5}{90}}$$

t_1 □ 0.43□ 56

= 5.4mm

6) *Step6:* design of Piston Rings

t_r □ D □ $\sqrt{\frac{3P_r}{\sigma}}$

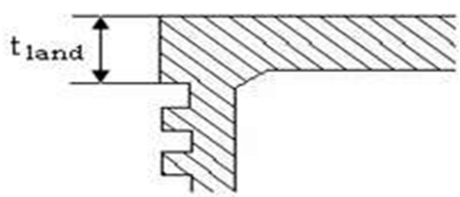
$$= 56\times\sqrt{\frac{3\times0.02746}{80}}$$

= 3mm

7) *Step7:* The depth of the piston (h)

h =0.7t_r

=0.7×3 = 2.1m



8) *Step8:* The distance from top to the first groove (t_g)

t_g = 1.0 *t1* to 1.2 *t2*

= 1.2 *t1*

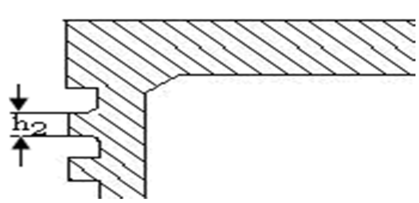
= 1.2 × 5.6 = *6.7mm*

9) Step9: The lands between the ring grooves (t_{land})

$t_{land} = h$

= *h*

= 2.1mm



10) Step 10: The minimum depth of the piston ring

$$h = \frac{D}{10i} \quad i = \text{no of piston rings}$$

$$i = \frac{D}{10h} = \frac{56}{10 \times 2.1} = 3\text{nos}$$

11) Step11: The maximum thickness of the piston barrel (t_3)

t_3 = 0.03 D + b + 4.5 mm,

b = depth of ring groove, mm

= t_r + 0.4 mm= 3 + 0.4 = 3.4 mm

t_3 = 0.03 x 56 + 3.4 + 4.5

= 9.58 mm

12) Step12: The wall thickness towards the open end of the piston (t_4)

t_4 = 0.25 t_3 to 0.35 t_3

= 0.3 t_3

= 0.3 x 9.58

= 2.874 mm

13) Step13: Stroke length (L_5)

L_5 = 1.3 D to 1.4 D

= 1.4 D = 1.4 x 56 = 78mm

14) Step14: Force on piston (F_p)

F_p = P x A

= 12.38 KN

Hence load acting on a piston is 12.34KN.

IV. FINITE ELEMENT ANALYSIS

Finite element analysis is a process, which can predict deflection, and stress on a structure. Finite element modeling divides the structure into a grid of elements, which form a model of the real structure. Each of the elements is a simple share (such as a square or a triangle) for which the finite element program has information to write the governing equations in the form of a stiffness matrix. The unknowns for each element are the displacements at the node point, which are the points at which the elements are connected. The finite element program will assemble the stiffness matrices for these simple elements together to form the global stiffness matrix for the entire model.

A. Steps in Finite Element Analysis (ANSYS)

Finite element consists of three steps, these are:

1) Pre-processing
2) Solution
3) Post-processing

Pre-processing includes the entire process of developing the geometry of a finite element model, entering physical and material properties, describing the boundary conditions and loads, and checking the model. The solution phase can be performed in the model solution task of the simulation application, or in an external finite element analysis program.

Post-processing involves plotting deflections and stresses, and comparing these results with failure criteria imposed on the design such as maximum deflection allowed the material static and fatigue strengths, this is usually not the case.

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B. Simulation Application

These are several tasks in the simulation application covering the three steps of pre- processing the model, solution and post-processing. The basic tasks used for the three steps of finite element modeling include.

1) Simulation Tasks

a) Pre-processing
- Master modeler
- Meshing
- Boundary conditions

b) Solution
- Model solution

c) Post-processing

Although nodes and elements can be created manually in the meshing task, finite element models are more easily built by automatically meshing parts created in the master modeler, either in the simulation application or the design application. The meshing task is used to create nodes and elements, check the model, and enter material properties. The boundary conditions task is used to apply boundary conditions to the part geometry or the codes and elements. Either meshing or boundary conditions may be done first, depending on the type of boundary conditions. When the model is complete, it is solved in the model solution task and the results displayed in the post-processing task.

C. SHELL181 Element Description

SHELL181 is suitable for analyzing thin to moderately-thick shell structures. It is a 4-node element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z-axes. If the membrane option is used, the element has translational degrees of freedom only. The degenerate triangular option should only be used as filler elements in mesh generation.

