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Optimization reduction on emissions in SI engines using catalytic converters

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Abstract
In this paper, the exploitation of thermal capacitance to keep the catalyst temperature high during a short parking period was studied. The present system consists of a Phase Change Material (PCM) fabricated in a special chamber enclosed at the top and bottom layers of the catalytic converter. Under normal engine operating conditions, the thermal energy of the exhaust gases heats up the PCM. During parking, the PCM undergoes partial solidification and the catalyst temperature is thus maintained inside the desired temperature range.
The main disadvantage of this method is that it is effective only within a specific length period after engine shut off, the time depending on the thermal specifications of the system.
This disadvantage is overcome by providing an electrical heating system. The electrical heating enables the heating up of the catalyst upto its operating temperature prior to engine start. This method is used when PCM mixture looses the heat retaining ability in due course of time. Thus the cold start emissions are largely controlled with these techniques.

Keywords: Optimization, reduction, emissions, SI engines, catalytic converters

1. Introduction

From the discovery of the Petrol Engine and to the present day Nano car, advances in the fields of Automobiles and Transportation in general have been enormous. We have witnessed a great change in the transportation sector in the last two decades.
Transportation in cars and scooters has become a way of life. Cars are no more considered a luxury, thanks to the rapid industrialization its now affordable even by the middle class. The number of vehicles on road has been increasing many a fold every year.
Internal Combustion Engines have been the only dominated power source for the vehicles till now. However, in recent times IC Engine powered vehicles have come under attack due to poor thermal efficiency and pollution caused by it. The entire world is at a huge risk owing to increased pollution levels.
In order to control pollution new innovative designing of combustion chamber has been brought about. Many systems are in place to make the engine more efficient. New concepts are being thought about to reduce pollution levels.
Air Pollution is the human introduction into the atmosphere of chemicals, particulates, or biological materials that cause harm or discomfort to humans or other living organisms, or damage the environment. Air pollution causes deaths and respiratory disease.
Air pollution is often identified with major stationary sources, but the greatest source of emissions is actually mobile sources, mainly automobiles. Gases such as carbon dioxide, which contribute to global warming, have recently gained recognition as pollutants by climate scientists, while they also recognize that carbon dioxide is essential for plant life through photosynthesis.
Transportation is the largest single source of air pollution in the World. It causes over half of the carbon monoxide, over a third of the nitrogen oxides, and almost a quarter of the hydrocarbons in our atmosphere. With the number of vehicles on the road and the number of vehicle kilometers traveled escalating rapidly, we are on the fast lane to smoggy skies and dirty air. Emission norms have been made stricter and stricter every year. The figure below shows the emission norms of Indian and Euro emission norms.

In order to satisfy these norms changes have been made in the design and fabrication of IC Engines. Methods to control CO, HC, Nox and other particulate emissions have been coming up.

Martin Heimrich *et al* (1991) have studied the performance of electrically heated catalyst systems including heating controls and air injection. They have concluded that significant reduction in cold start emission could be achieved.

Whittenberger and Kubsh (1991) have studied emission performance of an electrically heated catalytic converter for both low mileage tests and after exhaust aging. They have observed that the aged EHC system using a 300 hour engine schedule impacted cold start HC and CO emissions on par with low mileage EHC system. It has been reported that the aged EHC system reduced emission by 76% and CO emission by 92% during first 140 seconds of the FTP cycle when compared to that with the aged converter without heating.

Louis Socha *et al* (1994) have developed a low mass extruded electrically heated catalyst (EHC) operated at low power levels. They have found that EHC cascade systems were successful because they initiate the catalytic reaction quickly.

Paul Laing (1994) has developed an alternator powered electrically heated catalyst (APEHC) system and concluded that power provided directly from the alternator at an elevated voltage leads to reduced wire thickness and simple electrical circuit mechanism.

