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SendilVelan S

International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 4 (2015) pp. 11385-11392

Reduction of HC/CO Emission From SI Engine By Using Transition Metal Oxide Catalyst

N. Nithyanandan[1] S.Sendilvelan[2] K.Balasubramanian[3] and S.Manoharan[4]
[1] Professor, Panimalar Institute of Technology, Chennai-56, Tamilnadu, India
Email: nitabi1973@gmail.com
[2]DR.M.G.R. (Educational and Research Institute) UNIVERSITY, Chennai-95
[3] Associate Professor, Panimalar Institute of Technology, Chennai-56, Tamilnadu, India
[4] Assistant Professor, Panimalar Institute of Technology, Chennai-56, Tamilnadu, India

Abstract

The growing world needs to reduce the automobile cold start emission pollution. Much research work has been carried out in this way, this paper focused on to reduce the automobile cold start emission by using Low mass Electrically heated Catalysts (LMEHC), the Electrically heated Catalyst (EHC) filled with 145 cc volume of chromium oxide catalyst and additional air supply of 80 lpm for a multi cylinder SI engine. It is found that the main converter (MC) could to reach the Light of temperature early when an additional supply of air and the HC and CO emissions are reduced considerably.

Keywords: Cold-start, Electrically Heated Catalytic converter, chromium Oxide catalyst.

Introduction

Automobile vehicles emit substantial quantities of hydrocarbons (HC), carbon monoxide (CO) and particulate matter. These pollutants have significant adverse health effects and deteriorate environmental quality. To address the serious pollution problems posed by vehicles, a growing number of countries worldwide have implemented, or are in the process of implementing, motor vehicle pollution control programs aimed substantially reducing harmful emissions from spark ignited vehicles. Catalytic exhaust controls have been developed as a result of these regulations and are generally recognized to be the most cost-effective way to meet stringent emission standards. Catalyst exhaust control technology uses a precious metal catalyst to chemically convert the harmful components of the vehicle's exhaust stream of harmless gases. The catalytic material causes the desired chemical reactions to occur without being consumed. The catalytic system installed in the exhaust stream promotes the reaction of hydrocarbons (HC) and carbon monoxide (CO) with oxygen to form carbon dioxide and water, and destroys white smoke (particulate matter) as well. Catalytic technologies applied to vehicles are capable of reducing HC and CO emissions in the range of 60 to 80 percent respectively and particulate matter greater than 50 percent [1]. The present generation of gasoline vehicles tested according to the Federal Test Procedure emits 70-80 percent of exhaust emissions during the first minute or two of operation following the “cold-start” [2]. This is primarily due to the ineffectiveness of existing catalytic converter to hydrocarbons and carbon monoxide until they have reached catalyst light-off temperatures. Thus, rapidly increasing the temperature of a catalytic converter under vehicle “cold-start” conditions are of paramount importance in reducing HC and CO emissions to meet new standards. The new and innovative chemically heated catalyst approach prior to “cold-start” helps to reduce emission effectiveness [3]. The exothermic hydrogen-oxygen recombination reaction generates heat locally, right at the metal oxide catalyst particles, and the exhaust gas, which helps to heat the main converter quickly, carries the heat away from metal oxide surface. The catalytic converter reaches light-off temperature quickly due to the chemically heated catalyst approach [4].

Experimental Methods

Electrically heating the catalyst prior to cold engine cranking can help to achieve catalyst activity during the cold start. In this technique the main converter remains in its initial position, whereas the Electrically Heated Catalytic converter is placed in the vicinity of the exhaust manifold. This technique could be optimized if the following measures are taken:

- Positioning of the heated catalyst close to the main catalyst.
- Positioning of the heated catalyst and the main catalytic converter, close to the engine.
- Reduction of the heated catalyst mass

Reduction of the heated catalyst mass reduces the high electrical power requirement and the time required for heat-up. The EHC quickly reaches high temperature levels, and the heat generated by the exothermic oxidation is carried by the exhaust gas down to the main converter, which attains faster light off, resulted in low emissions at power levels as low as 1.5 kW [5-7]. The EHC is electrically connected to the vehicle electrical systems, including an electric power switch, to actuate the heating current, to monitor the whole system and allow for the exchange of necessary data with the engine management system.

