Temperature Distribution Analysis of MgZrO$_3$ Coated and Conventional IC Engine Components using FEM

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Abstract— **since the invention of automobile, man began to deal with high efficient system by low heat rejection and utilizing the heat for further operation. With the shortage of fuel, this problem got major attention to the researchers. The main idea was to effective utilization of heat obtained from combustion of fuel and to decrease heat loss from combustion chamber so it is utilized in power stroke. This paper deals with temperature distribution analysis of the conventional (uncoated) and ceramic material coated IC engine combustion chamber components. In this study, firstly, thermal analyses are investigated on a conventional (uncoated) diesel piston and cylinder head, made of aluminum silicon alloy and cast iron respectively. Secondly, thermal analyses are performed on pistons and cylinder head, coated with ceramic material MgZrO$_3$ by means of using a commercial code, namely ANSYS. After that, the results of ceramic coated components are compared with conventional one. The effect of coating on thermal behaviors of components are investigated. In which noted that the maximum surface temperature of the coated piston and cylinder head is increased about 479.4 ^{0}C and 108.6 ^{0}C respectively.**

Index Terms— **Thermal barrier coatings, MgZrO$_3$, Temperature distribution, Finite Element Method**

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I. INTRODUCTION

The automobile industry is facing a serious challenge to improve vehicle fuel efficiency. Global demand for cars is soaring - one forecast has the number of worldwide cars increasing five-fold by 2050 to 2.9 billion. In the scenario of increase of vehicle population at an alarming rate due to advancement of civilization, use of diesel fuel in not only transport sector but also in agriculture sector is leading to fast depletion of diesel fuels and increase of pollution levels with these fuels, efficient fuel utilization has become pertinent for the engine manufacturers, users and researchers involved in the combustion research. While search for alternate fuels continuing, researchers are also attempting to find different techniques of efficient fuel utilized in diesel engines [1].

Reductions in fuel consumption can be achieved by a variety of measures, including improved aerodynamics, weight reductions and hybrid power trains. Significant improvements must also be made to the efficiency of the internal combustion (IC) engine that powers nearly all the world's vehicles. One promising technology for improving IC engine efficiency, as well as performance and durability, is the Thermal Barrier Coating (TBC) [1]. Applying TBC on conventional engine means converting engine into Low Heat Rejection engine (LHRE).

II. THERMAL BARRIER COATINGS

Thermal barrier coatings are duplex systems, consisting of a ceramic topcoat and a metallic intermediate bond coat. The topcoat consists of ceramic material whose function is to reduce the temperature of the underlying, less heat resistant metal part. The bond coat is designed to protect the metallic substrate from oxidation and corrosion and promote the ceramic topcoat adherence. A thermal barrier application is shown in figure 1
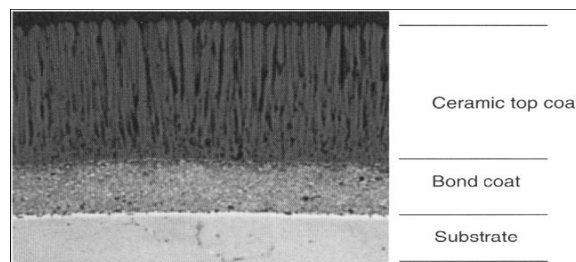

Fig. 1 Thermal barrier coating consisting of metallic bond coat on the substrate and ceramic top coat on the bond coat[3].

In a diesel engine almost 30% of the fuel energy is wasted due to heat losses through combustion chamber components. For that reason, lots of research activity has focused on applying thermal barrier coatings to diesel engines. Figure 2 shows a cross-sectional view of the diesel engine combustion chamber and points out the components that might be effectively coated with

thermal barrier coatings. In figure 2, 1 indicates piston head, 2 indicates cylinder liner, 3 indicates seating of intake valve, 4 indicates seating of exhaust valve, 5 indicates cylinder head, 6 indicates intake valve and 7 indicates exhaust valve.
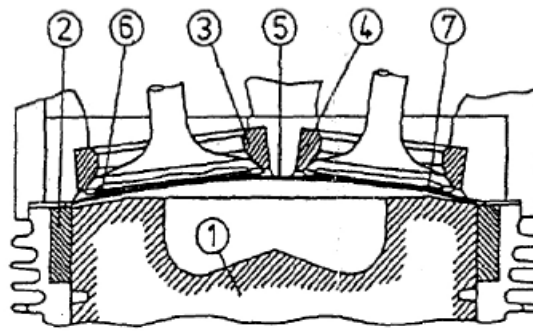

Fig. 2 Potential thermal barrier coated components in a diesel engine combustion chamber[2].