Louis Socha *et al* (1995) have developed a mathematical model to predict EHC system conversion efficiency as function of EHC power, heating time and inlet exhaust gas temperature to the EHC and studied the impact of the design parameters on cold start emission reduction. They have reported a reduction of up to 80 percent in non-methane hydrocarbon emission during cold start.

2. Cold Start Emission Control Techniques

2.1 Exhaust Gas Ignition

In an EGI system, rapid heating of engine out pollutants in a small combustion chamber placed before the main catalytic converter. For the employment of EGI the engine operates initially with very rich fuel condition, allowing a combustible exhaust gas mixture to reach the catalyst inlet where it is ignited with the help of a spark plug, located at the converter inlet.

An electric operated pump provides the additional air required for combustion of the exhaust gas mixture. Only part of the fuel is burned in the combustion chamber, whereas the remaining part is ignited as the catalyst inlet face.

The advantage of this system is that there is a good reduction of cold start emission with standard formulation. The conversion efficiency of EGI is more consistent than EHC where a temporary fall in the conversion efficiency occurs due to HC storage and release. The durability of this system is also reasonable.

The disadvantage of this system is that it is a less mature technology than EHC and it is relatively more expensive than other systems.

2.2 Electrically Heated Catalytic Converter

The EHC with secondary air injection is generally placed before the catalyst and resistively heated by the car battery prior to start up. This provides on active catalyst surface to convert cold start emissions. The secondary air injection is necessary since at cold startup, engines run rich until they go into closed loop control, and hence additional air is injected to the EHC to provide the extra oxygen necessary for the oxidation of HC and CO.

The advantage of this system is that there is a good reduction of cold start emissions. The durability of the system is also very good and since this is one of the very early technologies for cold start emissions the manufacturers have good experience to work with it.

The disadvantage of this system is that very high power is required for heating the catalyst up to light off temperature. The Nox conversion can be an issue in some systems. This system is also expensive.

2.3 PCM Based Thermal Heat Retention System

A phase change material (PCM) is a substance with a high heat of fusion which, melting and solidifying at certain temperatures, is capable of storing or releasing large amounts of energy. There are different types of PCM materials available depending on the nature of use and the amount and duration of heat it needs to retain. PCM's are generally placed in a separate chamber very close to the catalytic converter.

The exhaust gas tends to heat up the PCM mixture upto its melting point. On solidifying the PCM tends to retain the heat. Thereby, the retained heat is supplied back to the catalytic converter when the vehicle is started after some time. Thus the catalyst is maintained at its light off temperature, therby helping in maximum conversion of HC and CO.

3. Experimental Investigation

3.1 Emission Test: Baseline Readings

The graphs show the variation of CO and HC with respect to time. The engine was run at idling conditions for 5 minutes.

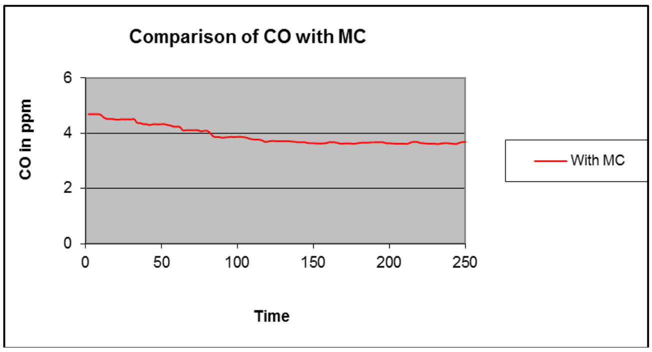

Fig 1: Variation of CO with Time

3.2 Emission Test: With EHC

The graphs show the variation of HC and CO with respect to time. The emission readings were taken after the Electrical Heating was done for 3 minutes.

