# PERFORMANCE EVALUATION AND EMISSION CHARACTERISTICS OF LOW HEAT REJECTION ENGINE USING AIR GAP INSULATION

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***ABSTRACT*---- 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 about 30% of energy utilization for useful purposes. In view of the above, the major thrust in engine research during the last two decades has been on the development of low heat rejection engines. The Low Heat Rejection (LHR) engine has been given considerable attention recently as engine builders struggle to find remaining avenues to improve economy and lower emissions. The concept of air gap insulated piston has been explored by providing 1mm air gap within the piston by using bolted type piston. The bolted air gap insulated piston provides complete sealing of air gap necessary for continued insulation. The design evolved provides high insulation combining adequate durability. In order to provide high insulation and reliability, proper designing of the air gap piston has to be ensured. The piston with 1mm thickness of air gap are designed with two different material. The insulation provides betterment in fuel consumption at normal operating condition than a conventional piston engine and also the delay period tends to reduce the emissions levels of Hydrocarbons and carbon monoxide. The combustion rate is increased because of insulation and hence there is reduced vibration and noise level.**

**Keywords: LHR engine, Air gap, Piston, Insulation etc.,**

## 1. INTRODUCTION

### 1.1 *LHR Engine.*

The subject of Low Heat Rejection (LHR) Engine has been given considerable attention recently as engine builders struggle to find remaining avenues to improve economy and lower emissions. Cooling an engine is a necessary evil which designer would gladly forego if it were possible. But local hot spots, high cost of materials able to survive at elevated temperature, and lubrication problems generally have prevented elimination of the cooling system.

Beyond the complication of a cooling system, there is the knowledge that sizable fraction of the energy input to the engine is simply being thrown away. In today's fuel economy conscious setting it is natural that ways are being sought to effect a double benefit in which cooling system can be dispensed with and, at the same time, more of the input energy put to work.

Energy conservation and efficiency have always been the most concern of engineers with internal combustion engine. The diesel engine generally offers better fuel economy than its counterpart petrol engine. Even the diesel engine rejects about two third of the heat energy of the fuel, one third to the coolant, and one third to the exhaust, leaving only about one third as useful work output. Theoretically if the heat rejected could be reduced, then the thermal efficiency would be improved, at least up to the limit set by the second law of thermodynamics. Low heat rejection engine aim to do this by reducing heat lost to the coolant.

The diesel engine with its combustion chamber, piston surfaces and valves insulated by ceramics and air gap provided within the piston is referred to as low heat rejection (LHR) engine. A large number of studies on performance evaluation of LHR engine have been carried out recently.

There are three different types of LHR engine: low grade, medium grade and high grade LHR engine. Low grade LHR engine[1] is the one which is obtained by providing thermal barrier coating over the piston surfaces or cylinder walls, medium grade LHR engine[2] is the one which is obtained by providing the air gap insulated piston and the high grade LHR engine[3] is the one which is obtained by providing the air gap within the piston material as well as thermal barrier coating is provided over the piston surface, valves and piston liners etc.,

**1.2.** ***Development Of Insulated Piston***

To satisfy the requirement for insulated pistons, the path used only known all-metal technology, and it is this approach that forms the main thrust of the present paper. The second path, which is being pursued, comprises longer term developments involving ceramics and combination of ceramics and metals. They are of two type of insulation method.

1. Ceramic Insulated Piston.
2. Air gap Insulated Piston.

**1.2.1.** ***Ceramic Insulated Piston.***

The use of low conductivity engineering ceramics for the piston crown[1,4], in combination with conventional aluminum or cast iron pistons bodies, has received considerable attention in recent years by most of the major engine manufacturers. This approach has obvious attractions, since the ceramic is restricted to the region where its low thermal conductivity and high temperature capability can be best exploited. The use of both thermally sprayed coatings and solid ceramics are inherently brittle and cannot accommodate any permanent strain thus localized high stresses, which in metallic components would be reduced by local yielding, are liable to result in catastrophic failure. Furthermore ceramics and metals are dissimilar in nature and cannot be joined by the conventional processes of brazing or welding. The use of screw threaded fastenings is also desirable since these usually produce unacceptable stress concentrations in the ceramic. These are many other formidable problems arising from the use of ceramic insulation are being tackled in Automobile Engineering’s long term work. Indeed some ceramic may be necessary in the insulated piston to withstand the highest levels of insulation that are now achievable. In consequence of the long time scale anticipated for the ceramic developments, readily available all-metal technologies such as air gap insulation.

