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Effect of Low Heat Rejection on Performance and Emission Characteristics of a 4-Stroke Diesel Engine

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Abstract: *Due to rapid depletion of natural resources, the cost of petroleum fuels continues to rise, making them unaffordable for the average person. This is especially true in the Indian context. Consequently, C.I. requires a variety of fuel alternatives. The value of engines is rising. The improvement of C.I.'s thermal efficiency is the subject of extensive research. Powerhouse of the High-Tech Industry. Only roughly one-third of the thermal energy from the fuel is transferred to meaningful work by even the most efficient engine; the other two-thirds are wasted as exhaust and coolant. If energy loss can be minimized, Engine performance will increase. Researchers and specialists agree on a number of approaches for improving Engine performance. The idea of a Low Heat Rejection (LHR) Engine is one of the most promising. By utilizing thermally insulated parts, the performance of the LHR Engine can be enhanced. These parts not only improve thermal efficiency but also reduce heat loss to the environment. Various insulations, including ceramic coating on the inner surface of the cylinder head and a 2mm air gap insulation around the piston crown, are used to transform a standard Diesel engine into an LHR engine. The C.I. is used to test out various levels of insulation. The goal of the engine is to achieve the optimal performance with respect to emissions and other combustion characteristics.*

Keywords: *ow Heat Rejection (LHR)Engine, compression Ignition (C.I.), Aluminium, Copper, Nimonic alloy, Brass and PSZ.*

1. INTRODUCTION

About 30 percent of a diesel engine's total output is lost as heat in the cooling water. The expansion of gases in the turbines can convert this wasted energy back into usable form. To create a Low Heat Rejection (LHR) Engine, also known as a semi-adiabatic Engine, insulation is added to the walls of the engine's combustion chamber. Piston, cylinder head, cylinder liner, valves, and exhaust ports are some of the parts that have been insulated. Enhancements to both power and higher cycle temperatures release a substantial amount of energy in the exhaust gases, while insulation recovers some of the thermal energy that would otherwise be lost to the cooling system. The idea of a Low Heat Rejection Engine has been around for a while. As engine manufacturers seek out any remaining opportunities to enhance performance and reduce emissions, low heat rejection engines have recently received a great deal of attention. Designers would love to do away with the "necessary evil" of engine cooling if they could. Several researchers have proposed the use of vegetable oils in LHR Engines, however no proof of a working LHR Engine has been found. Therefore, the rejection of heat loss to cooling medium has been given prominence in recent times as one of the strategies for improving the performance of compression Ignition (C.I.) engines. C.I. When it comes to farming, the engine has replaced the electricity in areas where it is not readily available. Since the inception of the internal combustion engine, there has been an ongoing quest to improve the engine's efficiency. Using ceramic thermal barrier coatings to insulate the cylinder components helps reduce heat loss to the Engine cooling medium.

2. EXPERIMENTATION

The regular Engine with Diesel is used to test various configurations of insulated components. For the first 20 minutes, the Engine is run at no load, and for each subsequent load, it is run for a sufficient amount of time to reach a steady state. All of our tests run at the maximum recommended speed of 1500 rpm. The performance, emission, and combustion characteristics are assessed based on the measured data. Composition Variation in the Piston Crown

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LHR-1 Cylinder Head Rebuild Kit has an Aluminum Crown Aluminum Piston with a 2 mm air gap and a PSZ coated inner surface. Copper Crown Aluminum Piston (LHR-2) with 2 mm Air Gap and PSZ Cylinder Head Coating. Crown Mnemonic alloy pistons with a 2 mm air gap and PSZ coated cylinder heads are standard equipment for the LHR-3 The LHR-4 features a PSZ-coated inner cylinder surface and a piston made of brass and aluminum with a 2 mm air gap.It has been determined that the experimental results are fruitful, and it is anticipated that these results will play a vital role in the future creation of an effective LHR Engine that can operate on Bio- Diesel fuels.

