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Diesel Engine Performance Enhancement Using Thermal Insulation

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ABSTRACT

Energy conservation and emissions have become of increasing concern over the past few decades. As automobiles are one of the major sources of energy consumption and urban emissions, engineers concerned are under significant pressure to improve their energy efficiency and reduce exhaust emission levels. While tremendous effort has been devoted in improving performance and reducing emissions of current engines, new technologies are also getting attention. One example is the Low Heat Rejection Engine (LHRE). A technological thrust is currently in progress to develop insulated, low heat rejection engines which exhibit higher thermal efficiency and improved exhaust emissions. The low heat rejection engine concept is not new. For the past two decades many have conducted experiments on low heat rejection engines. Although promising, the results of the experimental investigations have been somewhat mixed. Many have shown that insulation reduces heat transfer but none have shown substantial gains in efficiency, performance and emissions. Some investigators even concluded that insulation increases heat transfer and degrades the performance of the engine. The present investigations are planned carefully after a thorough review of literature in this area. The main objective of this work is to study the performance of the diesel engine by incorporating thermal barrier on the piston crown. The piston of the test engine is insulated by providing 2-mm air-gap between the nimonic crown and piston skirt. By providing piston insert with air-gap insulation, the crown forms as a reservoir of heat and hence acts as a heat regenerator. Tests were performed on a four stroke, vertical, single cylinder, water cooled direct injection 3.68 KW Kirloskar C.I.engine. at constant speed, to evaluate the performance of a low heat rejection (LHR) diesel engine with pure diesel operation. Performance parameters are determined at various magnitudes of brake mean effective pressure. Pollution levels of smoke and oxides of nitrogen (NOx) are recorded at the peak load operation of the engine. LHR engine showed improved performance, when compared with conventional engine (CE).

Keywords: *Low heat rejection, Performance, Pollution levels, Combustion characteristics,*

INTRODUCTION

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 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 is continuing, researchers are also attempting to find different techniques of efficient fuel utilization in diesel engines. It is well known fact that about 30% of the energy supplied is lost through the coolant and the 30% is wasted through friction and other losses, thus leaving only 30% of energy utilization for useful purposes. In view of the above, the major thrust in engine research

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during the last one or two decades has been on development of LHR engines. Several methods adopted for achieving LHR to the coolant are i) using ceramic coatings on piston, liner and cylinder head ii) creating air gap in the piston and other components The concept of LHR engine is to reduce heat loss to coolant and that too specifically from the piston top to the body of the piston. It should be expected that the thickness of the air gap play an important role on the insulation effect in LHR engines.

ORIGIN OF THE ADIABATIC ENGINE

Thermodynamically the adiabatic process is defined as a no heat loss process, hence, the name adiabatic Engine implies a no-heat loss Engine. The insulated high temperature components include piston, cylinder head, valves and cylinder liner. Adiabatic Engine, Semi-adiabatic Engine, uncooled Engine. Limited cooled engine, low heat rejection Engine and differentially cooled Engine are the terms being applied today to the heat insulated Engine. When the combustion chamber of a diesel Engine is insulated by using high temperature materials to allow hot operation with minimum heat transfer, only about one – third of the heat saved is given out as useful power output and the remaining part goes out as exhaust heat. Hence the exhaust energy is increased in the case of adiabatic engine compared to that of the conventional engine. Therefore, more technical innovations must be developed to extract useful energy from

the exhaust and to derive the maximum benefits from this adiabatic engine concept. Additional power and improved efficiency derived from an adiabatic engine are possible because thermal energy, normally lost to the cooling water and exhaust gas, is converted into useful power through the use of turbo machinery and high temperature with standing materials.

COMBUSTION CHAMBER

Piston

LHR diesel engine contains a two-part piston; the top crown ,shown in Fig.1, made of invar screwed to aluminum body of the piston, providing a 2mm-air gap in between the crown and the body of the piston. A nickel insert is screwed to the top portion of the liner in such a manner that an air gap of 2-mm is maintained between the insert and the liner body. Cylinder head and valves were coated heat resisting material. The stainless-steel gasket is introduced to minimize the heat loss through gasket.

