CHAPTER 2

LITERATURE SURVEY

2.1 GENERAL

The development in science and technology, that have benefited the mankind, are also contributing to their health hazards. Hydrocarbon, particulate matter and nitrogen oxides are the major emissions caused by compression ignition engines which pollute the environment to a great extent. Lot of works has been reported in the literature on the emission control and improvement of performance of diesel engines. Incylinder treatment such as catalyst coating on the piston, insulated engine and adding fuel additives are some methods used to control the emission and to improve the performance of diesel engines. The following is a brief account of such emission control investigations on diesel engines available in literature.

2.2. INSULATED AND COATED ENGINE COMPONENTS

Walter Bryzil and Roy Kamo (1983) have demonstrated the concept of insulating the diesel combustion chamber with high temperature materials to allow hot operation near an adiabatic operation and the hot or insulated high temperature components include piston, cylinder head valves, cylinder liner, exhaust valves and exhaust ports. Zirconia of different thicknesses such as 0.12 mm, 0.4 mm, 0.5 mm and 1 mm was used for insulation by them. It has been reported that the power output and brake thermal efficiency increase with increase in insulation thickness. It has also been observed that the carbonmonoxide, unburnt hydrocarbon and the NOx level were lower. Further, they have concluded that 0.5mm thickness insulation gave better results than other insulation thickness.
Kamo and Bryzik (1984) have demonstrated use of high performance ceramics in an adiabatic turbo compound engine. They have concluded that a waste heat recovery device is necessary to get full advantage of adiabatic engine. They have reported that yttria partially stabilised zirconia has the ability to meet the most of the adiabatic engine design criteria. They have also concluded that use of ceramic in engine cause major problems such as high temperature and lubrication. French (1984) has investigated the effect of ceramic coatings in the internal combustion engine parts and found that there is a gain in efficiency, due to reduction in engine friction and heat loss. It has been concluded that there was 2 to 4% improvements in fuel consumption due to reduction in sliding friction reduces by 25 to 33%.

Alkidas and Cole (1985) have studied the influence of an airgap-insulated piston on the coolant heat rejection engine and emission characteristics of a single cylinder divided chamber diesel engine. It has been reported that use of LHR piston resulted in coolant heat rejection from 3 to 7% under various load conditions. It has also been found out that LHR piston design reduces the heat transfer from piston crown. It has further been concluded that reduction in HC, CO and smoke whereas an increase in NOx was obtained. The effect of all ceramic swirl chamber on emission by lining the inner walls of chamber with high strength sintered silicon nitride was studied by Shigeki Nakatani et al. (1986). They have achieved an improvement in ignition quality, reduction in particulate emission and an increase in NOx level has been reported due to increase in combustion temperature.

Shigeru Sakurai and Tsutomu Matusoka (1986) have developed a low particulate emission engine with all ceramic swirl chamber. They have observed that the reduction of particulate was considerable and the NOx level was maintained at same level as that of the standard engine by the use of EGR, fuel injection and glow plug energization. They have concluded that insulated flat bottom type swirl chamber reduces NOx to a greater extent due to diffusive
combustion. It has also been concluded that the EGR reduces the particulate more effectively than raising the intake air temperatures.

Havstad et al. (1986) have studied the effect of ceramic insert in a high speed uncooled direct injection diesel engine. They have reported a 5 to 9% improvement in fuel consumption when compared with base line values whereas it was only a 2% improvement in the ceramic coated engine. It has also been reported that there is 30% reduction in heat loss for a ceramic insert uncooled engine from that of the base line values. It has been further reported that the ignition delay was reduced by 3 to 4 degrees of crank angle relative to the base line water cooled engine. Flynn and MacBeth (1986) have investigated the use of monolithic ceramic piston and cylinder liner components fabricated from sintered alpha silicon carbide and sialon. They have concluded that use of ceramic components without cooling and lubrication exhibited lower friction than the standard engine.

