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Reduction in Cold Start Emissions by Using PCM Based Catalytic Converter

V. A. Chinchole[1]*, Prof. A. V. Waghmare[2]

[1]AISSMS COE Pune

[2]AISSMS COE Pune

Abstract – Over the years air pollution has emerged as the biggest problem to the society. Governments are applying stringent norms for controlling these automotive emissions. There are many ways to reduce these emissions, out of which the use of catalytic converter appears to be the most efficient and reliable means of reducing automotive exhaust emissions. The problem with catalytic converter is that its efficiency is nearly zero during the engine starting and warm up period. As the temperature of catalytic converter increases, its conversion efficiency also increases. In the present work we tried to enhance the conversion efficiency of catalytic converter by using heat bath for storing latent heat in it. Phase change material (PCM) is used as a media for latent heat storage in heat bath. Under normal engine operating conditions, PCM will absorb the heat of exhaust gas and it will change its phase from solid to liquid. During discharging period i.e. engine off period, PCM will undergo partial solidification thereby giving its stored latent heat to the catalytic converter. This will help the converter to remain hot for maximum conversion efficiency which will help in reducing cold start emission for next cold start period. From the results it is clear that cold start emissions have decreased to a large extent at all compression ratios and loads.

Keywords— Cold start emissions, catalytic converter, phase change material, conversion efficiency

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INTRODUCTION

A catalytic converter is an emission control device that converts toxic gases and pollutants in exhaust gas to less toxic pollutants by catalyzing an oxidation and a reduction reaction. Catalytic converters are used with internal combustion engines fuelled by either petrol or diesel including kerosene heaters and stoves. The catalytic converter was invented by Eugene Houdry, a French mechanical engineer and expert in catalytic oil refining, who moved to the United States in 1930. When the results of early studies of smog in Los Angeles were published, Houdry became concerned about the role of smoke stack exhaust and automobile exhaust in air pollution and founded a company called Oxy-Catalyst. Houdry first developed catalytic converters for smoke stacks called "cats" for short and later developed catalytic converters for warehouse forklifts that used low grade, unleaded gasoline.

Major sources of environmental pollution are the motor vehicles & the Industries. Automotive vehicles consume petroleum based fuels and produce toxic gases like nitrogen oxide, carbon monoxide and unburned hydrocarbon. The pollution thus created causes irrevocable damage to the mankind and the earth itself. In order to control emission, catalytic converters are introduced in the exhaust system. The gas produced by the engine goes straight into the catalytic converter where it is treated and then it is delivered into atmosphere. Vehicles produce major emissions during first few minute in cold starting period.

Two important factors responsible for cold starting emissions are as follows:

- Un warmed catalytic converter
- Rich fuel air mixture for the prompt vaporization and starting.

Under the normal operating conditions, catalytic converter appears to be the most effective means of reducing air pollution from the internal combustion engine. The conversion efficiency however declines very steeply for temperatures below light off temperature and is practically zero during the starting and warming up period. The conventional methods using external heaters to reduce cold starting emissions are quiet effective; their disadvantage lies in the fact that this requires an external energy source. In the present work a heat exchanger is fabricated filled with PCM, surrounding the catalytic converter. This store exhaust waste heat during engine running period and releases it during the next start and warm up period, keeping the catalyst temperature high. By this method the performance of the catalytic converter is enhanced during the start and warm up periods. A phase change material with a transition temperature of 54°C is used and a system comprising of a catalytic converter embedded in PCM was fabricated and tested.

In this experimentation, efforts were made to reduce cold start emissions of a single cylinder four Stroke Compression Ignition Engine of 661CC.Here consideration is made that time gap between two consecutive starting of motorcycle as maximum half an hour.

BACKGROUND

Bharat stage emission standards are emission standards instituted by the Government of India to regulate the output of air pollutants from internal combustion engine equipment, including motor vehicles. The standards and the timeline for implementation are set by the Central Pollution Control Board under the Ministry of Environment & Forests and climate change. The standards, based on European regulations were first introduced in 2000. Progressively stringent norms have been rolled out since then. All new vehicles manufactured after the implementation of the norms have to be compliant with the regulations. Since October 2010, Bharat Stage (BS) III norms have been enforced across the country. In 13 major cities, Bharat Stage IV emission norms have been in place since April 2010. In 2016, the government announced that the country would skip the BS-V norms altogether and adopt BS-VI norms by 2020.

