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Design and Analysis of Piston Using Composite Material

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ABSTRACT: The piston is a heart of the engine and its working condition is the most exceedingly bad one of the key parts of the engine in the workplace. A piston is a segment of responding piston, responding pumps, gas compressors and pneumatic chambers, among other comparative systems. It is the moving part that is contained by a barrel and is made gas-tight by piston rings. In a piston, its motivation is to exchange force from growing gas in the barrel to the crankshaft through a piston bar and additionally associating pole connecting rod.

In this study, firstly, thermal analyses are investigated on a piston, made of Cast Aluminium alloy and titanium alloy. Then, structural analyses are performed on piston of titanium alloy & Aluminium alloy material by means of using ANSYS workbench. The effects of thermal behaviours of the pistons are investigated. The main objective is to investigate and analyse the thermal stress distribution of piston at the real engine condition during combustion process. This work advancement by utilizing finite element analysis to anticipate the higher stress and critical area are on the component. In order to find the displacement, thermal and stress appropriation of the piston, ANASYS software is utilized to analyse the piston under the thermal loads and mechanical loads. The outcomes are demonstrated that the temperature conveyance happens on the top point of the piston when the piston under the thermal load and the best stress happens on the piston stick when the piston under the heat structure coupling.

KEYWORDS: Piston, Stress Analysis, Heat Flux, Structural Analysis, Thermal Analysis

I. INTRODUCTION

The name internal combustion alludes likewise to gas turbines with the exception of that the name is normally connected to responding interior ignition (I.C.) motors like the ones found in regular vehicles. There are essentially two sorts of I.C. start motors, those which require a start plug, and those that depend on pressure of a liquid. Start motors take a blend of fuel and air, pack it, and touch off it utilizing a start plug. Figure 1.1 demonstrates a cylinder and some of its essential parts. The name 'reciprocating' is given on account of the movement that the crank mechanism experiences. The cylinder chamber motor is fundamentally a wrench slider component, where the slider is the cylinder for this situation. The cylinder is climbed and around the turning movement of the two arms or connections. The crankshaft turns which make the two connections pivot. The cylinder is typified inside an ignition chamber. The drag is the width of the chamber. The valves on top represent induction and exhaust valves necessary for the intake of an air-fuel mixture and exhaust of chamber residuals. In a spark ignition engine a spark plug is required to transfer an electrical discharge to ignite the mixture. In pressure start motors the blend touches off at high temperatures and weights. The most reduced point where the cylinder comes to is called base perfectly focused. The most noteworthy point where the cylinder comes to is called top dead lope. The proportion of base dead lope to top right on target is known as the pressure proportion. The compression ratio is very important in many aspects of both compression and spark ignition engines, by defining the efficiency of engines.

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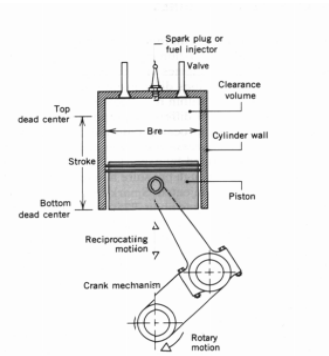


Fig 1.1 piston cylinder arrangement

A. Factors Considered For Proper Functioning Of Piston

1. The piston should have enormous strength and heat resistance properties to withstand gas pressure and inertia forces. They should have minimum weight to minimize the inertia forces.
2. The material of the piston should have good and quick dissipation of heat from the crown to the rings and bearing area to the cylinder walls. It should form an effective gas and oil seal.
3. Material of the piston must possess good wearing qualities, so that the piston is able to maintain sufficient surface-hardness unto the operating temperatures.
4. Piston should have rigid construction to withstand thermal, mechanical distortion and sufficient area to prevent undue wear. It has even expansion under thermal loads so should be free as possible from discontinuities

II. LITERATURE SURVEY

The cast iron pistons were superseded by aluminium alloy piston around the year 1920 (Sarkar 1975). Cole G.S. and Sherman A.M.(1995) explained that a considerable interest had been grown in replacing cast iron and steel in automotive component like piston with lightweight aluminium alloy casting to improve the performance and efficiency.