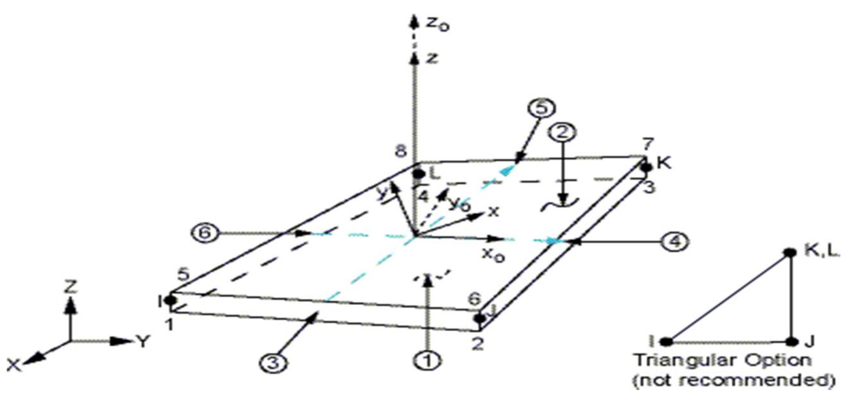
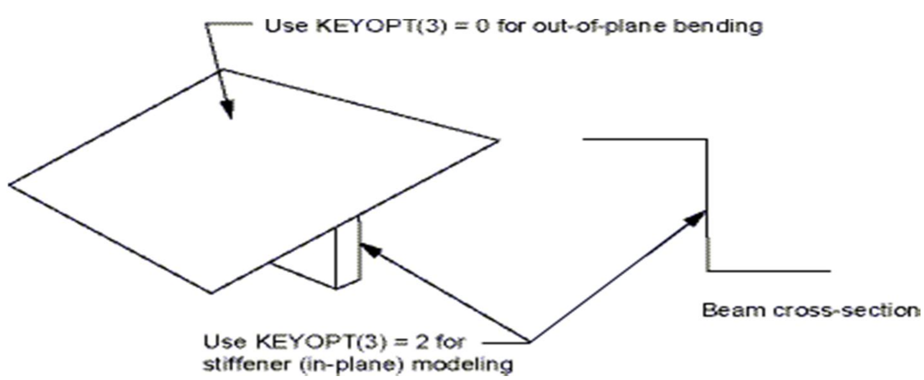
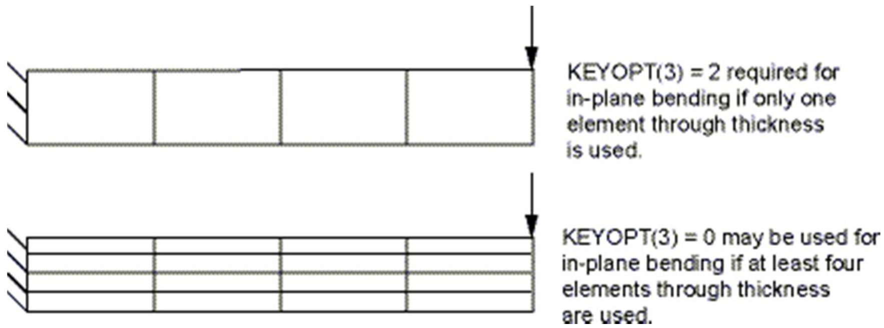


Fig 4.3.1.1 SHELL181 Geometry

x_O = Element x-axis if ESYS is not provided. x = Element x-axis if ESYS is provided.



D. SHELL181 Typical Bending Applications



The cantilever beam and the beam cross-section to be modeled with shells are typical examples of in-plane bending-dominated problems. The use of KEYOPT(3) = 2 is the most effective choice in these circumstances. Reduced integration would require refined meshes. For example, reduced integration for the cantilever beam problem requires four elements through the thickness, whereas the full integration with incompatible modes only requires one element

E. SHELL181 Output Data

The solution output associated with the element is in two forms:

1) Nodal displacements included in the overall nodal solution

2) Additional element output as shown in Table 181.2: "SHELL181 Element Output Definitions"

SHELL181 does not support extensive basic element printout. POST1 provides more comprehensive output processing tools; therefore, we suggest using **OUTRES** to ensure that the required results are stored in the database.

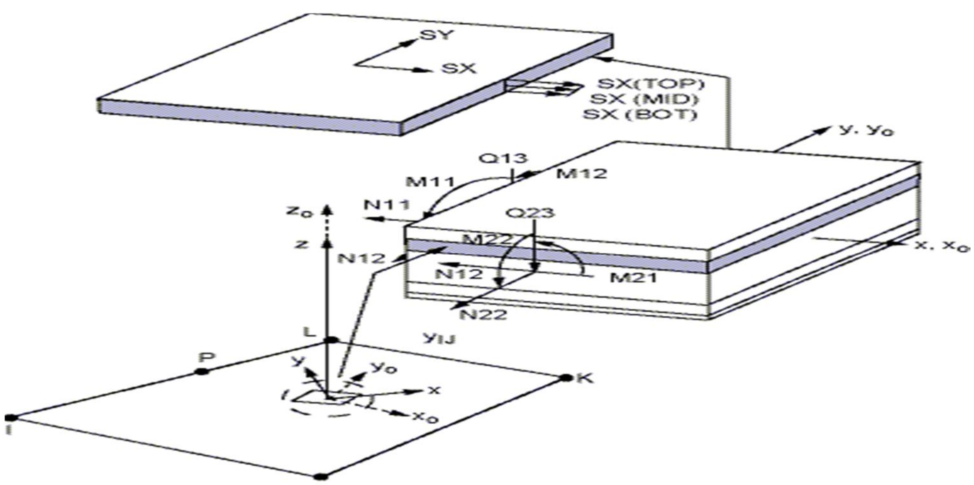


Fig 4.4.1.2 Stress Output

x_o = Element x-axis if ESYS is not provided. x = Element x-axis if ESYS is provided.

V. FEATURES OF COMPOSITE MATERIAL

Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Many of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (physical property of steel are similar to those of pure iron) . Favorable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc.

A. Matrix Phase

1) The primary phase, having a continuous character,
2) Usually more ductile and less hard phase,
3) Holds the reinforcing phase and shares a load with it.

B. Reinforcing Phase

1) Second phase (or phases) is imbedded in the matrix in a discontinuous form,
2) Usually stronger than the matrix, therefore it is sometimes called reinforcing phase.

C. Classification Of Composites

Composite materials are classified

1) On the basis of matrix material,
2) On the basis of filler material.

