International Journal of Inventive Engineering and Sciences (IJIES)
ISSN: 2319-9598 (Online), Volume-11 Issue-12, December 2024

Thermal and Structural Analysis of Piston by Ansys

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Abstract:** Automobile part happen in excellent demand presently because of raised use of automobiles. The raised demand exist due to made better depiction and reduced cost of these part. R&D and experiment engineers endure develop fault-finding part in abbreviated attainable period to minimize begin temporal length of event or entity's existence for new products. This make necessary understanding of new science and active absorption fashionable the happening of new products. A turbine happen a mobile component that is hold by a a geometrical form and is fashioned something not liquid or solid-close by piston rings. In an device that drives a machine allure purpose search out transfer from expanding something not liquid or solid fashionable the cylinder to the a device for revolving a shaft rod by way of piston bar and or joining rod. As an fundamental part fashionable an device that drives a machine piston sustain the recurrent gas pressure and hotness working and this active condition may cause the damage of the device that drives a machine. The thorough check indicate that excellent stress perform in contact the upper end of the device that drives a machine and stress aggregation is individual of the for the most part reason on account of high temperature and pressure of fuel. The facial characteristics of the engine are device that drives a machine head, device that drives a machine hold in place bore, piston attach, skirt, ring daily routine, ring land and piston ring. Finite Element Analysis exist a imitation method which evaluates the manner of conducting oneself of part, equipment and form for miscellaneous stowing conditions containing used forces, pressures and temperatures. Thus, a complex the science of applying power to use question accompanying non-standard shape and geometry maybe resolve using subject to limitations place where one feels comfortable reasoning where a shut form resolution is not ready for use. The subject to limitations essential feature analysis system influence the stress disposal, displacements and reaction loads at supports for the model. Finite place where one feels comfortable statement of results from examination techniques maybe second hand for any of scenarios as model mesh growth, design optimization, material pressure belittlement, shape addition and code agreement. Finite place where one feels comfortable analysis in addition to bear the ability to perform to perform FEA for airplane element, automotive components, device that drives a machine element and different mechanical /fundamental part. The design for various element happen examine for compliance against the ASME Code or different appropriate secret language system. Finite Element Analysis is act for two together design and statement of results from examination / evaluation position. Two-relating to space and size and three-dimensional FEA question exist devote effort to something for structural, warm, and warm stress evaluations [1].

***Keywords:** Auto cad, Ansys14.0*

Manuscript received on 06 April 2024 | Revised Manuscript received on 13 December 2024 | Manuscript Accepted on 15 December 2024 | Manuscript published on 30 December 2024.
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I. INTRODUCTION

This chapter are going to be explaining about the literature review. This chapter will introduce the elemental of the piston and therefore the basic sort of piston. Other various method and comparisons on different software approach associated with the project is additionally stated during this chapter [2].

A. Problems Statement

The piston is one among the foremost stressed components of a whole vehicle because it's placed within the cylinder that has processs [3]. Therefore, it's must be designed to face up to from damage that caused of the acute heat and pressure of process [4]. There are many damages or failures for piston thanks to high and warmth like piston skirt seizing, piston head seizing, seal damage and cylinder damage. the worth of stress that obtained the damages are often determined by using finite element analysis. With finite element analysis, the stresses value that act to the piston is decided by simulation [5]. Thus, it can reduce the value and time thanks to manufacturing the components and therefore the same time it can increased the standard of the merchandise [6].

II. OBJECTIVES

There three objectives for this dissertation which is specialise in the piston for IC engine supported the finite element analysis [7].

The objectives are:

- To design a 3D model of piston for IC engine
- To investigate the utmost stress using structural analysis
- To investigate the utmost temperature using thermal analysis

A. Scope of Study

There are three scope of study for this dissertation of finite element analysis of piston for IC engine [8].

There are:

Modeling the 3D of piston with using CAD software.

Structural and thermal analysis carried on by using Finite element software ANSYS [9].

Results are discussed for Aluminium casting alloy A380 piston and Aluminum/Graphite Fiber GA 7-230 Metal Matrix Composite piston [10].