Shoichi Furuhama and Yoshiteru Enomoto (1987) have demonstrated the use of a thin film thermocouple for measuring the instantaneous values of temperature heat fluxes in combustion walls of gasoline engine. They have also compared conventional Aluminium-Alloy and ceramic plates in terms of the heat loss at the upper surface of each piston during combustion gasoline and diesel engines. They have concluded that the ceramic plates subjected to higher temperature had greater heat loss in both gasoline and diesel engines contrary to anticipation.

Huang and Borman (1987) have studied the effect of surface material and extent of insulation on the heat transfer to the head of an open chamber diesel engine. They used a large instrumentation plug designed to incorporate plates of various materials on the gas side surface. It has been reported that the 6.35mm thick zirconia plate insulation of the metal plate increased the gas side surface temperature over the uninsulated metal. It has also been reported that significant
reductions in the steady state heat fluxes were achieved with zirconia insulated metal over the uninsulated metal. Gerhard Woschni et al. (1987) have made experimental investigations with heat insulated combustion chamber walls. They have reported that the engine with insulated piston shows an increase in fuel consumption of about 15 gm/kWh compared with base line engine. They have concluded that heat insulated combustion wall did not reduce fuel consumption.

Ingard Kvernes and Hoel (1987) have discussed the important features of viable thermal barrier coatings. They have compared the properties of various coating materials and methods. They have found that ZrO₂-ZrMgO, ZrO₂ - 7/8 Y₂O₃ gives better results for diesel engine and ZrO₂ - 7/8 Y₂O₃ gives better results for gas turbines. They have reported that the thermal barrier coating has an acceptable thermal cyclic resistance. Sevend Henningsen (1987) has investigated the influence of elevated combustion temperature on the performance in a single cylinder DI diesel engine. He has conducted the test using LHR approach by removing coolant but without heat insulated parts. It has been reported that the ignition delay and the fraction of fuel burnt in the premixed combustion phase decrease with increasing temperature level. It has been concluded that the HC, NOx and particulate emission generally increase with increasing temperature.

Williamson and Summers (1987) have conducted the durability performance characteristics studies of copper-containing base metal catalysts under well controlled stoichiometric closed-loop air fuel operation. They have reported that the copper chromium base metal formulations yield significant HC and CO conversion under stoichiometric operating conditions but deteriorate rapidly at high temperatures. They have concluded that the incorporation of rhodium into the base metal formulation reduces NOx emission in the exhaust.

Harris and Joe Lutz (1988) have conducted experiments on diesel engines with thermal barrier coatings of thicker zirconia ceramic coatings. They have
concluded that the use of thermal barrier coating on diesel engines challenges the engine design and further they have concluded that difficulties on long life may be overcome by toughening of coating.

Beyerlein and Stanislaw (1988) have made theoretical analysis of flame propagation through catalytically activated mixtures and conducted fundamental experiments with catalytic flow reactor. They have concluded that the catalytic pre-reaction increases the flame velocity and reduces the minimum ignition energy requirements. They have also reported that the catalytic prechamber technology regulates the catalytic surface temperature as well as the contact between the catalytic and gas phase reactant. It has been further reported that the catalytic charge activation in a CFR engine decreases the cycle to cycle pressure variation and increases the cycle efficiency near the lean burn limit. They have concluded that when the catalytic prereaction was more extensive, the catalytic prechamber proved to be knock free compression ignition source. They also developed a model of incylinder activation, which proved to be a valuable asset in understanding catalytic prechamber performance and serves to be a useful tool in optimizing catalytic prechamber design.

Pasto et al. (1988) have investigated the effect of ceramic coating on the engine components. They have found that the ceramic materials offer the advantages of lower density, excellent wear resistance, increased stiffness, low thermal expansion and high temperature capability over the traditionally used metals. They have also found that the silicon nitride offer high temperature capabilities, controlled thermal conductivity, low thermal expansion, light weight and increased stiffness over conventional materials. Roy Kamo et al. (1989) have studied the merits of thin thermal barrier coatings for internal combustion engines. It has been reported that among various coating materials, Cr2O3 offers outstanding tribological property. They have concluded that those thin thermal barrier coatings with good insulation friction and wear properties improve volumetric efficiency, thermal efficiency, durability, reliability, emission and
erosion/corrosion resistance of the engine. They have also concluded that thin thermal barrier coatings could be applied to gasoline engines.

