ISSN: 2319-8753
nternational Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 2, February 2013

Cold Start Performance Enhancement of Motorcycle Catalytic Convertor by Latent Heat Storage System

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Abstract*:* Sources of environmental pollution are the motor vehicle consuming traditional fuels and the industries. About 30% of the total heat generated is lost in the exhaust gases by an internal combustion engine. Under normal operating conditions Catalytic converters appear to be the most effective means of reducing air pollution from internal combustion (IC) engines. The conversion efficiency is practically zero during the starting and warming-up period. So it is very important to improve the conversion efficiency under these conditions particularly in large cities, where the number of starting per vehicle per day tends to be high. In the present work we tried to enhance the performance of the catalytic converter by maintaining it hot for maximum conversion efficiency. A Phase Change Material [PCM] based thermal energy storage system integrated with the catalytic converter is designed, fabricated and tested. After overnight stay motorcycle engine is operated during warm up condition for half an hour, some of the thermal energy of the exhaust gases is stored in the PCM during charging period. During engine shut down period (discharging period), PCM underwent partial solidification and the latent heat thus produced is used to maintain the Catalytic converter hot for maximum conversion efficiency. Due to this after half an hour when engine is started called as cold start period, it is observed that performance of the catalytic converter is improved.

Keywords: Energy conservation, catalytic converter, phase change materials, exhaust emission

I. INTRODUCTION

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 emissions, 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:

1. Un warmed catalytic converter
2. 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 180°C and is practically zero during the starting and warming up period for motorcycles incorporating catalytic converter having Capacity up to 220 cm3. 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 stores exhaust waste heat during engine running period and releases 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 formulated and a system comprising a catalytic converter embedded in PCM was designed and tested. Up to time no much work was done on the PCM storage system incorporated in catalytic converters.

In this experimentation, efforts are made to reduce cold start emissions of a single cylinder four Stroke Spark Ignition engine of Bajaj Pulsar 150 cm3 DTSi motorcycle. This is particularly used in urban areas where number of starting per day are more. For this study concentration is made on applications involving use of motorcycles like Courier Delivery

ISSN: 2319-8753

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Services, Pizza Delivery Services & Catering Delivery Services. Here consideration is made that time gap between two consecutive starting of motorcycle as maximum half an hour.

II BACKGROUND

In Asian countries rapid growth in vehicular population resulted in rapid increase in air pollution which impacts public health. The region has the highest concentration of two- and three-wheelers in world. While motorcycles are considered among the most fuel-efficient personal modes of transportation. The cumulative effects of the large fleet have a significant impact on overall energy use and road safety. Among all the vehicles, the major contributors of HC & CO emissions are motorcycles. In the 10 largest Asian vehicle markets motorized two- and three-wheelers comprise roughly an average of 66 percent of the total population (Table 1.1). By 2010 the fleet of two and three-wheelers in major Asian countries had surpassed vehicle the 200 million mark and by 2035 there will be more than 550 million two- and three-wheelers, assuming a 4.2 percent annual growth (CAI-Asia, 2011). India and China have experienced new motorcycle sales growth at an average rate of 11 percent each of the past 5 years. In India the share of HC and CO from two- and three-wheelers is also higher than HC and CO from other motor vehicles. According to ICCT's India Emissions Model, in 2010 the share of HC and CO are 92 and 74 percent respectively. It is evident that recent measures taken by the Indian government have helped reduce the contribution of two- and three-wheeler pollution. Motorcycle's share of HC and CO pollution accounts for 60 to 90 percent and 30 to 70 percent of pollution from the total vehicle inventory while PM emitted by diesel three-wheelers accounts for 14 to 42 percent of the total (ICCT, 2009). It should be noted that in all the cases presented, motorcycle fleet share was greater than 70 percent during the study. Hence the emission standards require further tightening to prevent an upswing in emissions.