D. Fibrous Composites

1) Short-fiber reinforced composites. Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter).
   a) Composites with random orientation of fibers.
   b) Composites with preferred orientation of fibers.

2) Long-fiber reinforced composites. Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers.
   a) Unidirectional orientation of fibers.
   b) Bidirectional orientation of fibers (woven).
   c) Laminate Composites

E. Reinforcements

Reinforcements for metal matrix composites have a manifold demand profile, which is determined by production and processing and by the matrix system of the composite material. The following demands are generally applicable :

VI. STEPS INVOLVED IN FEA

A. Pre-Processing

To do this, FEA software typically uses a CAD representation of the physical model and breaks it down into small pieces called finite “elements” (think of a 3-D puzzle). This process is called “meshing.” The higher the quality of the mesh (collection of elements), the better the mathematical representation of the physical model.

B. Solving

ANSYS employs 3 of the ANSYS solvers and automatically chooses the most appropriate or efficient solver for the job at hand. In addition to linear/static, ANSYS Workbench performs Coupled analysis types (thermal-stress, stress-modal, thermal-stress modal) as well as some limited non-linear analysis types (thermal with temperature-dependent material properties and convection, geometric/contact with contact supporting lift-off). All solver settings and iteration propagations from one solve step to the next are performed automatically.

C. Post-Processing (Interpretation Of Results)

The output of a solver is generally a very substantial quantity of raw data. This quantity of raw data would normally be difficult and tedious to interpret without the data sorting and graphical representation referred to as post-processing. Post-processing is used to create graphical displays that show the distribution of stresses, strains, deformations, temperatures, and other aspects of the model.

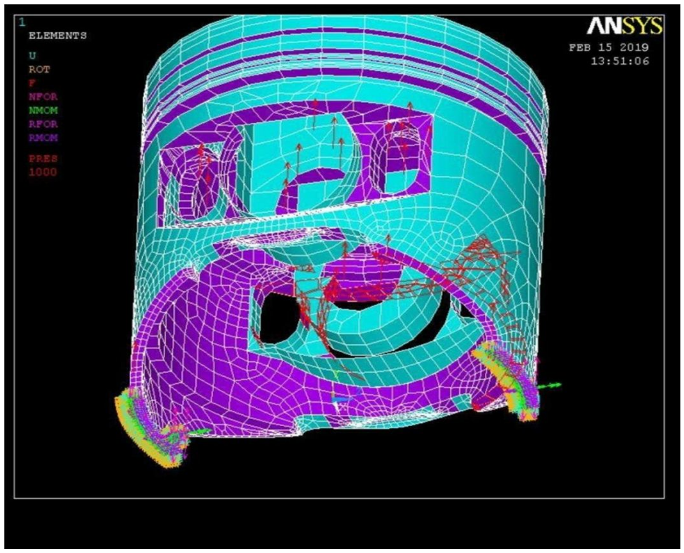


Fig-6.1. Piston with Boundary Conditions (Aluminium)

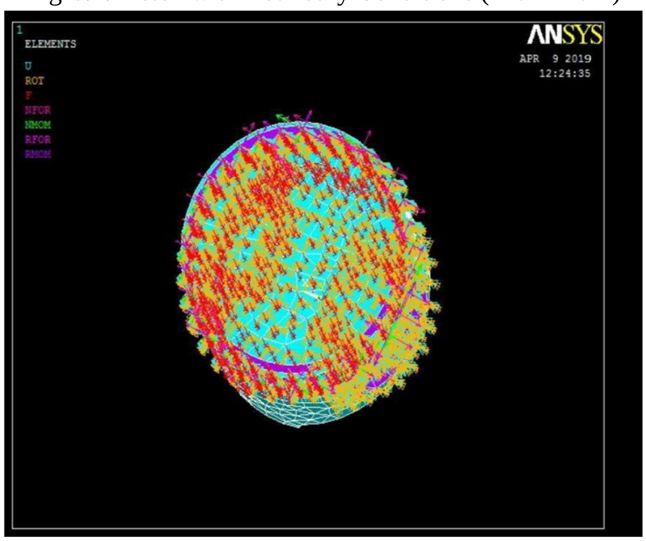


Fig 6.2. Pressure distribution on the Aluminum piston

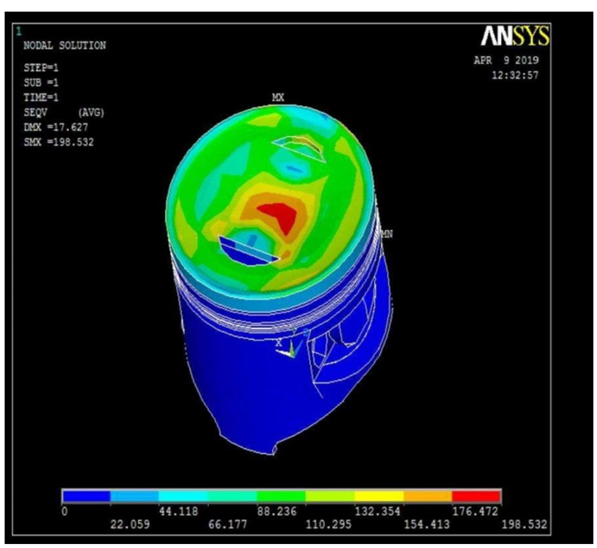


Fig 6.3. Vonmises Stress Distribution for Aluminium Piston values of stress taken from Vonmises Stress Plot

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1) MAX STRESS σ1=198.53N/mm2
2) INTERMEDIATE STRESS σ2=110.29N/mm2

MIN STRESS σ3=22.05N/mm2

(σ1-σ2) 2 + (σ2-σ3) 2 + (σ3-σ1) 2

By substituting the values in the above equation,

Max yield stress = 108.15N/mm^2

Allowable stress for aluminium = 230N/mm^2

Hence the yield stress is less than the allowable stress

$$\square_y < \square_u$$

108.15N/mm^2<230N/mm^2

Factor of safety = 230/108.15

= 2.1

Hence design is safe.