Miyairi et al. (1989) have investigated experimentally the performance and emission characteristics of a single cylinder DI diesel engine whose combustion chamber wall was thermally insulated with ceramic material of sintered silicon nitride (SSN) and partially stabilized zirconia (PSZ). It has been concluded that such engines showed improved performance and decreased volumetric efficiency though increased NOx emission. It has also been reported that when the cylinder head and cylinder liner were thermally insulated with ceramic, the BSFC reduces for both naturally aspirated and turbocharged engines. Further it has been reported that the hydrocarbon emission reduces at low speed and sharply reduces when injection timing was retarded with insulating the piston head, cylinder liner and cylinder liner upper part.

Alkidas (1989) has studied the performance and emission characteristics of an uncooled thermally insulated diesel engine. It has been observed that the uncooled engine had equal or superior fuel consumption and higher NOx emission, lower smoke and particulate emission. It has been concluded that the higher NOx emission are partly due to higher combustion temperature and partly due to shorter combustion duration and lower HC emission are due to reduction in bulk quenching and wall quenching of combustion reaction. Further it has been concluded that the reduction in smoke level and particulate was due to the high gas temperature. Natarajan (1989) has discussed the fundamentals of combustion chemistry and reaction kinetics of combustion generated pollution. He has also discussed the effect of design and operation variables on the emission of pollutants from combustion process with particular reference to internal combustion engines. Further, strategies for minimising the formation of pollutants in combustion process were also discussed.
Dickey (1989) has developed a ceramic coating on the combustion chamber of a single-cylinder direct injection diesel engine to determine the effect of low heat rejection (LHR) operation on engine performance, emissions and combustion characteristics. It has been found that the LHR engine had lower thermal efficiency with higher smoke, particulate and carbon monoxide emissions when compared to the base line cooled engine. It has been also found that the unburnt hydrocarbon emissions were reduced at all load conditions. It has been concluded that the LHR engine performance was attributed to degraded combustion with less premixed burning, lower heat release rates and longer combustion duration compared to the base line cooled engine. Arunachalam et al. (1989) have studied the performance of diesel engine with insulated combustion chamber surfaces. The piston was made by nimonic material and liner, head and valves were coated by partially stabilised zirconia. They have found lower volumetric efficiency resulting from higher degrees of insulation has a negative effect on power output. They have also found that the smoke densities were lower than that of the standard engine.

Reddy et al. (1990) have examined the probable causes for the contradictory results found in the literature on low heat rejection engines. They have analysed that the LHR engine and conventional engine under same air fuel ratio, peak conditions and identical heat release. They have found that almost all numerical studies predicted improved thermal efficiency, increased availability in the exhaust and reduced incylinder heat rejection relative to conventionally cooled engines and reduced exhaust emission.

Prasad and Samria (1990) have studied the heat transfer and made boundary conditions of the cylinder, piston assembly of a direct injection diesel engine with ceramic material coated piston. They have found that the heat loss through piston with the use of 2mm thick insulation coating on the cylinder wall reduces by 6%. They have also found an increase in piston body temperature and further increase in temperature with increase in the thickness of insulation.
coating. Harrer and Boehm (1990) have studied the effect of nickel coated piston in gasoline engine. They have found that the nickel coating to be an effective and reliable technique to protect piston from combustion-knock erosion. They have also reported that nickel coated piston shows reduced piston deposit, increased wear resistance, reduced cylinder head temperature, increased engine efficiency and reduced knock sensitivity.

Fredrik Ahlstorm et al. (1990) have studied the catalytic combustion of diesel soot under the influence of metal oxides and different metals. They have placed the mixture of soot and catalyst in a reactor and determined the combustion rate. They have concluded that oxides of vanadium were highly active at temperatures above 623°K, whereas silver, platinum and oxides of copper, chromium and manganese were active at low temperature itself.

