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Decarbonisation Of Exhaust Gas From Ic Engine

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***Abstract*—**Increased use of automobiles and two wheelers is the current trend in transportation. Even in Metros with well-connected public transport system, roads are not able to handle increasing volume of automobiles and two wheelers. Increased use, choked roads and falling support for public transport system lead to harmful effects on environment due to incomplete combustion of fuel from Internal Combustion engines. Carbon di-oxide(CO_2), carbon monoxide(CO), hydrocarbons(HC), oxides of nitrogen(NO_x), Sulphur dioxide(SO_2) and particulate emission(PM) are major pollutants out of emissions from IC engines. Other sources such as gas powerplants, industrial and domestic fuel consumer also contribute to the existing situation. In this paper, one such after-treatment of technique of passing exhaust gas from IC engines through limestone-charcoal mixture to reduce carbon di-oxide(CO_2) emission is studied.

I. Introduction

IC engines are any auto-maker's choice because of their higher power to weight ratio and compact size. Millions of automobiles exist worldwide and major emissions from IC engines constitute carbon di-oxide(CO_2), carbon monoxide(CO), hydrocarbons(HC), oxides of nitrogen(NOx), Sulphur dioxide(SO_2) and particulate emission(PM). Hence strict emission norms are imposed on IC engines. European Union research organization norms were introduced in 1970s. While India introduced Bharat norms in 2000s. As shown in Figure 1, exhaust emission per test kilometer were significantly reduced from EURO-I to EURO-IV. Gradual reduction can be seen thereafter and Euro VI standard implemented in 2014 shows major stress in reduction of NO_X emissions.

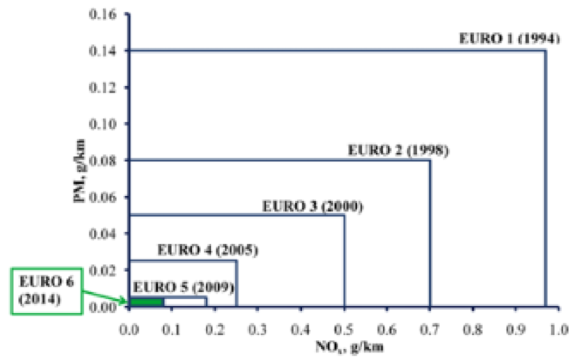

Figure 1. European emission standards for diesel vehicles

In the roll-out of Bharat norms, BS 1V to BS VI transition requires Diesel Particulate Filter(DPF) to reduce particulate emissions and Selective Catalytic Reduction Technology(SCR) to reduce NO_x emissions. Stages of roll_out of Bharat norms and emission levels to be achieved is shown in Figure 2.

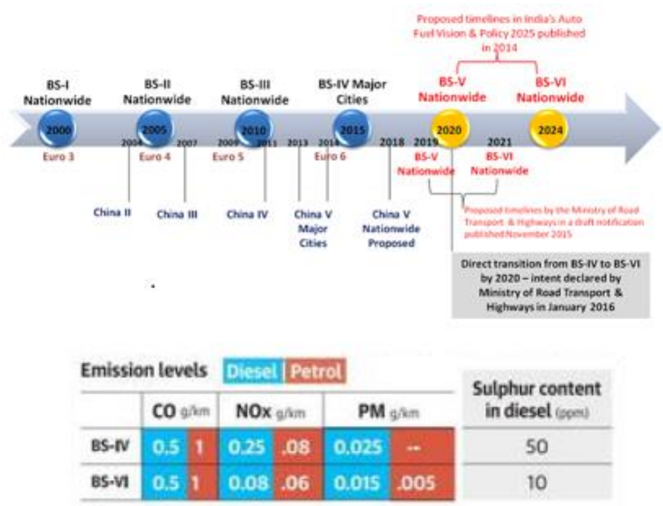

Figure 2. Bharat norms roll-out & emission levels in BS 1V & BS VI

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II. EMISSIONS

Incomplete combustion is due to lack of thermodynamic equilibrium in combustion owing to rapid combustion in short time(lack of complete oxidation), non-homogeneous mixture of fuel and non-uniform temperature distribution. CO and HC present in emissions along with CO_2 are due to incomplete combustion. Oxides of Sulphur(SO_x) are formed from the Sulphur content available in fuels and oxides of nitrogen(NO_x) are formed from reaction between nitrogen and oxygen at high temperatures. Nitric oxide(NO) is predominant among NO_x emissions owing to incomplete oxidation. Diesel engine produces lesser carbon dioxide, carbon monoxide and hydrocarbons compared to gasoline engines. Particulate matter emissions mainly come out from diesel engines while nitric oxide is produced in both.

CO_2 contributes to greenhouse effect, alters carbon cycle and modifies climate. CO blocks hemoglobin and thereby reduces oxygen availability to tissues. NO controls fixation of globulin. NO also causes acid rain. NO_2 affects pulmonary sysrem. HC, PM and SO_2 are considered as irritants.

