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An Experimental Analysis on Heat Transfer in a Low Heat Rejection C I Engine

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Abstract: Compression Ignition engines are these days essential into vital due to their fuel economic system and performance. In the latest developments, ceramic coating over the cylinder head, valves and the piston top surfaces are provided for thermal insulation. These thermal barrier coatings reduce the heat transfer from the combustion chamber to the cooling jackets and to the surroundings. This paper investigates the temperature distribution over the cylinder head, valves and the piston resulting from coating the ones the usage of Partially Stabilized Zirconia (PSZ) as a thermal barrier coating. This analysis is primarily based on the fact that coating thickness effect the heat transfer and temperature distribution in the cylinder head and piston. A 3-D Finite element analysis (FEA) the use of ANSYS is finished to evaluate the temperature distributions over the cylinder head, inlet valve, exhaust valve and the piston. Based at the evaluation, it may be concluded that a coating of PSZ over the combustion chamber increases the temperature over the combustion chamber and decreases the heat rejection to the surrounding.
Keywords: Thermal barrier coatings, PSZ, Temperature distribution.

I. INTRODUCTION

he diesel engine with its combustion chamber partitions insulated by using ceramics is referred to as Low heat-Rejection (LHR) engine. The LHR engine has been conceived basically to improve fuel economy by eliminating the traditional cooling system and changing part of the improved exhaust strength into shaft work the usage of the turbocharged system. In LHR engine the combustion chamber is insulated with excessive temperature materials which makes the engine perform at hotter environment with less heat transfer. The components which are commonly insulated include piston, cylinder head, valves, cylinder liner and exhaust ports. This has vital functions—to reduce the size of coolant system& to increase the exhaust energy available for turbo charging and thereby increasing power and efficiency. It is expected that additional power and improved efficiency is viable with engine insulated because thermal energy that is normally lost to the cooling water and exhaust gas is transformed to useful power through the use of turbo charging and high temperature materials. Thermal barrier insulation of the combustion chamber is carried out through coating it with ceramics. Partly stabilized zirconia and aluminiumtitanate are used for coating. The coating is specially achieved with the aid of plasma spraying. The modifications inside the combustion procedure because of insulation also have an effect on exhaust emissions. Better fuel temperatures are purported to reduce the concentration of incomplete combustion at the expensive of increase in oxides of nitrogen.

A. Boundary Conditions

For the evaluation a single cylinder, water cooled, constant speed DI diesel engine is taken into consideration. The cylinder head is made from solid iron, valves are made from hardened steel and the piston is constructed from aluminum-silicon alloy. A coating of PSZ is carried out over them to observe the heat transfer and the temperature distribution. Over the surface of the combustion chamber,.

hinnerau(k/B)uRe0.7+C/(Tg–Tw)u((0.01uTg)4
– (0.01 u Tw)4)
kcal/hr m2 K Where, a 0.35 to 0.8 increasing with increased engine speeds
B bore of the cylinder (m)
C=2.81 for CI engines
K=thermal conductivity of the gas in kcal/hr m2 K
ReBuCm/v,where, Cmme anpist on speed (m/sec)and v dynamic viscosity of the gas(m2/s)
Tg=working fluid temperature (K)
Tw=maximum wall temperature (K)

