CHAPTER 3

EMISSION CONTROL FROM DIESEL ENGINES

3.1 GENERAL

The enormous increase in the use of fossil energy sources in the industrialized nations has caused increased pollution of air, with vehicle emissions contributing a significant factor. Human health and environment demand very severe regulations for exhaust emissions from both spark ignition and compression ignition engines. The diesel engine is widely used in heavy-duty transport applications since it is having high efficiency and low operating costs. In recent years, diesel engines have begun to achieve a growing share even for light duty vehicle market as well. This trend towards increased dieselization can result in many positive environment benefits such as low levels of CO₂, CO and evaporative hydrocarbons when compared to petrol engines. But it emits higher levels of oxides of nitrogen and particulate matter to the atmosphere. Hence, to preserve the environment from pollution and save the human being, it is necessary to reduce emission by devicing suitable control methods.

3.2 EMISSION CONTROL METHODS

The emission from diesel engines can be controlled by the following methods:

* Design parameter
* Operating parameters
* Incylinder treatment
* Exhaust gas after treatment
3.2.1 Design parameters

3.2.1.1. Swirl chamber design

The swirl chamber design dominates in the diesel engines used in passenger vehicles. In this design, the combustion chamber is separated into two chambers of roughly equal size interconnected across a passage. The fuel is injected into the swirl chamber filled with some of the air. The eccentric location of the injection port in the swirl chamber produces swirl movement inside the swirl chamber.

3.2.1.2 Pre combustion chamber

The pre combustion chamber volume relative to the main combustion chamber volume is 35% to 40% smaller than that of swirl chamber design. If the pre combustion chamber is too small, the oxygen contents are no longer sufficient to ensure complete combustion and hence increases the HC, CO and particulate emission. Also as the peak temperature reduces with incomplete combustion NOx emission will be low.

3.2.1.3 Turbocharging

Turbocharging is being increasingly employed to improve specific power output of the engine. It, apart from its effect on spray formation increases the average gas temperature over the whole cycle. With the same oxygen concentration, the higher gas temperatures provide a better oxidation environment for CO and HC. Matched turbocharging requires lowering of compression ratio for reducing mechanical and thermal loading on the engine. Benefits of turbocharging on HC and CO emissions are evident. NOx and smoke are not affected significantly by turbocharging.
3.2.1.4 Compression ratio

The normal compression ratio of a diesel vehicle engine is approximately 20 to 23. Swirl chamber, pre chamber engines usually have slightly higher compression ratio than the direct injection engine. Increasing the compression ratio helps to improve HC and particulate emission. Part throttle operations reduces the content of soluble particulate but increases friction work and, hence, fuel consumption and NOx emission.

3.2.1.5 Injection nozzle

The injection nozzle geometry is also an essential feature in conjunction with injection hydraulics. Direct injection engines use either single hole or multi hole nozzles. Hydrocarbon emissions can be improved by reducing the volume of the injection nozzle (Sachole volume). The number of injection holes have a considerable influence on smoke number and formation of NOx emission. At an identical smoke, NOx emissions are lower if, a four hole nozzle is replaced by a five or six hole nozzle.

3.2.2 Operating Parameters

3.2.2.1 Engine Load

In diesel engine, the change in load is accomplished by controlling the amount of fuel injected. This produces variations in fuel distribution in the spray, amount of fuel deposited on the walls, cylinder gas pressure and temperature and injection duration. At low loads and idling, unburnt hydrocarbons originate mainly from the lean mixture regions of the fuel spray. Though in diesel engines carbon monoxide is quite low but at low fuel-air ratio i.e. at light loads, the gas temperatures are low and very little oxidation takes place, resulting in higher CO emissions. Increase in load results in lower CO emissions because of the
increased gas temperatures and the oxidation reactions. NOx emission is observed to increase with the increase in fuel-air ratio and reach maximum.

3.2.2.2. High pressure injection

Injecting fuel into the combustion chamber at high pressure creates turbulence and improved atomization of the fuel, which gives proper mixing of the fuel and air. High injection pressures may be achieved either by using pump nozzle element or common rail injection systems. At higher injection pressures, nitrogen oxides and particulate emission are lower.

3.2.2.3. Injection timing

Injection start and injection duration are two of the major factors that contribute significantly to the emission characteristics. As the injection timing continuous to be moved toward TDC, the combustion temperatures and, hence, nitrogen oxide emissions are lowered further and smoke level are also lowered. The reduction of above emissions, which comes at the expense of, increased specific fuel consumption and HC emissions. The optimised injection timing can be accomplished by using an electronic control system.

