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EXPERIMENTAL ANALYSIS OF CATALYTIC CONVERTER FOR REDUCING ENVIRONMENTAL POLLUTION FROM SI ENGINE USING ELECTRICALLY INITIATED AND CHEMICALLY HEATED CATALYST

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ABSTRACT

The environmental pollution is one of the major strategic question for decision-makers both in industry as well as in government. It has been established beyond doubt that the tailpipe emissions contribute significantly to climate change. It is clear that the vehicles form the predominant source of regulated and unregulated pollution. The environmental degradation all over the world has led to research to the development of ultra low emission vehicle and zero emission vehicle. In this investigation, an attempt is made to study the pollution from the automobile SI engine using Electrically Initiated and Chemically Heated Catalytic (EICHC) converter. This paper deals with the development and performance analysis of the EHC with different metal oxides. From this, the potential of catalytic systems with different catalyst is analyzed. It is found that the HC and CO emissions reduced significantly when EHC used with existing catalytic converter.

Keywords: electrically heated catalyst, HC and CO emission, catalytic converter.

INTRODUCTION

The advent of petrol engines several years ago was considered a feat in human history. But today the emission from it is considered as a threat to the very existence of mankind. In recent years, much attention has been paid to global environmental destruction. According to the data available the level of pollution is rising at an alarming rate which leads to several problems. Of the total pollution, the automobiles contribute nearly 50 %, so the control of emission in Internal Combustion engine is the need of the hour. In the cities, the worsening ozone problem has attracted attention and prompted reinforcement of regulations. One of them, which are directly related to the automotive industry, is the new Clean Air Act regulation (Burns, *et al*., 1991). The regulation caused the reduction in HC and CO emission, which becomes the most important challenge for automotive manufacturers. When clean air act becomes law, it is required that a 90 % reduction of automobile emission be accomplished within a specified time frame. The Federal Test Procedure (FTP) for measuring automobile emission is under standard ambient temperature conditions between 20 and 30°C (Terres, *et al*., 1996). A reduction of CO and HC from a cold engine is a challenge for the automotive industry. Usually cold engine uses a richer air-fuel mixture to achieve stable combustion and good derivability. About 50 to 60 % of HC and almost all CO and NO_x are from the tailpipe exhaust. The majority of CO and HC emissions are purified by a catalytic converter. The challenge is to reduce CO and HC emission, while an engine is still cold, and the catalytic converter is not yet activated. Because fuel vaporization during a cold-start is poor, combustion must usually be stabilized by an enriched air-fuel mixture, thus resulting in an increase of CO and HC emission. Approximately 60 % of the overall CO and HC emission coming out during the first 200 seconds of the cold-start period, when the catalyst is at temperature below its light-off temperature (Heywood, 1989). As the catalytic converter temperature rises when the engine warm-up, then 93 to 95 % of the emission can be purified (Burch *et al*., 1995). The reduction of cold start emissions can significantly reduce the overall traffic-induced emissions. One method to solve this is to electrically heat the catalyst initially, so that, it achieves the required temperature quickly to control CO and HC emissions (Whittenberger, *et al*., 1991). Because at high temperature, reaction kinetics are rapid and it will assist sustaining catalytic conversion (Laing, 1994).

MATERIALS AND METHODS

Electrically initiated and chemically heated catalyst

The concept of Electrically Heated Catalytic (EHC) converter is very effective in reducing cold-start CO and HC emission (Kubsh, *et al*., 1996). The preheating or post heating of EHC achieved large reduction of emissions. However, for practical application, the power consumption of the EHC is too large. These systems typically required currents of 600-700 A and electrical power greater than 4 kW (Yaegashi, *et al*., 1994). To supply the 4 kW by a conventional EHC, the following components, are needed:

a) A heavier duty alternator

b) Either a large size battery or a separate battery

c) Large diameter cables

d) Heavy-duty semiconductor switch.

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These results, cost increase, reduced fuel economy, due to extra weight. So, conventional EHC are not a practical solution. Recent EHC activities focussed efforts on electrical energy reductions. Low Mass Electrically Heated Pre-catalyst (LMEHP) is an effective method to reduce power consumption (Roychoudhury, *et al*., 1994). This type of heating provide sufficient "reaction ignition zones" distributed on the inlet converter surface, which provide local oxidation catalysis and subsequent release and transfer of chemical energy. The EHC consists of the heater element, the Light-Off Converter (LOC) and the Main Catalytic Converter (MC). The heater element should initiate the CO and HC oxidation in the subsequent LOC, as quickly as possible. Together with the enthalpy of the exhaust gas and additional electrical energy, the main catalytic converter is very quickly brought to its operating temperature.