Over the outside surface of the cylinder head, assuming air flows at the sides, the heat transfer is found out using the condition of free convection.
Assuming turbulent flow,
10–4<GrXPr<10–9,theNusseltnumberisgiven by,
Nu =0.59 u (Gr X Pr)0.25
Nu=houterul/k.Using this,{houtercanbe determined.
Where,Gr=Grash of numbergxβx ΔTxl3v2
Pr=Prandtl number =μxCp/k
g = acceleration due to gravity (m2/sec)
E constant 1/T (K– 1)
T= Bulk temper ture inside combustion chamber- temperature of the air(K)
L=length over which air passes over the combustion chamber(m)
μ = kinematic viscosity (N m/sec)
Cp = specific heat of the gas (KJ/kg K)
K=thermal conductivity of the gas (W/m K)Over the surfaces of the valves, the heat transfer is found out using the condition of free convection by assuming constant wall temperature and flow over longitudinal cylinder body,
Nu=0.48 X (Gr X Pr)0.25 houter u l/k
The flow over the cooling jacket pipes is found out using the condition of forced convection as the water is supplied by means of an external source namely the pump.
Nu=0.023 X Re0.8 X Pr0.4= h(cooling)u B/k(water)
Where, ReB= Reynolds number which can be calculated by calculating the discharge.
It is to be noted that the fluid properties are to be evaluated at the bulk mean fluid temperature.

II. THERMAL ANALYSIS USINGANSYS

A thermal evaluation calculates the temperature distribution and related thermal quantities in a system or aspect. A thermal analysis is completed the usage of ANSYS to find out the temperature distribution across the cylinder head, inlet valve, exhaust valve and the piston as characteristic of component. The element used is SOLID90 that's a three-D eight node thermal element. The detail has 20 nodes with a single degree of freedom, temperature, at every node. The 20-node factors have compatible temperature shapes and are well suited to model curved limitations. Effects indicated that the heat is greater focused close to the combustion chamber surfaces in a low heat rejection engine than in an conventional engine and the temperature in the place of the combustion chamber is extra close to the low thermal conductivity region i.e. the coated region. Also a thermal analysis is performed on the cylinder head assembly and the piston for a coated engine and an ordinary one over the combustion chamber temperature range of 973 ok to 1273 okay in increments of 100 K. The Fig 1(a), Fig 1(b), Fig 2(a) and Fig 2(b) illustrate the temperature distribution over the cylinder head. As visible inside the figures it can be concluded that the most temperature in a LHR engine (1104 k) is greater than that of a conventional engine (1007 k). The region of maximum temperature (as proven by red) is more distributed close to the exhaust valve region in a ordinary engine at the same time as in a LHR engine, the maximum temperature region is absolutely disbursed during the coated region (across the bore). This shows that the more heat is contained around the combustion chamber top surface in a LHR engine. It may also be seen that the temperature at the outer surface of the head is almost at atmospheric temperature in a LHR engine even as the temperature on a regular engine is higher. It is able to be concluded that in a LHR engine, less amount of heat is rejected to the atmosphere due to the presence of a low thermal conductivity ceramic coating which nearly reduces the heat loss to the atmosphere and to the cooling jackets. The Fig3 (a) and Fig 3 (b)depicts the temperature distribution across the regular inlet valve and a coated one. It could be seen that the temperature is more for a coated one (1032 k) than the normal valve (998 okay) and is greater densely focused over the entire valve face in a LHR engine. Fig 4(a) and Fig 4(b) illustrates the temperature distribution across the conventional piston and a coated one. As within the case of an ordinary piston (made from Aluminum has higher conductivity), the heat transfer rate is better from the crown to the side wall, but step by step decreased inside the skirt location because of the presence of earrings. An analysis is done to compare the temperature distribution for four exclusive combustion chamber temperatures over the piston assembly. In the case of LHR engine, it can be visible that heat is greater focused near the crown and the bowl region and little or amount of heat is transferred to the side walls. Additionally an analysis is executed to compare the temperature distribution for 4 one-of-a-kind combustion chamber temperatures over the head assembly. It is able to be visible that with increasing temperature, in both the cases, the maximum temperature also will increase and is higher for an LHR engine. Again, the outside temperature is almost of same as that of the atmosphere in a LHR engine as compared to a regular one wherein the surface temperature is still higher.