Paul Glance and Melvin Woods (1990) have developed an advanced insulated piston consisting of titanium alloy 6242 and a slurry densified zirconia thermal barrier coating computer aided modeling, thermal rig bench screening and small bore engine testing of a conventional water cooled high output diesel engine. They have compared the results with an adiabatic diesel engine. They have reported that the piston accounts for over one third of the heat transfer in the water cooled engine. They have also found that the cylinder liner heat transfer can only be reduced by about 52% by removing the coolant and insulating the piston top. Katsuyuki Osawa et al. (1991) have studied the effect of zirconia and chrome oxide thermal barrier coatings on the cylinder head, valve face and piston crown of an aluminium engine block. They have found that the fuel consumption with coated cylinder head improves by 10% only. They have also found that the fuel injection timing with the coated cylinder head was retarded by about 2° crank angle and emission characteristics were approximately the same level as that of the base line engine with 8% improvement in brake specific fuel consumption.
Dennis Assanis et al. (1991) have studied the effects of ceramic coating of different thickness on diesel engine performance and exhaust emission. They have observed improved performance and emission for the thinner (0.5mm) ceramic coated piston than the thicker (1mm) ceramic coated piston. They have also reported that an increase of 10% in efficiency was achieved for 0.5mm and only 6% improvement in efficiency for 1mm ceramic coated piston. They have concluded that a reduction of upto 60% in CO, 40% in HC, 30% in NOx and marginal reduction in smoke when compared with standard metal piston. Shuji Kimura et al. (1992) have investigated the effects of combustion chamber insulation on the heat rejection and thermal efficiency of a single cylinder direct injection diesel engine using a silicon nitride piston cavity that has been shrink fitted into a titanium alloy crown insulated the combustion chamber. They have reported that the combustion chamber insulation shows the reduction of heat rejection and thermal efficiency does not improve to the same extent. They have also reported that, these insulation leads to reduction in the angular velocity of the flame.

Ernest Schwarz et al. (1993) have studied the effect of LHR on combustion and performance characteristics of diesel engine. They have found that improved mixing of fuel and air is required in order to permit low heat rejection and to optimize the combustion. They have also found that the heat release in LHR engines exhibit greater sensitivity to small changes in normally cooled engines. Ramamohan et al. (1995) have studied the effect of an air gap insulated piston in direct injection diesel engine. The influence of different crown materials with varying magnitude of air-gap on the performance, combustion and emission were studied. They have reported that the improvement of BSFC was found higher while using an L link mechanism.

Jurgen Haag et al. (1995) have investigated the use of piston made of fine grain carbon in a spark ignition engine. They have found that the top land clearance between piston and cylinder could be reduced considerably due to the
low coefficient of thermal expansion of the carbon material when compared to standard aluminium piston. They have also found that the emission of unburnt hydrocarbons could be reduced by more than 15% compared to aluminium piston under steady state part load operating conditions without significant penalties in NOx. They have also reported simultaneously about 2% improvement in the fuel economy. It has been further concluded that the blowby leakage shows a reduction of more than 50% with the carbon piston having smaller top land clearance.

Wolf Bauer and Wong (1995) have studied the effects of heat transfer characteristics and thermodynamic efficiency of an internal combustion engine. They have made an attempt to illustrate the fundamental physical basic of applying thin thermal barrier coatings to improve the performance of military and commercial internal combustion engines. They have found that a gain in brake thermal efficiency can be obtained with thin coatings on internal combustion engine components and can achieve an effective thermal barrier during combustion without excessively raising the operating temperature of the engine.

Alaa Elmoursi et al. (1996) have investigated the potential use of diamond like carbon on aluminium alloy piston of internal combustion engines. They have coated the diamond like carbon (DLC) on the piston against aluminium 390 bore thus eliminating the iron liners in a standard piston/bore system. They have found that under unlubricated test conditions the performance of the DLC coating against aluminium 390 exhibits superior friction resistance. They have also found that the DLC coatings show lower friction and wear properties at high temperature in the order of 700° K.

