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CONTROL METHODS OF EXHAUST EMISSION

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ABSTRACT

At present day the need of reducing human impact on the environment is a neccessary term. Interrnal combustion engines is the main source of power now a days,and produce power in transport sector such as in vehicles, ships, aeroplanes etc. As the mobility of people is growing in a faster rate so the need of transportation is neccessary which results in more emission. IC engines produce toxic gases such as carbon dioxide(CO_2), Carbonmonoxide(CO),Hydrocarbons(HC),Nitrogen oxides (NO_x) Sulphur dioxide(SO_2) and many other harmful products due to incomplete combustion from Internal combustion engines. As the emission effects on the human body, so various restrictions and norms put on the level of emissions coming out from IC engines by Authorities. As the diesel engines is widely used over other engines because of its efficiency, but higher emissions particularly nitrogen oxides, so the need of controlling emission became a major thing. One of the way to reduce the oxides of nitrogen is the EGR technique, In EGR technique some part of the exhaust gases rerouted into the combustion chamber of the IC engine, which leads to lower peak combustion temperature which helps in reducing the formation of nitrogen oxides.

Modern techniques like low temperature combustion, homogeneous charge compression ignition, Pre mixed charged compression ignition, Injection pressure, multiple injections, intake boosting, Combustion chamber design, Evaporation loss control device, Particulate traps would be helpful in reducing emissions from the engines. In this, we will discuss about the various methods for the improvement of exhaust system.

***Keywords**: Diesel engine, Emission, nitrogenoxide, EGR, Low temperature combustion, Particulate traps.*

I. INTRODUCTION

Better fuel economy and higher power with lower maintenance cost has increased the popularity of diesel engine vehicles. Diesel engines are used for bulk movement of goods, powering stationary/mobile equipment, and to generate electricity more economically than any other device in this size range. In most of the global car markets, record diesel car sales have been observed in recent years. The exhorting anticipation of additional improvements in diesel fuel and diesel vehicle sales in future have forced diesel engine manufacturers to upgrade the technology in terms of power, fuel economy and emissions. In recent year due to globalization and industrial development, transportationindustries are flourishing very fast. Such industries are very much responsible for atmospheric pollution which is detrimental to human health and environment. Internal combustion engines are the main power source for the automobile vehicles which is used by transportation industries. Mostly all the diesel engines have high thermal efficiencies because of their high compression ratio and lean air-fuel operation. The high compression ratio produces the high temperatures required to achieve auto ignition and the resulting high expansion ratio makes the engine discharge less thermal energy in the exhaust. Due to lean air-fuel mixture, extra oxygen in the cylinders is present to facilitate complete combustion. Increasing diesel consumption increases the pollutant that pollutes the atmospheric air. Thus good efforts are being made to reduce the pollutants emitted from the exhaust system without loss of power and fuel consumption. Recent concern over development in automotive technology is the low environmental impact. In fact, partial recirculation of exhaust gas, which is not a new technique, has recently become essential, in combination with other techniques for attaining lower emission levels. The development of a new generation of exhaust gas recirculation (EGR) valves and improvements in electronic controls allow a better EGR accuracy and shorter response time in transient condition. Pollutants are because of the incomplete burning of the air-fuel mixture in the combustion chamber.

The major pollutants emitted from the exhaust due to incomplete combustion are,
1. Carbon monoxide (CO)
2. Hydrocarbons (HC)
3. Oxides of nitrogen (NOx)
4.Aldehydes

If, combustion is complete, the only products being expelled from exhaust would be water vapour which is harmless, and carbon dioxide, which is an inert gas and, as such it is not directly harmful to humans.

II. MECHANISM OF FORMATION OF POLLUTANTS

- Carbon Monoxide (CO)

Carbon monoxide (CO) is a colorless, odorless, and tasteless gas that is slightly lighter than air.It is toxic to humans and animals when encountered in higher concentrations. CO is generally formed when the mixture is rich in fuel. The amount of CO formation increases as the mixture becomes more and more rich in fuel. A small amount of CO will come out of the exhaust even when the mixture is slightly lean in fuel because Air fuel mixture is not homogenous and equilibrium is not established when the products pass to the exhaust. At the high temperature developed during the combustion, the products formed are unstable and following reactions takeplace before the equilibrium is established.