III. GEOMETRICAL

A. Parameter of Piston

Engine parameters for design the piston
Engine Type = Four stroke petrol engine
Cylinder bore = 100mm
Maximum gas pressure = 0.35 N/mm² Indicated mean effective pressure = 0.35 N/mm²

Fuel consumption = 0.3 kg / bhp/ hr Higher caloric value of petrol = 47.3x10³ kJ/kg [11]
Speed = 2000rpm
Temperature at the centre of the piston head (*T*C) =280ºC
Temperature at the edges of the piston head (*T*E) =200ºC
All other parameters are based on the chaper-2 section 2.7
Piston head or crown
Thickness of piston crown based on the strength

$$t_H = \sqrt{\frac{3pD^2}{16\sigma_t}} (\text{ in mm})$$

tH = 9.68 mm
tH= 10mm
Thickness of piston crown based on the basis of heat dissipation [12]
The engine is a four stroke engine, therefore, the number of working strokes per minute.
n = N/2 n =
n = 1000 rpm
Cross section area of the cylinder A = 7855 mm²
Indicated power IP = 5727.6 W Brake power
BP = IP x η
BP = 5.727 x 0.8 BP = 4.58 kW

The heat flow through the piston head

$$t_H = \sqrt{\frac{3pD^2}{16\sigma_t}} (\text{ in mm})$$

$$H = 0.05 \times 47.3 \times 10^3 \text{ x } (0.3/3600) \text{ x } 4.58$$
$$H = 0.9026 \text{ kWH} = 902.6 \text{ W}$$

Thickness of piston crown based on the basis of heat dissipation

$$t_H = \frac{H}{12.56k(T_C - T_E)} (\text{in mm})$$

tH = 0.00504 m
tH = 5.04 mm
Taking the larger of the two values, [13]
we shall adopt
tH = 10 mm
Radial ribs
No of ribs are = 4
Thickness of ribs(tR) = *t*H / 3 to *t*H / 2 tR = *10* / 3 to *10* / 2
tR = *3.33* to *5*
Let us adopt tR = 4 mm
Piston Rings
Total number of rings assumed as = 4 nos
Total number of compression rings = 3 nos
Number of oil ring = 1 no
Piston rings are made up of cast iron. Radial thickness of piston ring

$$t_1 = D\sqrt{\frac{3p_w}{\sigma_t}}$$

t1 = 100*

t1 = 3.4 mm
The axial thickness (*t*2) of the rings *t*2 = 0.7 *t*1 to *t*1.
*t*2 = 0.7x3.4 to 3.4
Let us adopt t2= 3 mm
The minimum axial thickness (*t*2) may also be obtained from the following empirical relation:

$$t_2 = \frac{D}{10n_R}$$

t2 = 2.5mm
Thus the axial thickness of the piston ring as already calculated is satisfactory [15]
Width of top ring land

$$b_1 = t_H t01.2t_H$$

b1 = 10 to 1.2x10 b1 = 10 to 12mm Let us adopt
b1= 12 mm
The width of other ring lands

$$b_2 = 0.75t_2 \text{ to } t_2$$

b2 = 0.75x3 to 3 b2 = 2.25 to 3mm Let us adopt [16]
b2= 3 mm
Piston barrel
b = Radial depth of piston ring groove which is taken as 0.4 mm larger than the radial thickness of the piston ring (*t*1)
b = *t*1 + 0.4 mm b = *3.4* + 0.4
b = *3.8 mm*
The maximum thickness (*t*3) of the piston barrel may be obtained from the following empirical relation:

$$t_3 = 0.03D + b + 4.5 \text{ mm}$$

t3 = 0.03*100 + 3.8 +4.5 t3 = 11.3 mm
Piston Wall thickness towards open end
t4 = 0.25*t*3 to 0.35 *t*3.
t4 = 0.25x11.3 to 0.35x11.3 t4 = 2.8 to 3.9 mm
Let us adopt
t4= 3.4 mm
Piston skirt
The side thrust due to gas pressure
R = μ x xp
R = 0.1 x( ) x 3.5 R = 2747.5 N
The side thrust due to bearing pressure
R = pb x D x l
R =0.45x 100 x l R = 45l N
45l = 2747.5
l = 61.05 mm = 62 mm Total length of the piston
L = Length of skirt + Length of ring section + Top land
L = l + (4t2 + 3b2) +b1
L = 62 + (4x3 + 3x3) + 12
L = 95 mm = 100mm (square engine/piston)
The ratio of L/D = 1, therefore a cup in the top of the piston head with a radius equal to 0.7D = 70mm
Load on the piston pin due to bearing pressure or bearing load = Bearing pressure × Bearing area = *pb*1× *d0* × *l*1
25 x *d0* x (0.45*100)

Retrieval Number: 100.1/ijies.B1010046221
DOI: 10.35940/ijies.B1010.11121224
Journal Website: www.ijies.org

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1125 *d0* N

We know that load on the piston due to gas pressure or gas load [14]

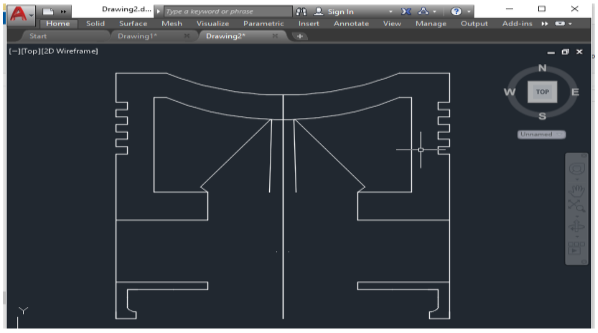
$$= \frac{\pi\ D^2}{4} \times p$$

= 27475 N

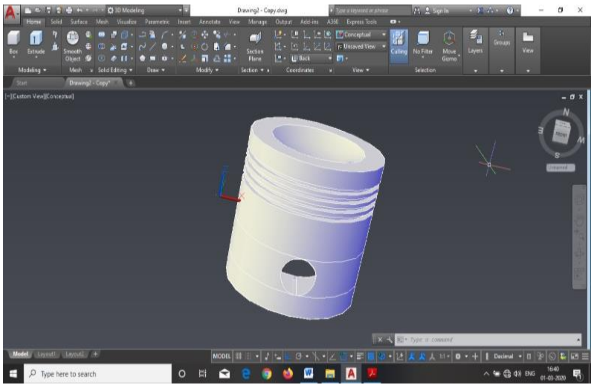
1125 *d0* = 27475 N

d0 = 24.42 mm = 25 mm

Piston model (2D view) AT AUTO CAD



[Fig.1: Piston Geometry According to Piston Design Calculation (All Dimensions are in mm)]



[Fig.2: Piston Model (Solidview) at AUTOCAD]

IV. PROJECT ANALYSIS

A. Loading Parameters

Pressure on piston = 0.35 x 106 N/m2

Combustion temperature = 1093 K

Piston edge temperature = 473 K

B. Problem Definition

This project is mainly carried out with the intention of selecting the suitable material of the piston used in SI engine. The piston, it is modeled in Pro/Engineer software packages. Structural and thermal analysis is carried out in ANSYS software determining stress, deformation and thermal flux are formed due to pressure and Combustion

pressure on the piston.

C. Analysing procedure

i. Auto cad

Auto cad file is imported to ANSYS Material properties applied

Solid mass element Solid- Brick 20 node 186 is selected for meshing (structural analysis).

Thermal mass element Solid 20 node 90 is selected for meshing (Thermal analysis)

Pressure on piston is $0.35 \times 10^6\, 10^6$ N/m2

Combustion temperature is 1093K

Piston edge temperature is 473 K

Boundary conditions are, top pressure/ temperatures are applied of the piston crow. Edges of the piston considered as a low temperature region (473 K). Bottom of the piston crown fixed at UX, Inner bottom of the piston pin is fixed at UZ and Outer bottom of piston pin is fixed at UY.

V. STRUCTURAL ANALYSES

Piston is modeled by using sketch and extrudes commands in software Engineering.