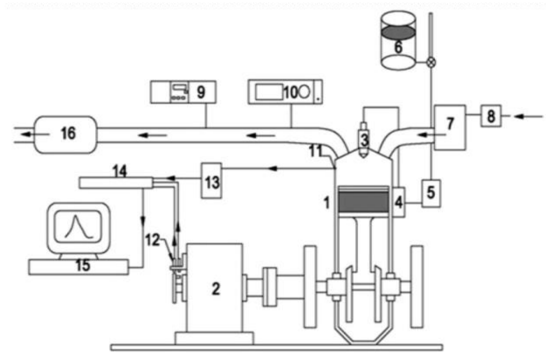

FIGURE 1. Schematic diagram for Experimental setup

1. Kirloskar Engine	9. AVL Smoke Meter
2. Eddy Current Dynamometer	10. INDUS 5--Gas Analyzer
3. Injector	11. Pressure ransducer
4. Fuel Pump	12. TDC Encoder
5. Fuel Filter	13. Charge Amplifier
6. Fuel Tank	14. Indimeter
7. Air Stabilizing Tank	15. Monitor
8. Air Filter	16. Exhaust silencer

Due to its low heat conductivity, air is used here as a shielding medium. The conventional piston is made of aluminum alloy and has an air gap between its metal crown and the piston. Gaskets made from the right materials separate and connect the two parts. The metal crown must function at high temperatures (90 kgf/cm2 at 9000C-10000C) and pressures (approximately 5-6mm at 9000C), hence it must be made from a material that can endure mechanical and thermal loads. The material is also resistant to corrosion and oxidation in harsh environments. As a first step, we fit an aluminum piston with a two-millimeter air gap and a crown made of the same material to see what happens. Standard aluminum pistons have their tops machined down by 7 millimeters. Aluminum alloy rod of 87.5 mm in length is formed into a 5.0 mm thick crown that conforms to industry standards for piston crowns. Concave and convex turning tools are used to create the asymmetrical hemisphere. The crown's flange and bowl each measure 5 millimeters in thickness. End milling creates the notch needed for valve clearance. The aluminum body is sealed off from the aluminum crown using copper and stainless-steel gaskets. A stainless-steel gasket of thickness 1.0 mm is used in between two copper gaskets of thickness 0.5 mm each. There is a 2.0 mm gap between each of the three gaskets. In the first instance, an Aluminum crown is fitted on Aluminum 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 is reduced by 7.0 mm at the top by machining. An Aluminium crown of 5.0mm thickness is turned out of Aluminum alloy rod of 87.5 mm to the shape of the standard piston crown. The hemispherical shape is turned using concave and convex turning tool. A thickness of 5mm is maintained on the flange and bowl area of the crown. The recess for valve clearance is provided by end milling. The Aluminum crown is separated by gaskets made of copper and stainless steel from the Aluminum body. Two copper gaskets of each0.5 mm thickness and a stainless-steel gasket of 1.0mm thickness placed in between the two copper gaskets aroused. The totalthicknessofthethreegasketsis2.0mm. Pistons typically measure 110 mm in height. To keep the modified piston's overall height (with the crown added at 5 mm and the gaskets added at 2 mm) at the same amount (110 mm), its standard height is reduced by 7 mm.

3. PISTONINSULATION

The insulating the piston is to reduce the heat a from the crown to the skirt and the maximum possible area of the crown has to the insulated to fulfill this objective.

FIGURE 2. Photo Graphic View of Aluminum Piston with Brass Crown and Air Insulation