3.2.2.4. Injection rate

Injection rate influences the HC emissions, the soot and particularly, at idling, the noise. Higher rates of fuel injection reduce the exhaust smoke as the injection process ends early. Size of nozzle holes and the ratio of the hole length to its diameter have an effect on smoke concentration. A larger hole diameter results in less atomization and increased smoke. An increase in the ratio of the hole length to its diameter beyond a certain limit also results in increased smoke.
3.2.3 Incylinder treatment

3.2.3.1 Catalyst coatings in the combustion chamber

The catalysts coated on the combustion chamber induce faster chemical reaction and complete combustion results reduction of emission from the engine. Figure 3.1 shows the schematic view of coating on the engine components. The following techniques are generally used to coat the combustion chamber and other engine components.

3.2.3.1.1 Anodic coating

Anodic coating is obtained by coating metals, which are anodic base metal. For example, coating of zinc, aluminum and cadmium on steel are anodic because their electrode potentials are higher than that of the base metal that is steel. In the case of zinc and iron, zinc being anodic to iron, will dissolve anodically whereas the iron being cathodic will not dissolve. Thus no attack on the iron occurs until practically all the zinc has first corroded in the vicinity of the exposed iron. So zinc coating protects iron satisfactorily.

3.2.3.1.2 Cathodic coating

Cathodic coatings are obtained by coating a noble metal, having lower electrode potential than the base metal. Cathodic coating provides effective protection to the base metal only when they are continuous and free from pores and breaks. If such coatings are punctured much more corrosion damages will be done at the base metal than without it. For example, tin coating on a sheet of iron, provides protection only as long as the surface of the metal is completely covered since tin is lower than iron in electromotive series. However, if the surface coating is punctured the tin becomes cathode while the exposed iron acts as anode.
Fig. 3.1  Incylinder coating using catalyst materials
3.2.3.1.3 **Hot dipping**

In this process the article to be coated is placed in the perforated bucket and dipped into the molten metal catalyst covered by a molten flux layer (zinc chloride) which prevents oxidation of the coating surfaces. This process is used for coating metals such as palladium, aluminium and nickel etc. on iron, which has relatively higher melting point.

3.2.3.1.4 **Immersion plating**

It involves simple process of immersing the base metal in an electrolyte solution containing a salt of the cathodic coating metal. The deposition occurs by simple displacement. The ions of the noble metals are displaced from the salt solution by the ions of the less noble base metals.

3.2.3.1.5 **Metallized coating**

In this process the coating metal in the molten state is sprayed on the roughened surface of base metal either by wiregun method or powder metal coating technique. The metals thus sprayed adhere to the base metal surface.

3.2.3.1.6 **Diffusion coating**

It is obtained by heating the base metal spread with the powder of the coating metal. Diffusion of coating metal into the base metal takes place resulting in the formation of layers of alloys of varying composition. The layer just adjoined to the base metal may be intermediate compound, a solid solution. The outer layer is rich in the coating metal.

3.2.3.1.7 **Electroplating**

This is the process by which the coating metal is deposited on the base metal by passing a direct current through an electrolytic solution containing the soluble salt of the coating metal. This technique has been used in this present
investigation. A detailed description about this technique is given in chapter 4. (Sec. 4.4.1)

3.2.3.2 Fuel modification

A principal requirement of fuels for high speed diesel engines is good ignition quality. Fuels of poor ignition quality can lead to extended ignition delay and result in 'diesel knock'. Excess fuel is injected into the combustion chamber during the delay period and during combustion more rapid and greater rises in cylinder pressure causes. These results increase in engine stress, noise and fuel consumption. To modify the fuel quality, additive can be added in small quantity either to enhance engine performance or reduce the emissions.

By adding the additive, the following advantages are obtained.

- Higher power output
- Lower fuel consumption
- Low maintenance cost
- Effective emission control
- Longer engine life.

The following different types of additives have been utilised in the emission control and improvement of the engine performance.

3.2.3.2.1 Detergents

Deposits can form between the extremely precise and close fitting pump and injector moving ports and also form in just inside the injector tip as well as on the combustion chamber side of the injector tip. The amount and location of these deposit can results loss of power, poor economy, rough running and hard starting. Detergent additives can effectively prevent these deposits when used at treatment levels from 33 to 84ppm.
3.2.3.2.2 Cetane improvers

Cetane number is a measure of ignitability and is one of the most critical properties of diesel fuel and it controls the ignitability of diesel fuel as it is sprayed into the engine combustion chamber. The main function of cetane improver is to reduce the ignition delay period for the fuel to which it is added. During ignition delay period, these chemicals undergo precombustion reactions this generating free radical species that can accelerate oxidation of the fuel hydrocarbons and actual combustion of the fuel and air mixture. The examples of cetane improver are alkyl nitrates, nitroso and nitro compounds and peroxides. These additives cause easier starting, reduced misfiring, lower exhaust emission and smoother operation.