For the analysis of piston model created in Auto cad was taken.

From the preferences menu the type of analysis is selected as structural.

The element type is selected as Solid- Brick 20 node 186

The model is meshed using this element.

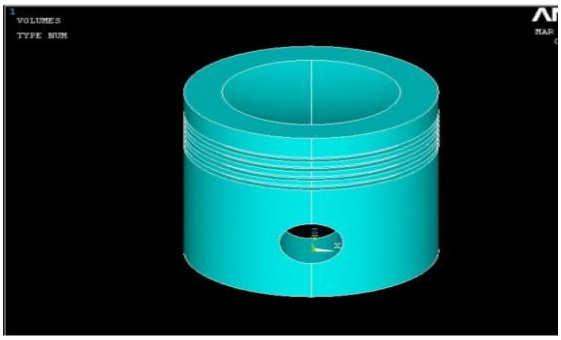
The material properties for Aluminium A380/ Aluminum-Graphite Fiber GA 7-230 Metal Matrix Composite are defined.

Applying boundary conditions like displacement and force

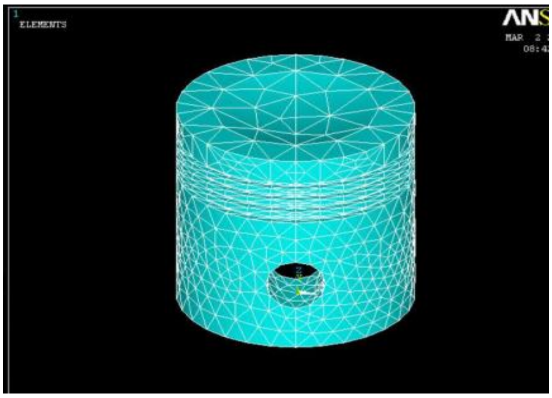
Then the problem is solved using SOLVE command.

The deflection and stress are plotted using the General Postprocessor.

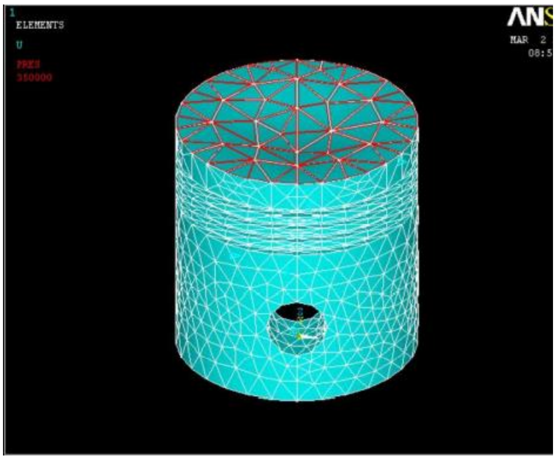
Then the results are solved in the Database and the screen is cleared.



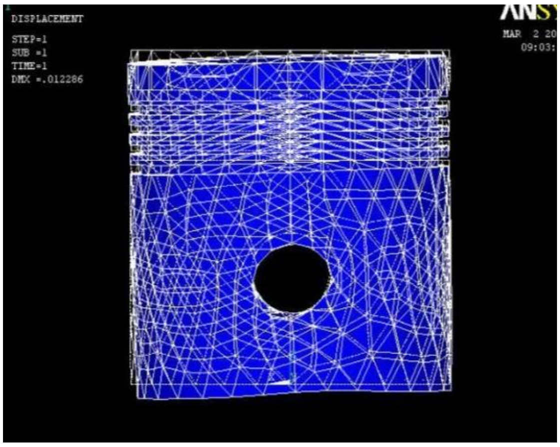
[Fig.3: Piston Model Imported into ANSYS Environment]