**1.2.2.** ***Air gap insulation Insulated Piston.***

The air gap piston has a conventional skirt and ring pack together with a crown piece whose contact with the piston body is arranged to provide adequate mechanical strength with the minimum of conductive heat transfer. At relatively low temperature, heat transmission across the air gap is controlled by conduction and convection at a very low level. However, as the temperature of the crown rises, radiative heat transfer becomes predominant, and in the most advanced designs special precautions have to be taken to minimize this. From the operational view point the location of the principal insulating region in the piston is very important. According to the principles set out. If the insulation can be situated above the ring pack later can operate at normal, or even reduced, temperature relative to an insulated piston.

**1.2.2.1*****Advantages of Air Gap Insulated Piston***

When the air is inducted to the combustion chamber its temperature is raised because of the average temperature of the combustion chamber is raised. Due to this the fuel which is injected in to the combustion chamber attains the self ignition temperature quickly and so the combustion occurs smoothly. The pressure rise in the uncontrolled combustion is very less and the maximum temperature of the cycle is comparatively less. The complete burning of fuel occurs smoothly in the controlled phase.

**1.2.2.2.** ***Reduction in delay period***

Due to the average temperature in combustion chamber increases, the air temperature which is inducted into the chamber also increases which helps the fuel to attain self ignition temperature quickly and mixes with air readily and atomized easily.

**1.2.2.3.** ***Increase in thermal efficiency***

The conduction through the piston is desirably reduced. This increses the thermal efficiency of the cycle.

**1.2.3.** ***Criteria for the selection of air gap thickness***

To increase the engine efficiency, and performance of the individual surface areas of the combustion chamber of an engine, the piston offers an attractive area for insulation because a large portion of the total combustion chamber surface heat transfer occurs through this area. The study from earlier research on the engine says about 50% of heat rejection occurs in the liner cooling zone, to which the largest contributor is the piston. Hence in this work, heat rejection on piston will be studied,

In this work, piston insulation is taken as major area. On this, heat loss due to conduction on the piston is to be prevented. An hemispherical air gap is provided just below the piston crown surface to achieve the above, since the heat transfer within the air gap is very minimum. And the thickness of the air gap is selected based on various research work. As per many literature survey[2,5,6] the air gap which was carried out already is 3mm but in this work the thickness is reduced due the increase in thickness of air gap offers reduction in heat transfer but further increase in thickness of air gap in LHR engine causes the very high temperature differences between the air gap which cause the radiation heat transfer to play dominant role of hear transfer within the air gap which causes the increase in heat transfer.

This criteria does not occur in high grade LHR[3,5] engine since the conductive heat transfer within the coating material itself reduces the temperature to some extent thereby the temperature differences within the air gap is not that much high. Since the medium grade LHR engine offers reduction in heat transfer only by providing the air gap the temperature difference within the gap surfaces are high and material selected to have good strength in this work also a very high emissivity material which cause the radiation heat transfer mode to be dominant. In order to avoid the radiative heat transfer the air gap thickness is reduced to 1mm.

## 2. EXPERIMENTAL PROCEDURE:

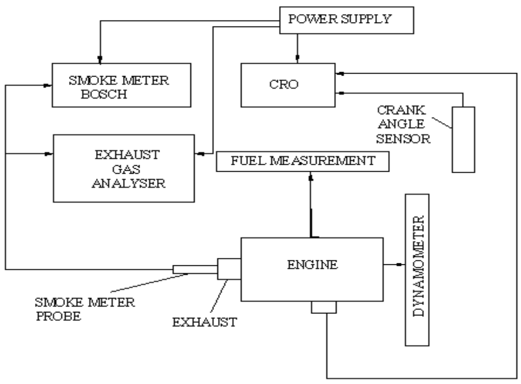
### 2.1. *Engine Specification:*

| | | |
|---|---|---|
| Engine | : | 4 Stroke Single Cylinder<br>Direct Injection Diesel Engine |
| Bore Diameter | : | 88mm |
| Stroke Length | : | 110mm |
| Lubrication System | : | Water Cooled System |
| Brake Power | : | 7.5 BHP |
| Engine RPM | : | 1500 (Constant) |
| Control | : | Auto Governor |
| Lube | : | 20E/40W |

### 2.2. *Machining Process:*

CNC machine is used with the help of dish tool to prepare a bowl shape in the existing piston of R26 to R30 and then the facing operation is carried out for 10mm and then the bowl shaped is prepared with the outer radii of R29 in the stainless steel to obtain the top portion of the crown. Then the drilling operation is carried out in the bottom and top portion of the air gap insulated piston with drilling holes of M5. Then the bottom and top portion is assembled rigidly.