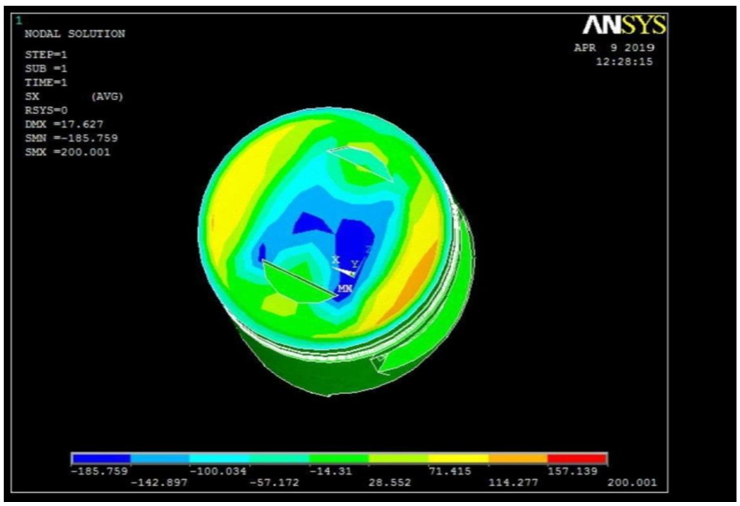

FIG 6.5. XY Shear Stress for Aluminium piston

D. Orthotropic Properties of MMC Piston

Youngs modulus in x-direction E1= 97.082N/mm^2 Youngs modulus in y-direction E2= 7.04N/mm^2 Youngs modulus in z-direction E3= 4.9208N/mm^2

Poissons ratio μ1 = 0.27 Poissons ratio μ2 = 0.18 Poissons ratio μ3 = 0.12 Rigidity modulus G12 = 39.14N/mm^2 Rigidity modulus G23 = 3.18N/mm^2 Rigidity modulus G31 = 2.98N/mm^2

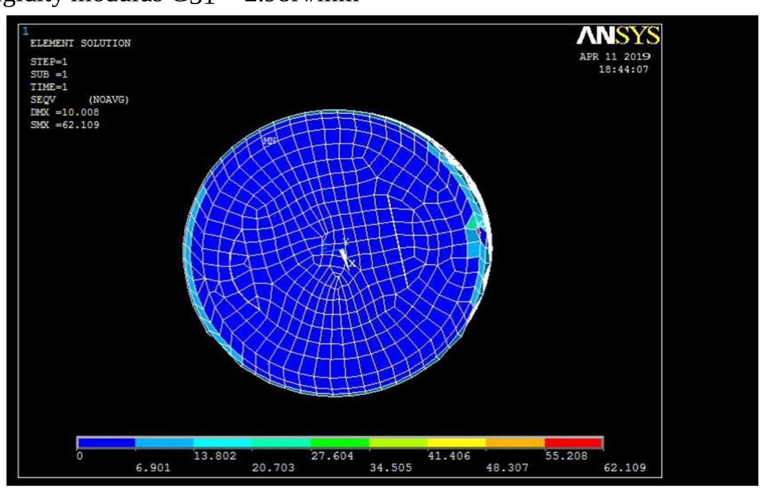

Fig 6.6. Vonmises Stress for Carbon Carbon Piston (structural)

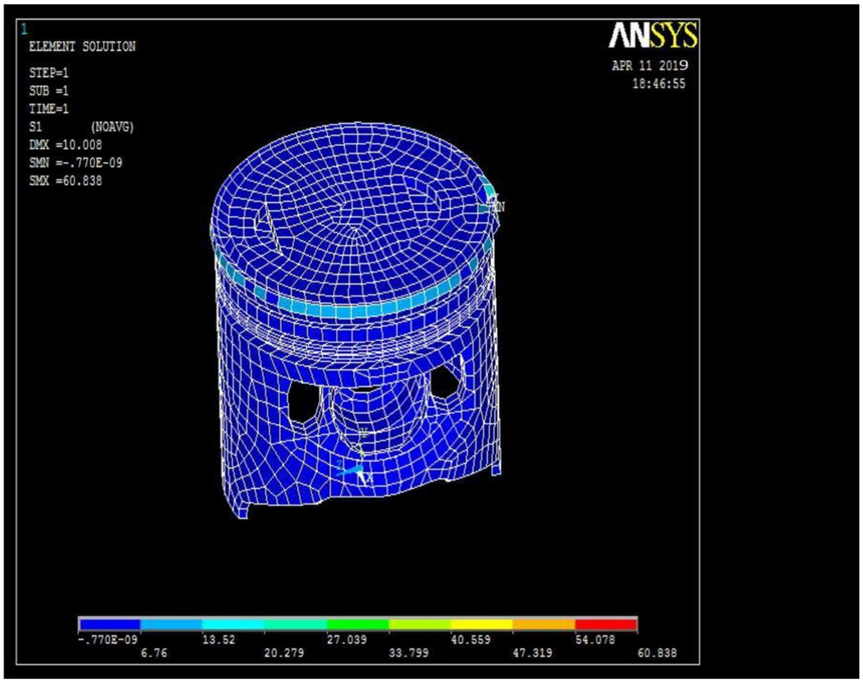

Fig 6.7 First Principal Stress For Carbon Carbon Piston (Structural)