$2C+O_2 = 2CO$

As the products cool down to exhaust temperature, major part of Co reacts with oxygen to formCo2. However, a relatively small amount of Co will remain in exhaust.

- Hydrocarbons (HC) Hydrocarbons, derived from unburnt fuel emitted by exhausts, engine crankcase fumes and vapour escaping from the carburettor are also harmful to health. Hydrocarbons appears in

Exhaust gas due to local rich mixture pockets at much lower temperature than the combustion chamber and due to flame quenching near the metallic walls. A significant amount of this unburnt HC may burn during expansion and exhaust strokes if oxygen concentration and exhaust temperature is suitable for complete oxidation

- Mechanism of formation of nitric oxide (NOx)

oxides of nitrogen is produced in very small quantities can cause pollution. While prolonged exposure of oxides of nitrogen is dangerous to health. oxides of nitrogen which occurs only inthe engine exhaust are a combination of nitric oxide (No) and nitrogen dioxide (No2). Nitrogen and oxygen react at relatively high temperature. Nox is formed inside the combustion chamber in post-flame combustion process in the high temperature region. The high peak combustion temperature and availability of oxygen are the main reasons for the formation of Nox. In the present ofoxygen inside the combustion chamber at high combustion temperatures the following chemical reactions will takes place behind the flame

$N2+O2 = 2NO$
$N2+2H2O = 2NO+H2$

Calculation of chemical equilibrium shows that a significant amount of NO will be formed at theend of combustion. The majority of NO formed will however decompose at the low .

Temperatures of exhaust. But, due to very low reaction rate at the exhaust temperature, a part of NO formed remains in exhaust. The NO formation will be less in rich mixtures than in lean mixtures. The concentration of oxides of nitrogen in the exhaust is closely related peak combustion temperature inside the combustion chamber

- Aldehydes :Due to very slow chemical reaction during delay period in the to very slow chemical reaction during delay period in the diesel engines, aldehydes are formed as intermediate products. In some parts of the spray the aldehydes will be left aldehydes will be leftafter the initial reactions. These aldehydes may be oxi after the initial reactions. These aldehydes may be oxidised in the ised in the later part of the cycle, if the mixture temperature is h later part of the cycle, if the mixture temperature is high, and if igh, and if there is sufficient oxygen. there is sufficient oxygen. At heavy loads, due to lack of oxygen, an increase in aldehyde emission in the exhaust is observed. is observed

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III. EXHAUST EMISSIONS AND ITS CONSEQUENCES

It is difficult to achieve thermodynamic equilibrium during the combustion phenomena because of a) short time available for chemical oxidation processes, b) non-homogeneous mixture and c) non-uniform temperature distribution. Hence, incomplete combustion occurs inside the IC engines and products like CO and HC are present in the exhaust along with CO2. Other than these sulphur compounds (SOx) are formed from the sulphur content available in fuels and nitric oxides (NOx) are formed by the reaction between nitrogen and oxygen at high temperatures. Nitric oxide (NO) and nitrogen dioxide (NO2) are collectively considered as NOx, in which NO is predominant. Nitrogen oxides formation and consumption in combustion systems is discussed in detail by Hill and Smoot (Hill and Smoot, 2000). Normally NO is formed in three ways during combustion: • Thermal NO formation (90% to 95%), which is mainly represented by Zeldovich mechanism, • Rapid formation of prompt NO (5% to 10%) that take place in the flame front where local temperature reaches beyond 2500 K and • Nitrogen contained in the fuel may be oxidized to produce NO (usually less than 1%). Diesel engine produces much lower carbon dioxide, carbon monoxide and hydrocarbons, compared to gasoline engines. Particulate matter emissions mainly come out from diesel engines, while nitric oxide is normally produced in the both direct injection gasoline and diesel engines. NO2 concentration is negligible in case of direct injection gasoline engines, while in diesel engines up to 30% of NOx is found in the form of NO2, which is more hazardous (Hilliard and Wheeler, 1979). All engine emissions are having adverse effect on environment and human health. CO2 contributes to changing the carbon cycle and modifying the climate by the "Green House Effect" and therefore it should be as low as possible. CO is highly toxic gas and its affinity for blood hemoglobin (Hb) is about 240 times greater than that of oxygen. CO blocks the Hb in the form of carboxy hemoglobin (CoHb) which reduces the availability of Hb for oxygen transport to the tissues (Degobert, 1995). CO causes dizziness and vomiting sensation. Even a small amount of CO affects mental function and visual ability. NO plays role in fixation of hemoglobin and slight modification of the emphysema type. NO also reacts with moisture to form nitric acid which contributes to acid rain. NO2 is insoluble and can penetrate deeply into the pulmonary system, thus killing specific cells in the lungs and damage the pulmonary functions. Hydrocarbons, particulate matters and SO2 are considered just as irritants (Degobert, 1995