### 2.3. *Experimental Setup:*




### 2.4. *Smoke Measurement:*

A spring loaded sampling pump draws a fixed volume of exhaust of exhaust gas from the exhaust stream through a controlled density paper filter disc. Soot particles from the samples on the paper filter disc, causing it to darken in proportion to soot particle concentration. A separate 110V AC or battery powered photoelectric device measures the light reflected from the darkened filter disc. Readout is by millimeter calibration in 0 to 10 units.

### 2.5. *Engine Test Procedure:*

A conventional engine some connections are to be made they are emission measuring machine, smoke meter, exhaust Temperature measuring instrument. The engine is started and allowed to warm-up for about 15 minutes. The readings on dynamometer scale (load) time taken for 10cc of fuel consumption. Nox, CO, HC emission in emission measuring instrument, exhaust temperature and smoke measurement in smoke meter have been recorded. This procedure is repeated by changing the loads from No Load, 3 Kg, 6Kg, 9Kg, 12Kg and 15Kg. After this work the piston is over changed with newly machined air gap insulated piston. The above said procedure is repeated.

## 3. RESULT & DISCUSSION:

Based on the test procedure and calculation. The Reading are tabulated and then the difference between the conventional piston engine and Air Gap Insulated Piston engine is plotted in graph as shown in Fig. [1- 4].

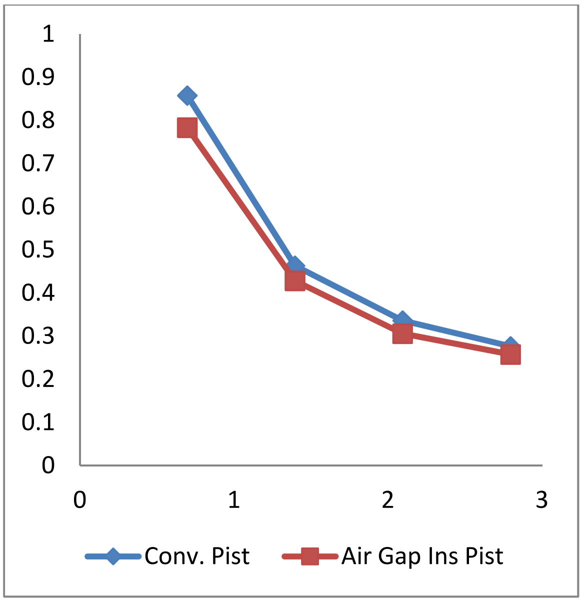



Fig. 1. Comparison of BP vs bSFC between Conventional and Air Gap Insulated Piston

Fig. 1. Shows the Brake Power vs Brake Specific Fuel Consumption for Conventional and Air Gap Insulated Piston engine. The result of the graph shows that the fuel consumption in Air Gap Insulated Piston Engine is reduced due to the high combustion rate in Air Gap Insulated Piston. With high Combustion Temperature will lead to obtain good combustion of the byproducts which results in less fuel consumption than that of the conventional diesel engine.

The Fig. 2. Shows that the brake thermal efficiency of the Air Gap Insulated Piston Engine is increased with that of the conventional Piston engine. This in because heat rejection in this Air Gap Insulate d Piston engine to the coolant is less compared to the conventional engine which gives the increased brake Thermal Efficiency than Conventional Diesel Engine.

Fig. 3&4 shows that the Carbon monoxide(CO) And Hydrocarbon emissions in Air Gap Insulated Piston is less compared to the conventional Piston because of high combustion temperature which leads to obtain complete burning of fuel and results in obtaining lesser CO & HC emissions.

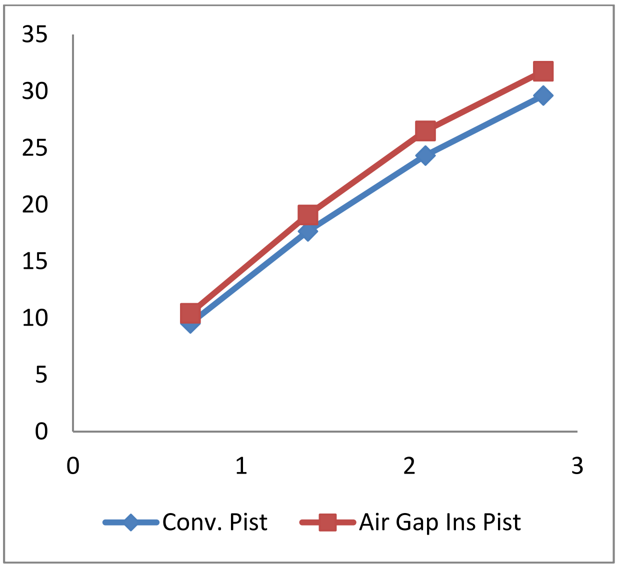



Fig. 2. Comparison of Brake Power vs Brake Thermal Efficiency between Conventional and Air Gap Insulated Piston Engine

