THINK INDIA JOURNAL

ISSN: 0971-1260

Vol-22-Issue-17-September-2019

A Technical Review on Vehicular Emission Control Techniques

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Abstract

Today, Environmental Pollution is becoming the most serious issue around the world, which leads to Global Warming. Along with that, pollution results in adverse health effects. As per the "Paris Agreement 2016" (UNFCCC), the earth's temperature is getting raised by more than 2^0C every year. It happens due to the emission of chemicals such as Green House Gases (GHG), mostly CO_2, in to the atmosphere. There are various sources from which these pollutants are being emitted. One of the major sources of these emissions is automobiles which run with Internal Combustion Engines. Mostly, the possible emissions from automobiles are CO, HC, NO_x and Particulate Matter. There are various devices like Exhaust Gas Recirculation (EGR), Catalytic Converter, PCV Valve, Charcoal Canister etc, are used in an automobile to reduce these pollutants from the tail pile. The paper attempts to provide the brief review on the application of those methods and technologies to reduce emissions.

Keywords: Vehicular Emission, Emission Control Techniques, Exhaust Emission, Non-Exhaust Emission

Introduction

Vehicles which run on Internal Combustion (IC) Engines are the primary option for entire transportation sector. Fossil fuels like Gasoline (Petrol) and Diesel are the principle fuels used to run the IC engines. When these burning fuels produce useful power during the combustion process, they often release significant a mounts of contaminating materials into the atmosphere..These are carbon monoxide (CO), carbon dioxide (CO2), unburned hydrocarbons (HC), nitrogen oxides (NOX), and particulates.Carbon dioxide is primary responsible for global warming, as it creates a layer that reflects the radiation from the Earth back to Earth's surface, as a result the average temperature of Earth increases. Carbon monoxide (CO) is a poisonous gas, when it enters into our blood stream; it reduces the oxygen carried to brain. The high temperature during the combustion process results in formation of oxides of nitrogen (NO_X) which leads to different health problems and also contributes to acid rain. So, these harmful emissions from vehicles should be reduced by implementing some techniques and methods, to protect the environment. An significant area of research is growing worry over the future effects of global warming, rising exhaust emiss ions and increasing the fuel economy of IC engines.

Emission control in IC engines

Mostly, In IC engines, emissions can be classified in to two types: Exhaust and Non-Exhaust emissions. Exhaust emissions are those which are produced inside the cylinder as by products of combustion process, where as non–exhaust emissions are occurred due to the Evaporative losses of fuel tank (EVAP), Crank case blow by and Carburettor losses. Following are various methods and devices used in an automobile to reduce different kinds of pollutants from the exhaust and non-exhaust emission.

METHODS TO REDUCE EXHAUST EMISSION

Air Injection

Air injection, sometimes referred to as secondary injection, is one of the first developments to regulate exhaust emissions. It is employed to provide oxygen to unburned and partially burned hydrocarbons by injecting air to exhaust ports so that they burn completely, finally, results in reduction of hydrocarbons emission. But, now this system is used in catalytic converter to support the oxidationreaction.The catalytic converter does not work until it reaches its own operating temperature under the cold starting conditions.The pumped air of the converter promotes combustion in the exhaust core duct, speedi ng up catalyst heating and increasing the amount of hydrocarbons released from the tailpipe.

Exhaust Gas Recirculation (EGR) valve

The method used to reduce the NOX pollution and restore those exhaust gasses to the intake system is the recirc ulation of exhaust gas..The unit incorporates an EGR pump that is connected to a vehicle tailpipe.This valve ret urns a few exhaust gasses to the intake system of Engine; this dilutes the air and fuel mix to reduce the temperat ure of the burning Chamber.As high temperatures of the combustion chamber encourage nitrogen oxides to for

ISSN: 0971-1260

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m, the engine cylinder needs to be retained at low heat.Though EGR is the most powerful nitrogen oxide contro l method, it has a strong impact on the motor output in its nature.The engine was not designed for exhaust gas o peration.There is therefore a need to monitor and control the quantity of exhaust inserted into the intake system. Since the EGR action dilutes air / fuel mixture and reduces efficiency, when the engine is cold or the engine nee ds full energy the mechanism doesn't permit EGR operation,. (Zheng, Reader, & Hawley, 2004)