Haque M.M and Young J.M. (2001) referred the low expansion group of aluminium-silicon alloy as piston alloy, since this group of alloy provides the best overall balance of properties. Near eutectic aluminium silicon piston alloy exhibit complex fatigue behaviour due to their multi component microstructure (Moffat et al 2005).

Vaillant Phand Petit J.P. 1995 studied on liquid aluminium which strongly reacts with iron, it forms brittle inter metallic compounds at the reinforcement region.

Durrant G. et al (1996) explained about the aluminium alloy reinforced with mild steel insert by squeeze cast technique. The bonding of aluminium silicon alloy with the reinforced insert plays a vital role in improving the service life of the component. The importance on the suitable registry between these reinforced insert and alloy is restricted by the surface contaminants and surface oxides (Stefaniay et al 1987). The aluminium alloy casting having a porous metal insert improves the bonding strength by squeeze casting technique. The porous insert may be pre heated before the casting process in order to improve packing (Takatsuki 1990). The insert can also be coated by electro plating method which was explained by Han and More K.L. (2003). A stamped steel insert is used as an insert in metal die cast articles. The insert includes first and second interconnected stamped steel insert halves spaced from one another at certain locations to define a void. The edges of the insert lie below the surface of the casting to avoid bimetallic machining. However this is still in the early stages of development (Shimmell 1998).

Dwivedi et al (2007) studied about reinforcement of the crown of a piston of aluminium or aluminium alloy for an internal combustion engine comprises the preparation of a reinforcement member which need not be exactly in the shape of disc, and it may be of any convenient shape (Graham 1986). Brittle intermetallic phases observed at interface reduce the life of component. Such problems can be alleviated by suitable techniques such as vibration assisted casting and heat treatment. Piston industries require such techniques

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III. MATERIALS

According to the requirement of the piston design, the material of piston should meet the following requirements:

- 1) High-intensity heat. When the temperature is 300~400 degree, it has also enough mechanical properties to prevent the parts damaged.
- 2) Good thermal conductivity and poor heat absorptive. Not only reduce the temperature of the top and ring, but also reduce the thermal stress.
- 3) The expansion coefficient is small. Keep the small gap with the piston and cylinder.
- 4) The specific gravity is small. Reduce the reciprocating inertia force of the piston group to reduce the mechanical load of the crankshaft and connecting rod.
- 5) Good wear properties.
- 6) Good manufacturability and cheap.

Based on the related researches, aluminium alloy is mostly used material in making car pistons, and experiments using other material such as cast iron, cast steel, ceramics and carbon. Here we consider a high-performance material, titanium alloy, which has very high tensile strength and toughness. It is light in weight, have extraordinary corrosion resistance and the ability to withstand extreme temperatures. Then analyse if it is feasible or not to expand the service life in the normal design way.

The main performance parameters of titanium alloy are shown as Table.3.1. The whole thickness of titanium alloy piston is large, but due to the small density of the titanium alloy, the mass is lighter than the cast iron piston, so it's good for the high speed engine. At the same time, due to the high thermal conductivity of the titanium alloy, it make the water four stroke engines keep the good temperature when the engine injects the oil to cooling the temperature of inner wall. But the expansion coefficient of titanium is big, it is broken the gap of the cylinder and increase the friction loss.

