Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
International Conference of Trends in Information, Management, Engineering and Sciences (ICTIMES)
Volume 5, Special Issue 02, Feb.-2018 (UGC Approved)

EFFECT OF CONSTRUCTIONAL CHANGE IN I.C ENGINE PISTON BY PARTIALLY CERAMIC COATING

M.PONMURUGAN[1] A.SUNDARAMAHALINGAM[2] S.PRAKASH RUBERT[3] M.RAVIKUMAR[4]

[1,2]Assistant Professor, Bannari Amman Institute of Technology, Sathyamangalam-638401,

[3]Assistant Professor, J.K.K. Nataraja College of Engineering & Technology, Komarapalayam, Namakkal Dt – Tamil Nadu,

[4]Professor, Bannari Amman Institute of Technology, Sathyamangalam-638401,

ABSTRACT:- *To modify the construction of the piston in S.I. engine is the main goal of this project. Modifying the construction improves the engine operating parameters.As a consequence, the durability of the piston gets reduced. In order to increase the durability of the piston, "Partially ceramic coating" is given on the piston.*
Thermal analysis is to be investigated on a conventional (uncoated) SI engine piston, made of AlSi alloy and steel. Secondly, thermal analysis is to be performed on piston, coated with MgO-ZrO2 material by means of using a commercial code, namely ANSYS. Finally, the results of different pistons will be compared. The effects of coatings on the thermal behaviour of the piston are to be investigated and improved.

INTRODUCTION

In general, the efficiency of any petrol engines is around 55% i.e. only 55% of the heat input obtained by burning the fuel is utilized for useful work and the remaining 45% is wasted in the form of heat losses. An effort has been made to maintain high temperature inside the cylinder by reducing the heat transfer through the coolant and exhaust gases, for complete combustion and to increase the efficiency.

The demand for higher specific output diesel engines and increasingly radical bowl geometries used to meet legislated emission regulations has focused on the need for improvements in aluminium alloy pistons. At high engine outputs, steel- crowned articulate pistons have been substituted for aluminium pistons with great success because of the increased strength of steel at higher temperatures. However, articulate steel piston usage results in increased cost, increased reciprocating weight. Therefore, some geometrical compromises, e.g. an offset piston bowl, are not practical.

Given that the application of a thermal barrier coating and constructional change to the aluminium piston crown results in a reduction in the substrate temperature, it may be possible to return the aluminium piston to historic durability levels at the higher engine output levels.

The intent of this investigation is to determine whether a finite element analysis can be used to provide accurate estimates of temperatures and stresses occurring within the constructional change thermal barrier coating applied to an aluminium alloy piston crown for various coating thicknesses.

PETROL ENGINE

The Otto cycle is the ideal cycle for SI engines. The CI engine, first proposed by A.N. Otto, it is very similar to the SI engines, the air-fuel mixture is compressed to a temperature that is below the self ignition temperature of the fuel. The combustion process is initiated by firing a spark plug. In CI engines, air alone is compressed to a temperature that is above the auto ignition temperature of the fuel and the combustion starts as the fuel is injected into this hot air. Therefore, the spark plug and carburetor in petrol engines are replaced by a fuel injector in diesel engines. The compression ratio of an SI engine is between 6 and 10 and that for a CI engine is from 16 to 20.

THERMAL BARRIER COATING

Thermal barrier coating usually consist of two layers (duplex structure). The first layer, a metallic one, is the so-called bond coat, whose function is, on the one side, protects the basic material against oxidation and corrosion and, on the other side, to provide with good adhesion o he thermal insulating ceramic layer. The second layer containing the thermal barrier, a ceramic coating is mostly made of Yttria partially Stabilized Zyrconia (YSZ), since this material has turned out particularly stabilized during the last decades. Recently, nevertheless, new developments are coming up but are still in research stage.

In industries there are two different processes for the manufacturing of thermal barrier coatings: the electron beam – physical vapor deposition (EB-PVD) and the plasma sparing (PS). Whilst EB-PVD process is usually used to applies vacuum plasma – sprayed bond coats, which are mostly made of MCrAIYs (M=Ni, Co). Recently, the high velocity oxy-fuel technology (HVOF) is also increasingly used for this task. The ceramic layer is usually deposited by means of the atmospheric plasma spraying (APS).

STUDY OF EXISTING SYSTEM

The existing system is an experimental low speed petrol engine used for power generation. It has an open type combustion chamber, clearly indicating that it is a low speed engine. An old worn out piston of this engine is used for modeling the piston (as it needed the sectioning of the model).