The design of the thermal barrier coatings and the environment in which it operates impose restrictions on the materials of construction.

Properties of different material used for Analysis

Table 1 Thermal properties [4]

Properties	Material			
	AlSi	Cast Iron	NiCrAl	MgZrO3
Density	2700 kg /m^3	7150 kg /m^3	7870 kg /m^3	5600 kg /m^3
Coefficient of Thermal Expansion	2.1e-005 1/^{0}C	1.255e-005 1/^{0}C	1.2e-005 1/^{0}C	8.e-006 1/^{0}C
Thermal Conductivity	155 W/m^{0}C	30.8 W/m^{0}C	16.1 W/m^{0}C	0.8 W/m^{0}C
Specific Heat	960 J/kg^{0}C	460 J/kg^{0}C	764 J/kg^{0}C	650 J/kg^{0}C

III.FINITE ELEMENT METHOD

What is FEA?

 • *Finite Element Analysis* is a way to simulate physical loading conditions on a design and determine the design's response to those conditions [15]
   • The design is modeled using discrete building blocks called *elements*. Each element has exact equations that describe how it responds to a certain load. The "sum" of the response of all elements in the model gives the total response of the design. The elements have a finite number of unknowns, hence the name *finite elements*.
   • The finite element model, which has a *finite* number of unknowns, can only *approximate* the response of the physical system, which has *infinite* unknowns.
     – So the question arises: *How good is the approximation?*
     – Unfortunately, there is no easy answer to this question. It depends entirely on what is being simulated and the tools that are being used for the simulation.

The following figure shows the physical structure to be analyzed. The physical structure to be analyzed is ladder which is subjected to weight of the applicant. The physical system to be analyzed, then, divided into finite elements and they are connected at the common joints so called "nodal points". An element is the building block of a finite element model which exactly represents the behavior of the physical structure to be analyzed. Each element has exact equations that describe how it responds to a certain load. The "sum" of the response of all elements in the model gives the total response of the design. The elements have a finite number of unknowns, hence the name *finite elements*. More the number of elements, greater is the accuracy of the result.

Conversion of Solid model into Finite element model

Finite element method requires finite element model that has element, nodes and it does work on solid model. Therefore solid structure to be analyzed should be converted into finite element model. Finite element model can be obtained by dividing the structure into finite elements and then connecting them together as solid structure is physically continuous. There are variety of element types depending on the type of analysis and physical problem. The element selection has dramatic influence on the result obtained. The type of element and its capability should be very well known to the analyst before carrying out any analysis.

Meshing is the process used to "fill" the solid model with nodes and elements, i.e., to create the FEA model. An element is a building block of a finite element model, which exactly represents the behavior of the physical structure to be analyzed. There are different types of elements conceptualized as per the type of analysis geometry of the structure such as1-D, 2-Dimensional analysis or 3-Dimensional analysis. Solid stress analysis requires 3-D element.
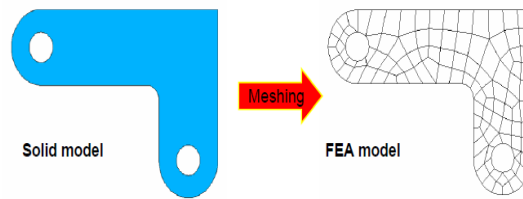
Figure 3 Conversion of solid model into FEA model.