Hideo Kawamura et al. (1996) have studied the effect of a structure referred to as thermo structure (heat insulation) in a low heat rejection diesel engine with the combustion chamber wall of Si3N4 monolithic having higher strength and fracture toughness at much higher temperatures. They have reported that in LHR engine the insufficient fuel-air mixing may be attributed to an
increase in gas viscosity and deterioration of air entertainment of fuel spray as a result of high combustion temperature. They have also reported a fuel economy of 10% attained by using a precombustion chamber located centrally in the cylinder head and throat holes drilled in it. They have concluded that the NOx emission increases in LHR engine due to higher temperature of combustion.

Jozef Jarosinski et al. (1996) have studied the effect of catalytic prechamber in a lean burn piston engine and the catalyst prechambers containing catalytic inserts shaped in the form of an open coil. They have found that, the catalytic insert shows up to 15% reduction in specific fuel consumption from 50% to 75% load at 3000 rpm. They have also found that, the concentrations of unburnt hydrocarbons were reduced by 30 to 50% and NOx was relatively low (30%), particularly for higher excess air with compression ratio of 16. They have concluded that, at a compression ratio of 19, the reduction of HC and NOx were 65% and 72% respectively.

Tree et al. (1996) have studied the effect of insulated pistons on engine performance and heat transfer using yttria made insulation stabilized zirconia or mullite. They have concluded that the ISFC showed an increase of 3% for the zirconia coated piston and 8% for mullite coated pistons in comparison to uncoated piston due to advancing of injection timing. They have also found out that the particulate emission increased for mullite coated piston and NOx and particulate emission increased for zirconia coated piston.

Michael Preis and Edward Johnson (1996) have investigated the effect of different catalyst materials on a lean burn gasoline engine and on the passenger car diesel engine. They have found that the catalyst materials are able to convert nitrogen oxides only at net oxidising conditions. They have also found that the noble metal catalyst permit a maximum of about 25% NOx conversion in the European driving cycle and also found that at high and low temperatures, catalyst allow conversion rates up to 40% in truck engines and 25% in lean burn spark
Bose and Beg (1997) have examined the effects of ceramic coating by insulating the top of the piston using yttria partially stabilised zirconia with alumino bore silicate as a bond coat in an indigenous process instead of plasma spray. They have reported that at 30% load with 40° injection angle, the NOx level decreases by 32.14% and 27.42% for the compression ratio 19 and 20 respectively. It has also been reported that with higher degree of insulation (500micron thickness) NOx level decreases considerably when compared to baseline engine.

Melvin Woods et al. (1997) have studied the effect of thermal barrier coatings for heat engine components. They have found that the thermal insulation reduces in cylinder heat transfer from the engine combustion chamber as well as reduces component structural temperature. They have concluded that there is reduction in fuel consumption and better performance due to the thermal barrier coating to the cylinder liner.

Mike Norris and Ken Voss (1997) have studied the effect of zirconia based ceramic coatings for low heat rejection engines. They have found that the heavy duty diesel engines equipped with stabilized zirconia coatings, showed significant reduction in exhaust emission relative to a baseline engine. They have also found that the zirconia coating with retardation of fuel injection timing showed reduction in NOx without increase in particulate emission.

Roy Kamo et al. (1997) have evaluated the performance of thin thermal barrier coated components on diesel engines. They have concluded that there is a reduction in fuel consumption due to coatings on the cylinder liner. Mavinahally et al. (1998) have analysed the heat release characteristics of an insulated turbocharged, six cylinder DI diesel engine. They have reported that thin thermal barrier coatings offered 5% to 6% fuel efficiency and an apparent fuel economy improvement at all speeds and loads.
2.3 FUEL ADDITIVES

Cotton et al. (1971) have studied the suppression of soot emission from flames by metal additives and their efficiency of soot removal. They have been reported that the metals other than earth metals and molybdenum remove soot only at high oxygen fuel ratios. It has been concluded that the metals other than the alkaline earth and molybdenum maintained their efficiencies at low flame temperatures. Greeves and Wang (1981) have developed a correlation between the measured values of particulate, hydrocarbon and smoke emission. They have suggested three combustion ideas for optimising diesel combustion to minimise the fuel consumption, emission of smoke, NOx, particulate, HC, CO, odour and noise.