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Fig 1: Invar Piston Crown Insert

In the first instance, an invar crown was fitted on aluminium piston with 2.0 mm air-gap, in order to investigate the effect of air-gap alone. The total height of the standard aluminium piston was reduced by 9.0mm at the top by machining. An Invar crown of 7.0 mm thickness was turned out of Invar alloy rod of 85 mm to the shape of the standard piston crown. The hemispherical shape was turned using concave and convex turning tool. A thickness of 5mm was maintained on the flange and bowl area of the crown. The recess for valve clearance was provided by end milling. The crown was separated by gaskets made of copper and stainless steel from the aluminium body. The stainless steel gasket is introduced to minimize the heat loss through gasket.

Cylinder Liner

A thin mild steel sleeve was circumscribed over the cast iron liner maintaining a 2mm layer of air in the annular space between the liner and the sleeve. The joints of the sleeve were sealed to prevent seepage of cooling water into the air-gap region. Fig 2 shows the constructional details of the air gap liner. Insulation of the liner brought about considerable reduction in the heat lost to the cooling water and an increase in overall thermal efficiency of the engine.

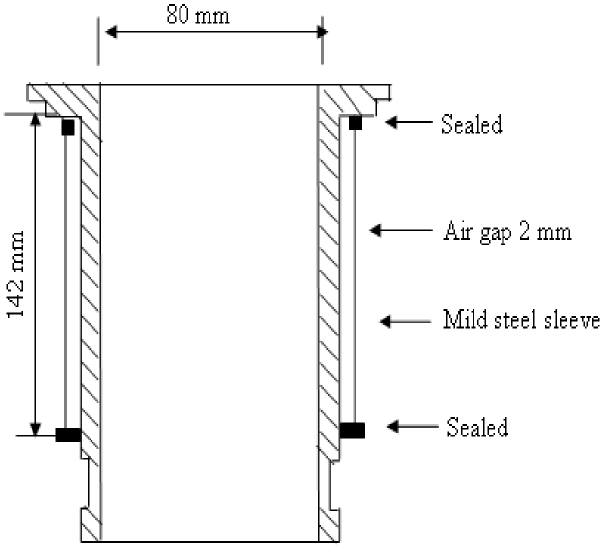

FIG 2 AIR GAP INSULATED LINER

Cylinder Head

Ceramic coating is a simpler method of insulation for cylinder head compared with other methods. The head was insulated by coating the area exposed to the combustion chamber with heat resisting material.

The combustion chamber area f the cylinder head was machined to a depth of 0.5 mm. The surface was then sand blasted to form innumerable pores for heat resisting material deposition.

Valves

The bottom surfaces of the valves were machined to a depth of 0.5mm and coated with heat resisting material of equal thickness. With the valves assembled on the cylinder head the area of the combustion chamber was about 90 to 92% of the total area.

EXPERIMENTAL INVESTIGATIONS

Experiments were conducted on the standard engine with diesel in various combinations of insulated parts. The standard engine was tested at the recommended injection timing of 27^0 bTDC at various loads. The engine was operated under no load for the first 20 minutes and for each load the engine was operated long enough to stabilize the condition. All the tests were conducted at the rated speed of 1500 rpm. The Aluminium piston engine is chosen as a base engine. Also, there is no insulation over the piston.

Fig 3:Experimental Setup

RESULTS & CONCLUSIONS

A set of experiments are conducted with Diesel to evaluate the performance differences between LHR engines and a conventional base engine.

SPEIFIC FUEL CONSUMPTION

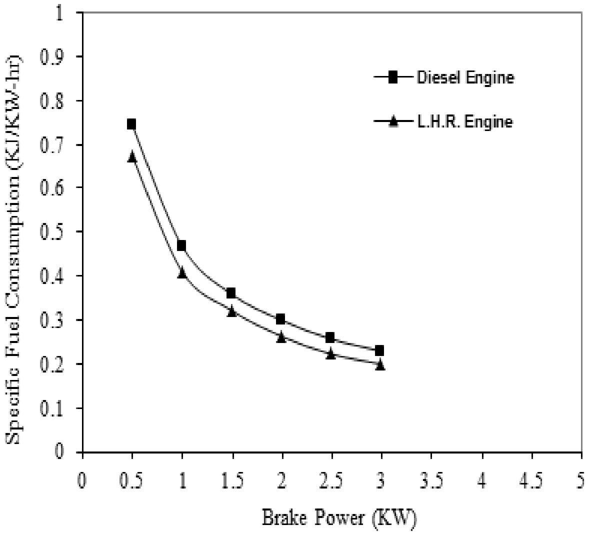

Fig 4: Comparison of Specific Fuel Consumption with Power output

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Fig 4 shows a plot representing the relation between the Brake Power and the Specific Fuel Consumption. It is clear from the plot that the S.F.C. of the LHR Engine is 13.04% less than that of the conventional engine. This is possible due to high temperature prevailing in the cylinder which increases the combustion efficiency and further leads to the instantaneous high pressure in the chamber.