E. *Failure Theories of A Composite Material*

1) *Tsai-hill Theory:* Hill extended the von Mises criterion for ductile anisotropic material. Azzi-Tsai extended this equation to anisotropic fiber reinforced composites. Failure occurs when the LHS of the following equation is equal to or greater than one.

$$A\sigma_1^2 + b\sigma_2^2 + C\sigma_1\sigma_2 + D\tau^2 = 1$$

From longitudinal, transverse, and shear stress on a unaxial laminate A ,B ,and D are determined

$A=1/F_1^2$ $B=1/F_2^2$ $D=1/F_6^2$ From equal biaxial test

Failure occurs when the transverse stress (□2) reaches F_2 $C_1=-1/F_1^2$

2) *Tsai-Hill Failure Criterion*

3) σ 2 σ 2 σ1σ2 τ 2 + _ + =1 F12 F22 F12 F62 σ 2 σ 2 σ1σ2 ---- + ----- _ -------=1-k 2 k= τ 2 /F6 F12 F22 F12

4) *Analytical Calculations*

$$A\sigma_1^2 + b\sigma_2^2 + C\sigma_1\sigma_2 + D\tau_6^2 = 1$$

A= longitudinal B= transverse D= shear stress

5) *For Tensile*

$$A = \frac{1}{F_1^2} = \frac{1}{(331)^2} = 9.12\times10^{-6}\ N^{-2}$$

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$$B = \frac{1}{F_2^2} = \frac{1}{(8.3)^2} = 0.0145\ N^{-2}$$

$$D = \frac{1}{F_6^2} = \frac{1}{(10.3)^2} = 9.425\times10^{-3}\ N^{-2}$$

6) For Compressive

$$A = \frac{1}{F_1^2} = \frac{1}{(208.9)^2} = 2.29\times10^{-5}\ N^{-2}$$

$$B = \frac{1}{F_2^2} = \frac{1}{(33.1)^2} = 9.12\times10^{-4}\ N^{-2}$$

$$D = \frac{1}{F_6^2} = \frac{1}{(10.3)^2} = 9.42\times10^{-3}\ N^{-2}$$

$$C = -1/F_1^2 = -1/(208.9)^2$$

$$= -2.29\times10^{-5}\ N^{-2}$$

$$A\sigma_1^2 + b\sigma_2^2 + C\sigma_1\sigma_2 + D\tau_6^2 = 1$$

Substituting the values in the equation we get the

= 0.0434+0.09066-0.099

= 0.19

So hence LHS is less than RHS , 0.19<1,
So design is safe.

7) TSAI – HILL Failure Critertion

$$\frac{\sigma_1^2}{F_1^2} + \frac{\sigma_2^2}{F_2^2} - \frac{\sigma_1\sigma_2}{F_1^2} + \frac{\tau_{12}^2}{F_6^2} = 1$$

$\sigma_1 = 62.10 N/mm2$, $\sigma_2 = 6.90 N/mm2$

$$= \frac{(62.10)^2}{(331)^2} + \frac{(6.90)^2}{(8.3)^2} - \frac{(62.10 \times 6.90)}{(331)^2} + \frac{(7.2)^2}{(10.3)^2} = 1$$

0.03611+0.5729-0.0036 = 0.109

hence LHS <RHS 0.109<1
So design is safe.

8) Tsai-Wu Theory

Tsai-Wu theory is a simplification of Gol'denblat and Kapnov's generalized failure theory for **anisotropic materials. It is stated as**

$f_i\sigma_i + f_{ij}\sigma_i\sigma_j = 1$ I,j=1,2,3,4,5,6

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$f1\ \sigma1 + f2\ \sigma2 + f11\ \sigma\ 2 + f22\ \sigma\ 2 + f66\ \tau6\ 2 + 2\ f12\ \sigma1\ \sigma2 = 1$ Failure occurs when the LHS of the following equation is equal to or greater than one.

Shear strength is independent of sign of the shear stress, therefore all linear shear stress terms must vanish. Therefore we get

$f1\sigma1+f2\sigma2+f11\sigma1\ 2+f22\sigma\ 2+f66\tau\ 2+2f12\sigma1\sigma2 = 1$ Now we will evalute all six constants for tests:

a) Longitudinal Tension & Compression Tests

f1 =1/F1t - 1/F1c and f11=1/F1t F1c = f 11=1.4462*10-5N f1 = -1.768*10-3N

(b) Transverse tension & compressiontests: f2 =1/F2t - 1/F2c and f22=1/F2t F2c = f 22 =3.6399*10-3N =0.0902N

(c)Sheartests: f66=1/F 2 = 9.4259*10-3N $f1\sigma1+f2\sigma2+f11\sigma\ 2+f22\sigma\ 2+f66\tau\ 2+62f12\sigma1\sigma2=1$ Substituting

Hence LHS<RHS 0.73<1
so design is safe

F. Thermal Analysis For Aluminium And Composite Material

ANSYS is capable of both steady state and transient analysis of any solid with thermal boundary conditions. Steady-state thermal analyses calculate the effects of steady thermal loads on a system or component. Users often perform a steady-state analysis before doing a transient thermal analysis, to help establish initial conditions. A steady-state analysis also can be the last step of a transient thermal analysis; performed after all transient effects have diminished. ANSYS can be used to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by thermal loads that do not vary over time. Such loads include the following:

1) Convection
2) Radiation
3) Heat flow rates

G. Thermal Properties Of Aluminium

1) Density = 2707Kg/m^3
2) Thermal conductivity = 204.2W/mK
3) Specific heat = 896J/KgK
4) Emmisivity = 0.4
5) Max temp = 3000^0 C
6) Thermal coefficient of expansion = 40W/m^{2}k

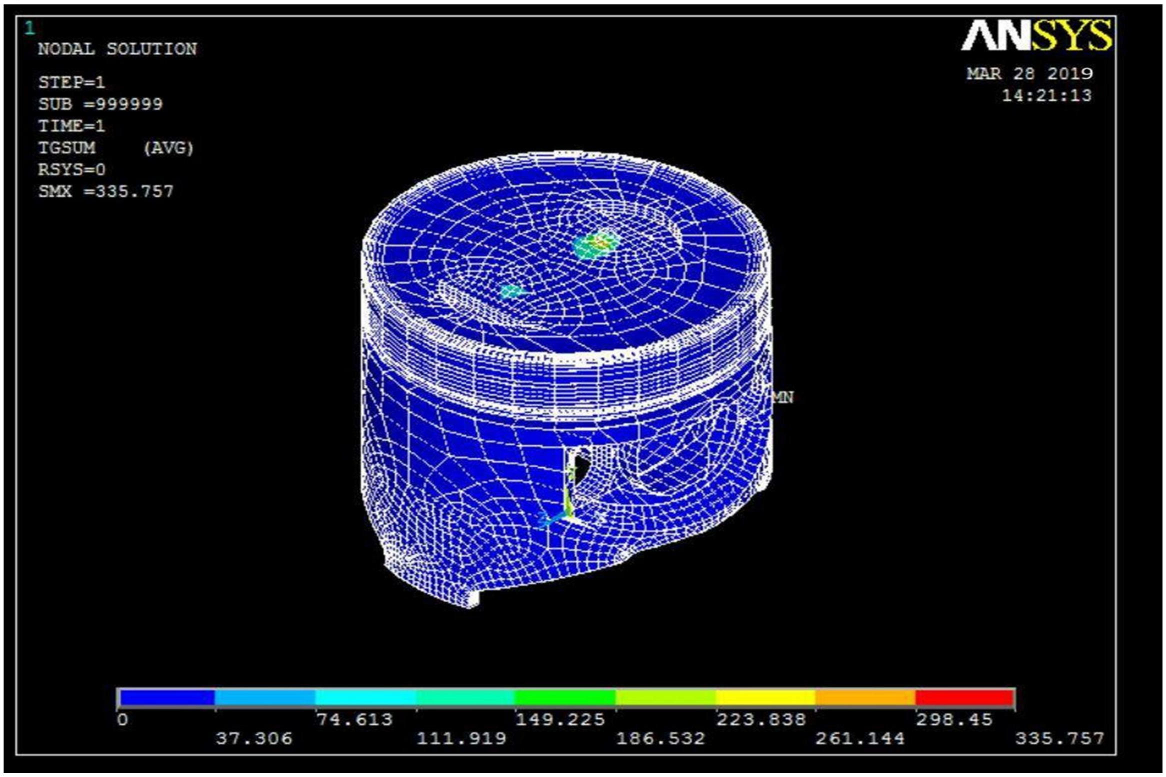
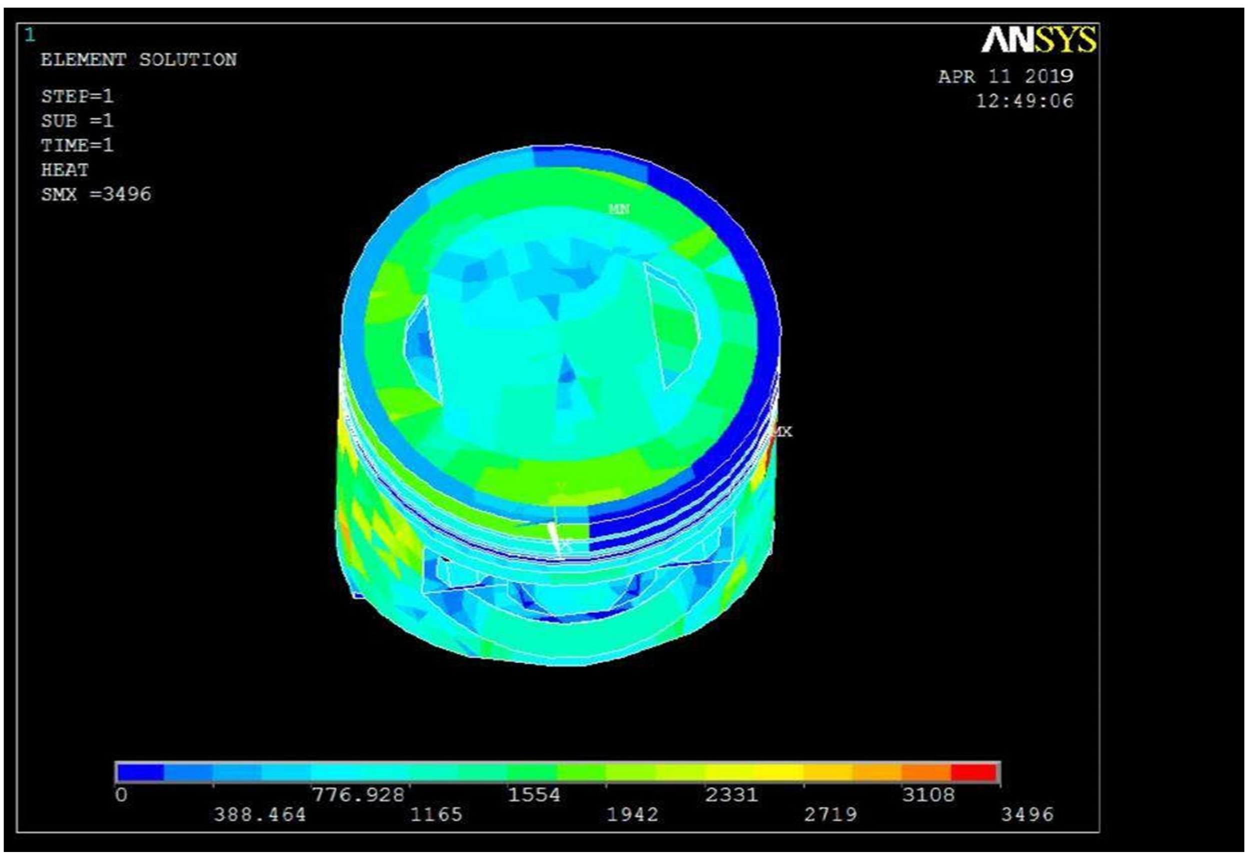