The analysis needed a clear definition of the material properties, selection of element, boundary conditions and initial conditions. For which the certain data are calculated using the petrol engine cycle and some are taken from the literatures. All the data assumed in the analysis are theoretical values and hence the analysis is purely theoretical.

ENGINE SPECIFICATION

Table 1. Engine specification

Make	**Specification**
No. of cylinder	One
Type of cooling	Oil
Ignition	Spark Ignition
Bore	95 mm
Stroke	110 mm
Compression ratio	8.8:1
Speed	1500 rpm
Fuel oil	Petrol
Brake power	3.9kW
SFC	0.251 kg/kW hr

MATERIAL PROPERTIES

The piston is made of cast aluminium alloy (AlSi). Its material properties are presented in Table 2. It has good strength and hardness at elevated temperatures with good wear resistance.

Table 2 Properties of cast aluminium alloy

Material property	Al Alloy
Thermal conductivity, k (W/mK)	155
Density, ρ (kg/m^3)	2700
Specific heat, C (J/kg K)	965
Coefficient of thermal expansion (1/k)	19.5×10^{3}
Young’s modulus, E (MPa)	90×10^{3}
Yield strength (MPa)	410
Poisson’s ratio	0.3

FINITE ELEMENT MODELING AND MESHING

The piston is modeled in PRO-E WILDFIRE-3, which is one of the most effective modeling packages. PRO-E is very-friendly and comprehensive. IGES (Initial Graphics Exchange Specification) is the ANSI standard that defines a natural format for the exchange of information between CAD/CAM systems, with an IGES translator; you can translate a

PRO-E modeling into a format that can be read CATIA or other CAD systems. IGES format reduces the number of translators required to move the information among multiple CAD/CAM formats.

STRUCTURAL BOUNDARY CONDITION

There are two boundary conditions and various constraints are applied to this model. Basically there are two constraints that are applied in this model. One on the piston rings region and the other at the gudgeon pin.

The first boundary condition is the pressure applies at the piston head as shown in the fig indicated by red arrows the applied pressure is around 15.25 bar as calculated at the end of the compression of the theoretical constant pressure cycle.

Pressure at the end of the compression,

$$P_2 = P_1 \times \left(\frac{T_2}{T_1}\right)^{\gamma/(\gamma-1)}$$

P_2 = 15.25 bar

Where, P_1 – Absolute Pressure
T_1 – Ambient Temperature
T_2 – Temperature at the end of compression
γ - Isentropic index, 1.4 (for air)

The second boundary condition on the gudgeon pin, there the resultant force of 821.45 N is applied along the Y-direction. The resultant force is obtained through the theoretical calculation of petrol cycle.

The actual engine power,

$$P = F \times r \times \frac{2\pi N}{60}$$

F= 451.8 N

The force obtained is an actual force calculated with respect to the output but the calculation is based on the theoretical cycle. The efficiency of the engine is only 30%, hence, the theoretical reaction force ($F_{theoretical}$) acting on the gudgeon pin is calculated.

$F_{theoretical}$ = 821.45 N

Where, N – Engine Speed in rpm
r – Half of stroke length in m
F – Reaction force in N

DESIGN CALCULATION OF EXISTING PISTON

- Calculations of total volume of the cylinder any reduction of compression rings, oil ring, cylinder inner cut portion and Gudgeon pin portions,

Volume of the solid cylinder,
$V_{solid} = \pi r^2 h$
where, r = 26.50 mm
h = 41.06 mm
$= \pi \times (26.50)^2 \times 41.06$
V_{solid} = 90539.968 mm^3

Calculations of the compression rings,
Volume of the compression ring= $\pi \times (26.50)^2 \times 1$
where, r = 26.50 mm
h = 1 mm
= 2205.06 mm^3 -------- 1

where, r = 24.50 mm
h = 1 mm
$= \pi \times (24.50)^2 \times 1$
= 1884.785 mm^3------ 2

Subtract equation number from 1 to 2
$V_{comp.ring1}$ = 2205.06 - 1884.785
= 320.28 mm^3

Both the compression rings are same dimensions so,
Volume of the compression ring,
$V_{comp.ring2}$ = 320.28 mm^3

Volume of the compression rings,
$V_{comp.\ rings} = V_{comp.ring1} + V_{comp.ring2}$
= 320.28 + 320.28
= 640.56 mm^3