THERMAL EFFICIENCY

The plot representing the relation between the Brake Power and the Brake Thermal Efficiency is shown in the Fig 5. It reveals that the thermal efficiency of LHR engine is 6.07 % more than that of the conventional engine. This is due to less heat rejection in LHR engine compared to the conventional engine.

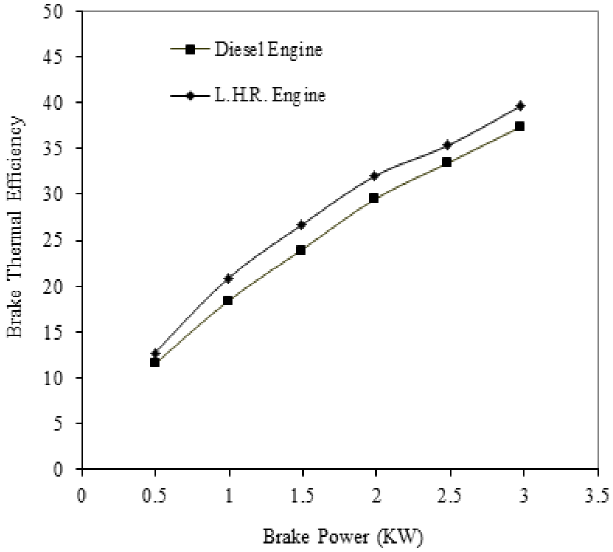

Fig 5: Comparison of Brake Thermal efficiency with Power output

EXHAUST GAS TEMPERATURE

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The comparative study of the exhaust gas temperature between the LHR and the conventional engine is shown in the Fig 6. It is observed that the exhaust gas temperature is 10.25% more for LHR than that of conventional engine. The reason for this is the air-gap insulation that is provided in the bottom of the crown portion of the piston for LHR engine. The amount of heat that is being conducted to the engine components is reduced and some part of this saved energy is converted into useful work.

VOLUMETRIC EFFICIENCY

The variation of volumetric efficiency with power output for four LHR configurations is shown in Fig.7 and the comparison is made with the normal engine. The general trend is that the volumetric efficiency drops with increase in power output. At standard condition, the volumetric efficiency varies from 88.09 percent at no load to 84.01 percent at full load. With LHR configuration the volumetric efficiency comes to 83.9 percent at no load and to 78.45 percent at full load. The volumetric efficiency has a bearing on power output. Because of insulation, the combustion chamber surface temperature increases. And there will be more heat loss to incoming air, resulting in a drop in volumetric efficiency. Since the incoming air density suffers, the combustion phenomenon is also affected. Therefore in insulated engines, the drop in volumetric efficiency is a major problem. The drop in volumetric efficiency can be compensated by supercharging or by turbo-charging. Additional power and improved efficiency can be derived from LHR engine through supercharging or Turbo-compounding.

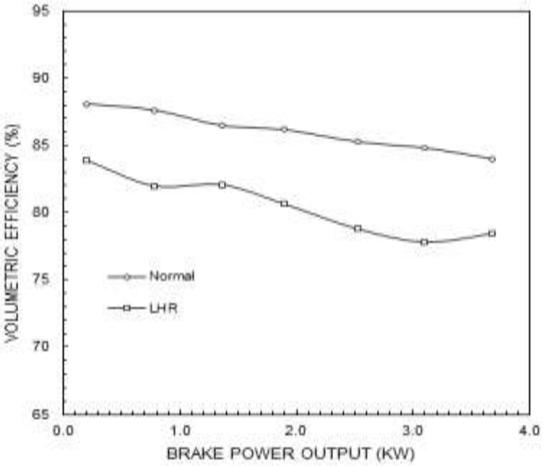
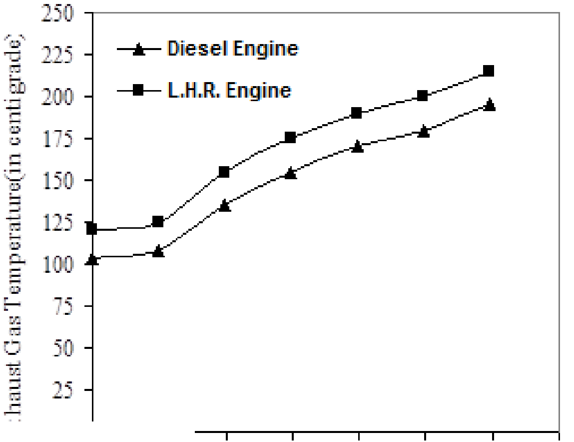