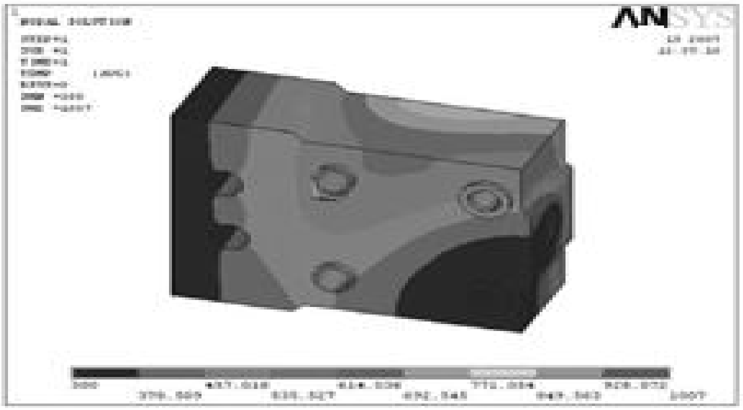

Fig 1 (a) Ordinary cylinder head

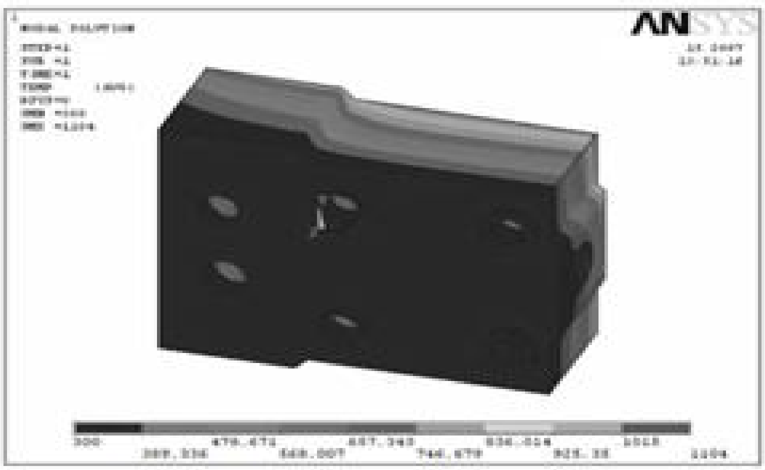

Fig 1 (b) Coated cylinder head

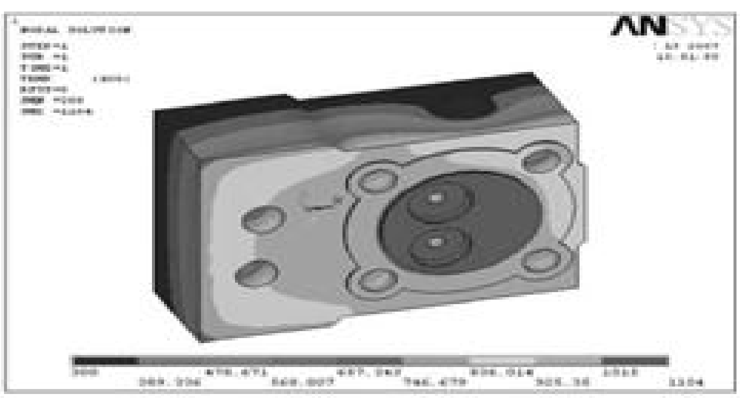

Fig 2 (a) Ordinary cylinder head

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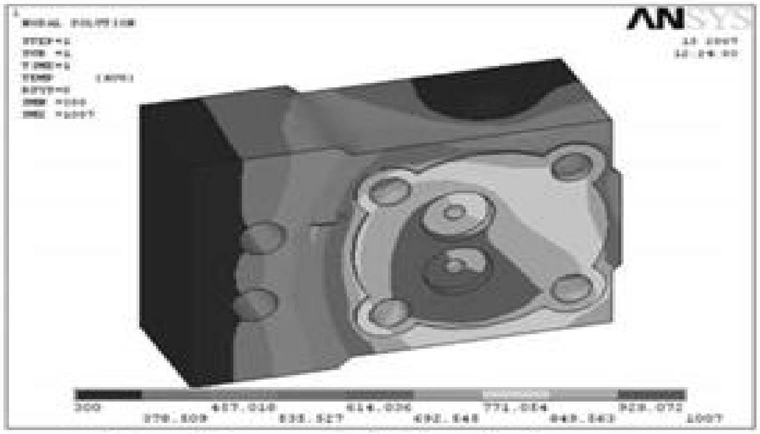