- Calculations of the oil ring,

where, r = 26.50 mm

h = 1.21 mm

$= \pi \times (26.50)^2 \times 1.21$

$= 2668.128\ mm^3$ ------- 3

where, r = 24.50 mm

h = 1.21 mm

$= \pi \times (24.50)^2 \times 1.21$

$= 2280.589\ mm^3$ ----- 4

Subtract equation number from 3 to 4

=2668.128-2280.589

$V_{oil\ ring} = 387.539\ mm^3$

- Calculations of the Gudgeon pin portions V_g,

There are two Gudgeon pin portions.

where, r = 7 mm

h = 3.7 mm

$= \pi \times (7)^2 \times 3.7$

Volume of the portion $V_{g1} = 569.282\ mm^3$

Both the Gudgeon pin portions are same dimensions so,

Volume of the portion $V_{g2} = 569.282\ mm^3$

Volume of the both the Gudgeon pin portions, $V_g = V_{g1} + V_{g2}$

$V_g = 1138.564\ mm^3$

- Calculations of the cylinder inner cut portion,

There are two inner cut portions.

where, r = 19.62 mm

h = 10.47 mm

Volume of the cylinder inner cut portion, $V_{innercut\ 1} = \pi \times (19.62)^2 \times 10.47 = 12655.35mm$

where, r = 22.8 mm

h = 20.59 mm

Volume of the cylinder inner cut portion, $V_{innercut2} = \pi * (22.8)^2 * 20.59 = 33609.007mm^3$

Total volume of the piston,

$V = V_{solid} - V_{comp.\ rings} - V_{oil\ ring} - V_g - V_{inner\ cut\ 1} - V_{inner\ cut\ 2}$

= 90539.968 - 640.56 - 387.539 - 1138.56-12655.355-33609.007

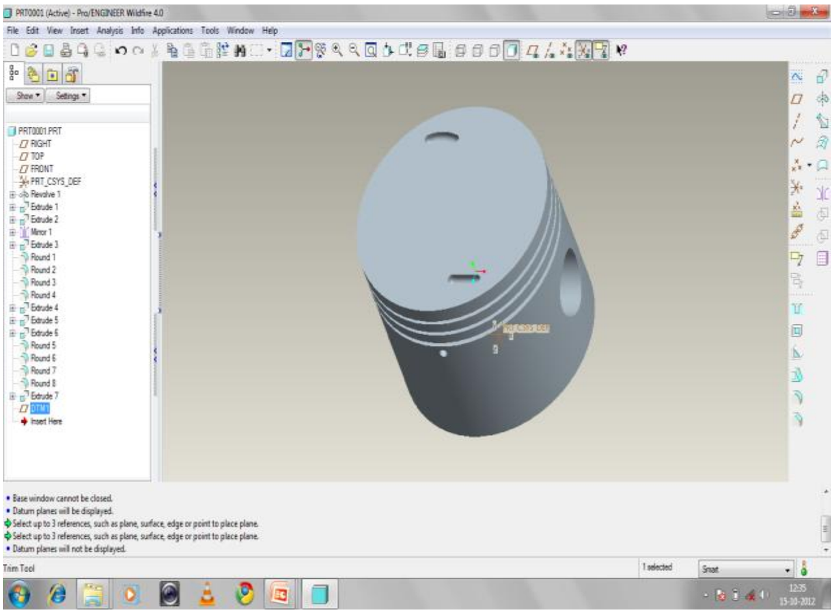
$V = 42108.943\ mm^3$

Mass, m = ρV

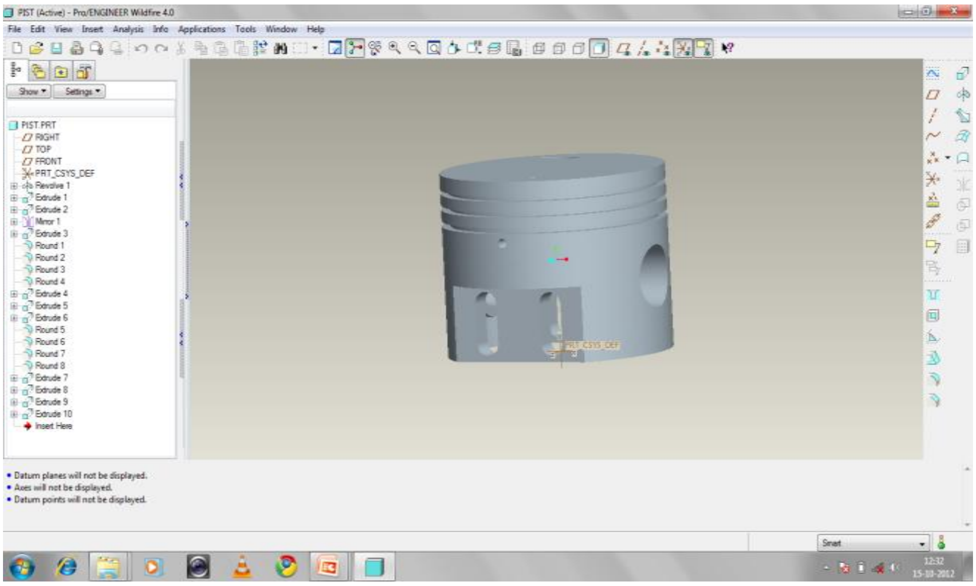
$= 2700 \times 42108.943 \times 10^{-9}$