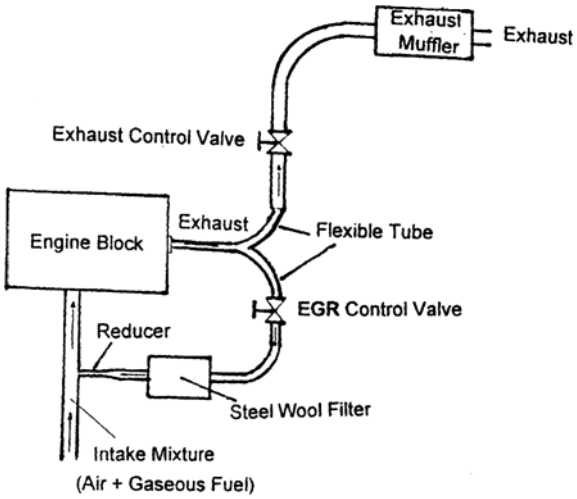

Fig1: Exhaust Gas Recirculation System (Abd-Alla, 2002)

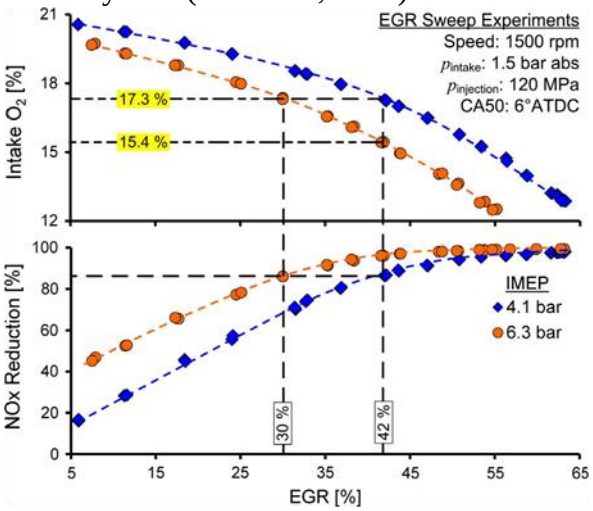

Fig 2: Effect of engine load on EGR (Asad & Zheng, 2014)

Three-Way Catalytic Converter

A catalytic converter reduces significantly the amount of hazardous pollutants when these are taken and convert ed by a number of chemical reactions to water vapor and less harmful gas.. Generally catalytic converters are known as three- way converters as they reduce concentration of CO, HC and NO_X in exhaust. A base of ceramics with pores smaller than 1 mm tests the catalytic converter..Powdered catalysts comprising el ements, including gold, palladium and rhodium, are used on the pores.Due to the proximity of the engine, the p ores heat up and change the chemical structure of the exhaust emissions to remove harmful smog gasses and co nvert them into nitroge and oxygen.Carbon monoxide and carbon dioxide are separated and transformed into co al and liquid.Inside the catalytic converter, oxidation and reduction processes takes place as follows:

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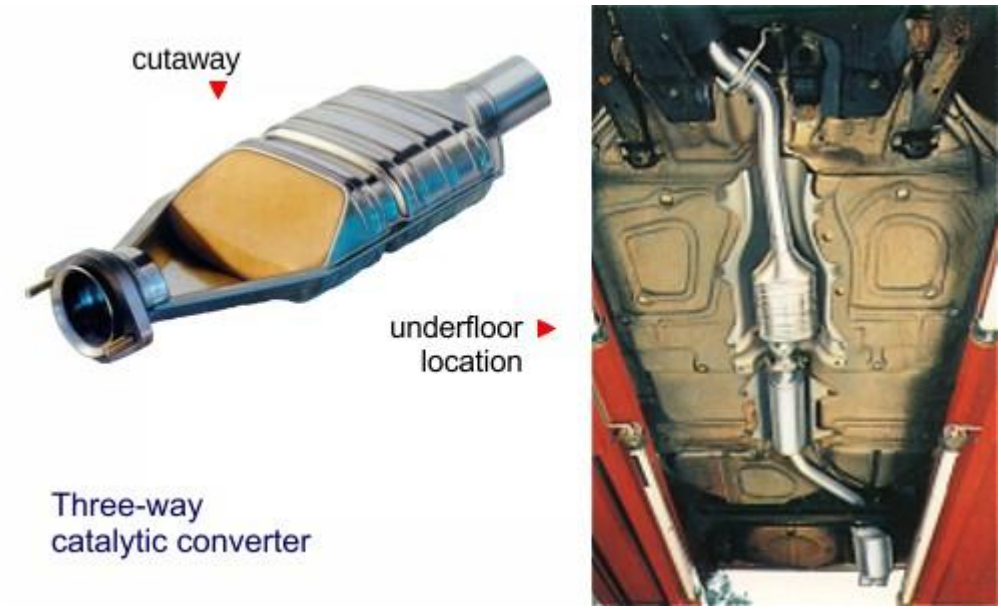