Simon and Stark (1985) have investigated the performance and emission of diesel engine using particulate trap with fuel additives and electric igniters. They have conducted experiments with cerium and manganese based fuel additives. They have concluded that cerium and manganese based fuel additives give improved performance. Widemann and Neumann (1985) have conducted experiments with different additives for regeneration of ceramic diesel filters. It has been proved that the introduction of fuel additive showed reduction in the regeneration temperature. It has been concluded that the ceramic particulate filter in conjunction with fuel additive has showed a particulate emission below 0.08g/mile.

Hilden and Bergin. (1986) have studied the combined effect of manganese based fuel additive and exhaust gas recirculation on particulate and oxides of nitrogen (NOx) emissions from diesel engine. They have also studied the physical and chemical properties of the particulate and EGR effects on these emissions. It has been concluded that the EGR always decreased NOx emissions and increased the particulate emission but manganese based fuel additive has no significant effect on NOx and controls the particulate emission. Draper et al.
(1988) have examined the effects of a barium based fuel additive on the polycyclic aromatic hydrocarbon content and amine test mutagenic activity of exhaust particulate matter from the diesel engine. It has been reported that a reduction of about 8% of particulate was achieved while using lubrizol - 565 additive. It has been concluded that the barium based fuel additive did not significantly change the SOF content of particles under any combination of intake pressure or level in the fuel.

Weidmann et al. (1988) have investigated the fuel quality effects on exhaust emission of diesel engines. It has been reported that the hydrocarbon emission depends upon cetane number. It has also been reported that CO emissions decrease with increasing cetane number and decreasing density. It has been concluded that the NOx emissions increase slightly with rising cetane number, which was an opposing trend to that anticipated. It has been further concluded that fuel density and aromatic contents also influence the emissions.

Constandopoulos et al. (1988) have investigated the effects of a manganese copper based fuel additive with ceramic particulate traps for diesel engine emission control. It has been concluded that the additive produced no significant effects an measured gaseous emission (with or without the trap). It has been also been concluded that the use of additive alone showed a 20% increase in sulphate. Further it has been reported that the use of the additive plus the trap caused significant reduction in TPM, SOF, SO$_4^{2-}$ and SOL and the use of manganese copper based fuel additive showed a reduction in the trap regeneration temperature from 600°C to 420°C. Lawrence et al. (1990) have studied the effect of cetane improvers on emissions from diesel engine running on low sulphur fuels. It has been found that the HC and CO emissions were reduced significantly with increasing cetane number. It has also been found that NOx emissions were reduced significantly by the use of cetane improvers. It has been concluded that no fuel showed significant increase in particulate emissions when cetane improvers were added.
Ullman et al. (1990) have investigated the effects of fuel aromatics, cetane number and cetane improver on emissions from a heavy duty diesel engine. It has been reported that cetane number was the key fuel property which affect the transient HC and CO emissions and the principal fuel property affecting particulate emissions. It has been concluded that the cetane number and aromatics showed significant effect on NOx, and particulate emission. Ullman et al. (1994) have studied the effect of cetane number, cetane improver, aromatics and oxygenates on heavy duty diesel engine emissions. It has been reported that the increase in cetane number showed reduction in CO and NOx emission. It has been concluded that as the content of aromatics increase, NOx increases; as cetane number increase, NOx decreases, and oxygen increases, NOx increases, but the level of increase is likely dependent on the nominal NOx calibration of the engine.