Fig 7: Comparison of volumetric efficiency with power output



ıparison of Exhaust Gas temperature with Power output

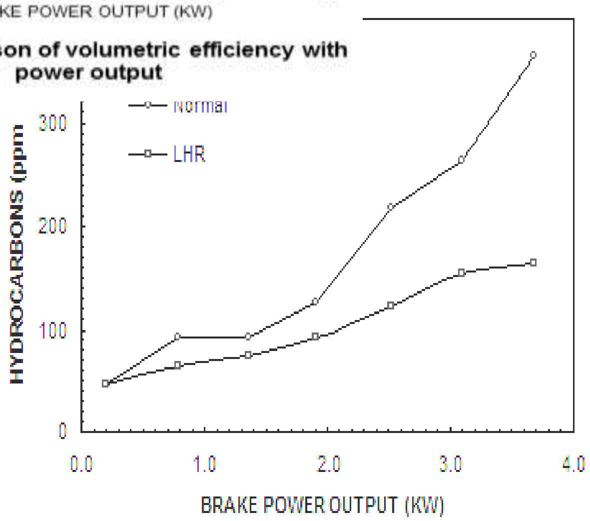


Fig 8: Comparison of Hydrocarbons with power output

HYDROCARBON EMISSIONS

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The Hydrocarbon emissions of LHR configuration and normal engine are compared in Fig. 8. The main sources of these emissions in CI engine are lean mixing, burning of lubricating oil, and wall quenching. Because of hotter combustion chamber, Hydrocarbon emission formation is found to be less in LHR Configuration. LHR configuration has shown the maximum reduction in Hydrocarbon emission levels and is about 200 ppm at rated load when compared to base engine.

CARBONMONOXIDE EMISSIONS

Carbon monoxide levels in the exhaust of base engine and LHR configuration are shown in Fig 9. Because of better and complete combustion in the insulated engines, carbon monoxide levels are lower. Lowest carbon monoxide emissions are observed in the case of LHR configuration, the reduction is about 0.28% by volume at rated load. Compared to part loads, the reduction is more at higher loads

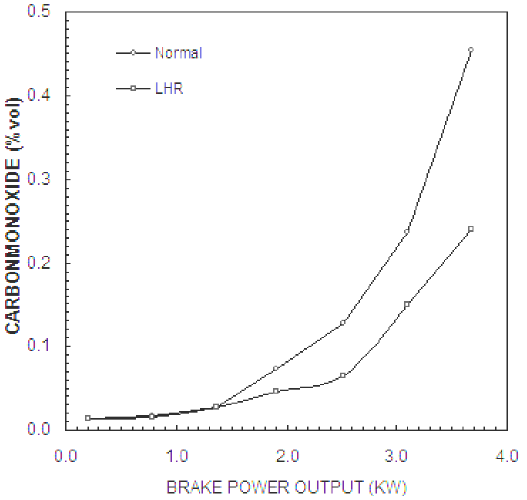

Fig 9: Comparison of Carbonmonoxide with power output

CONCLUSIONS

The following conclusions can be drawn from the processed results of the experimentation.

- LHR engines performed better when compared to base engine.

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- For the LHR-4 configuration (Invar Crown Aluminium Piston with Air gap, an Air gap liner and coated head and valves) , the brake thermal efficiency improvement is found to be 6.07 % at the full load operation compared with the base engine.
- Volumetric efficiency drop is maximum in the case of LHR configuration. And it is about 6.61% at the full load operation compared to the base engine.
- S.F.C. of the LHR Engine is 13.04% less than that of the conventional engine.
- Due to hot environment in the LHR engines, a reduction in the ignition delay is observed. The ignition delay is lower by 7.30CA for the LHR configuration.
- Better vaporization of injected fuel is possible in these engines. Therefore smooth engine operation is possible with this LHR configuration.
- Frictional losses are higher with LHR engines and are proportional to the level of insulation applied.
- From the experimental investigations, it can be concluded that the LHR configuration performs well.

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