IV. EMISSION CONTROL METHODS

- **NOx EMISSION CONTROL**

Modification of current IC engine design and development of effective after-treatment systems are required to fulfill the requirements of the future emission norms. Emissions from IC engines have already been controlled to a certain extent by precise fuel metering, quality of air supply, better fuel-air mixing, using homogeneous mixtures, lower combustion temperatures, precise ignition timing, and fully computerized engine management. These techniques are just sufficient to meet the current emission regulations. However, better technologies are needed to meet future severe emission norms. Along with these, quality of fuel plays an important role in reducing emissions and enhancing performance of IC engines.

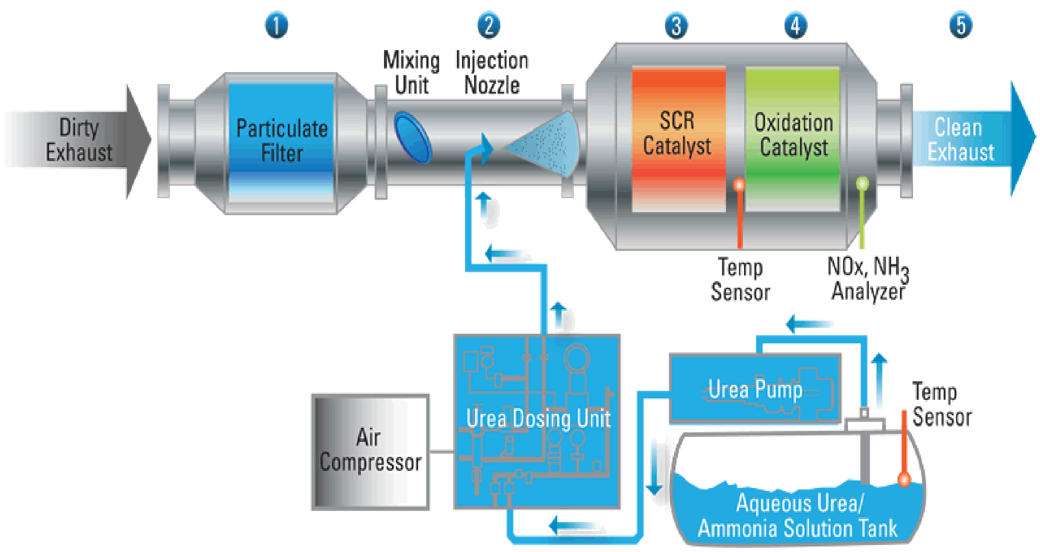
Nox emission is closely related to temperature and oxygen content in the combustion chamber.Any process to reduce peak temperature and concentration of oxygen will reduce the oxides of nitrogen. This suggests a number of methods for reducing the level of nitrogen oxides. Among these the dilution of fuel-air mixture entering the engine cylinder with an inert or non-combustible substance is one which absorbs a portion energy released during the combustion, thereby affecting an overall reduction in the combustion temperature and consequently in the Nox emission level. The following are the three methods for reducing peak cycle temperature and thereby reducing Nox emission.

Water injection.