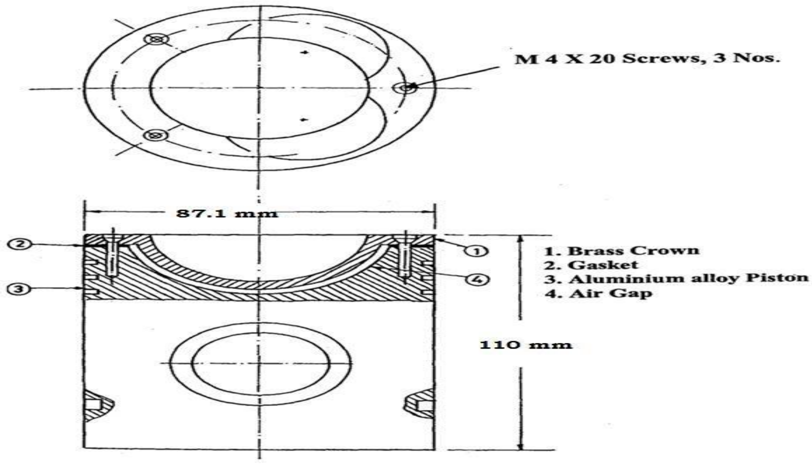

FIGURE 3. Brass Piston Crown with Air Gap Insulation

FIGURE 4. Three-dimensional view of Piston with Crown and Gaskets

FIGURE 5. Photographic view of Aluminum crown

FIGURE 6. Photographic view of Copper alloy crown

FIGURE 7. Photographic view of Nimonicalloy crown

4. CYLINDERHEADINSULATION

PSZ is used to insulate the part of the head that faces the combustion chamber. Machined to a depth of 0.5 mm, the combustion chamber area of the cylinder head is roughened surface is then degreased with chemical agents. The PSZ is coated to a thickness of 0.425 mm after a bond coat of 0.075 mm has been applied using a plasma arc spraying torch. We anticipate that the adhesion properties of ceramic layers over the cast iron surface will degrade with increasing thickness, hence we have set the maximum coating thickness at 0.5 mm. On the head, extraordinary adhesion of PSZ to the head material was required, and additional increases in thickness were not possible due to a decrease in PSZ layer adhesion over cast iron surface with increased thickness. About 35% of the surface area of the combustion chamber was taken up by the valves and the hole for the fuel injector nozzle, while the remaining area was covered with PSZ.

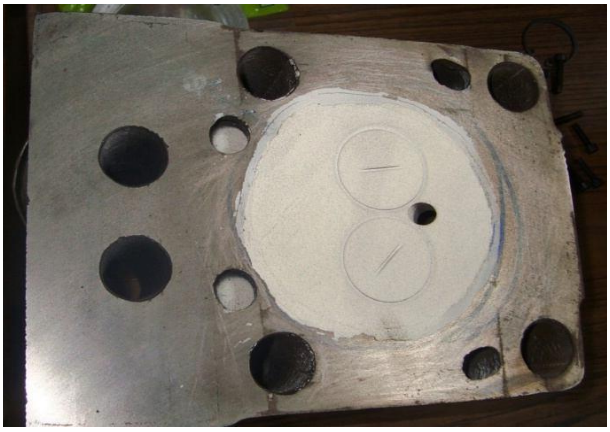

FIGURE 9. Photo Graphic View of PSZ Coated Cylinder Head

5. RESULTSANDDISCUSSIONS

Brake Thermal Efficiency: The brake thermal efficiency with power output forkful HR configurations is showninfigure10.

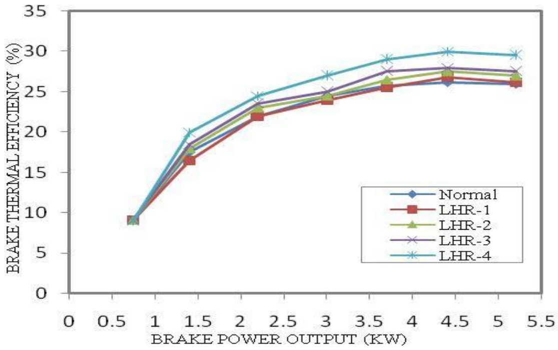

FIGURE 10. ComparisonofbrakethermalefficiencywithpoweroutputforfourLHRconfigurations.

Figure 10 displays that all LHR combinations, compared to the standard Engine, result in greater brake thermal efficiency. At full load (4.4 kW), the LHR-4 configuration's efficiency rises to 30%, while the efficiency of a standard Engine at full load (4.4 kW) is just 26%. According to the results, the Engine's thermal efficiency can be improved by installing insulation to prevent heat from escaping while braking. For the LHR-4 setup, the thermal efficiency of the brakes improves by about 4% under maximum load. Due to its strong thermal conductivity, the brass crown piston is built with an inbuilt heat regeneration system. The brass crown acts as a reservoir of heat, taking up energy from the hot gases at peak cycle temperature and releasing it to the new charge during the suction and compression strokes of the following cycle. This is why the LHR-4 insulation with the brass crown piston has a better thermal efficiency than the partial insulation.