Air injection

Air injection also required during cold-start engine operation in order to achieve major reductions in exhaust emissions. The secondary air should be injected in to the exhaust pipe before EHC. When the secondary air is injected into the exhaust, oxidation occurs which in turn provides reaction heat. The heat produced by the oxidation reactions increases the exhaust gas temperature, resulting in a fast catalyst light off. Air injection ahead of the EHC is required only for a short period following the cold-start (Heimrich, 1990). The amount of emission was at a minimum, when the secondary air supply was between 80 to 100 lpm. (sendilvelan, *et al*., 2001). Therefore in this investigation, 90 lpm. air injection was selected.

Metal catalyst

Generally catalysts are made from a precious metal such as platinum, palladium and rhodium etc., the noble metals are costly and other ceramic and pallets are not possible to heat quickly. Transition metal oxides are cheap and easily available and they are good conductors of heat. Some of the transition metal oxides are copper oxide, nickel oxide and chromium oxide etc. The copper oxide shows greater reduction in CO and HC level during cold-start of the engine (sendilvelan, *et al*., 2001). Therefore in this investigation an attempt has been made to reduce cold-start emission of a multi–cylinder SI engine using Low Mass Electrically Heated Catalytic converter with different metal oxides as catalyst.

EXPERIMENTAL SET-UP

The schematic diagram of the complete experimental set-up is shown in Figure-1. Experiments have been conducted on a multi-cylinder, vertical, water cooled, four stroke, spark ignition engine. The engine was coupled to a hydraulic dynamometer. This Electrically Initiated and Chemically 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. The substrate was made-up of stainless steel mesh. The concentric surface of the mesh was filled copper oxide and covered by coned mesh and inner cylinder was filled with different metal oxides as shown in Figure-2. The mesh was heated with 1kW band type electrical heater. The EHC is electrically connected and the temperature of the heated catalyst is maintained at 400°C before starting the engine. The inlet, bed, and outlet temperature of the EHC was measured by three cromel-alumel thermocouples. The bed temperatures of the main converter were measured by a thermocouple. A PC based data acquisition system is used to analyze the temperature variation. Air was supplied through a nozzle provided on the leading side of the EHC in the exhaust

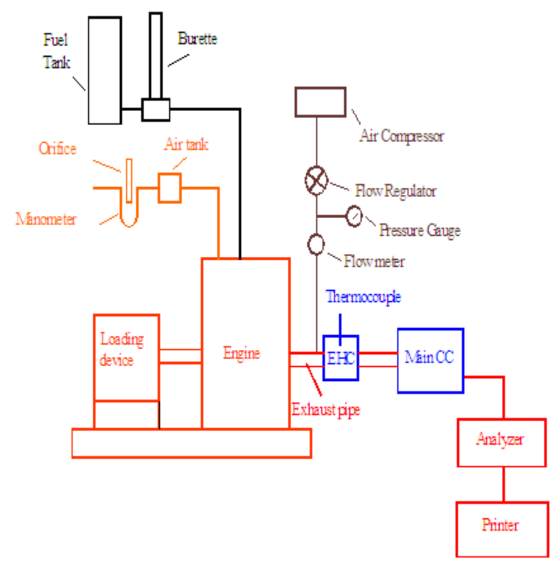

Figure-1. Experimental set-up.

pipe regulator and rotometer 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. Tests were conducted with different metal oxides as catalyst.

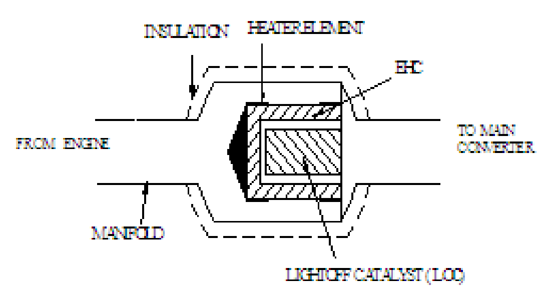

Figure-2. EICHC Assembly.

RESULTS AND DISCUSSIONS

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

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Figure-3 shows the variations of CO % by vol. versus time in sec. from cold start of the engine with main catalytic converter, engine with main catalytic converter with EHC and engine with main catalytic converter with EHC and 90 lpm. air injection for 40 sec., where the LOC is filled with copper oxide. It is seen that the present CO are higher and decreasing with time, where as it is lower than base line values and reduces for EHC without air and further it reduces for EHC with air injection. The reduction in CO % by vol. is 1.41 in 60 sec. and gradually decreases and reaches 0.87 at 300 sec. in case of main converter with EHC with air injection. The maximum reduction achieved with the main catalytic converter with EHC without air injection was about 2.22 % by vol. in 120sec. and the percentage reduction is 55.77%. The maximum reduction achieved with the catalytic converter with EHC with air injection was about 2.7 % by vol. in 120sec. and the percentage reduction is 67.83%.