= 113.69 gram

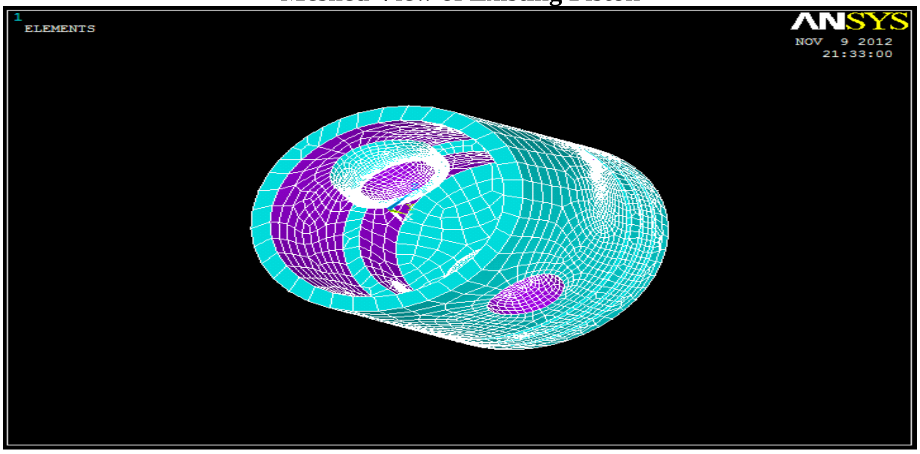
EXISTING PISTON



Modified Piston without Ceramic Coating



Meshed View of Existing Piston

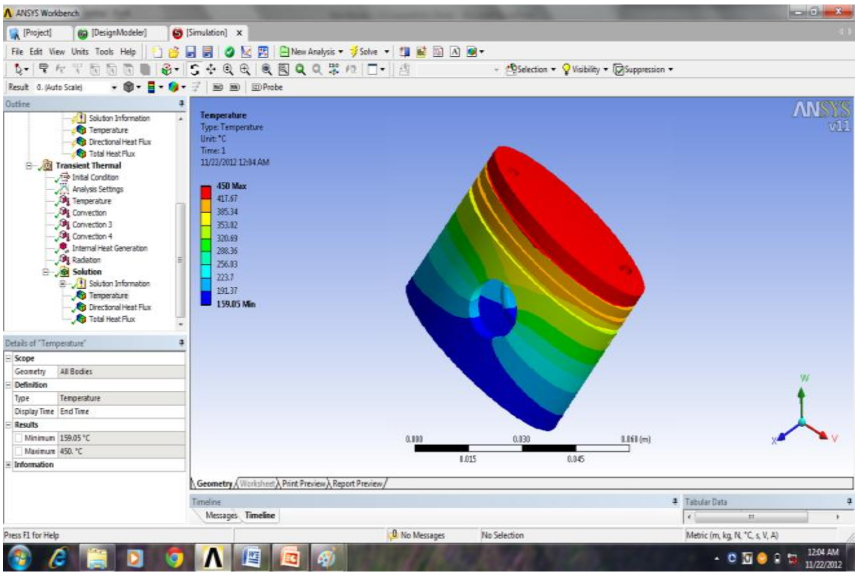


POST PROCESSING

Once the boundary conditions are applied, the problem is solved using the Ansys 11.0 solver. The results obtained are temperature distribution, heat flux, deflection and total stress.