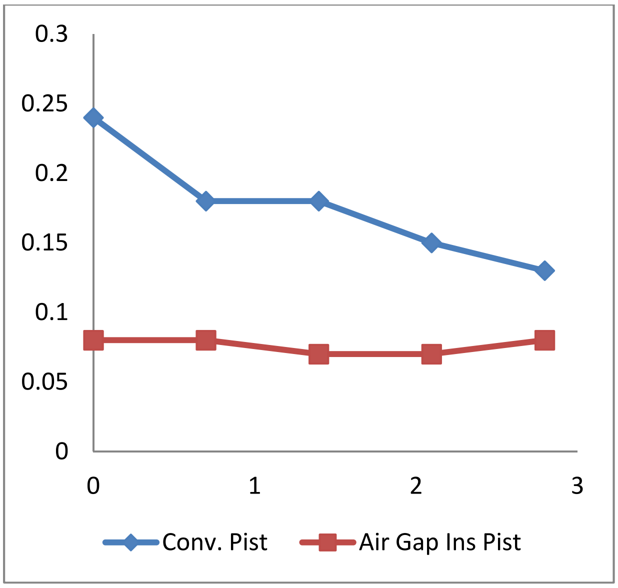



Fig. 3. Comparison of BP vs CO emissions between Conventional and Air Gap Insulated Piston.

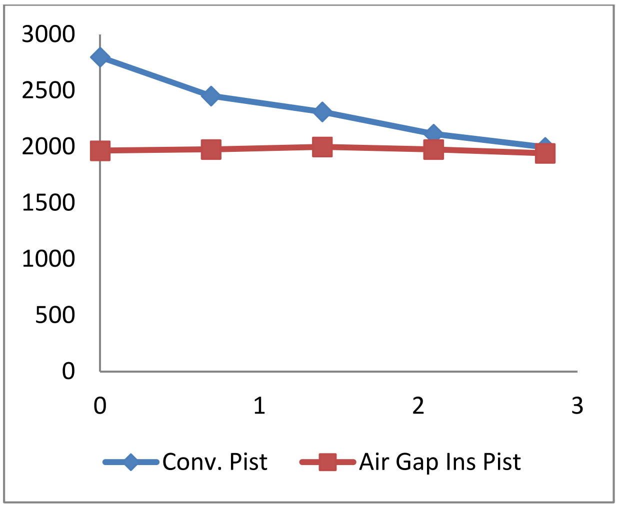



Fig. 4. Comparison of BP vs HC emissions between Conventional and Air Gap Insulated Piston.

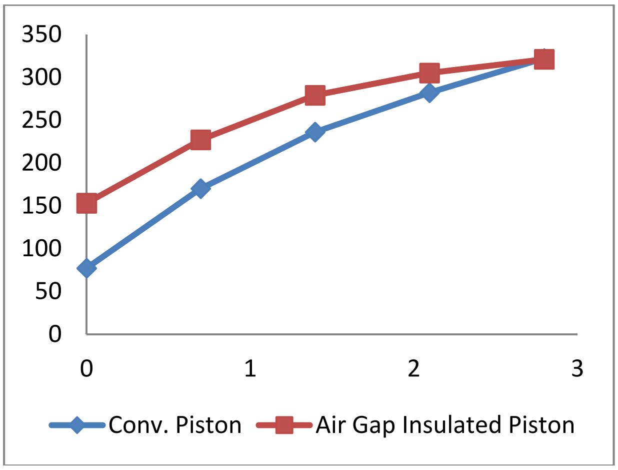



Fig. 5. Comparison of BP vs NOx emissions between Conventional and Air Gap Insulated Piston.

Fig.5. shows that the NOx emission is higher in Air Gap Insulated Piston compared to the Conventional Piston. This is because of the high combustion chamber temperature in Air Gap Insulated Piston Engine. But from the graph it shows that at high load the NOx emission is approximately same that of the

conventional engine further increase in loads may give the lesser emission when compared to the conventional piston engine.

## 4. CONCLUSION

With the experimental investigations it is concluded that the air gap thickness of 1mm is suitable for LHR engine and with this we obtain the reduction in fuel consumption and increased in thermal efficiency from that of the conventional piston engine. Also the emissions like HC and CO are comparatively reduced. And an increased in NOx emission is obtained which can be reduced by a modern catalytic converter.

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