Brake Specific Fuel Consumption: Brake specific fuel consumption is reduced in all LHR setups compared to the baseline Engine

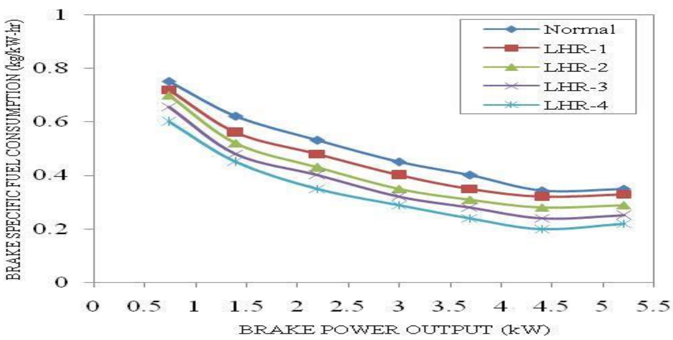

FIGURE 11. Comparison of Brake Specific Fuel Consumption with power output for four LHR configurations.

in figure 11. The LHR-4 setup reduces specific fuel consumption by 0.20 kg/kW-hr for the brakes at maximum load, and by 0.34 kg/kW-hr for the engine under normal conditions. Consistent mixture formation and full burning of the fuel are crucial to the brake specific fuel consumption. When fuel is vaporized more efficiently, the charge is more uniform, leading to more efficient burning. The LHR-4 design Brass Crown Aluminium Piston with 2 mm air gap and PSZ coated inner surface of the cylinder head acts as heat reservoir, raising the temperature of the combustion chamber and enhancing its efficiency. Improved fuel economy results from the increased combustion power afforded by the piston's brass crown's superior thermal characteristics. The incoming air temperature and combustion efficiency will both improve as a result.

Hydro carbon Emission: The Hydrocarbon emissions with power output for four LH Crone figurations is showninfigure12.

The LHR-4 configuration has shown in figure12 the maximum reduction in hydro car bonemission levels and is about 100ppmatrated load when compared to base Engine.

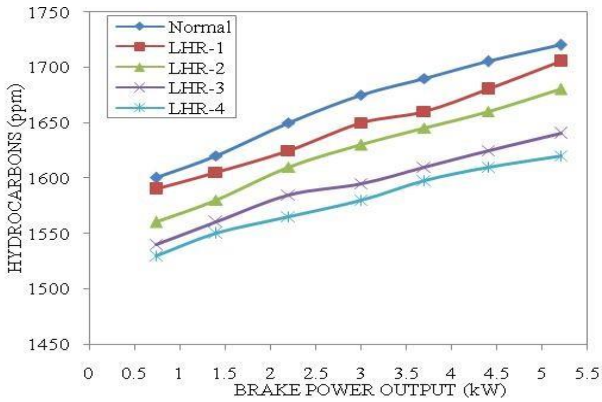

FIGURE 12. Comparison of Hydrocarbons with power output for four LHR configurations.

Hydrocarbon emissions for all other configurations fall somewhere between those of the base Engine and the Engine with LHR-4 configuration; it has been found that, for all piston crown materials used in this work, HC emissions rise as engine load rises. LHR-4 design has lower HC emission compared to other piston crown materials. Brass's high thermal conductivity may explain why it is able to insulate the combustion chamber better than other materials, leading to a decrease in emissions of hydrocarbons (HC). Hotter combustion chamber causes engine problems like lean mixing, oil burning, and wall quenching.