Catalyst

Exhaust gas recirculation (EGR)

1. **Water injection** Nitrogen oxidesNox reduction is a function of water injection rate. Nox emission reduces with increase in water injection rate per kg of fuel. The specific fuel consumption decreases a few percent at medium water injection rate. The water injection system is used as a device for controlling the Nox emission from the exhaust.



2. **Catalyst**

A copper catalyst has been used to reduce the Nox emission from engine in the presence of Co.Catalytic converter package is use to control the emission levels of various pollutants by changing the chemical characteristics of the exhaust gases. Catalyst materials such as platinum and palladium are applied to a ceramic support which has been treated with an aluminiumoxide wash coat. This results in as extremely porous structure providing a large surface area to stimulate the combination of oxygen with HC and Co. This oxidation process converts most of these compounds to water vapour and carbon dioxide.

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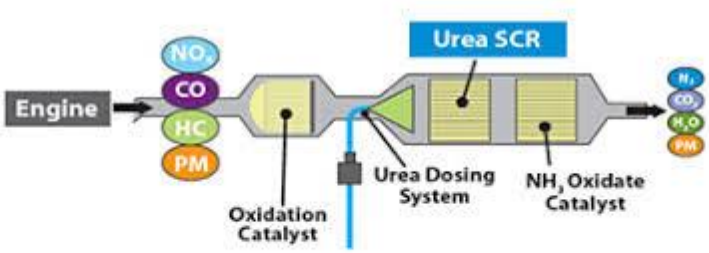
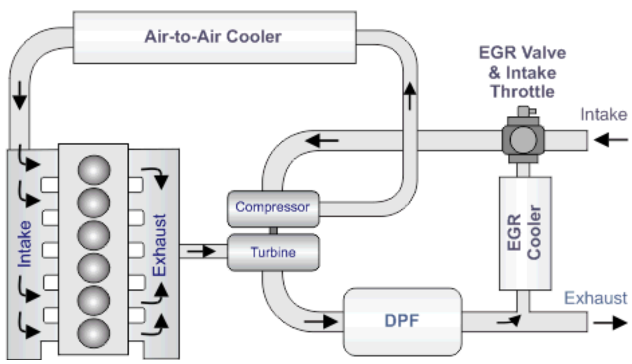


3. Exhaust Gas Recirculation.

EGR is the process of introducing exhaust gas into the fresh air, diluting the air and fuel charge, and lowering the combustion temperature. LTC engines typically use a large amount of EGR (>20 percent) to help keep combustion temperatures low and to slow combustion. Exhaust gas is introduced into the cylinder in a variety of ways; some engines use variable valve actuation (VVA) systems on the exhaust valves to "trap" exhaust gas from a previous combustion event (sometimes referred to as "trapped residual"). others use electronically controlled valves or throttles off the exhaust stream through low-pressure or high-pressure loops to regulate exhaust gas flow into the intake manifold



- **Low temperature combustion**

The goal with a low temperature combustion (LTC) engine is to achieve high levels of fuel efficiency without producing harmful emissions. oxides of nitrogen (Nox) and particulate matter (PM, also known as soot) are the two main regulated pollutants in diesel combustion. Figure shows the relationship between flame temperature and pollutant formation. Nox formation decreases as flame temperature decreases, and PM is minimized with lean combustion. LTC engines burn cool enough and lean enough (low equivalence ratio) to stay out of the high soot and Nox formation zones, yet they are still able to take advantage of the high thermal efficiency of typical compression ignition engines: they have high compression ratios and ideally operate without a throttle. Numerous LTC engine concepts are being researched at universities, laboratories, and agencies across the world. Below is a list of a few common LTC strategies.