Typical finite element method procedure [15]

1. Divide the structure or continuum into finite elements. Mesh generation programs, called preprocessor, help the user in doing this work.
2. Formulate the properties of each element
3. Assemble the elements to obtain the finite element model of the structure.
4. Apply known loads: apply known loads and/or moments in stress analysis, nodal heat fluxes, convection loads in heat transfer.
5. In stress analysis, specify how the structure is supported. This step involves setting several nodal displacements to known values (which often are zero).In heat transfer analyses, where typically certain temperatures are known, impose all known values of nodal temperature.
6. Solve simultaneous linear algebraic equations to determine nodal degree of freedom (nodal displacements in stress analysis, nodal temperatures in heat transfer)
7. In stress analysis, calculate element strains from the nodal displacements and finally calculate stresses from strains. In heat transfer analysis, calculate element heat fluxes from the nodal temperatures. Output interpretation programs, called post processors, help the user sort the output and display in graphical form.

The power of the finite element method resides principally in its versatility. The method can be applied to various physical problems. The structure can have arbitrary shape, loads, and support conditions. Mesh can mix elements of different types, shapes, and physical properties. This great versatility is contained within a single computer program. User input data controls the selected problem type, geometry, boundary conditions, element selection, and so on. Another attractive feature of finite elements is the close physical resemblance between the actual structure and finite element method. The finite element method also has disadvantages [15] . A specific numerical result is found for a specific problem: A finite element analysis provides no closed form solution that permits analytical study of the effects of changing various parameters. A computer, a reliable program, and intelligent use are essential. Experience and good engineering judgments are needed in order to carry out real analysis [15] .

Nomenclature	
R	Characteristics Gas Constant
C_p	Specific heat at constant pressure
C_v	Specific heat at constant volume
γ	Adiabatic index
R_{ch}	Change in gas constant
M_{ch}	Change in mass
$C_{p\,ch}$	Change in specific heat at constant pressure
$C_{v\,ch}$	Change in Specific heat at constant volume
$P_1=P_a$	Inlet pressure
T_1	Inlet temperature
V_1	Inlet volume
$P_2=P_3$	Pressure after compression
T_2	Temperature after compression
V_2	Volume after compression
GCV	Gross calorific value
LCV	Lower calorific value
$Q_s=H_s$	Heat supplied
M_f	Mass of fuel
T_3	Temperature after combustion
V_3	Volume after combustion
P_4	Pressure after expansion
T_4	Temperature after expansion
V_4	Volume after expansion

$Q_R = H_R$	Heat rejected
ρ	Cut off ratio
η_{diesel}	Efficiency of diesel engine

IV. BOUNDARY CONDITION

For boundary condition for calculating different parameter engine specification and calculation given below.
ENGINE : Water cooled 4 – stroke twin cylinder direct injection diesel engine Test rig

Table 2 Specification of vertical twin cylinder engine

Cylinder heads	Vertical twin cylinder with individual cylinder
Engine HP	10 (7.35 KW)
Engine speed	1500 RPM
Bore X Stroke	80 X 110
Compression ratio	16:1
Cooling	Water cooling
Diesel Fuel Consider	$C_{16}H_{34}$ (Hexadecane)

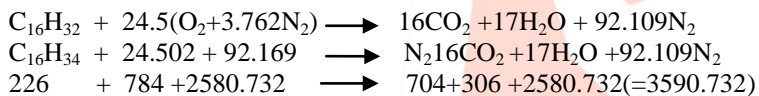Engine working on constant pressure cycle (Diesel Cycle)
1-2 Isentropic Compression
2-3 Addition of heat at constant pressure
3-4 Isentropic Expansion
4-1 Rejection of heat at constant volume

Point 1 represent that the cylinder is full of air. Let P_1, V_1 and T_1 be the corresponding pressure, volume and absolute temperature. The piston then compresses the air adiabatically i.e. PV^γ = constant) till the values become P_2, V_2 and T_2 respectively (at the end of the stroke) at point 2. Heat is then added from a hot body at a constant pressure. During this addition of heat let volume increases from V_2 to V_3 and temperature T_2 to T_3, corresponding to point 3. This point is called the point of cut off. The air then expands adiabatically to the condition P_4, V_4 and T_4 respectively corresponding to point 4. Finally, the air rejects the heat to the cold body at constant volume till the point 1 where it returns to its original state.