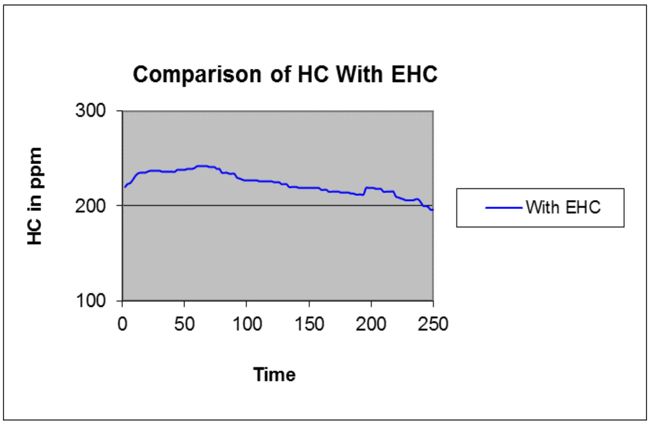

Fig 2: Variation of HC with Time

4. Comparison of Results

The results of the emissions without catalytic converter, with catalytic converter and with catalytic converter & electrical heating have been compared through graphs.

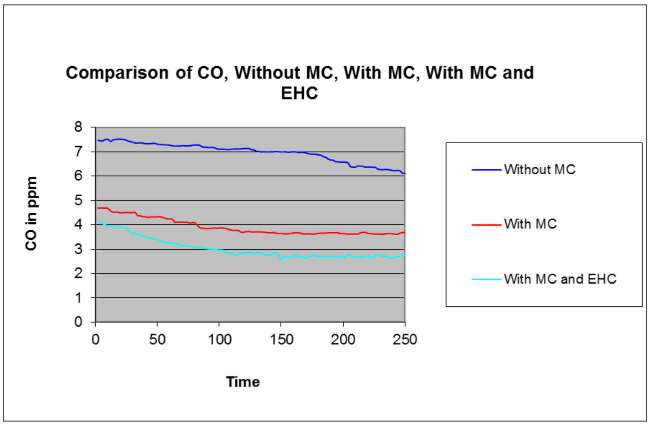

Fig 3: Variation of CO with Time

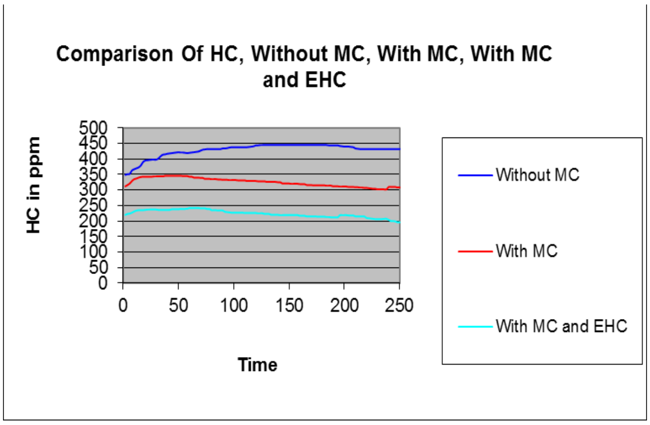

Fig 4: Variation of HC with Time

From the graphs the following results are inferred:

- The HC emission was found to be considerably less when the engine was operated with EHC.
- It is further inferred that the HC emission decreased by 31% when compared to the emissions taken under the catalytic converter alone.
- The CO emission was found to be considerably less when the engine was operated with EHC.
- It is further inferred that the CO emission decreased by 25% when compared to the emissions taken under the catalytic converter alone.
- The EHC has reduced the cold start emissions considerable when compared top the normal engine emissions.

5. Conclusion

From the present Investigation on emission control from SI engines using Electrical Heating and PCM Based Cold Start Management System (EHPCMS) in combination with main converter the following conclusions are arrived.

Electrically heating the catalytic surface before starting engine shows the significant reduction in cold start HC (30%) and CO (25%) emissions.

The main converter reaches the light off temperature very quickly in the EHC configuration due to exothermic heat generated in the EHC and with sensible heat of the exhaust.

The Phase Change Material is able to retain heat for a considerable period of time.

Thus EHPCMS system was able to considerably reduce the cold start emissions.

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