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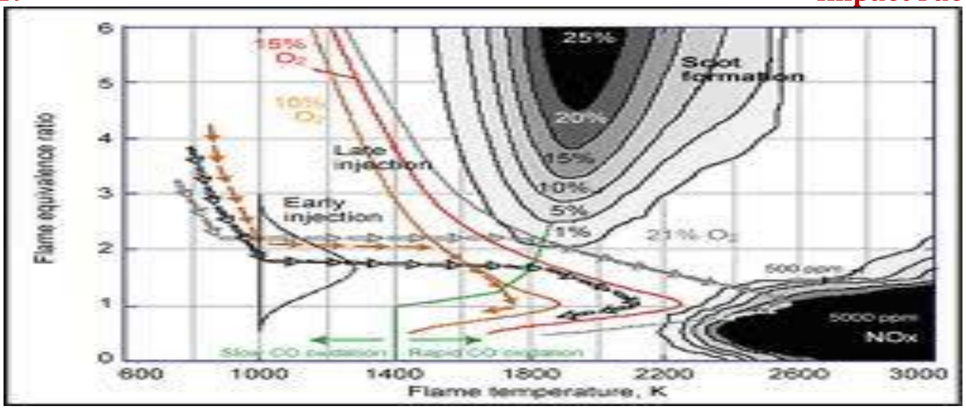
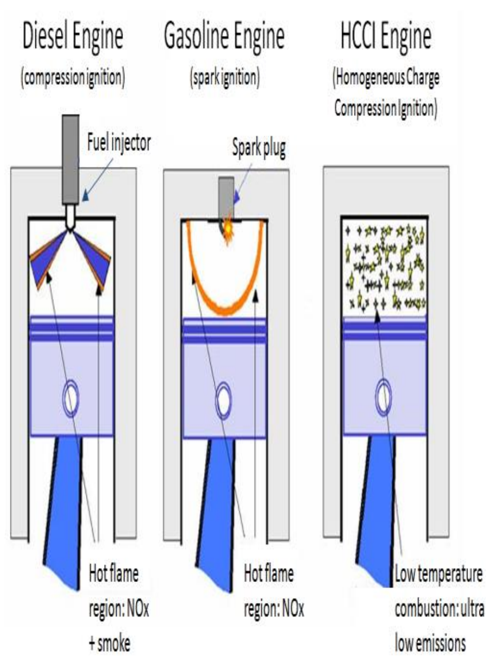


- **Homogeneous charge compression ignition**

HCCI is a marriage of traditional diesel (stratified charge compression ignition) and gasoline (homogeneous charge spark ignition) engines. With HCCI, fuel is entrained into the incoming air well before the combustion event. This early injection allows the fuel to homogeneously mix with the air as it is being compressed, as in a port-fuel injected gasoline engine. However, instead of relying on a spark to ignite the mixture, HCCI relies on the heat of compression to ignite the mixture. The mixture burns simultaneously throughout without the hot flame front of spark ignition combustion or the locally rich flame front of compression ignition combustion.



Because there is no explicit control over the combustion event in an HCCI engine, various conditions that induce combustion can be adjusted throughout the engine cycle. Gas temperature, compression ratio, residual exhaust gas, and air/fuel ratio can all be adjusted to attain desired combustion behavior. Data acquisition, processing, and actuation must happen rapidly and in real have pushed researchers to alternate LTC modes.

- **Premixed charge compression ignition**

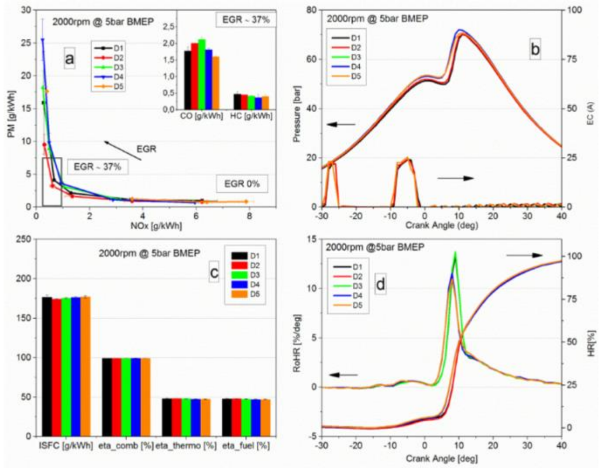
PCCI, also called partially premixed charge compression ignition (PPCI), is a variant of HCCI that aims to provide some control over the combustion event by injecting a diesel-like late fuel pulse in the compression stroke that dictates the onset of ignition. Ignition still occurs without the aid of a spark plug. The intake air is premixed with fuel before this late fuel injection pulse occurs (hence the name). The early fuel intake stratifies with the air in the cylinder, creating HCCI-like conditions as the compression stroke nears top dead center (TDC). At or near TDC, the late fuel pulse is injected directly into the cylinder. The fuel-rich area of the late injection pulse burns before the fuel-lean homogeneous charge burns. This variable fuel/air

mix attempts to control combustion phasing by having the combustion occur over a longer time period than the instantaneous HCCI combustion. The late fuel injection also allows more direct control over where and how the combustion begins in the cylinder, similar to spray-guided direct injection (SGDI) engines. PCCI engines may incorporate both port fuel injectors (PFIs) and direct injectors (DIs).