$C_{16}H_{32}$ + $24.5(O_2+3.762N_2)$ $\longrightarrow$ $16CO_2$ + $17H_2O$ + $92.109N_2$
$C_{16}H_{34}$ + 24.502 + 92.169 $\longrightarrow$ $N_2 16CO_2$ + $17H_2O$ + $92.109N_2$
226 + 784 + 2580.732 $\longrightarrow$ $704 + 306 + 2580.732(=3590.732)$

Air fuel ratio (A : F) = Mass of air / mass of fuel
 (A : F) = (784 +2580.732)/226 = 14.888 : 1
Stoichiometric Condition (Ch = Charge)
R_{ch} = IR/M_{ch} =8314/ M_{ch}

$\sum$moles = $\sum$mass /$\sum$mol. mass   = 117.669 = $\dfrac{3590.732}{\sum moles.mass}$

$\sum$mol. mass = M_{ch} = 30.51553 kg/kg moles
So R_{ch} = 272.4514 J/kg-K

Table 3 Composition of fuel gas on mass and moles bases

Constituents	Mass	Mol. Mass	Moles	Compositions on	
				% Mass	% Moles
(A). Reactions					
$C_{16}H_{34}$	226	226	1	6.293988	0.84984
O_2	784	32	24.5	21.83398	20.82111
N_2	2580.732	28	92.169	71.87203	78.32904
$\sum$ mass reactant	$\sum$3590.732		$\sum$ moles =117.669	$\sum$100%	$\sum$100%
(B). Products					
CO_2	704	44	16	19.60603	12.78271
H_2O	306	18	17	8.52193	13.58163
N_2	2580.732	28	92.169	71.87203	73.63564
$\sum$ mass product	$\sum$3590.732		$\sum$moles=125.169	$\sum$100%	$\sum$100%

From thermodynamics of equation
C_P – C_{avy} = R
$C_{p\ ch}$ – $C_{v\ ch}$ = R_{ch}
C_P / C_v - 1= R_{ch} / C_v

$\gamma - 1 = 272.4514/825$

$\gamma = 1.3302$

At site condition of engine

Atmospheric pressure $P_1 = P_a = P_{bx}/P_r = 744/750 = 0.992$ bar

Suction temperature $T_1 = 28^0C$

Analysis of engine cycle

(a). during suction from ideal gas equation

$P_1 V_1^\lambda = M_{ch}. R_{ch}. T_1$

Assume $M_{ch} = 1.00$ kg

$0.992 \times 10^5 \times V_1 = 1 \times 272.45 \times (28 + 273)$

$V_1 = 0.82669$ m^3 (1)

Compression ratio $= r = V_1/V_2 = 16 = 0.82669/V_2$

$V_2 = 0.0516682$ m^3 (2)

(b). 1-2 compression process

$P_1 V_1{}^\gamma V_1^\gamma = P_2 V_2{}^\gamma$

$0.992 \times 10^5 \times (16)^{1.3302} = P_2$

$P_2 = 39.62700 \times 10^5$ N/m$^2 = 39.63700$ bar   (3)

$P_2 V_2 = MRT_2$

$39.62700 \times 10^5 \times 0.0516682 = 1 \times 272.45 \times T_2$
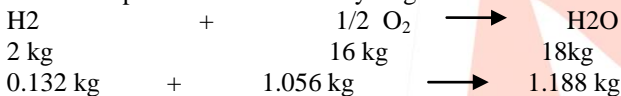
$T_2 = 751.5{}^0K = 478.5{}^0C$

(c) 2-3 Combustion Process at constant Pressure

Stoichiometric complete combustion condition of 1 kg of fuel

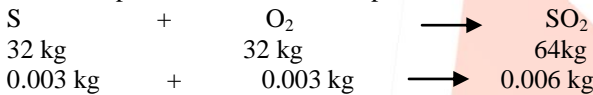1 For complete combustion of carbon

C	+	O_2	$\longrightarrow$	CO_2
12 kg		32 kg		44kg
0.865 kg	+	2.30662 kg	$\longrightarrow$	3.1716 kg
0.8650	+	(32/12) x 0.8650	$\longrightarrow$	(44/12) x 0.865
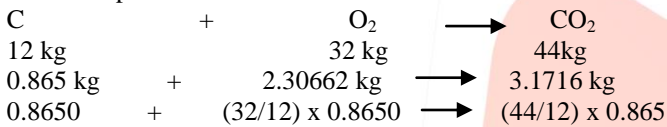
2 For complete combustion of hydrogen