FIG 6.8. Thermal Gradient for Aluminium Piston (Thermal)



Heat Flow In Aluminium Piston (Thermal)

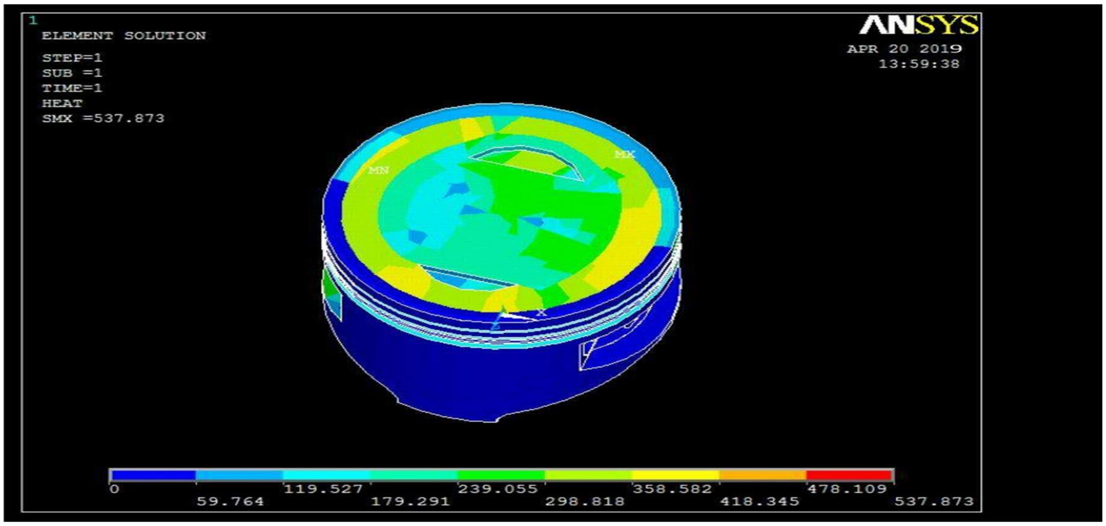


Fig-6.11 Heat Flow In Carbon Carbon Piston

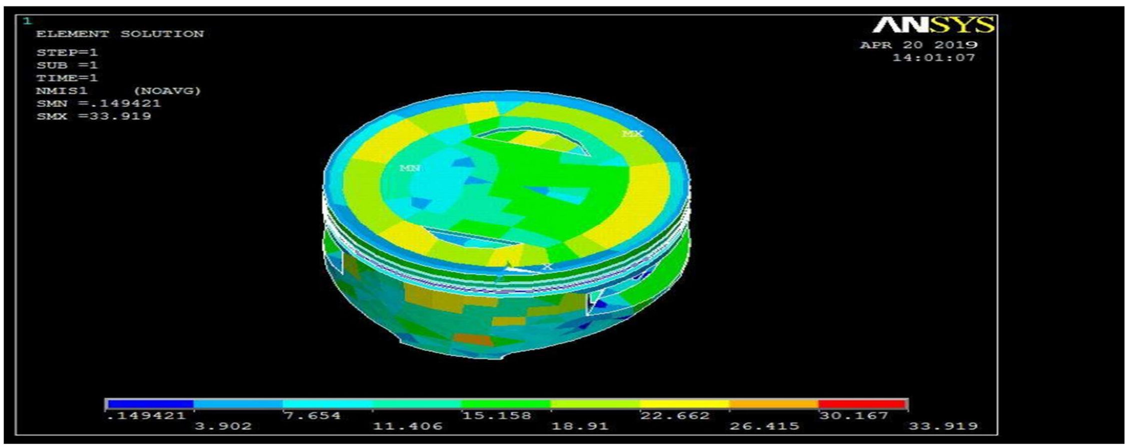


Fig 6.12 Thermal Stress For Carbon Carbon Piston

VII. RESULTS AND DISCUSSION

The following table shows the results for the structural and thermal analysis carried on a piston of a 4 stroke engine with convention material and composite material using FEA.