Experiments have been conducted on a multi-cylinder, vertical, water cooled, four stroke spark ignition engine as shown in Fig.1. The engine was coupled to a hydraulic dynamometer.

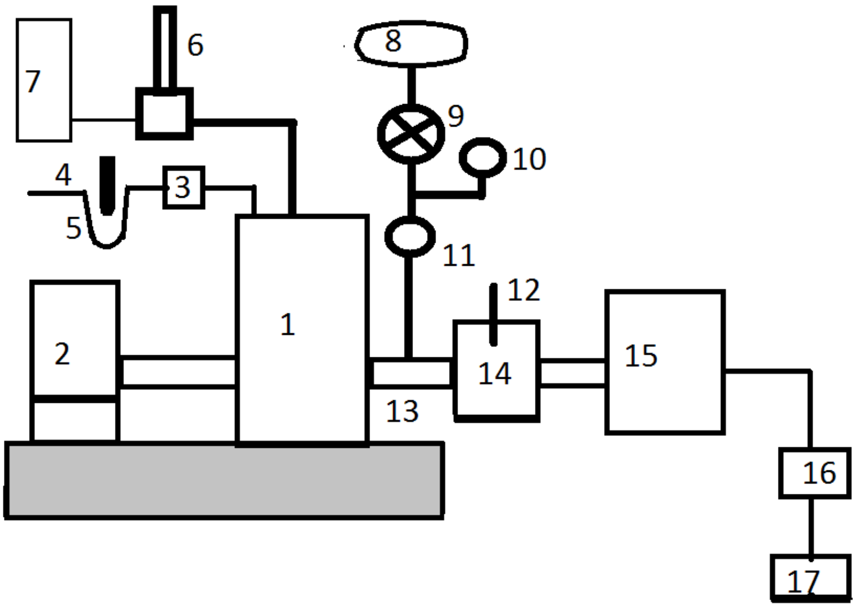

Figure 1: Experimental Set-up

1. Engine	10.Pressure Gauge
2. Loading Device	11. Flow meter
3. Air Tank	12. Thermocouple
4. Orifice	13. Exhaust Pipe
5. Manometer	14. LMEHMC
6. Burette	15. Main CC
7. Fuel Tank	16. Analyzer
8. Air Compressor	17. Printer
9. Flow Regulator	

The engine was run at 1750 RPM [8] with no load during first 20 seconds after starting the engine and then part load was applied. The Electrically Heated Catalytic converter was placed before the main catalytic converter on the exhaust pipe. The EHC housing was made of stainless steel and insulated with a thick layer of asbestos rope to prevent heat loss from the piping to the surroundings.

The substrate is made-up of stainless steel mesh. The concentric surface of the mesh was filled with chromium oxide catalyst (145cm3 volume) [9] and the mesh were heated with 1.5 kW band type electrical heater as shown in Fig. 2. The inner cylinder was also filled with chromium oxide catalyst, which acts as a light-off catalyst (LOC). Generally catalyst is made from precious metals such as platinum, palladium and rhodium, etc. are best suited as the noble metals are costly and other ceramic and pallets are not possible to heat quickly.

Transition metal oxides are cheaply and easily available and they are good conductors of heat. Some of the transition metal oxides are copper oxide, nickel oxide, sliver oxide and chromium oxide. The metal oxides were obtained from electroplating and oxidation process.