Fig 2 (b) Coated cylinder head

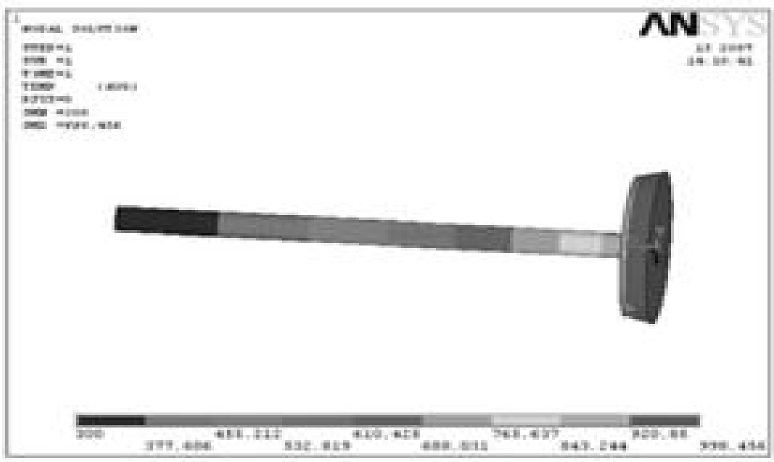

Fig 3 (a) ordinary inlet valve

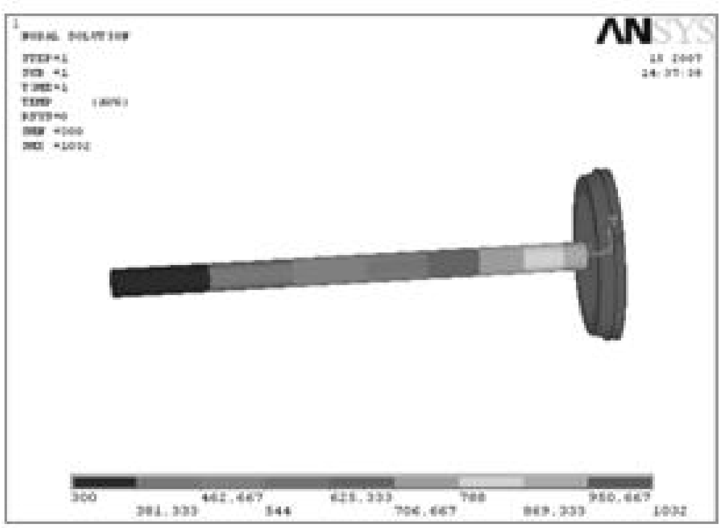

Fig 3 (b) coated inlet valve

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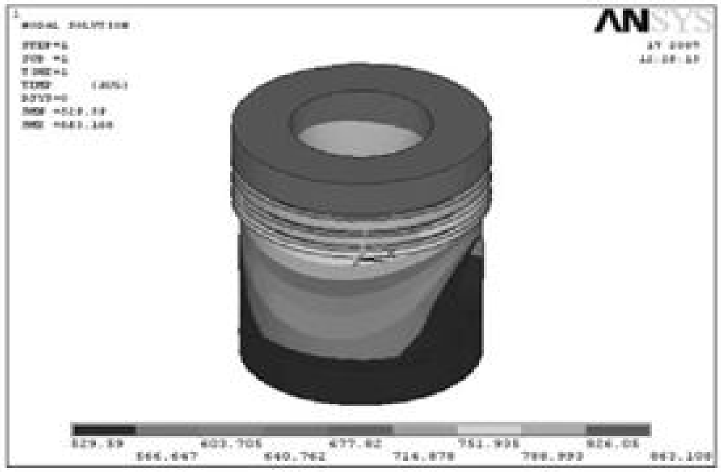