H2	+	1/2 O_2	$\longrightarrow$	H2O
2 kg		16 kg		18kg
0.132 kg	+	1.056 kg	$\longrightarrow$	1.188 kg

3 For complete Combustion of sulpher

S	+	O_2	$\longrightarrow$	SO_2
32 kg		32 kg		64kg
0.003 kg	+	0.003 kg	$\longrightarrow$	0.006 kg

$\sum_P n = nSO_2 + nCO_2 + nH_2O$

    $= 0.006/64 + 3.1716/44 + 0$

    $= 0.0721755$ kg moles

$\sum_R n = nO_2I_c + nO_2I_H + nO_2I_S$

    $= 2.3066/32 + 1.056/32 + 0.003/32$

    $= 0.1051756$ kg moles

$\Delta n = \sum_P n - \sum_R n$

    $= 0.0721755 - 0.1051756$

    $= -0.033000$ kg moles

$GCV_{C=P} = 47269.$ Kj/kg

$LCV_{C=P} = 43957$ Kj/kg

$GCV_{C=P} = GCV_{C=v} + \sum \Delta n. R_{CH} T$

$47269 = GCV_{C=v} + (-0.033) \times 8.314 \times (28+273)$

$GCV_{C=v} = 47351.5829$ kj/kg

$GCV_{C=V} = LCV_{C=V} + 2305.09 XMW$

$47351.5829 = LCV_{C=V} + 2305.09(9 \times 0.132)$

$LCV_{C=V} = 44613.1359$ Kj/kg

Mass of fuel $= 0.06293980$ kg/cycle   (4)

$Q_S = H_S = Mf \times LCV_{C=V}$

    $= 0.0629398 \times 44613.135$

    $= 2807.94$ kj/kg cycle

$Q_S = H_S = M_{ch} \times CP_{Ch} \times (T_3 - T_2)$

  $2807.94 = 1 \times 1.192 \times (T_3 - 751.5)$

$T_3 = 3107.15$ K

$T_3 = 2834.15{}^0C$

2-3 Heat supplied at constant pressure

$\frac{P_2 V_2}{T_2}$ $P_2 V_2/T_2$ $=$ $P_3 V_3/T_3$

$0.0516682/751.5 = V_3/3107.15$

$V_3 \qquad = 0.213651 \ m^3$

$R_{ch} \qquad = IR/M_{ch} \qquad \frac{IR}{M_{ch}} = 8314/ \ M_{ch}$

$\sum moles \ = \ \sum mass \ / \sum mol. \ mass \ = \ 125.169 \ = 3590.732 \ / \sum mol. \ mass$

$\sum mol. \ mass \ = \ M_{ch} \ = \ 28.68 \ kg/kg \ moles$

$R_{ch} \qquad = \ IR/M_{ch} \frac{IR}{M_{ch}} = 8314/ \ 28.68 \ = 289.816 \ J/kg\text{-}K$

From thermodynamics of equation

$C_P - C_v \ = \ R$

$C_{p \ ch} - C_{v \ ch} \ = \ R_{ch}$

$C_{P/} \ C_v \ - 1 = R_{ch}/ \ C_v$

$\gamma - 1 \ = \ 289.816/903$

$\gamma \ = \ 1.321$

Process 3-4 Isentropic expansion

$P_3 \ V_3 \ ^\gamma V_1^\gamma = P_4 \ V_4 \ ^\gamma$

$39.62700 \times 10^5 \times 0.213651^{1.321} = P_4 \ 0.82669^{1.321}$

$P_4 \ = \ 6.633179 \times 10^5 \ N/m^2 = 6.63179 \ bar$

$P_4 V_4 \ = \ MRT_4$

$6.63179 \times 10^5 \times 0.82669 \ = \ 1 \times 289.816 \times T_4$

$T_4 \ = \ 1892.09 \ ^0K \ = \ 1619.09 \ ^0C$

Table 4 Result table

P_1 :	0.992 bar
T_1 :	301 ^{0}K
V_1 :	0.82669 M^3
P_2 :	39.63700 bar
T_2 :	751.5 ^{0}K
V_2 :	0.0516682 M^3
P_3 :	39.63700 bar
T_3 :	3107.15 ^{0}K
V_3 :	0.213651 M^3
T_4 :	1892.09 ^{0}K
V_4 :	0.82669 M^3