Fig 3: Three-way catalytic converter

Reduction of nitrogen oxides to nitrogen (N_2)

$2\ CO + 2\ NO \rightarrow 2\ CO_2 + N_2$

$HC\ (Hydrocarbon) + NO \rightarrow CO_2 + H_2O + N_2$

$2\ H_2 + 2\ NO \rightarrow 2\ H_2O + N_2$

Carbon monoxide oxidation and unburned Carbon and Water hydrocarbons

$2\ CO + O_2 \rightarrow 2\ CO_2$

$HC\ (Hydrocarbon) + O_2 \rightarrow H_2O + CO_2$ (Taylor, 1987)

Selective Catalytic Reduction (SCR)

Selective catalytic converter is mostly used in diesel engine vehicles to transform nitrogen oxides to water vapour (H_2O) and nitrogen (N_2) with the help of a catalyst.Urea transformed into NH_3 (ammonia), interacts with NOx to innocuous N_2 and H_2O in the hot exhaust gases.The volume of urea must be specifically dosed according to the engine NOx performance and the workin g conditions of the catalyst.When gas travels through the catalyst tank, the NOx reduction reaction takes place. The ammonia and other mitigating agents (such as urea) are pumped and blended with gasses before reaching t he catalyst chamber.For a selective catalytic reduction system, the chemical formula is used for an anhydrous or aqueous ammonia: (Müller, Ölschlegel, Schäfer, Hakim, & Binder, 2018)

$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$

$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$

$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

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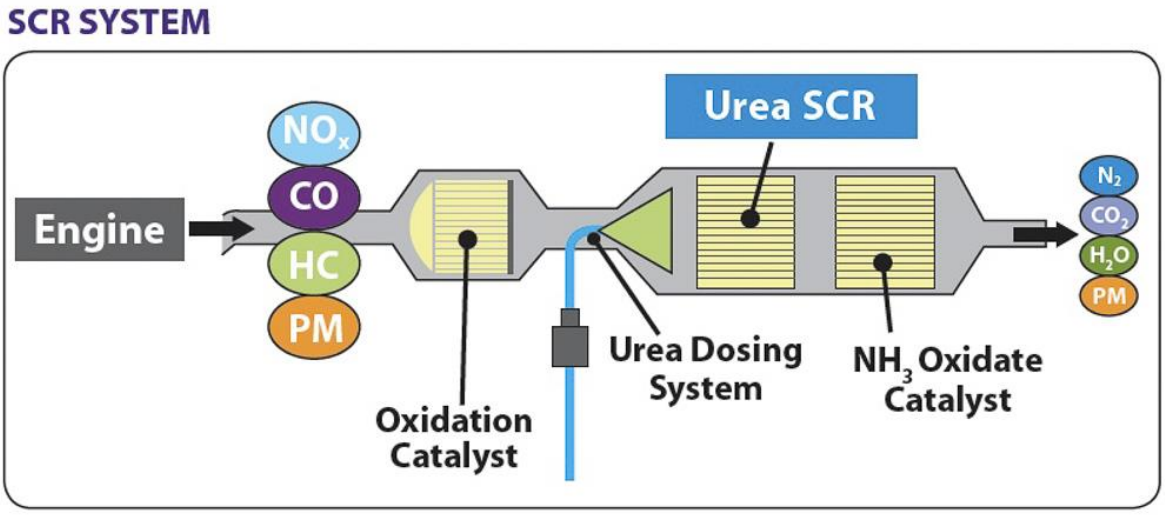