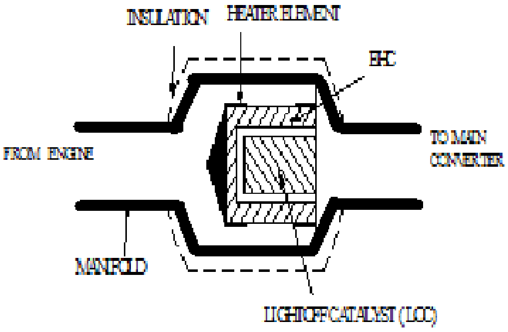

Figure 2: Emc Assembly

The base metal substrate, stainless steel mesh was first decreased by trichloro-ethylene at 70 C° then de-rusted by solvent to remove dust particles. Later, it was heated with dilute sulfuric acid to make free from surface scales, other foreign materials, etc. then coated with different metals by electroplating process. Then, oxidation process takes place at 100 C°, fresh catalysts were used for this test. The EHC was placed before the main catalytic converter on the exhaust pipe. The inlet, bed, and outlet temperature of the EHC was measured by three chrome-alumel thermocouples. The bed temperatures of the main converter were measured by a thermocouple. A PC based data acquisition system was used to analyze the temperature variation. The air was supplied through a nozzle provided on the leading side of the EHC in the exhaust pipe. Regulator and rotameter were used to regulate and measure the air supply. The gas analyzer (Crypton 285 OIML II- SPEC) was used for the measurement of HC and CO in the exhaust.

Results and Discussion

The experiments have been conducted with Electrically Heated Catalytic converter and main catalytic converter in the four-stroke SI engine. The discussions on the results are given below.

Figure 3 Shows the surface temperature of the main catalytic converter alone and surface temperature of the EHC in no heat and no air, the surface temperature of the EHC with the heat of 1.5 KW and no air this is for baseline reference, the surface temperature of the EHC with the heat and supply of 80 lpm [10] air at in 20 seconds, and supply of 80 lpm air at in 40 seconds taken for the experiment.

When the EHC and the LOC was filled with chromium oxide, the MC temperature reaches 256° C at 120 seconds after cold-start which is the light-off temperature of the main converter due to additional supply of air at 20 seconds.

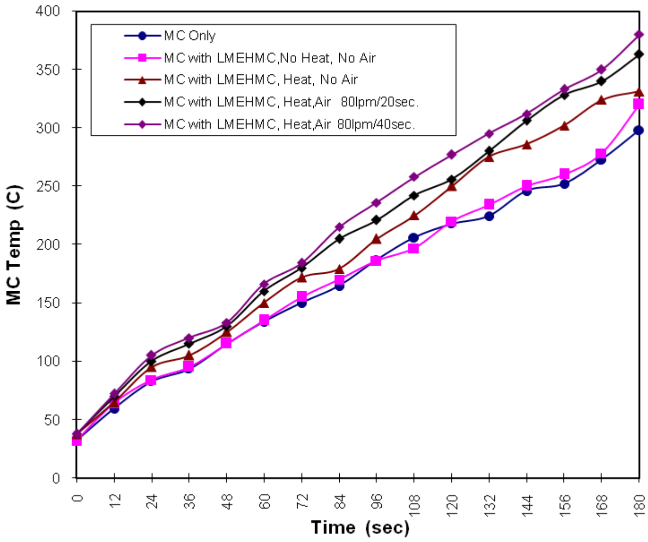

Figure 3: Variation of Temperature Vs Time

This is very early than the condition of without air supply to get the light of the temperature of the main converter to attain 250° C at 120 seconds after cold-start, then MC temperature reaches 258°C at 108 seconds after a cold - start due to additional supply of air at 40 seconds. This is very early than the condition of with air supply at 20 seconds. This indicates the additional supply of air which increases the exothermic reaction.

Figure 4 Shows the variation of CO versus time after a cold start of the engine, the main catalytic converter alone and the MC with EHC in no heat and no air, the MC with EHC with heat of 1.5 KW and no air, the MC with EHC with heat and supply of 80 lpm air at in 20 seconds and 40 seconds, where the EHC and the LOC is filled with chromium oxide. It is seen that the present CO is higher and decreasing with time, whereas it is lower than baseline values and reduces for MC with EHC with air injection. The reduction in CO % by vol. is 4.73 in 12 seconds and gradually decreases and reaches 1.85 at 180 seconds in case of main converter with EHC without air injection.

The reduction in CO % by vol. is 4.3 in 12 seconds and gradually decreases and reaches 1.7 at 180 seconds in case of main converter with EHC with air injection of 80 lpm for 20 seconds. In case of main converter with EHC with air injection of 80 lpm for 40 seconds the reduction in CO % by vol. is 4.3 in 12 seconds and gradually decreases and reaches 1.65 at 180 seconds.