MATERIAL PROPERTIES

Table 3.1 Properties of titanium Alloy

Density	$4.62e^{-6}$ kg/mm ³
Coefficient of Thermal Expansion	$9.4e^{-6}$ C ⁻¹
Specific Heat	$5.22e^5$ mJ kg ⁻¹ C ⁻¹
Thermal Conductivity	$2.19e^{-002}$ W mm ⁻¹ C ⁻¹
Resistivity	$2.19e^{-002}$ W mm ⁻¹ C ⁻¹
Young's Modulus [MPa]	96000
Poisson's Ratio	0.36
Shear Modulus [MPa]	35294

Table 3.2: Material properties of Cast Aluminium Alloy

Density	$2.65e^{-6}$ kg/mm ³
Coefficient of Thermal Expansion	21 K ⁻¹
Specific Heat	900 J/K-Kg
Thermal Conductivity	120 W/Km
Young's Modulus [MPa]	75000
Poisson's Ratio	0.34

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IV PRO-E DESIGN

Pro/ENGINEER is a parametric, integrated 3D CAD/CAM/CAE solution created by Parametric Technology Corporation (PTC). It was the first to market with parametric, feature-based, associative modeling software. The application runs on Microsoft-Windows platform, and provides modeling, assembly and drafting, finite element analysis, and NC and tooling functionality for mechanical engineers.

Initially 2D drawings were created using sketcher toolbar; tools in profile tool bar such As line, circle, rectangle, points, reference lines etc. and sketch references like grid, vertex, and dimensions are used.

The created drawings were then completely constrained using the tool in constraint tool bar like constraint and auto constraint. Then 2D drawings were converted into 3D using sketch based features tools such as revolve command. 3D objects are modified as required using engineering feature tool bar, tools such as edge fillet, chamfer are used.

Table 4.1 the main dimension of piston

Piston diameter D	90mm
Compressed height H1	54.5mm
Piston height H	94mm
Skirt height H2	54mm
The top land height h	15mm
Upper skirt height H4	13.5mm
Down skirt height H3	39.5mm
pin hole diameter d	29mm
First ring shore height h1	7.4mm

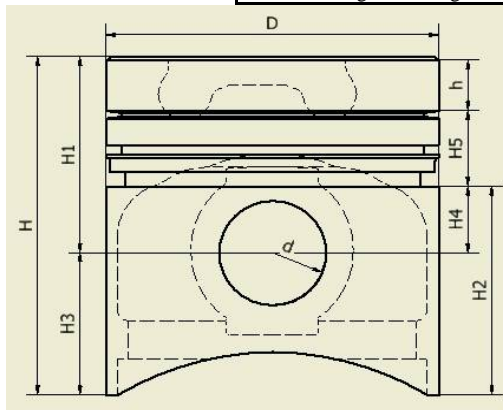


Fig 4.1 piston design

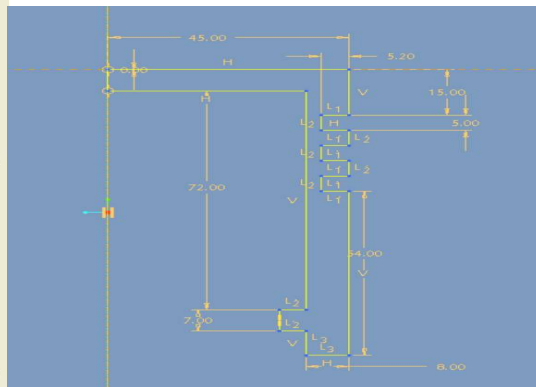


Fig 4.2 2D sketch

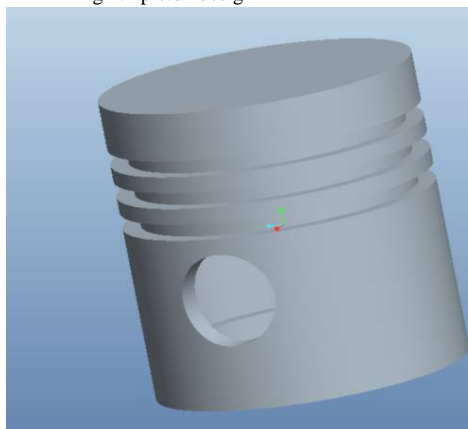


Fig 4.3 Solid Model

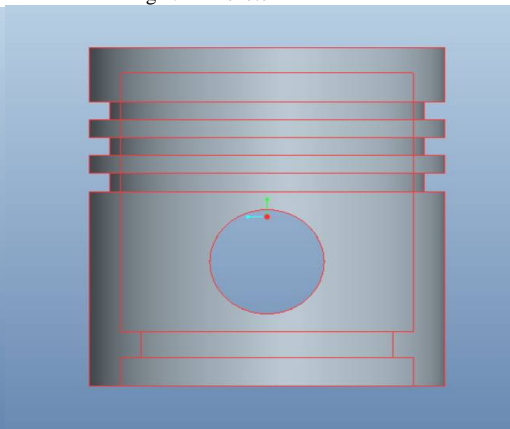


Fig 4.4 Solid Model front view

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PISTON STRENGTH CHECK:

Analytical calculations of stresses developed on piston:

Piston top mechanical stress

$$\sigma_u = 0.68 \left(\frac{D^1}{2\delta} \right)^2 = 304.7 \text{ MPa}$$

Bending stress

$$\sigma_w = 4.5 p_z \left(\frac{D}{h_1} \right)^2 \times 10^{-2} = 49.92 \text{ MPa}$$

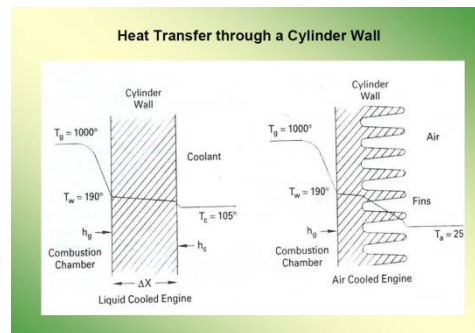
Shear stress

$$\tau = 3.14 \left(\frac{D}{h_1} \right)^2 = 286 \text{ MPa}$$

Total stress

$$\sigma = \sqrt{\sigma_w^2 + 3\tau^2} = 497.7 \text{ MPa}$$

Heat flux generated:



$$\begin{aligned} \text{Convection heat transfer } q &= \frac{Q}{A} = hg(Tg - Tw) \\ &= 320(1000 - 190) = 0.3950 \text{ w/mm}^2 \end{aligned}$$

According to the theory, all kinds of stress are within safety limits. Now using ANSYS workbench all the values are calculated and comparing with analytical values for finding the errors.

V. FINITE ELEMENT ANALYSIS

The piston shape is irregular, especially in the presence of various curved surfaces of inner cavity. Firstly, Automatic meshing method is used to mesh the model. The mesh grid is shown as figure. The model has a total of 37471 nodes and 23128 elements.

A. Static forces boundary conditions

Since this is a static analysis of the piston, to consider a number of reasons, ignored the engines reciprocating inertia force, only consider the gas pressure on the piston side and thrust force. For diesel, due to the throttling effect of the gap between the piston head and the cylinder, in the first ring shore around the gas pressure was $0.9Pg$, around the second ring shore gas pressure was $0.2Pg$, and the surrounding gas pressure of the other ring shore can be negligible.

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Table 5.1 static loading conditions

Load types	Role location	Effect size [MPa]
	The top of the piston	7.4
Gas force	The first ring of the shore around	6.75
	The second ring of the shore around	1.5

B. Thermal boundary conditions

When the internal combustion engine works, the value of the coefficient of radiation heat transfer is much smaller than the value of the convection of heat transfer, so ignored the thermal radiation. When calculate the temperature field of piston, determined the boundary conditions of the piston reasonably, this can be based on the value of the temperature of the piston's surface point and use it to identify and revise. The third kind boundary condition is used to analyse the temperature distribution. Whatever the theoretical analysis and experimental studies, it is not possible to get the actual and experimental operation of piston by the first and second kind of boundary conditions.