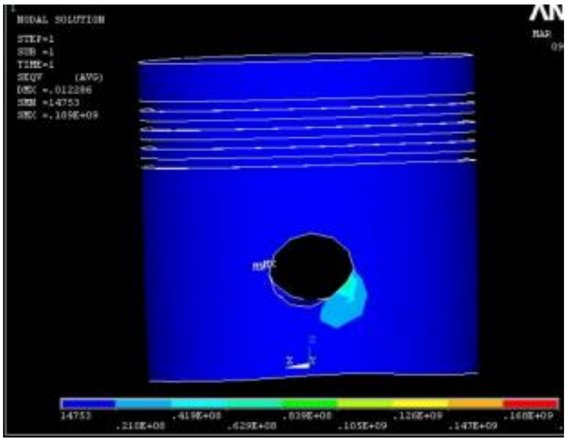
[Fig.4: Piston Meshed Model]



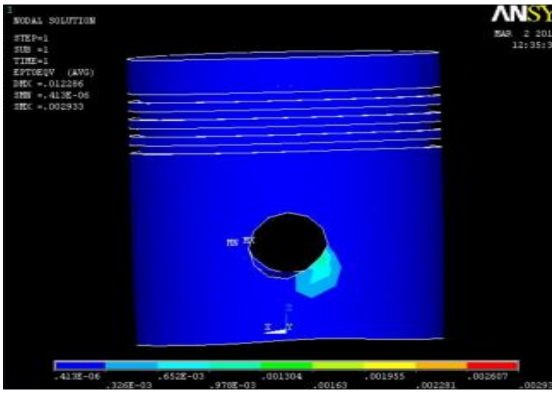
[Fig.5: Structural Analysis Boundary Conditions are Applied]



[Fig.6: Deformation of Aluminium A380 Piston]



[Fig.7: Stress of Aluminium A380 Piston]



[Fig.8: Strain of Aluminium A380 PistonStrain of Aluminium A380 Piston]

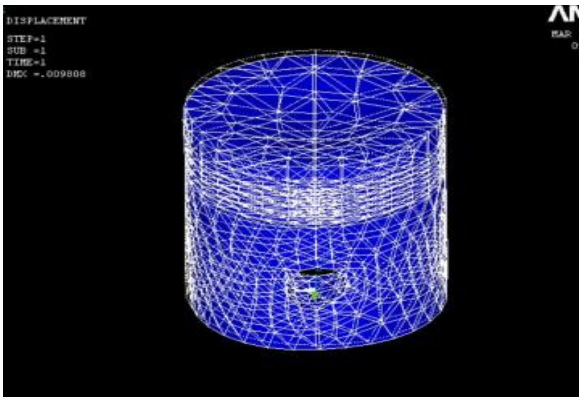
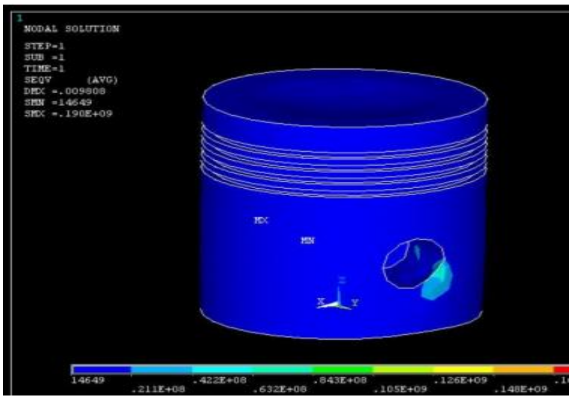
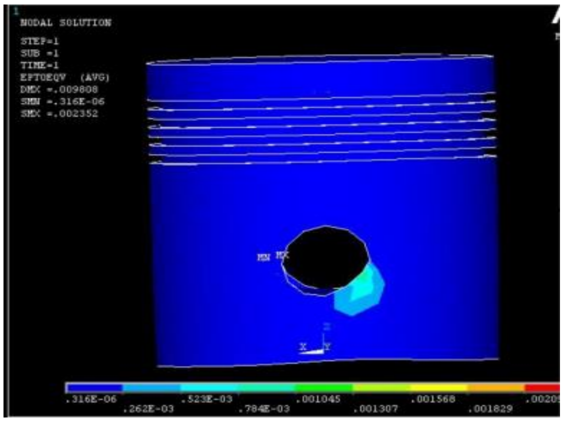


Fig.9: Deformation of Aluminum-Graphite Fiber GA 7-230 MMC Piston]



[Fig.10: Stress of Aluminum-Graphite Fiber GA 7-230 MMC Piston]



[Fig.11: Strain of Aluminum-Graphite Fiber GA 7-230 MMC Piston]

Thermal analyses

Piston is modeled by using sketch and extrudes commands creo Engineering.