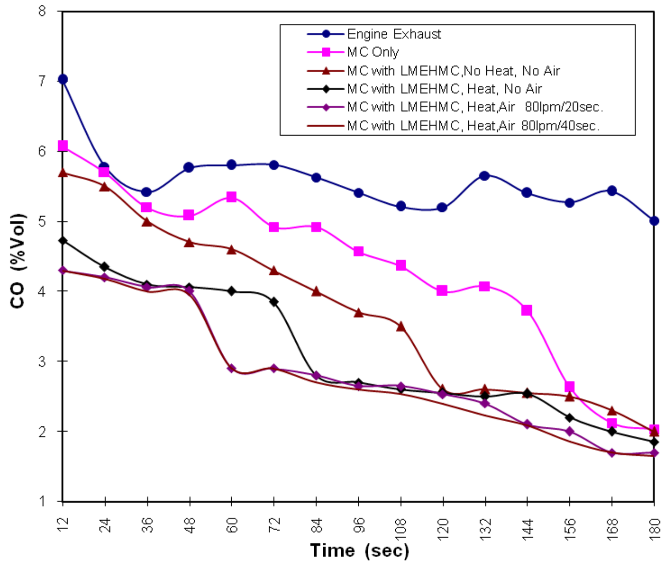

Figure 4: Variation of CO Vs Time

Figure 5 Shows the variety of HC in ppm versus time after a cold - start of the engine, the main catalytic converter alone and the MC with EHC in no heat and no air, the MC with EHC with the heat of 1.5 KW and no air, the MC with EHC with the heat and supply of 80 lpm air at in 20 seconds and 40 seconds where the EHC and the LOC is filled with chromium oxide. It is seen from that the HC values are lower for the condition of the catalytic converter with EHC with air injection than the baseline readings. The reduction in MC with EHC was about 750 ppm in 12 seconds from cold-start and gradually decreases and reaches 230 ppm at 180 seconds in the case of main converter with EHC without air injection.

The gradual reduction obtained with MC and EHC with air injection of 80 lpm for 20 seconds was about 730 ppm in 12 second from cold-start and gradually decreases and reaches 170 ppm at 180 seconds, further maximum reduction achieved in the case of MC with EHC with the heat and supply of 80lpm air at in 40 seconds was about 735 ppm in 12 seconds from cold start and gradually decreases and reaches 165 ppm at 180 seconds.

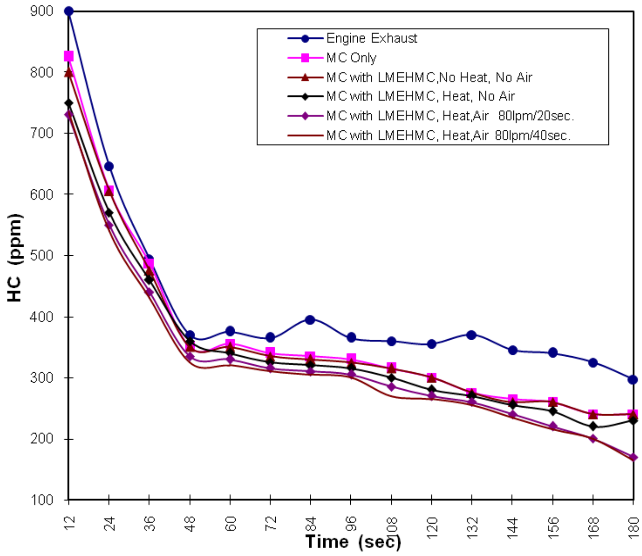

Figure 5: Variation of HC Vs Time

Conclusion

Based on the experimental investigation on a four-stroke SI engine with chromium oxide, it is concluded that there is a significant reduction in CO and HC emission by the use of EHC with air injection, due to complete oxidation in the presence of high temperature air. The maximum reduction is achieved when the EHC and LOC were filled with chromium oxide and 80lpm of air injection of 40 seconds after starting the engine from cold start.

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