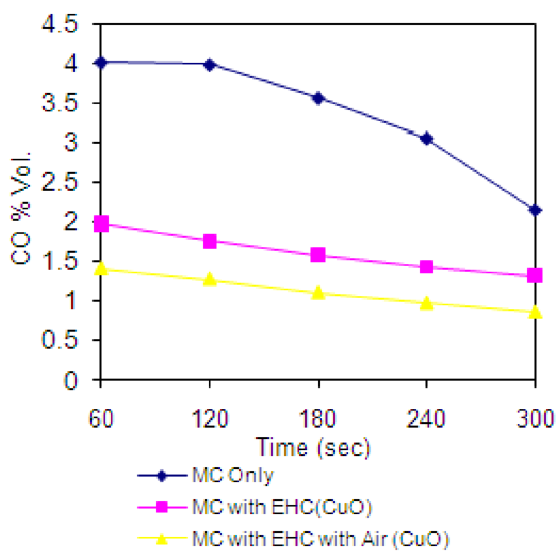

Figure-3. Variation of CO % by volume versus time in seconds using copper oxide as catalyst.

Figure-4 shows the variations of CO % by vol. versus time in sec. from cold start of the engine with main catalytic converter, engine with main catalytic converter with EHC and engine with main catalytic converter with EHC and 90 lpm. air injection for 40 sec., where the LOC is filled with nickel oxide The reduction in CO % by vol. is 1.8 in 60 sec. and gradually decreases and reaches 1.05 at 300 sec. in case of main converter with EHC with air injection. The maximum reduction achieved with the main catalytic converter with EHC without air injection

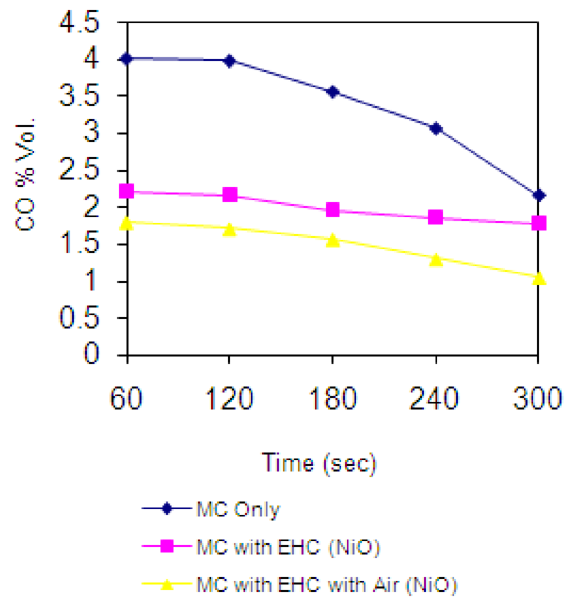

Figure-4. Variation of CO % by volume versus time in seconds using nickel oxide as catalyst.

was about 1.83 % by vol. in 120sec. and the percentage reduction is 45.97%. The maximum reduction achieved with the catalytic converter with EHC with air injection was about 2.27% by vol. in 180sec. and the percentage reduction is 55.00%.

Figure-5 shows the variations of HC in ppm versus time after cold-start of the engine with main catalytic converter and engine with main catalytic converter with EHC without air injection and engine with main catalytic converter with EHC with 90 lpm air injection for 40 sec., where the LOC was filled with copper oxide. It is seen from that the HC values are lower for the condition of catalytic converter with EHC with air injection than the base line readings, as well as catalytic converter with EHC. The maximum reduction achieved with catalytic converter and EHC without air injection was about 570 ppm in 120 sec. from cold-start, when compared with that of catalytic converter only. The maximum reduction achieved with catalytic converter and EHC with air injection was about 545 ppm. in 60 sec. from cold-start, when compared with catalytic converter only.

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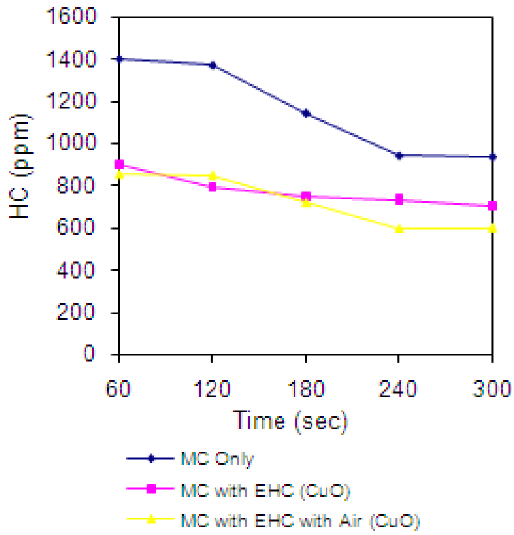

Figure-5. Variation of HC in ppm versus time in seconds using copper oxide as catalyst.