Table 5.2 Piston convection boundary conditions

Piston	Convection coefficient	Temperature[°C]
Top	320	720
Side of combustor	550	740

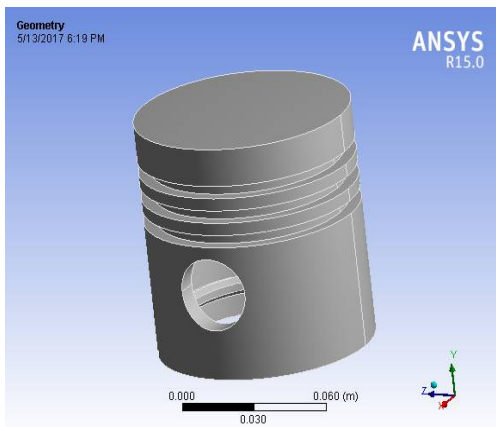


Fig 5.1 IGES file of Piston

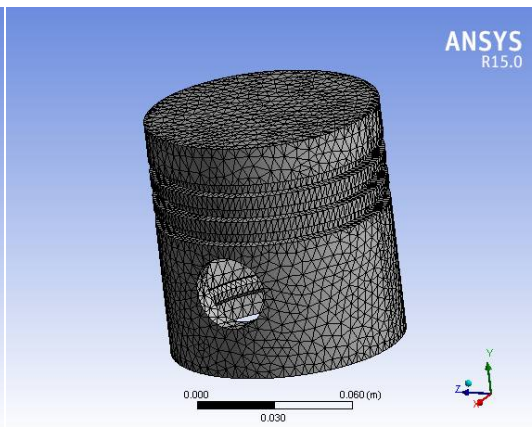


Fig 5.2 The mesh grid of piston

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C. RESULTS ON TITANIUM ALLOY