Fig 4: Schematic layout of Selective Catalytic Reduction system

Diesel Particulate Filter (DPF)

DPFs are systems that mechanically trap fuel pollutants to avoid release into the environment..Diesel particulate filter materials display amazing filter performance, exceeding 90 percent and good mechanical and thermal resi stance were created..Diesel particulate filter has become the most effective system for emission control, with pa rticulate mass as well as high efficiency figures..The filters are most powerful to monitor the solid fraction of di esel emissions, including elemental carbon(soot) and associated black smoke pollution, due to particle depositio n mechanisms in these systemsFor charge of nonsolid percentages of PM pollutants of the organic fraction (OF) and the sulphate particulates, filters can either have minimal or be totally ineffective.DPF systems can integrate additional operational components aimed at OF catalysts for total emissions in order to control maximum PM p ollution, while ultra low sulphur fuels may be required to control sulphate particulates. Apart from DPF, we can also control the emission of particulate matter by following some pre-combustion control techniques like using Biodiesel as a fuel, by varying injection pressure, injection timing, and multiple injections. (Mohankumar & Senthilkumar, 2017)

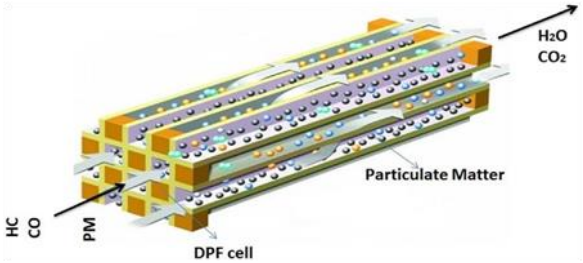

Fig 5: Schematic layout of DPF cell (Mohankumar & Senthilkumar, 2017)

METHODS TO REDUCE NON-EXHAUST EMISSION

Charcoal Canister

A canister for the trap of petrolorgasoline is used.Gas vapors from the carburist's floating chamber and fuel tank reach the canister via a pipe.. Fuel vapors from the fuel tank enter the canister via a new passage..If the engine i s not working, the fuel vapor flows into the tank via the inlet port.Petrol vapors are captured in the canister by t he charcoalparticles.When the motor rises and works, air enters the freight canister because of the engine suctio n in the intake control system of the generator..Itatmosphere carries the hydrocarbons in the oil vapor to the eng ine supplier and the gas absorbs in the system. (Streicher, 1999)

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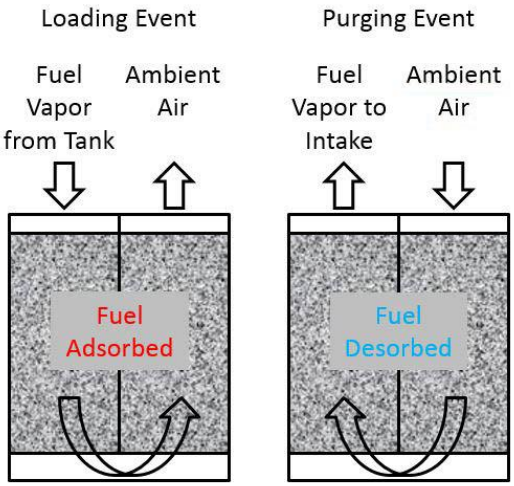

Fig 6: Carbon canister and Evaporative emission control system

Positive Crankcase Ventilation (PCV) System

Positive Ventilation case is a device that is used for extracting destructive vapors from the engine and avoiding the evacuation into the atmosphere of those vapors.The PCV system uses several vacuums to remove vapors in the intake control from the crankcase.Vapor is then carried into the combustion chambers where it has been bur ned with the fuel / air mixture.The PCV valve controls the stream or leakage within the system.The PCV valve i s active as a crankcase ventilation mechanism and as a pollution control device.PCV systems may be defined as open or closed systems.Both systems are pretty similar. However, since 1968, the closed system used to control air pollution is much etter.The devices vary because fresh air comes into the cabinet and unnecessary heat is for ced back..