The instant gas temperature values were calculated according to measured gas pressure in combustion chamber and Woschni formula as followed was employed in this work to obtain the instant CoHT. [12]

$$h_g = 453.6 D^{-0.214} (C_m P_g)^{0.786} T_g^{-0.525} \qquad (5)$$

where hg was defined as instant CoHT of gas at piston top surface, D diameter of cylinder, Cm average velocity of piston, Pg instant gas pressure and Tg instant gas temperature which could be obtained from following equations.

Here h_g is calculated for peak condition at point 3

$$T_g = P_g V_x/(mR) \qquad (6)$$

$$V_x = V_c + \pi D^2 S_x/4 \qquad (7)$$

$$S_x = S[1 - \cos \varphi + 1/\lambda \ \{1 - (1 - \lambda^2 \sin^2 \varphi)^{1/2}\}]/2 \qquad (8)$$

where Vx was defined as instant cylinder volume, Vc chamber volume, m gas mass in the cylinder, Sx piston displacement, and λ stands for ratio of crank radius to connecting rod length, S stroke of piston.

In this case crank radius r = 55 mm connecting rod length l = 258.5 mm and crank angle φ = 30^0 after TDC [12]

By putting this value in equation (8)

S_x = 16.760 mm

by using equation (7)

$V_x = V_c + \pi D^2 S_x/4$

$= 0.0516682 + \pi (0.08)^2 (0.016760)/4$

$= 0.0516893$ m^3

By putting value of maximum gas pressure P_g = 39.63700 (from equation 3) and value of m from equation (4) in equation (6)

we get, T_g = 2835.53 ^{0}C

velocity of piston $C_m = \omega r$

$\omega = 2\pi N/60 = 2\pi(1500)/60 = 160.64$ rad/s
$C_m = (160.64)(0.055) = 8.8352$ m/s

For heat transfer coefficoent

$h_g = 453.6D^{-0.214} (C_m P_g)^{0.786} T_g^{-0.525}$ by putting above values in this equation we get,

h_g = 5100.14 W/m^2 ^{0}C
So Boundary conditions for convections are

h_g = 5100.14 W/m^2 ^{0}C
T_g = 2835.53 ^{0}C

According to author experience
And bottom temp 241^0C [16]
Boundary conditions for cylinder head
For inside condition
h_g = 5100.14 W/m^2 ^{0}C
T_g = 2835.53 ^{0}C it is same as in case of piston

And top surface temperature is read by using K-type thermocouple which have a range of about -200 to 1100 ^{0}C and error of +/-1 ^{0}C is 41^{0}C

V.FEM ANALYSIS USING ANSYS
Assumption used in analysis
- Metal piston is made of Al-Si alloy. Piston alloy and coating are isotropic and linearly elastic. Convection coefficients and temperatures of surroundings at bottom and side piston surfaces are constant throughout the cycle. The contact between successive layers of material is tight.
- The heat is applied on the piston through a certain portion which is inside the cylinder. But it assumed that the heat is falling on the piston only and no other part is coming in contact with cylinder gas.
- Load on the piston is not uniform on its surface but it is considered same heat load over entire surface of piston.
- The piston is surrounded by the oil layer and then the solid part of of the engine. Then the heat is removed by water flowing through the cylinder body. But during the analysis, the resistance of oil film and solid part of cylinder is considered negligible.
- Piston was motionless, the effect of gas forces is omitted.
- The temperature distribution in the piston through its body varies in the piston itself as measured practically but it is considered that temperature is same radially at all location but can be varied along its length.