EXPERIMENTATION

Latent heat storage system

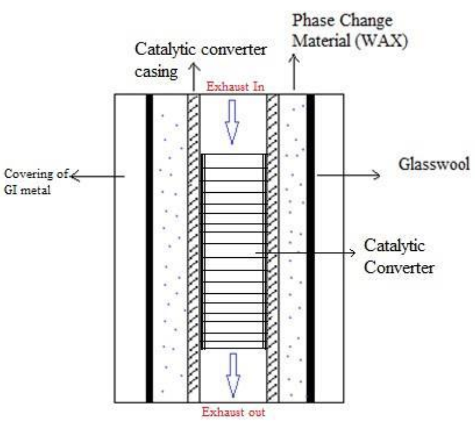

Fig. 1 Latent heat storage system

A cylindrical latent heat storage encapsulating the catalytic converter of exhaust assembly was designed and fabricated as shown in Fig [1]. Then this latent heat storage system assembly is attached to a single cylinder, 4 stroke, 661cc, Kirloskar Engine, coupled to an eddy current dynamometer. To measure the temperature at different zones of the catalytic converter, digital thermometers were attached during the fabrication process. PCM selected for the experiment is commercial paraffin wax having Phase change temperature 58°C and latent heat of fusion 189kJ/kg.

Experimental Setup

The experimental setup consists of single cylinder four-stroke variable Compression Ratio (VCR) diesel engine. The compression ratio of the engine can be changed within the range of 12 to 18. This is done by specially designed tilting cylinder block arrangement, which slightly tilts the head of the cylinder.

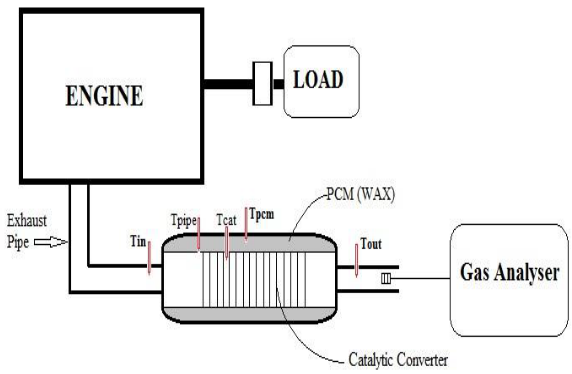

Fig. 2 Diagrammatic representation of setup

The above figure shows diagrammatic representation of project setup. Load can be adjusted manually with the help of load adjuster. Modified Catalytic converter covered with PCM jacket is attached to the exhaust pipe of VCR diesel engine. Digital thermometers having the temperature range from -50^{o}C to 400^{o}C are fixed at various positions as shown in figure. With the help of these digital thermometers, the temperature of Exhaust gas coming out from engine, temperature of PCM, temperature of Catalytic converter, temperature of pipe covering catalytic converter and temperature of exhaust gas leaving the catalytic converter can be easily recorded. Arrangements are made in such a way that emission contents of exhaust gas can be recorded on gas analyser in real time for respective load and compression ratio.

Fig. 3 Test Engine setup

Test procedure

1) Initially Thermal Jacket was filled with phase change material (PCM)-Paraffin wax. Then the jacket was allowed to cool. It took 3.5 hours to solidify and stabilise close to room temperature.

2) After proper settling of PCM, the thermal jacket assembly was attached to the exhaust pipe of Variable Compression Ratio Diesel Engine

3) All four digital thermometers were attached to the Latent heat storage system

4) During engine warm up condition, the engine was started and maintained in idling condition. With the help of exhaust gas analyser, engine exhaust readings were recorded at different time intervals, at different compression ratios and at different loads as shown in the observation table. At the same time temperatures of PCM, catalytic converter, and exhaust inlet and exhaust outlet from catalytic converter were also recorded.

5) Then the engine was switched off. During the engine off period, temperature readings of PCM and, catalytic converter were recorded. It is found that the temperature of PCM jacket does not fall rapidly as it was covered with insulating material.

6) During next cold start, i.e. after half an hour of engine off period, the engine was started again and same procedure was repeated and observations were recorded. During engine off period, temperature of PCM jacket and catalytic converter were recorded for next half hour.

7) During this period, it was found that at some points, at higher compression ratios and higher loads, catalytic converter was able to reach light off temperature 175°C.

RESULTS AND DISCUSSIONS

1) For CR 14:

- *CO, HC & NOx emissions at No Load condition*

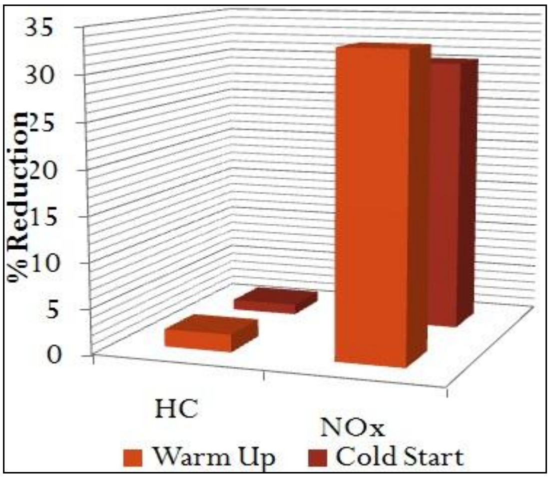

Fig. 4 HC and NOx emissions during warm up & cold start

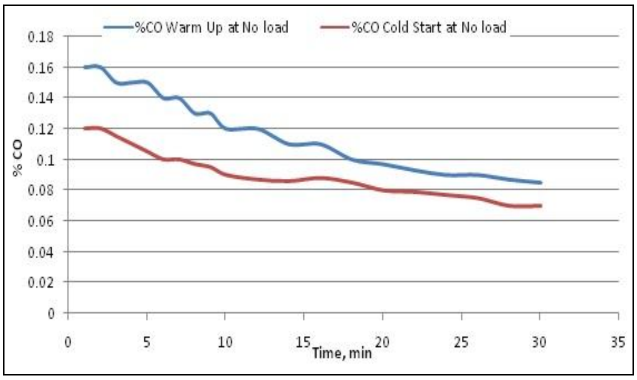

Fig. 5 CO emissions during warm up & cold start at CR 14

- It has been observed that overall reduction in CO emission was 20.72% for CR 14
- Overall Reduction in HC was 11.49%
- Overall Reduction in NOx was observed to be 9.11%

2) For CR 16:

- *CO, HC & NOx emissions at No Load condition*

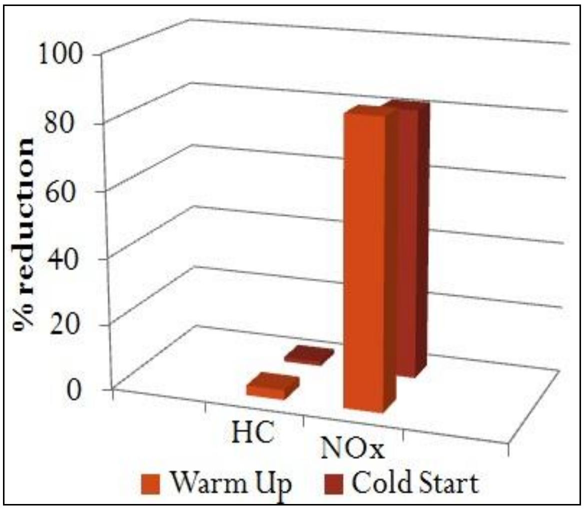

Fig. 6 HC and NOx emissions during warm up & cold start at CR 16

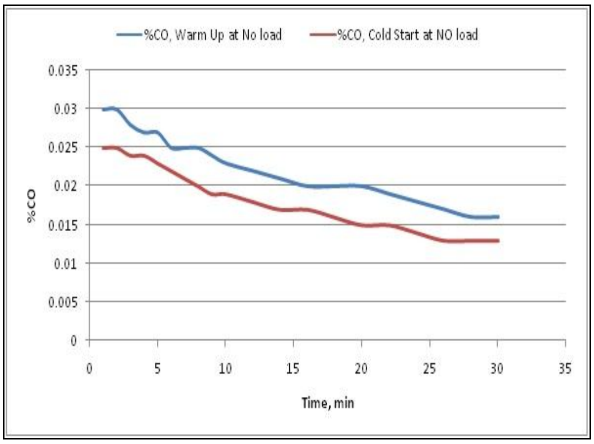

Fig. 6 CO emissions during warm up & cold start at CR 16

- 19.24% reduction in CO emissions
- 7.95% reduction in HC emissions
- *5.27% reduction in NOx emissions*

3) For CR 18: No Load Condition

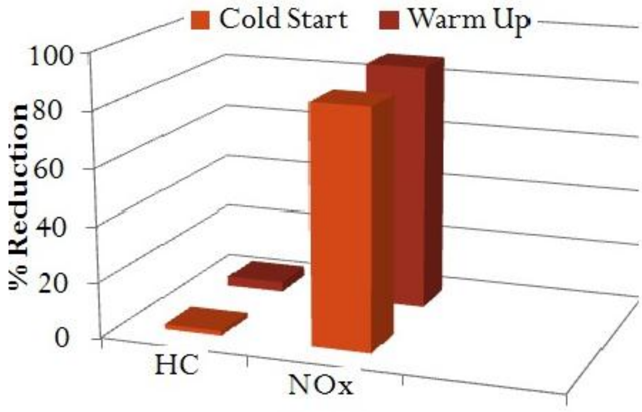

Fig. 5 CO emissions during warm up & cold start at CR 18

- 12% reduction in CO emissions
- 6.92% reduction in HC emissions
- *7.62% reduction in NOx emissions*

CONCLUSION

From the experimental results, we conclude that the cold start emissions of the C.I. engine are reduced as compared to emissions of the engine during warm up period by using PCM based catalytic converter.

- On an average, 21.73% reduction in cold start emissions of %CO is achieved.
- On an average, 6.45% reduction in cold start emissions of HC ppm is achieved.
- On an average, 8.9% reduction in cold start emissions of NOx ppm is achieved.
- The performance of Latent Heat Storage system improves as the number of starting of engine increases.
- As charging period increases, the performance of Latent Heat Storage system also improves.

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Corresponding Author

V.A. Chinchole*

AISSMS COE Pune

E-Mail – vish.chinchole@gmail.com