Carbon Dioxide Emission: Carbon dioxide levels are higher for LHR engines due to improved combustion brought about by the insulation, as seen by the graphs. Figure 13 depicts the greatest CO2 levels at full load for the LHR-4 configuration, at 10.2% volume, and the standard Engine at 9.3% volume

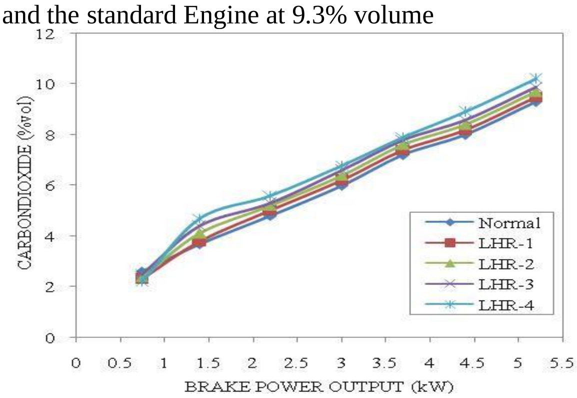

FIGURE 13. Comparison of carbon dioxide with power output for four LHR configurations.

The LHR-4 arrangement has the lowest carbon monoxide emissions, decreasing them by around 0.28% by volume at rated load due to the CO being converted into CO2 during operation. The savings are greater at full loads than at portion loads. Higher amounts of carbon monoxide emission have been observed for the LHR-2 and LHR-3 configurations compared to those of other variants. With the LHR-4 setup, carbon monoxide emissions are significantly diminished.

Carbon Monoxide Emission: The Carbon monoxide emission with poweroutputforfourLHRconfigurationsisshowninfigure14.

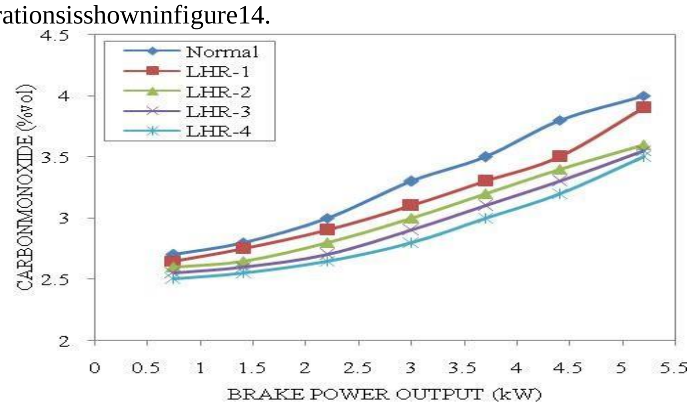

FIGURE 14. Comparison of carbon monoxide with power output for four LHR configurations.

Carbon monoxide levels in the exhaust of base engine and all the four LHR configuration sires honing figure15. Because of better and complete combustion in the insulate engines, this surplus oxygen offered within the LHR- 4 configuration converts the some of the Coin to carbon dioxide and thus the CO emission is reduced. Lowest carbon monoxide emissions are observed in the case of LHR-4configurations, the reduction is about 0.28%by volume at rated load. Compared to part loads, the reduction is more at higher loads. LHR-2 and LHR-3 configurations have shown higher levels of carbon monoxide emission compared to other configurations. Agora mound to reduction in carbon monoxide levels is observed with LHR-4 configuration.

Nitrogen Oxide Emissions: The Nitrogen oxide emission with power output for four LHR configurations is shown in figure15. NO_x levels in the exhaust of base Engine and all the four LHR configurations are shown in figure 15. Because of better and complete combustion in the insulated Engines, Nitrogen oxide levels are higher for insulated Engines.

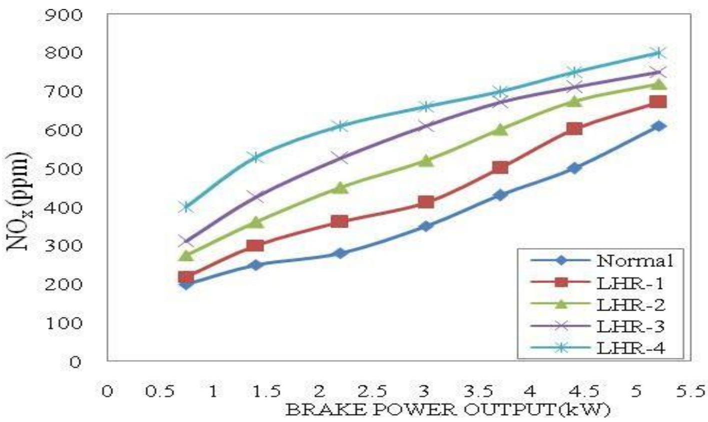

FIGURE 15. Comparison of nitrogen oxide with power output for four LHR configurations.