Results and their physical interpretation
Standard (Conventional) piston
- After applying this boundary condition solution of temperature distribution is shown in fig 4
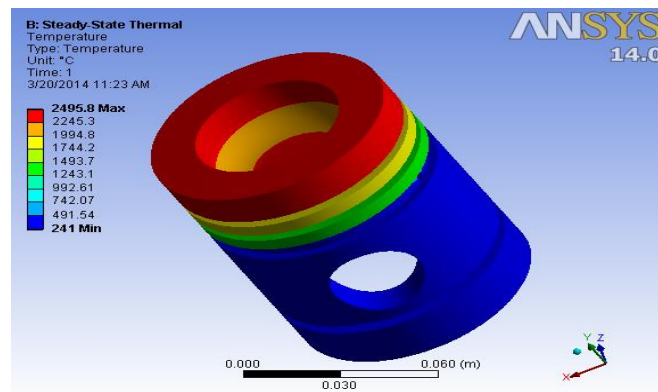
Figure 4 Temperature distributions of the piston made up of aluminum silicon.

Maximum temperature achieved is 2495.8 ^{0}C

Minimum temperature achieved is 241 ^{0}C

Temperature at 350 µm from top surface of piston is 2420.3 ^{0}C

Temperature at 500 µm from top surface of piston is 2414.5 ^{0}C

Binder material-NiCrAl of 150 µm and Coating material-MgZrO$_3$ of 350 µm

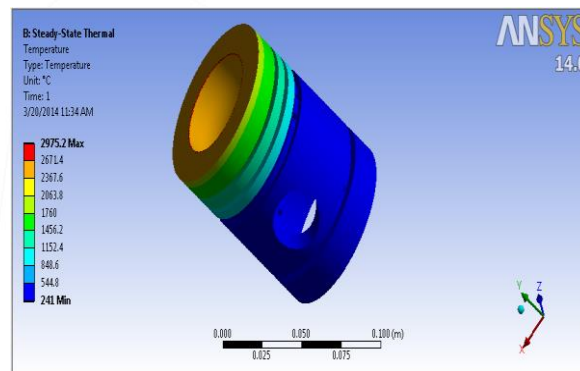Coated piston consist of 150 µm thickness binder of NiCrAl and 350 µm thickness of MgZrO$_3$ coating.

Figure 5 Temperature distributions of the piston coated with MgZrO$_3$.

Maximum temperature achieved is 2975.2 ^{0}C

Minimum temperature achieved is 241 ^{0}C

Temperature at 350 µm is 1822 ^{0}C

Temperature at 500 µm is 1806.5 ^{0}C

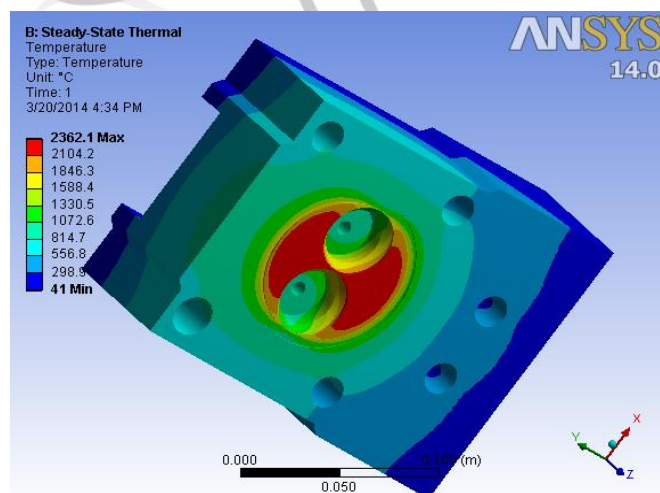Standard (Conventional) cylinder head without coating

Figure 6 Temperature distributions of the cylinder Head made up of cast iron.