Fig 4 (a) Ordinary piston

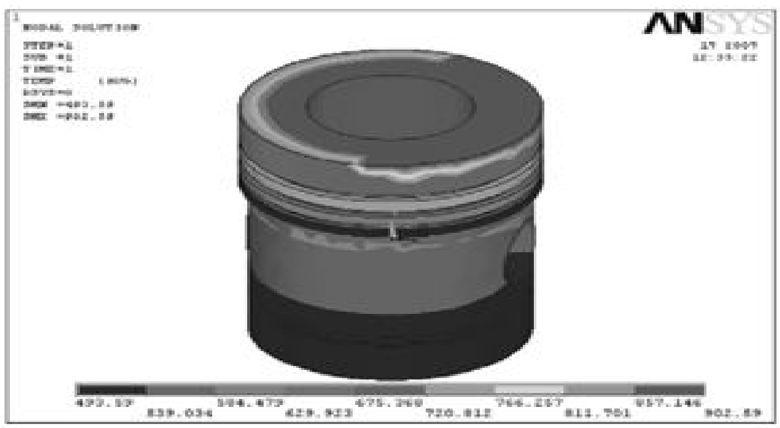

Fig 4 (b) Coated piston

III. DISCUSSIONS

Table1 Maximum Heat at the nodes for the cylinder head.

Temp of the combustion chamber(K)	Max heat on the cylinder head without coating(W)	Max heat on the cylinder head with coating (W)
973	8283	12456
1073	12606	15463
1173	12836	18752
1273	13679	20898

The table 1 gives the values of heat at the maximum temperature node over the cylinder head assembly and the figure shows that with increasing temperature in the combustion chamber, the maximum heat at the cylinder head is also increasing. It is visible that for a covered engine, the maximum heat on the cylinder head assembly node is around 25%-40% higher than the conventional engine.

Table 2 Maximum Temperature in the Piston

Temp of the combustion chamber(K)	Max temp of the piston without coating(K)	Max temp of the piston with coating (K)
973	778.178	876.337
1073	863.108	902.59
1173	956.089	1023
1273	1043	1084

The table 2 gives the values of maximum temperature over the piston shows that with increasing temperature within the combustion chamber, the most crown temperature on the piston is increasing and so does the heat transfer to the aspect walls; but because of the presence of ring over the piston groove, the heat transfer drops below the skirt region. It is seen that for a coated engine, very much less heat is transferred below the crown due to the ceramic barrier, which shows more heat is retained over the crown and the bowl and therefore very less heat is transferred below the grooves (skirt region).

IV. CONCLUSIONS

Based at the results of the thermal analysis finished in ANSYS, the subsequent conclusions are drawn.

The temperature distribution inside the cylinder head is higher in a low heat rejection engine than the conventional one and the zone of most temperature is greater broadly spread across the bore compared to that of a conventional one, in which it is more allotted near the exhaust valve. The heat rejection to the atmosphere is reduced in a LHR engine. The temperature distribution over the inlet and the exhaust valves indicates that the valve face heats up greater in a LHR engine than the conventional engine. This suggests that the heat carried away the exhaust gases are retained with the aid of the coating within the combustion chamber.

The consequences suggest that with increase in combustion wall temperature, the most temperature over the head assembly and the maximum heat at the nodal point additionally increase for a LHR engine and is higher than that of the conventional diesel engine.

The evaluation outcomes at the conventional piston indicate that the maximum temperature happens over the crown and spreads up to the ring belt while for the coated piston, the maximum temperature occurs over the crown and the bowl region and very less heat is transferred to the side walls up to the crown. In this example also, with increasing in combustion chamber temperature, the most temperature over the piston and the most heat on the nodal point increase for a LHR engine and is higher than that of the base line engine.

V. ACKNOWLEDGEMENT

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