Open PCV Systems

A vented oil filler cap draws fresh air from the opening system.There is no problem if the volume of vapor is lo w.But when the crankcase vapor becomes intense, it is forced back into the open air through the oil filler cap.Th e Open PCV system is not completely efficient as a pollution control device, even if it is effective in removing contaminated vapors from the case..

Closed PCV Systems

The closed PCV extracts cool air from the air filter frame.In this system, the oil filling cap is NOT released.The refore, excess vapor is returned to and into the intake manifold from the air filter housing.The closed systempre vents vapor from reaching the open atmosphere, whether normal or excessiveas an air pollution control device, the closed system is very efficient.

The PCV Valve

A flow control van, commonly called a PCV valve, is the most critical element of the PCV system.The PCV val ve helps to calculate the vapor stream from the crankcase to the exhaust collector.This is important so that the c rankcase is properly ventilated while the combustion combination of oil and air is not disturbed.. Blow-by gases and vapour should be removed at about the same rate they enter the crankcase. Since blow-by is minimal at idle and increases during high speed operation, the PCV valve must control the flow of vapour accordingly. The PCV valve is designed to compensate for the engine ventilation needs at varying engine speeds. The vacuum power is compounded, and increases or decreases as motor speeds shift.. (Ding, 2011)

Modification in CI engine to reduce emission

Commercial vehicle emission control

Several improvements are needed. These could be achieved through redesigning of engines and application of new technologies: · Improvement in fuel injection system and use of higher injection pressure. .

Passenger Car Diesel Engine

In India, Indirect Injection (IDI) diesel engines are commonly used in passenger cars. Due to the pricing policies of fuels, the running cost of diesel cars is lower than those of petrol cars. Diesel engines are popular for

ISSN: 0971-1260

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taxis, most of which are retrofitted by diesel engines. Private cars with OE diesel engines are also in demand. Major directions for engine development to control different pollutants are as follows:

HC emission control requires,

- low sac volume nozzles;
- Complete combustion of injected fuel;
- minimum lube consumption.

NOx emission control is helped by,

- cooling of intake air before entering the engine;
- Retarded combustion; and
- Moderate air motion.

Particulate emission control is helped by,

- high injection pressure;
- fine fuel atomization;
- intensive air motion;
- high excess air; and
- Minimum lube consumption. (Raja, Priyadarshini, & Akilan, 2015)

Conclusion

Efforts are being made to reduce the consumption of fossil fuels and maximize the utilization of environment friendly energy sources and fuels for meeting energy needs. In India, the demand for oil for the transport sector is estimated to increase over the next decade.The Government provides government assistance, fiscal stimulus and regulatory measures for the production ofalternative energy automobiles and fuels. This field is the largest consumer of oil products.In this context, vehicles operated by batteries and fuel cell vehicles, vehicles powered by hydrogen and biofuel have been identified.In consideration of their environmental protection value, the production operation of these fuels and automobiles must be further promoted.The pairing of a traditional engine vehicle's motor with the electric motor powered by friction batteries and/or battery is used for hybrid electric motors.The approach leads to the attainment of energy and environmental priorities.The use of a large number of such vehicles would help us to reduce environmental benefits, oil consumption and emissionsPower is usable from more than one power source in hybrid electric car propulsions.HEV's three configurations are hybrid system collection, parallel network hybrids and split device hybrids.Fuel cells generate electricity through electrochemical reactions between hydrogen and oxygen gasses.Fuel cells are powerful, ecofriendly, lightweight, versatile and energyefficient.Protons Exchange Membrane Fuel Cells (PEMFC), Phosphoric Acid Fuel Cells (PAFCs), Molten Carbonate Fuel Cells (MCFCs), Solid Oxide Fuel Cells(SOFCs) etc., are various types of fuel cells currently under development.As a clean fuel and effective processing medium for vehicles, hydrogen is attracting worldwide attention.Oil used in road transport may be substituted by hydrogen or augmented. Biofuel is a 100% natural energy substitute to oil fuel, effective and environmentally friendly.In recent years biofuels have been given great attention as a replacement for petroleum fuel in view of their potential in several agriculture sources and their low emission characteristics.The two biofuels that are knownas possible fuels for surface transport are ethanol and bio-diesel.

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