Nitrogen oxide levels peak at 800 ppm for the LHR-4 configuration and at 610 ppm for a standard Engine at full load. The amount of heat available in the combustion chamber is a key factor in the generation of NOx. The LHR-4 layout speeds up fuel evaporation while decreasing heat losses through the piston. As a result, the combustion process is enhanced, and NOx emissions rise. Nitrogen oxide levels in the exhaust that are higher than normal indicate that the combustion process was successful.

Ignition Delay: The Ignition delay with power output for four LHR configurations isshowninfigure16. Eduction in the ignition delay is observed for the Diesel fuel when tested in LHR configurations.

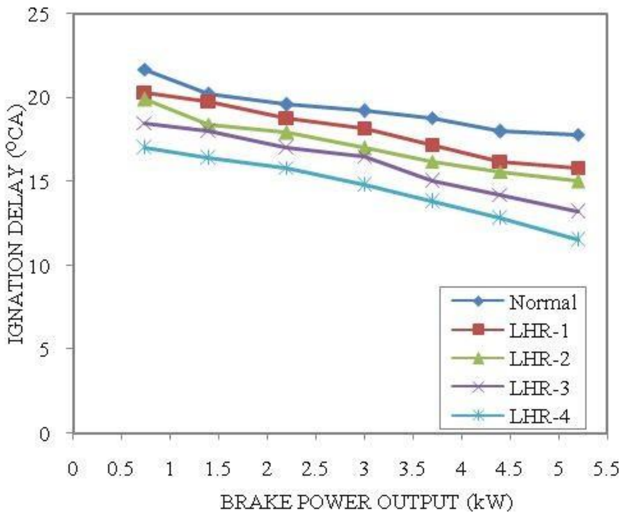

FIGURE 16. Comparison of Ignition delay with power output for four LHR configurations.

The reduction in the ignition delay is normally expected because of higher temperatures in these configurations. The ignition delay variation with brake output is showninfigure16.The LHR-4 arrangement achieves the shortest ignition delay compared to the other options. This setup has a 6.30CA shorter ignition latency compared to the standard Engine under maximum load. The amount of insulation used determines how much of a delay in starting the engine may be eliminated. The capacity to use fuels with low cetane numbers (Vegetable oils) is facilitated by a short ignition delay.

6. CONCLUSIONS

The following conclusions can be drawn from the processed result sof the experimentation. TheLHR-4configurationhas shown the bester romance. The analyzed experimental results support the following inferences. The LHR-4 setup has shown to be the most effective. Brake thermal efficiency is improved by 4% at peak load operation when using the LHR-4 configuration (Brass Crown Aluminum Piston with air gap and PSZ coated cylinder head). When compared to the standard Engine, the LHR variations all have a lower brake specific fuel usage. When using the LHR-4 arrangement, the particular fuel consumption for the brakes is decreased by 41% under maximum load. While all four LHR setups demonstrate lower HC emissions than the standard Engine, the LHR-4 setup reduces emissions by an average of 5.8 percent at full load. Better combustion in the LHR-4 configuration has resulted in a volumetric decrease of the CO emission to around 0.28%. The percentage increase in NOx emissions caused by the LHR-4 layout is roughly 23.75 percent. The LHR- 4 configuration has a 6.3°CA shorter ignition delay My name is Dr. GANAPATI RAMAVAT, and I'm an associate professor at ANURAG Engineering College in Kodad, Telangana, India, teaching in the field of mechanical engineering. Propulsion systems developed at JNT University in Anantapur, Andhra Pradesh. I have presented 17 conference papers and 6 research articles at national and international conferences.

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