A. *Validation of Structural And Thermal Analysis Results*

Material	Vonmises Stress N/MM^2		Heat Flow Watts
	Analytical	FEA	
Aluminium	108.48	198.4	3496
CARBON CARBON	33.8	62.09	534.6

B. *Percentage of Saving In Material By Conversion Of Aluminium Piston To Carbon Carbon Piston*

Material	Deflection (mm)	Weight of The Piston In (gms)
Aluminium	17	265
Carbon Carbon	10	179

Percentage of weight reduced =(265-179)/(265)×100= 36.4%

VIII. CONCLUSION

Thus the project work says about the strength of piston using conventional and composite material supported by STRUCTURAL analysis and THERMAL analysis using FEM of ANSYS 12.0

The following are the conclusions derived from the project

A. The strength of a component is known clearly when the stress produced on the component is less . In convention material the stress produced on the piston due to the application of loads on apt positions of the product is high comparing the metal matrix composite piston

B. Hence it can be said that based on the stress values the weight of composite piston is less comparingly the conventional piston

C. By performing the thermal analysis on the piston made out of conventional and composite material it can be stated that MMC piston is highly temperature resistive comparing to the conventional material as per the results of thermal stresses using FEA. Thus this project determines the optimum material at which the piston is high strength and temperature resistant.

IX. FUTURE SCOPE

To Continuing the research work some suggestions can be made for further research work they are as follows

A. The performance of a piston in engine can be increased by modifying the design parameters like piston crown diameter, piston lining material thickness , piston pin hole diameter .

B. Torsional vibrational analysis can also be carried out to minimize the deflection of piston.

C. Some alloy coatings applied on the piston material which will make the piston to with stand fatigue results .

D. The thermal parameters can be altered by reducing manufacturing defects which will further increase the thermal efficiency of the piston ,and using optimization techniques like Genetic algorthim and design of experiments.

All the above points can be done experimentally and also can be proved using MINITAB software

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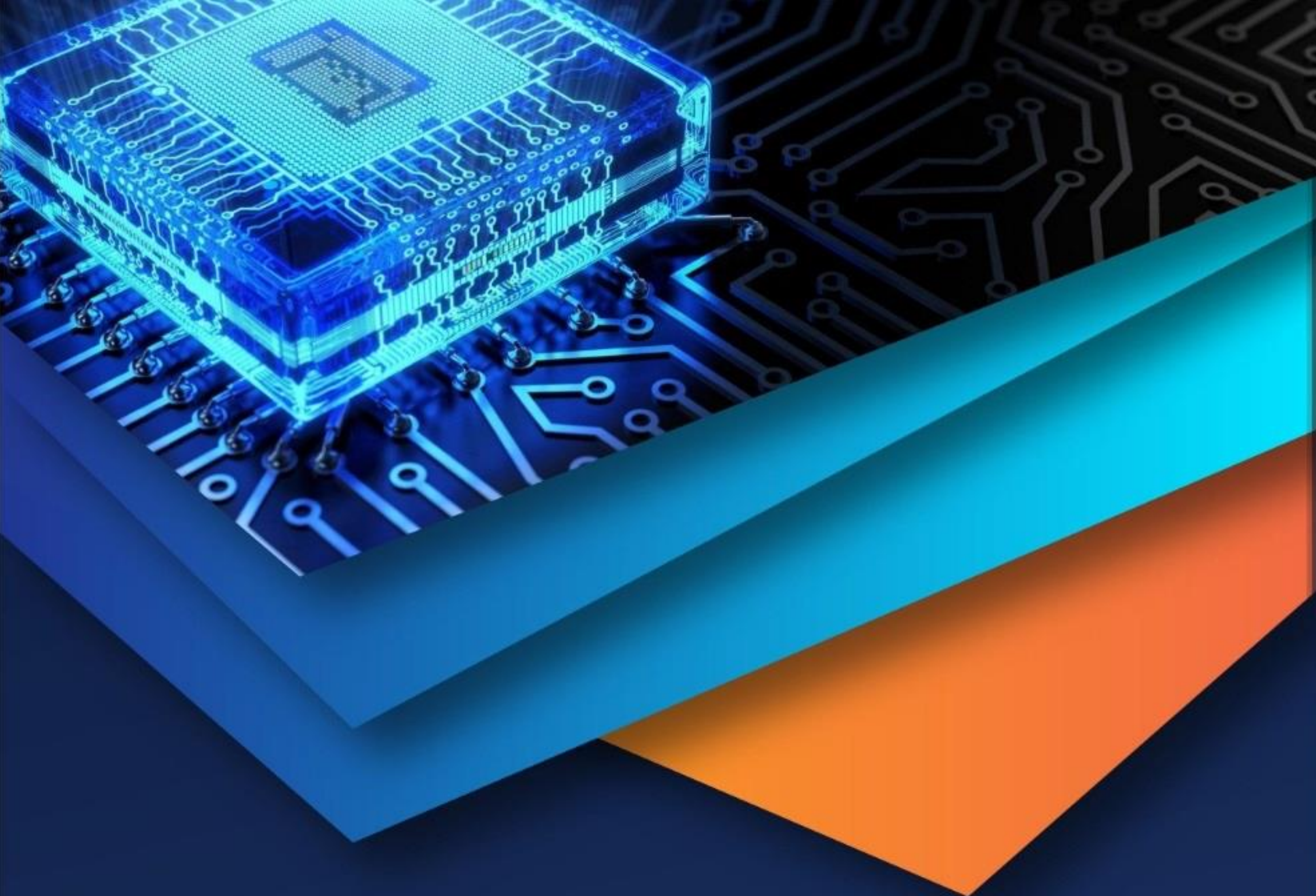

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