From the preferences menu the type of analysis is selected as thermal.The element type is selected as Thermal mass element Solid 20 node 90 The model is meshed using this element. The material properties for Aluminium A3808/ Aluminium Graphite Fiber GA 7-230 Metal Matrix Composite are defined. Thermal loads are applied on the top and outer surface area of the piston.

Then the problem is solved using SOLVE command. The thermal flux is plotted using the General Postprocessor. Then the results are solved in the Database and the screen is cleared. condition of piston (Temperature distribution)

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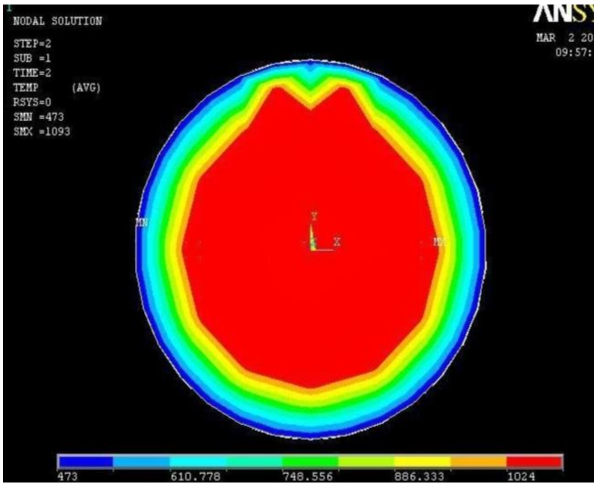
Results	Aluminium A380 Piston	Aluminum-Graphite Fiber GA 7-230 MMC Piston
Deformation (m)	0.012286	0.009808
Stress (N/m²)	0.189 x 10^9	0.19 x 10^9
Strain	0.002933	0.002352
Thermal flux (KW/ m²)	34211	67568



[Fig.12: Temperature Boundary]

VI. CONCLUSION

The piston based on Aluminum-Graphite Fiber GA 7-230 MMC has a lower mass compare with the piston based on Aluminium A380. Total mass reduction obtains 73 grams (9.16%) by using composite material. Reducing the piston mass in IC engine further reducing the balancing mass of the crankshaft, it totally reduces huge mass of IC engine.

Reducing the mass reduce the fuel consumption of the vehicle because engine spend less fuel to pull it own mass of the vehicle. In other hand reduction of fuel usage reduce the emission of the vehicle.

On strength basis, AluminumGraphite Fiber GA 7-230 MMC has alower deformation and strain compare with Aluminium A380. Deformation reduces up to 22.43% and strain reduced up to 21.98%. In other side composite material stress is little higher than aluminium A380, in percentage it is 0.53%. Reducing the deformation and strain make piston life longer against piston ring cracking, piston ceasing and fatigue life. Increasing stress in piston pin boss make crack on the pin, so special consideration required to design the piston boss. In this project we propose to increase piston boss thickness slightly more than aluminium A380.

On thermal analysis basis, Aluminum-Graphite Fiber GA 7-230 MMC has a higher thermal flux compare with Aluminium A380.,thermal flux increased up to 65.55% .Increasing the thermal flux improve the heat transfer rate through the surface of the piston.

It gives better cooling effect of the piston, reducing the piston crow temperature reduce the NOx formation, detonation and knocking of the IC engine. The Finite element analysis of piston with composite material gave better results compare the existing material. Aluminum-Graphite Fiber GA 7-230 MMC was found to be the best material due to its lower mass, deformation and strain value. We also calculate the Heat flux, it the existing material.

DECLARATION STATEMENT

I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been funded by any organizations or agencies. This independence ensures that the research is conducted with objectivity and without any external influence.
- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is **contributed** solely.

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