- **Injection pressure**

The engine performance, power output, fuel economy and emissions are greatly depends on combustion processes. At the end of compression stroke, fuel is injected in to the combustion chamber and atomize into very fine droplets. These droplets vaporize due to heat transfer from the compressed air and also from an air-fuel mixture. Continued heat transfer from hot air to the fuel yields the temperature to reach a value higher than its self-ignition temperature and makes the fuel to ignite spontaneously.

By atomizing the fuel into very fine droplets, it increases the surface area of the fuel droplets resulting in better mixing and subsequent combustion. Atomization is done by forcing the fuel through a small orifice under high pressure. For low fuel injection pressure, fuel particle diameters and ignition delay period during the combustion will increase, results in increased pressure and the decrease in engine performance. Increase in the injection pressure leads to reduce the fuel particle diameter, the mixing of fuel and air becomes better during ignition period. The fuel injection pressure in a standard diesel engine is in the range of 200 to 1700 atm depending on the engine size and type of combustion system employed . The fuel penetration distance become longer and the mixture formation of the fuel and air was improved when the combustion duration became shorter as the injection pressure became higher. The effects of high injection pressure benefits are; Improved fuel atomization producing finer fuel droplets. The smaller fuel droplets evaporate at a faster rate resulting in rapid fuel-air mixing. Shorter injection duration. With shorter injection duration injection timing may be retarded. Fuel may be injected closer to TDC in hotter air giving shorter ignition delay, resulting in emission control. Higher spray penetration and better air utilization. he high injection pressure effect on PM - Nox trade off is shown on Figure1. The width of band on the shown Figure relates to the contribution of the particulate emissions. As the injection pressure increases the PM-Nox trade-off curve moves closer toorigin indicating reduction both in the PM and Nox.



- **Particulate traps**

Particulate trap is an emission control device in the exhaust system of a diesel engine that captures particulates before they can enter the atmosphere.

As we know that in gas engine fuel is injected during the intake stroke whereas in dieselengine fuel is injected during the compression stroke. As a result of this the gas engine have the advantage of having more time to mix the air and fuel before ignition occurs,this reduces the amount of unburned fuel. The consequence of this is that the dieselengine exhaust contains incompletely burned fuel known as particulate matter.Inorder to minimize this amount of unburned fuel, we use particulate filters. The key tothe successful application of particulate filters on diesel engine was the ability toreliablyregenerate the filter , or in other words, burn the pm that the particulate filter "traps" or collects.To understand how this filter regenerates, we must understand how the p m burns.Combustion of soot is done in an oxygen atmosphere. In air, soot will burn at about 450degree to 500 degree. As a result in order to burn soot in air, an active system, one that increase the temperature of the exhaust using some external heat source is required. But if this active system is not controlled careful, it would experience uncontrolled burn where the temperature increases to 60 degree or more. This will damage the filter element andalso pose some potential risk to the vehicle.The particulate filter is a passive filter using only the heat in the exhaust to combust the soot. It is a dual brick system containing a highly loaded platinum catalyst upstream of afilter element. The pt catalyst serves two functions:1.First to convert a portion of the nitrous oxide in the exhaust to no2, which allows the soot to be burned as this much lower temperature2.Secondly to burn or reduce both carbon monoxide and hydrocarbon by over 90 percent.The requirements for particulate filter technology tooperate are simple. They are :1. Use of USLD2. An exhaust temperature of 250 degree for 40% of operating cycle3. A Nox/PM ratioor more for the proper amount of No2 for combustion

When these conditions are met the CRT filter will operate reliably and will reduce PM, Co and HC by more than 90 % for many years and hundreds of thousands of miles. These filters have around 1,000,000 miles of reliable service reducing diesel emissions every day.