Figure-6 shows the variations of HC in ppm versus time after cold-start of the engine with main catalytic converter and engine with main catalytic converter with EHC without air injection and engine with main catalytic converter with EHC and 90 lpm. air injection for 40 sec., where the LOC was filled with nickel oxide. It is seen from that the HC values are lower for the condition of catalytic converter with EHC with air injection than the base line readings, as well as catalytic converter with EHC. The maximum reduction achieved with catalytic converter and EHC without air injection was about 513 ppm in 120 sec. from cold-start, when compared with that of catalytic converter only. The maximum reduction achieved with catalytic converter and EHC with air injection was about 541 ppm. in 60 sec. from cold-start, when compared with catalytic converter only.

Figures 7 and 8. Shows the comparison of emission reduction, when the LOC was filled with copper oxide and nickel oxide. It is seen that, copper oxide shows greater reduction with EHC with air injection and without air injection. But for HC emission, the nickel oxide shows comparable reduction with copper oxide then the CO reduction.

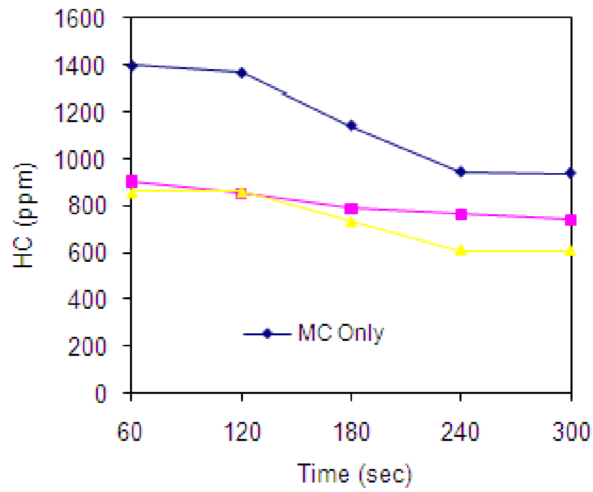

Figure-6. Variation of HC in ppm versus time in seconds using nickel oxide as catalyst.

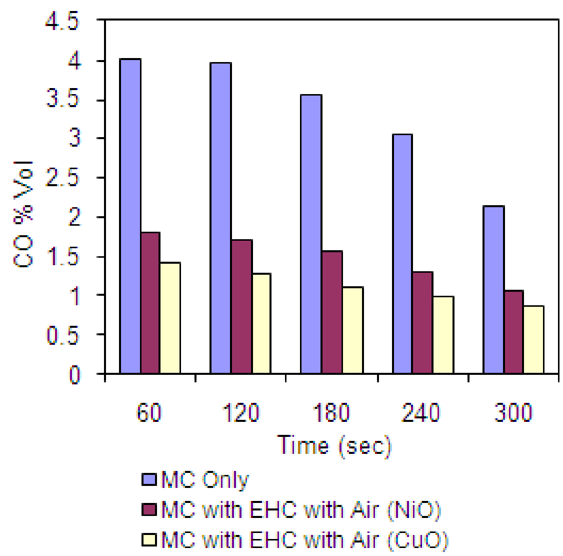

Figure-7. Variation of CO % by volume versus time in seconds for all configurations.

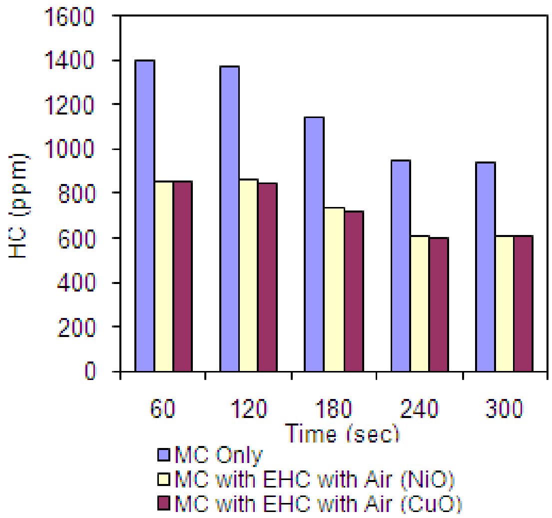

Figure-8. Variation of HC in ppm versus time in seconds for all configurations.

CONCLUSIONS

Based on the experimental investigation on a four-stroke SI engine with copper oxide and nickel oxide catalysts, it is concluded that there is significant reduction in CO and HC emission by the use of Electrically Initiated and Chemically Heated Catalyst with air injection, due to complete oxidation in the presence of high temperature air. The maximum reduction is achieved when the LOC was filled with copper oxide and 90 lpm of air injection. The nickel oxide shows comparable reduction with copper oxide for HC emission.

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