III. EMISSION CONTROL METHODS

Optimization of current IC engine design and development of effective, economical and compact sized after treatment techniques are required to meet current emission regulation as well as strict future emission norms. Though after-treatment system draws its techniques from known chemical reactions, they are costly and occupy more space. In-cylinder solutions are preferred in reducing emissions. Other emission control steps include better quality fuel, controlled fuel input, quality of air supply, better fuel-air mixing and attaining homogenous mixtures, lower combustion temperatures and controlled ignition timing using computerized management.

A. After-Treatment

Exhaust gas is chemically treated with oxidation and reduction processes outside the engine before letting it to the atmosphere. After treatment techniques convert CO, HC and NO_x into non-hazardous byproducts. After-treatment systems tend to be costly and occupy more space.

B. Oxidizing catalytic converter

Complete oxidation of CO and HC emissions is possible with using oxidizing catalytic converters. Reduction of CO and HC emissions depend on catalytic coating, converter location and temperature levels. Hydrocarbons are absorbed as soot particles in catalytic convertor mixture.

C. Three-way catalytic converter

The three-way catalytic converter has corrugated metal or ceramic matrix with wash coat to provide large surface area for chemical reactions. The wash coat has catalytic materials, which consist of noble metals like platinum(Pt), rhodium(Rh) and palladium(Pd). Pt and Rh are used as reduction catalyst, while Pt and Pd are used as oxidation catalyst. They have good conversion rates but ineffective at high temperature. They are suitable for diesel engines which run near stoichiometric mixture. Diesel engines run on an overall lean mixture, hence benefit of catalyst is very less.

D. Diesel Particulate Filter

Particulate Filter consist of ceramic fibres and metal substrates used to absorb particulates of very small size. Particulate deposits promptly block particulate filter which affects engine output and increases fuel consumption due to increased backpressure. High temperatures to burn off soot is achieved under full load condition.

E. In-cylinder Solutions

In-cylinder solutions are a better way to reduce emissions during combustion process itself. Higher compression ratio, modified fuel injection systems, intake air management, electronic engine control, exhaust gas recirculation(EGR) are various parameter variation and technologies involved in achieving emission standards.

IV. EXPERIMENT

In our experiment, limestone and charcoal was used to reduce emissions such as CO, $NO_{x,}$ CO_2 and HC. The limestone and charcoal filter was constructed and tested. The limestone was placed inside a house-box to prevent a high pressure drop and the house-box is connected to the exhaust of the IC engine and clamped as shown in figure 2. The house-box has restrictions to increase contact surface area with exhaust gas. The limestone and charcoal filter setup has water cooling support.

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Experimental techniques includes i) The engine was started until it reaches the operating temperature; ii) the emission control of limestone and charcoal after-treatment technique was studied.

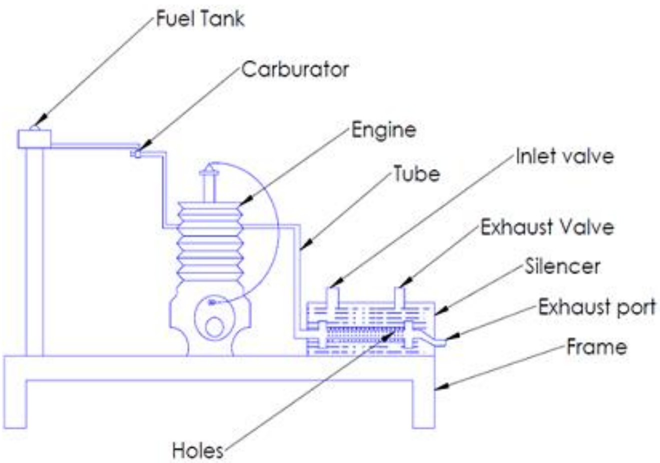

Figure 3. Experimental Setup

V. RESULTS AND DISCUSSION

Carbon Monoxide (CO) Emission

CO is produced due to deficiency of oxygen to oxidise all carbon atoms of fuel into CO_2. CO emission increases with increase in speed, increase in turbulence and non-uniform mixture distribution within cylinder. The reduction of CO is due to the ability of limestone filter absorbing the CO from exhaust gas to produce calcium oxide as the following reaction:

$CaCO_3(s) + 2CO(g)........CaO(s)+2CO_2(g)$

Carbon Dioxide (CO_2) Emission

The average reduction of CO with and without use of limestone and charcoal filter was more than the average reduction of CO_2 with and without use of limestone and charcoal filter. The reduction of CO_2 was occurred when calcium carbonate reacts with water that is saturated with carbon dioxide to form soluble calcium bicarbonate, according to the following chemical reaction,

$CaCO_3(s) + CO_2(g)+H_2O(l)........Ca(HCO_3)_2(aq)$

Unburned Hydrocarbon(HC) Emission

Particulate emission occurs due to unburned hydrocarbon and are mainly due to i)misfired combustion, ii)flame quenching, iii) absorption and desorption in oil film and inside chamber iv)liquid fuel in the cylinder v)exhaust valve leakage and crankcase blow. There was a great reduction in amount of HC after using limestone filter.

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