Maximum temperature achieved is 2362.1 ^{0}C

Minimum temperature achieved is 241 ^{0}C

Temperature at 350 µm from top surface of piston is 1960 ^{0}C
Temperature at 500 µm from top surface of piston is 1933.3 ^{0}C
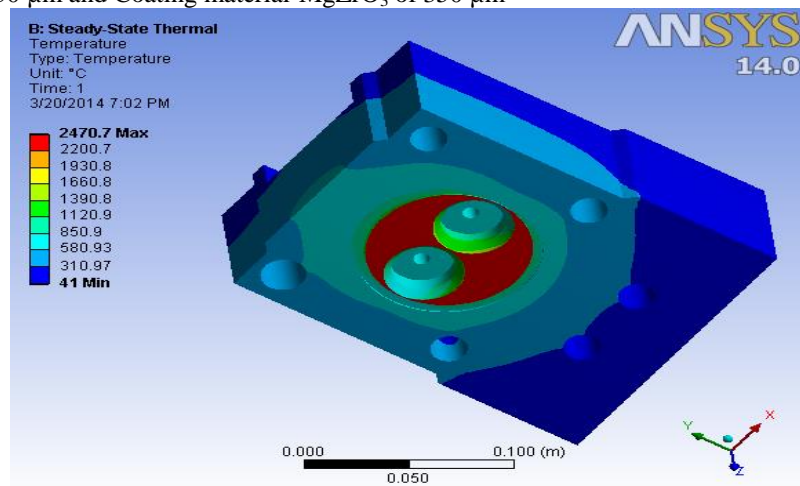Binder material-NiCrAl of 150 µm and Coating material-MgZrO$_3$ of 350 µm

Figure 7 Temperature distributions of the cylinder head coated with MgZrO$_3$

Maximum temperature achieved is 2470.7 ^{0}C
Minimum temperature achieved is 41 ^{0}C
Temperature at 350 µm is 1282.7 ^{0}C
Temperature at 500 µm is 1251.1 ^{0}C

Temperature distribution analysis is carried out using ANSYS software on diesel engine combustion chamber components are shown in Fig 4 to Fig 7. In which comparison of conventional engine piston, cylinder head and MgZrO$_3$ coated piston, cylinder head are shown.

Fig 4 shows the temperature distribution analysis of conventional piston without coating in which different temperature are shown. Secondly, temperature distribution is carried out on MgZrO$_3$ coated piston as shown in fig 5.

Temperature on conventional piston at top surface is maximum temperature i.e. 2495.8 ^{0}C, temperature at 350 µm from top surface of piston is 2420.3 ^{0}C and temperature at 500 µm from top surface of piston is 2414.5 ^{0}C. For MgZrO3 coated piston these temperatures are 2975.2 ^{0}C, 1822 ^{0}C and 1806.5 ^{0}C respectively. So increase in surface temperature is 479.4 ^{0}C i.e. 19.21%.Decrease in temperature at 350 µm from top surface of piston is 598.3 ^{0}C i.e. 24.72%. Decrease in temperature at 500 µm from top surface of piston is 608 ^{0}C i.e. 25.18%.

Temperature on conventional cylinder head at top surface as shown in fig 6 is maximum temperature i.e. 2362.1 ^{0}C, temperature at 350 µm from top surface of cylinder head is 1960 ^{0}C and temperature at 500 µm from top surface of cylinder head is 1933.3 ^{0}C. From fig 7 MgZrO3 coated cylinder head these temperatures are 2470.7 ^{0}C, 1282.7 ^{0}C and 1251.1 ^{0}C respectively. So increase in surface temperature is 108.6 ^{0}C i.e. 4.6 %. Decrease in temperature at 350 µm from top surface of cylinder head is 677.3 ^{0}C i.e. 34.56 %. Decrease in temperature at 500 µm from top surface of cylinder head is 682.2 ^{0}C i.e. 35.29%.

So the surface temperature increases and transferring less heat to base piston metal. So combustion temperature increases and heat transfer through the engine parts is minimized by applying the thermal barrier coating materials on the top surface of the engine piston and cylinder head. So this heat energy is used in shaft work so efficiency of engine is increases.

VI.CONCLUSIONS

It can be concluded that in a LHR engine i.e. MgZrO3 coated engine, less amount of heat is rejected to the atmosphere because of the presence of a low thermal conductivity ceramic coating which almost reduces the heat loss to the atmosphere and to the cooling jackets.

It is concluded that increase in surface temperature of piston is. 19.21%, decrease in temperature at 350 µm from top surface of piston is 24.72%.and decrease in temperature at 500 µm from top surface of piston is 25.18%.

In Case of Cylinder head increase in surface temperature is 4.6 %.,decrease in temperature at 350 µm from top surface of cylinder head is 34.56 % and decrease in temperature at 500 µm from top surface of cylinder head is 35.29%.

VII.ACKNOWLEDGEMENT

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