TEMPERATURE DISTRIBUTION

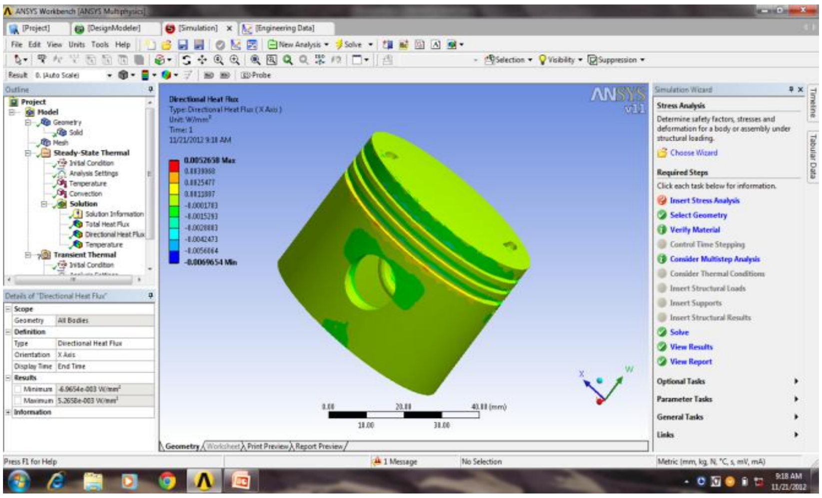
The fig. shown above gives the temperature distribution over the volume of the piston at steady state after and application of thermal loads. The maximum temperature occurs at the top of the piston. Even though the working medium is at the higher temperatures, the surface temperature at the combustion temperature is comparatively low (Around 790.52K).



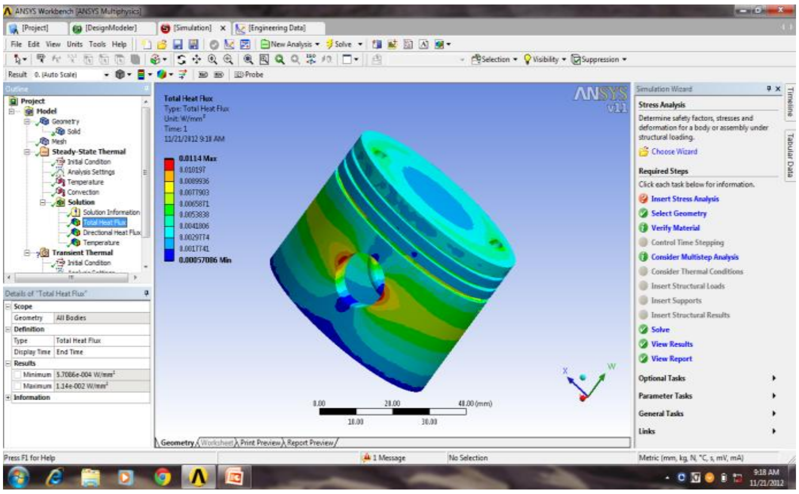
Temperature distribution

HEAT FLUX

The figure gives the thermal flux distribution over the volume of the piston at steady state after the application of thermal loads.



Directional Heat flux



Total heat flux

FUTURE WORK

The existing piston is designed using Pro-E software and analysed by ansys software. The coating of ceramic (magnesium oxide (MgO) and zirconium oxide (ZiO)) over existing aluminium alloy piston will be done and behavior will be analyzed to improve the performance of the given engine.

REFERENCES

1. Bhaumik Patel, AshwinBhabhor, "Design and prediction of temperature distribution of piston of reciprocating air compressor", International journal of Advanced Engineering, IJAERS/Vol. I/ Issue III/April-June, 2012/172-174
2. P. Gustof, A. Hornik, "The influence of the engine load on value and temperature distribution in the piston of the turbocharged Diesel engine", Vol.35, Issue 2, Aug.2009.
3. Ekrem Buyukkaya , Muhammet Cerit "Thermal analysis of a ceramic coating diesel engine piston using 3-D finite element method- Surface and coatings technology", June 2007.
4. Muhammet Cerit "Thermo mechanical analysis of a partially ceramic coated piston used in an SI engine- Surface & coatings Technology", December 2010.
5. M.M.Ragman, A.K.Arifin, N.Jamaludin, "Fatigue life prediction of two stroke free piston engine mounting using frequency response approach" European journal of scientific research, Vol 22 No.4, 2008.
6. Mirowslawkarczewski, Krzysztof kolinski jerky walenty nowcisz "Optical analysis of combustion engine elements" journal of KONES Powertrain and transport , Vol.18, No.1, 2011.
7. Jing Yang, Yi Wang, "Heat load analysis of piston based on the ANSYS", Advanced materials research, pp.199-200, 2011.
8. EkremBuyukkaya, MuhammetCerit, "Theoretical analysis of ceramic coated petrol engine piston using finite element method", Sakarya University, Engineering Faculty, Department of Mechanical Engineering, Esentepe Campus, Sakarya 54187, Turkey (2007).
9. ImdatTaymaz, "The effect of thermal barrier coatings on Petrol engine performance", Faculty of Engineering, University of Sakarya, Esentepe Kampusu, 54178, Adapazan, Turkey (1993).