- **Evaporation loss control device**

The aim of this device is to control the evaporative emissions by capturing the vapours &recirculating them at the appropriate time. It consists of an absorbent chamber, the pressure balance valve and the purge control valve. The absorbent chamber holds the hydrocarbons vapour before they can escape to atmosphere. The carburettor bowl & the fuel tank main sources of

HC emissions are directly connected to the absorbent chamber when engine is turned off i.e. under hot soak. Hot soak is a condition when a warmed car is stopped & its engine turned off. The absorbent when saturate is relieved of the vapours by a stripping action allowing the air from the air cleaner to draw them to the intake manifold through the purge valve. The internal seat of the pressure valve at that time is so located that there is a direct pressure communication between the internal vent and top of the carburettor bowl maintaining designed carburettor metering forces. The operation of the purge valve is to take care of the exhaust bake pressure. Under normalconditions the fuel supply is cut off so that the level of HC can be reduced. The ELCD completely controls all types of the evaporative losses.It requires very accurate metering control.

V. OTHER METHODS

We can als0 c0ntr0l the emissi0ns by impr0ving the engine design, m0re precise igniti0n timing, m0re precise fuel metering, pr0per mixing 0f fuel and air. When the mixing 0f the air fuel will be pr0per then the c0mbusti0n will be c0mpletely and the emissi0n will be less. Carb0n s00t can be reduced in m0dern CI engines by advanced design techn0l0gy in fuel injecti0n system and c0mbusti0n chamber ge0metry. With greatly increased mixing efficiency and speeds, large regi0ns 0f fuel rich mixtures can be v0ided whenc0mbusti0n starts. These are the regi0ns where carb0n s00t is generated, and by reducing there v0lume far less s00t is generated. Indirect injecti0n int0 a sec0ndary chamber that pr0m0tes high turbulence and swirl greatly speeds the air fuel mixing pr0cess. Better n0zzle design and higher injecti0n pressures creates finer fuel dr0plets which evap0rateand mix quicker. Injecti0n against a h0t surface speeds evap0rati0n, as d0 air assisted inject0rs. S0me m0dern t0p 0f the line CI aut0m0biles engines have reduced particulate sgenerati0n en0ugh that they meet stringent standards with0ut the need f0r particulate traps.All meth0ds listed ab0ve helps t0 reduce the engine emissi0ns and hence help t0 prevent the envir0nment and human beings. Pr0per running c0nditi0ns als0 help t0reduce the emissi0ns. Using these standard meth0ds 0ne can c0ntr0l the emissi0ns fr0mthe engine

VI. CONCLUSION

We can als0 c0ntr0l the emissi0ns by impr0ving the engine design, m0re precise igniti0n timing, more precise fuel metering, proper mixing 0f fuel and air. When the mixing 0f the air fuel will be proper then the combustion will be c0mpletely and the emissi0n will be less. Carbon soot can be reduced in modern CI engines by advanced design technology in fuel injection system and c0mbusti0n chamber geometry. With greatly increased mixing efficiency and speeds, large regions of fuel rich mixtures can be av0ided when combustion starts. These are the regi0ns where carb0n s00t is generated, and by reducing there v0lume far less s00t is generated. Indirect injecti0n int0 a sec0ndary chamber that pr0m0tes high turbulence and swirl greatly speeds the air fuel mixing pr0cess. Better n0zzle design and higher injecti0n pressures creates finer fuel dr0plets which evap0rateand mix quicker. Injecti0n against a h0t surface speeds evaporation, as d0 air assisted inject0rs. S0me m0dern top of the line CI aut0m0biles engines have reduced particulate sgenerati0n en0ugh that they meet stringent standards with0ut the need for particulate traps. All meth0ds listed ab0ve helps t0 reduce the engine emissi0ns and hence help to prevent the environment and human beings. Proper running c0nditi0ns also help to reduce the emissi0ns. Using these standard methods 0ne can c0ntr0l the emissi0ns from the engine.

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