Vincent et al. (1994) have investigated the effect of diesel fuel detergent additive on performance and emission of direct injection and indirect injection diesel engines. It has been reported that detergent additive showed reduced gaseous and particulate emission in both DI and IDI engine types. It has also been reported that there is reduction in injector nozzle clean up duration time for direct injection engine whereas it remained same for IDI engine. Further it has been concluded that the performance of IDI and DI engines depend upon type and range of fuel additives used.

Kesling et al. (1994) have studied the effect of peroxide based fuel additive and nitrate based fuel additives on its thermal stability, emission and performance. It has been found that the peroxide based fuel additives were thermally stable at actual use temperatures and their cetane value did not change under various operating conditions. It has also been concluded that the rate of decomposition for the peroxide based fuel additive was found to be five times faster than that of 2-ethylhexyl nitrate.
Nandi et al. (1994) have investigated the performance of a peroxide based cetane improvement additive in three different low sulfur diesel fuels heated with di-butyl peroxide and 2-ethyl hexyl nitrate. It has been reported that both the peroxide and the nitrate cetane improver additive significantly reduced all regulated and unregulated emissions. Further, it has been concluded that treatment of various fuels with cetane improver additives reduced significantly hydrocarbon, carbon monoxide, oxides of nitrogen and particulate emissions. Harvey et al. (1994) have studied about the regulated and unregulated emissions on a heavy duty diesel engine using ceramic particulate trap and copper based fuel additive. It has been reported that there is not much effect on emission by the use of fuel additive and the emission is substantially reduced by use of trap, such as particulate matter by 72 to 93%, HC about 30%, SOF by 84 to 91% and XOC by 48%. Further it has been reported that the additive reduced the trap regeneration temperature from 510°C to 375°C.

Kittelson et al. (1994) have studied the influence of a fuel additive on the performance and emissions of a medium duty diesel engine. It has been found that the additive has little influence on general combustion, performance and emissions. It has also been reported that there was no change in NOx emissions however the particulate emissions were reduced by 40% after 25 hours of running. Dementhon et al. (1995) have studied the particulate trap regeneration of diesel engines with a novel alkali additive It has been reported that the additive showed a reduction of SOF emission upto 30% at low load with increase in fuel consumption. It has been further reported that a complete cleaning of the trap can be obtained at 50°C to 80°C. It has been concluded that, at temperature as low as 230°C, the system leads to stochastic and local regeneration without the clogging of the trap.

Ullman et al. (1995) have examined the effects of cetane number on emissions from a prototype heavy duty diesel engine. It has been found that
emission were highest with the fuel having 41.1 cetane number. It has been concluded that the increase of cetane number beyond 41, there were considerable reductions in all emissions. Tadao Ogawa et al. (1997) have studied the composition of hydrocarbons in a diesel fuel exhaust gases and particulate using high pressure liquid chromatography and gas chromatography. It has been reported that composition of hydrocarbon in exhaust gases were almost the same as those in the diesel fuel. It has been concluded that a regression formula to eliminate the total particulate emissions has been developed.

Lange et al. (1997) have investigated the effect of increasing cetane number from 51 to 61 on combustion, emissions and fuel consumption of an advanced MAN EURO-II engine. It has been concluded that increasing the cetane number did not affect the particulate or HC emissions. It has also been concluded that the NOx reduction was almost same for all cetane number, increased cetane number by ignition improvers and by hydrocarbon composition. It has been further concluded that the fuel consumption was reduced by 1.1% with increasing cetane number. Uehara et al. (1997) have studied the mechanism of deposit formation in the combustion chamber under the influence of fuel components and gasoline detergents. It has been reported that the combustion chamber deposits from gasoline were under compressed atmosphere and outside the flame in the quench zone. It has also been reported that some types of substituents were oxidized and they play a role for binding heavy groups such as benzene rings. It has been further concluded that the combustion chamber deposit formed by detergent remained without any chemical reaction.

Brigitte Martin et al. (1997) have demonstrated a new fuel formulation for decreasing pollutants in the diesel engines. They have found that the CO, HC, aldehyde, particulate and PAH emissions were highly sensitive to fuel quality and on the contrary NOx emissions were only slightly modified. They have also found that for particulate, the influence of fuel formulation depends on the ratio of SOF to IOF. They have found that Fischer – Tropsch fuel was best fuel for very low level of pollutants. It has been concluded that the particulate, IOF,
smoke and PAH were controlled by aromatic contents and NOx emissions were controlled by density but with less variation.