In Thermal Temperature values are applied on top area of the piston

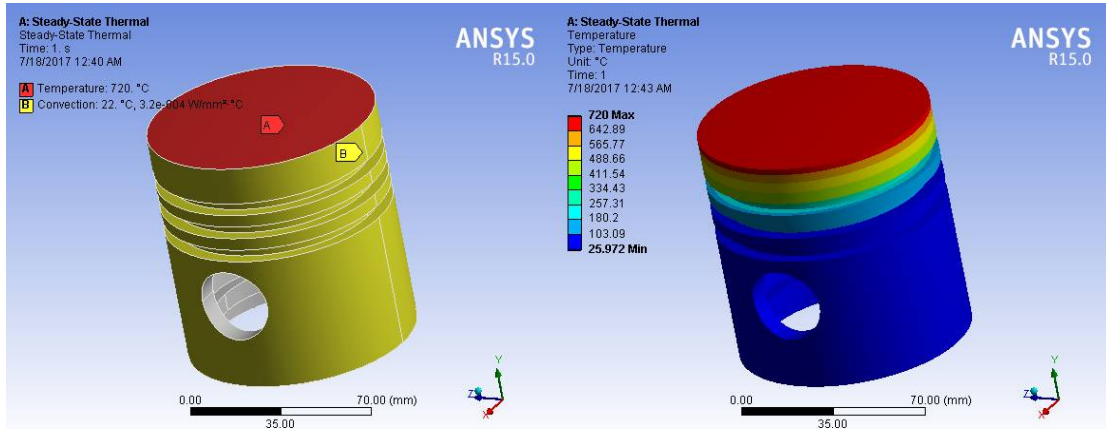


Fig 5.3 Applied boundary conditions

Fig 5.4 temperature distribution

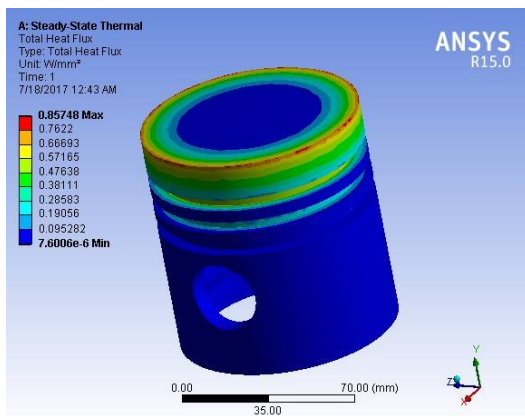


Fig 5.5 Heat flux

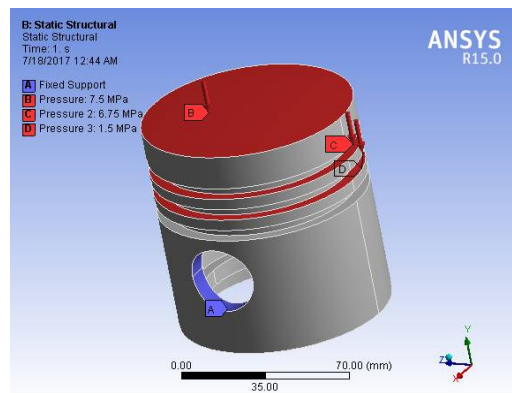


fig 5.6 Applied boundary conditions

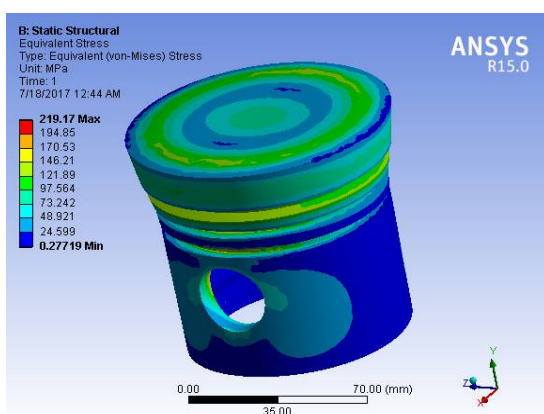


Fig 5.7 Equivalent stress

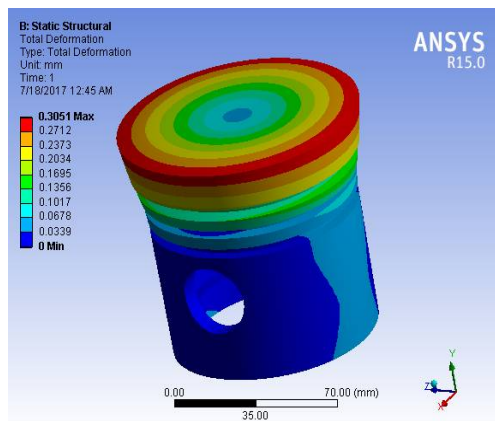


fig 5.8 Total deformation

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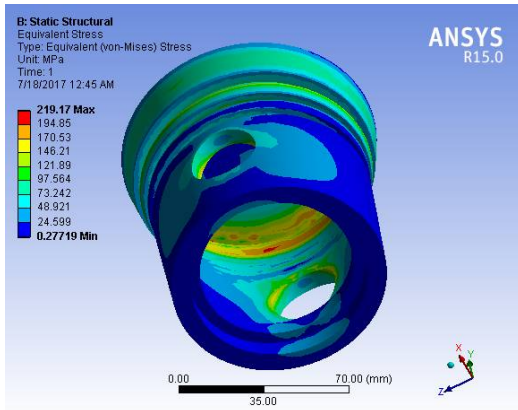