3.2.3.2.3 Combustion catalysts

It refers to a group of metallic, or ash containing, additives that reduce exhaust smoke or particulate. The possible mechanism is to inhibit the cracking of fuel droplets to carbon during the evaporative and burning process. As the liquid droplet grows smaller within the flame envelop, it approaches flame temperature of 1700 to 2500°C. If the droplet evaporates completely and burns to CO₂ and H₂O before it cracks to carbon, there will not be resultant particulate. It may be added in the fuel with level of 500 to 700 ppm. Examples of the this type are, copper barium, calcium, manganese and iron.

3.2.3.2.4 Deposit modifiers

The main function of this additive is the metallic components combine with and modify the injector deposits to make them less dense and friable. In this case the treatment levels are much lower of about 50 to 200ppm. The more effective additives of this type are barium, copper and calcium.
3.2.3.2.5 Flow improvers

It is an important aid for improving the low temperature flow properties of diesel fuels. The main function is by altering the crystal structure as the wax begins to separate from the oil. This does not affect the cloud point, which is the initial stage. However the additives must present during this stage in order to have this maximum effect on keeping the crystals smaller and less cohesive. This inhibits rigid lattice structure that ultimately cause fuel gelling. The pour point of fuel is defined as 3°C above the temperature at which gelling occurs. For effective operation of this additive, this may be blended in the fuel at temperature above the cloud point. The examples of this type are ethylene-vinyl acetate polymers, chlorinated hydrocarbon and polyolefins.

3.2.3.2.6 Smoke suppressants

Various additives exist which are effective in reducing smoke emission from the diesel engines. The majority of these are organometallic in nature and components containing, manganese, iron, copper and barium are generally considered most useful. However, the performance of additives varies significantly with type of application and additive containing barium and copper which have been shown to be particularly effective in reducing smoke from diesel engines.

3.2.3.2.7 Oxygenated fuel additives

Oxygenated fuel additives is added to the diesel fuel for cleaner burning of diesel fuel. This cause addition of oxygen to the diesel fuel and reduces the particulate emission. Further the Oxygenated fuel additives has lower aldehyde and ketone emissions. Glycol ether is suitable oxygenated fuel additive for diesel fuels.
3.2.3.3 Exhaust gas recirculation

Figure 3.2 shows the schematic of exhaust gas recirculating system. A portion of exhaust gas is recirculated to the cylinder intake charge, which reduces the peak combustion temperature, since the inert gas serve as a heat sink. This reduces the quantity of oxygen available for combustion and also reduces the cylinder temperature, which results in the reduction of NOx emission. Simultaneously unavailability of oxygen causes increase in particulate emission due to incomplete combustion.

3.2.4 Exhaust Gas Aftertreatment

As an alternative method, after treatment of the exhaust gases from the diesel engine have also been reported. The after treatment is one in which the exhaust gases after they leave the engine is treated to reduce the pollutant in the exhaust. The device is known as after treatment device. The following are different types of exhaust after treatment.

3.2.4.1 Catalytic converter

Figure 3.3 shows a typical catalytic converter. It is used to remove the unwanted pollutants in gaseous from CO, HC and the NOx from the engine exhaust. These pollutants are converted by chemical reaction to CO2, H2O and N2. The catalyst material chosen are usually platinum and rhodium. There are different types of catalytic converters used in vehicles namely, oxidation, reduction and three way catalytic converters.

3.2.4.2 Thermal reactors

The exhaust of spark ignition engine contains the pollutant CO and HC in larger volume. If these are exhausted to the atmosphere it will cause pollution hazards. Therefore, it has to be controlled before let it into the atmosphere. A device called thermal reactor, is shown in Fig. 3.4 which is directly connected to
Fig. 3.2   Exhaust gas recirculation
Fig. 3.3  Catalytic converter
Fig. 3.4  
Thermal reactor

Fig. 3.5  
Particulate trap
the exhaust manifold of the engine, is used to minimise the CO and HC level in the exhaust. In the reactors, an air stream is injected into it for sufficient time to oxidize the HC and CO emissions.

3.2.4.3 Particulate traps

As today’s exhaust emission levels are very stringent, the exhaust of a diesel engine entering the atmosphere has to be controlled particularly to reduce the particulate matter. This improvement can be achieved by allowing the exhaust gases pass through a filter trap, as shown in Fig. 3.5 there by removing the pollutants continuously. The blocked particulate (which is accumulated on the filter media) are removed by the hot gases oxidizing the solid particulate. The trapping and burn up of the collected particulate produce a self cleaning cycle which present the filter passage ways from becoming clogged.

3.3. CLOSURE

In the proceeding paragraphs, various types of emission control methods were discussed. In the aftertreatment of exhaust, due to increase in back pressure the efficiency will get reduced and fuel consumption increases. Therefore, the aftertreatment of exhaust can not be taken as a useful method for controlling emission. Hence, in this present investigation it is proposed to adopt incylinder treatment by using catalyst coated pistons, insulated engine and additives.