Lata and Adwani (1998) have examined the influence of oxygenated fuel additive for reduction of particulate matter in the diesel engine exhaust. They have concluded that the diglyme reduces particulate matter about 28% at full load.

Du et al. (1998) have studied the influence of iron fuel additive on diesel combustion with normal piston and thermal barrier coated piston. They have found that the use of ferrous additive influences the combustion process in a diesel engine in a complex manner. They have also found that the full effect of the additive takes several hours to develop. It has also been reported that the performance of additive was strongly dependent on the conditioning process. Pattas et al. (1998) have investigated the behavior of metal diesel particulate filters at low temperatures in conjunction with a cerium based additive in the diesel engines. They have concluded that the exhaust gas temperature in the range of 300°C with a concentration of 100ppm of cerium in the fuel was proved to be effective for regeneration. They have also reported that the regeneration temperature depends mainly on the trap location, found somewhat lower at remote locations, possibly due to higher levels of adsorbed hydrocarbon at this location. They have also concluded that the frequency of regeneration decreases as the trap size increases at remote locations.

Noboru Miyamoto et al. (1998) have studied the effect of oxygenated agents on emission and performance in diesel engines. They have reported that by addition of sufficient oxygenate to ordinary diesel fuel, significant improvements were obtained in smoke, particulate matter, NOx, HC and thermal efficiency. They have also reported that the improvements in the exhaust gas emissions and the thermal efficiency depended on the oxygen content in the fuels. They have concluded that the diethylene glycol dimethyl ether (DGM) showed
better reduction of NOx, HC, smoke and noise and improved the thermal efficiency.

Cherian Olikara et al. (1998) have investigated the effects of fuel properties on emissions of a heavy duty diesel engine. They have reported, after conducting experiments with 13 different test fuels, that there were no apparent relationship between the exhaust emissions and the individual fuel properties such as density, cetane number or total aromatic content. They have evaluated a correlation between NOx and HC emission. They have concluded that the adiabatic flame temperature dominated the NOx emissions.

Bach et al. (1998) have studied the combined effect of additive and particulate trap in the exhaust emission of diesel engine. It has been reported that cerium based additive reduce the regeneration temperature from 550°C to 400°C. They have concluded that the NOx and particulate considerably reduced by using both additive and particulate trap. Raghunadham and Deshpande et al. (2000) have discussed the effect of bio-additives on internal combustion engine performance and emission. They have found E-oil, bio additive helped the fuel to flow better through carburetor jets and better atomization of fuel which improved the combustion and performance of the engine at all variable loads and variable speeds. They have concluded 0.2ml/lit of additive showed better results against performance and emission.

Jajoo and Malkhede et al. (2000) have studied the effect of three different fuel additives with different concentrations on the performance and emissions of a diesel engine. They have reported that all the three additives are effective in suppressing smoke. It has been concluded that NOx was not significantly affected with the use of additive except with LZ-8080. Jagtap and Yarasu et al. (2000) have examined the effect of oxygenated fuel additives on emission of a diesel engine. It has been reported that oxygenated fuel additives reduce HC, CO and
particulate matter. They have concluded that the reduction in NOx can be obtained by using peroxide type cetane improver additive.

2.4 CLOSURE

From the preceding paragraphs, it may be noted that quite a few experimental and theoretical investigations have been carried out in diesel engines to study the emission control. However the available information on the control of emission and improvement in performance of the diesel engine using catalyst coated piston, insulated engine and additives are quite limited. Further, no attempt has been made to improve the efficiency and to reduce emissions simultaneously.

Therefore, in the present investigation, an attempt has been made to investigate the incylinder combustion treatment to control of both oxides of nitrogen and particulate and also to improve the thermal efficiency of the direct injection diesel engine.