Fig 5.9 detailed view of stress

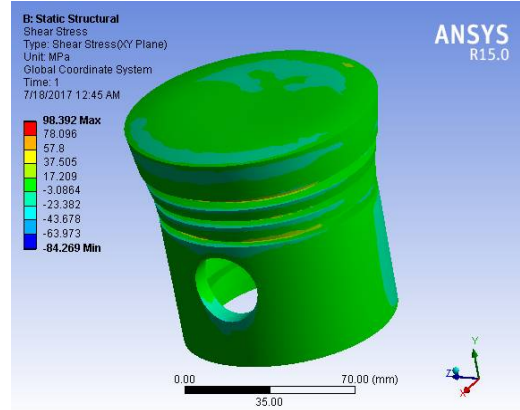


Fig 5.10 Shear Stress

D. RESULT FOR CAST ALUMINIUM ALLOY

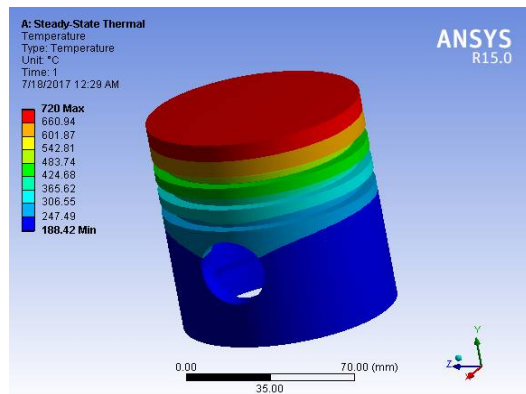


Fig 5.11 Temperature distribution

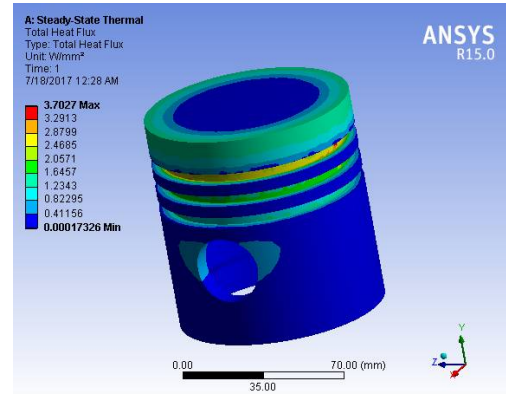
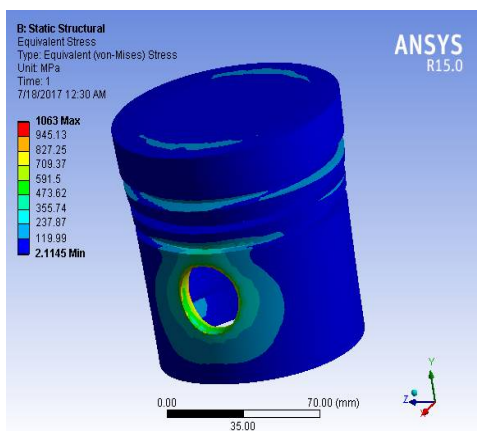


Fig 5.12 heat flux



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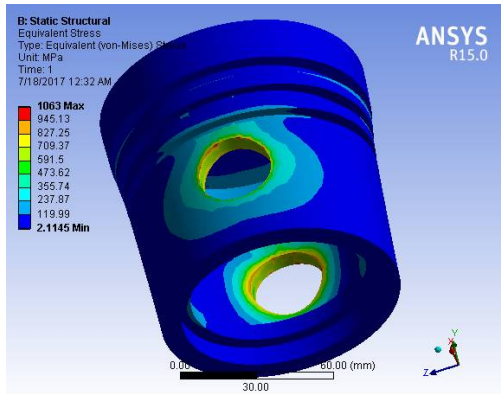


Fig 5.15 detailed view of stress

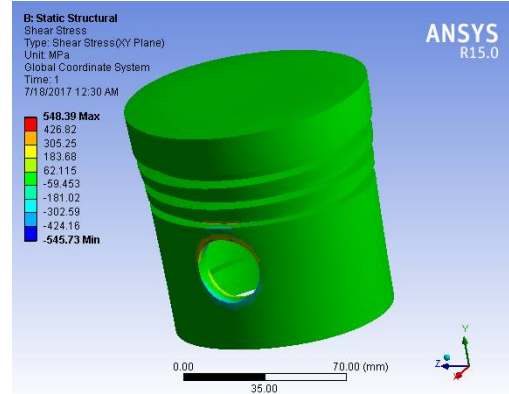


Fig 5.16 Shear Stress

VI. RESULTS AND DISCUSSION

Comparison between results FOR CAST ALUMINIUM ALLOY

S. No.	Parameters	Analytical Results	FEA Results	Percentage Variation
1	Equivalent stress (MPa)	497.7	1063	5.65
2	Shear stress (MPa)	286	548	2.62
3	Total deformation (mm)		0.87245	
4	Heat flux (w/mm ²)	0.3950	3.7027	0.033

Comparison between results FOR TITANIUM ALLOY

S. No.	Parameters	Analytical Results	FEA Results	Percentage Variation
1	Equivalent stress (MPa)	497.7	219	2.79
2	Shear stress (MPa)	286	98.89	1.88
3	Total deformation (mm)		0.3051	
4	Heat flux (w/mm ²)	0.3950	0.85748	0.0046

VII. CONCLUSION

The result showed that titanium alloy piston has a better performance in stress and deformation in comparison with cast aluminum alloy. Considering that the melting point of aluminum is 500 °C and for titanium is 1700 °C, regarding to its melting point, we improved it by 25%. A conclusion can be drawn that titanium has better thermal property than Aluminum Alloy.

Combined CAD, ANSYS and MATLAB results of stress and deformation and temperature when the piston under the mechanical loads and thermal loads then The FEA is carried out for standard piston model and the result of analysis indicate that the maximum stress has noted as 1063MPa on Aluminium alloy and 219MPa on Titanium alloy. And maximum deformation has been noted as 0.87245mm on AL alloy and 0.3051mm on Titanium alloy.

Besides it can be seen that titanium can help us to improve piston qualities. Although titanium is expensive and maybe it is uneconomical for large-scale applications, it can be used in some special cases.

Experimental approach can be used to determine the convection coefficient of the piston to get the realistic temperature field.

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REFERENCES

- [1] A.AtishGawale, A. Shaikh and VinayPatil, "Nonlinear Static Finite Element Analysis and Optimization of connecting rod World *Journal of Science andTechnology*, Vol. 2(4), pp .01-04, 2012.
- [2] A. R. Bhagat, Y. M. Jibhakate, Thermal Analysis and Optimization of I.C. Engine Piston Using Finite Element Method, *International Journal of Modern EngineeringResearch (IJMER)*, Vol.2, Issue.4, pp.2919-2921, 2012.
- [3] R.S.Khurmi,J.K.Gupta, A Text Book of Machine Design, S.Chand& Co., pp. 1132-1144, 2004.
- [4] P. Carvalheira1, and P. Gonçalves, FEA of Two Engine Pistons Made of Aluminium Cast Alloy A390 and Ductile Iron 65-45-12 Under Service Conditions, 5th International Conference on Mechanics and Materials in Design Porto-Portugal, 24- 26, pp .1-21, 2006.
- [5] ANSYS'S Element Reference http://www1.ansys.com/customer/content/documentation/121/ans_elem.pdf pp 1-1688.
- [6] Gudimetal P. Gopinath C.V. Finite Element Analysis of Reverse Engineered Internal Combustion Engine Piston, King Mongkut's University of Technology North Bangkok Press, Bangkok, Thailand AIJSTPME, Vol. 2(4), pp 85-92, 2009.
- [7] MirosławWendeker, PawełMagryta Adam Majczak, MichałBiały, "Modeling The Thermal Loads in the Subaru EJ25 Engine" *Journal of KONES Powertrain and Transport*, Vol. 18, No. 1, pp. 683-688, 2011.
- [8] D.Janko „Jovanovi,” Finite Element Evaluation and Optimization of Geometry with DOE”, *International Journal for Quality research UDK- 005*. Vol.5, No.1, pp 39-45, 2011
- [9] *EkerenBuyukkaya, MuhammetCerit*, Thermal analysis of a ceramic coating diesel using 3-D finite method, *Surface & coating Technology* 202 (2007) 398-402.
- [10] *EkerenBuyukkaya*, Thermal analysis of functionally graded coating AlSi alloy and steel pistons, *Surface & Coatings Technology* 202 (2008) 3856–3865.
- [11] *Al-Beirut, Dr.Basim M. Al Quraishi&IsamEzzulddinyusif*, Thermal effects on Diesel Engine Piston and Piston Compression Rings, *Eng. & Tech Journal* Vol. 27, 2009
- [12] *Shuoguo Zhao*, Design the piston of Internal Combustion Engine by PRO\ENGINEER,EMEIT-2012