Table 1 *Top ten largest markets of 2 and 3 wheelers in Asia and their growth. Data from world road statistics (WRS, 2010)*

Country/ Region	Year	Other Vehicles	Motorcycles and Moped	Percent Motorcycles	Average Annual Growth of other Vehicles	Average Annual Growth of Motorcycles
China	2009	62,136,896	95,805,176	60.7%	30.9%	10.4%
India	2009	21,200,140	82,402,105	79.5%	10.7%	12.1%
Indonesia	2009	18,281,437	52,433,132	74.1%	22.6%	20.9%
Vietnam	2007	1,146,312	21,779,919	95.0%	ND	ND
Thailand	2006	8,923,447	15,674,941	63.7%	6.8%	2.6%
Taiwan	2009	6,718,746	14,604,330	68.5%	2.3%	3.3%
Pakistan	2009	2,170,430	3,383,493	60.9%	10.4%	13.0%
Philippines	2009	2,990,743	3,200,968	51.7%	2.0%	23.5%
Sri Lanka	2009	951.362	2,339,916	71.1%	ND	8.0%

III EXPERIMENTATION

A *Latent heat storage system:*

A cylindrical latent heat storage encapsulating the motorcycle catalytic converter of silencer assembly was designed and fabricated as shown in Fig [1]. Then this latent heat storage system with silencer assembly is attached to a single cylinder, 4 stroke, 150cc, Bajaj Pulser motorcycle, 15 bhp 1500 rpm, petrol engine, coupled to a hydraulic dynamometer. To measure the temperature at different zones of the catalytic converter, RTD Pt 100 type thermocouples were attached during the fabrication process. stainless steel pipe and flanges were used while fabricating the whole device, keeping in mind the temperature of operation and nature of the PCM. PCM selected for the experiment is commercial paraffin wax having Phase change temperature 58°C and latent heat of fusion 189kJ/kg. Fig. [1] shows location of thermocouples in designed latent heat storage system.

T1- Temperature of exhaust out gases at the inlet of TES jacket
T2- Temperature at the surface of exhaust pipe near the catalytic converter in TES jacket
T3- Temperature of PCM in TES jacket
T4- Temperature of catalyst of the catalytic converter
T5-Temperature of exhaust gases at the outlet of TES jacket

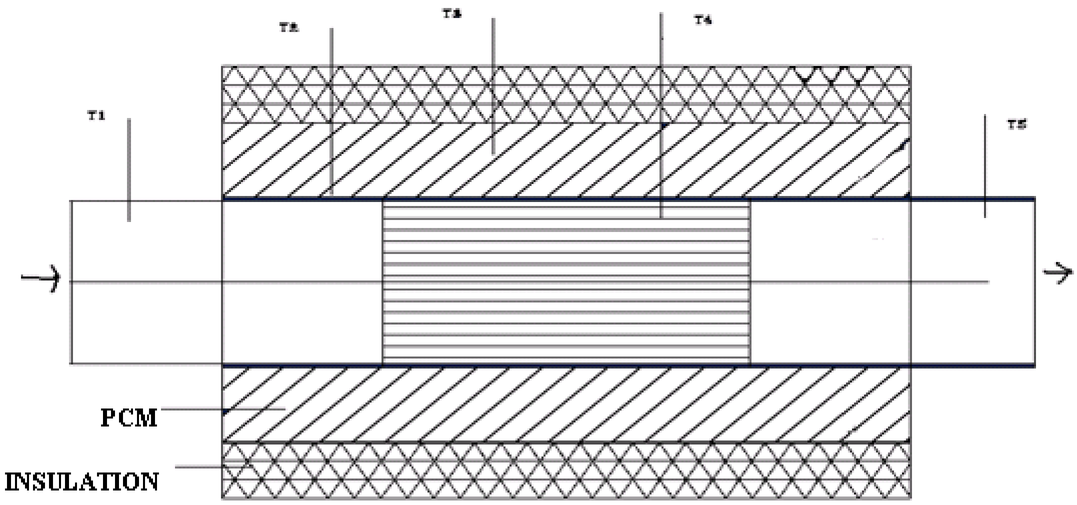

Fig.1 Latent heat storage system.

B *Experimental setup:*

Experimental setup is shown in Fig. 2.

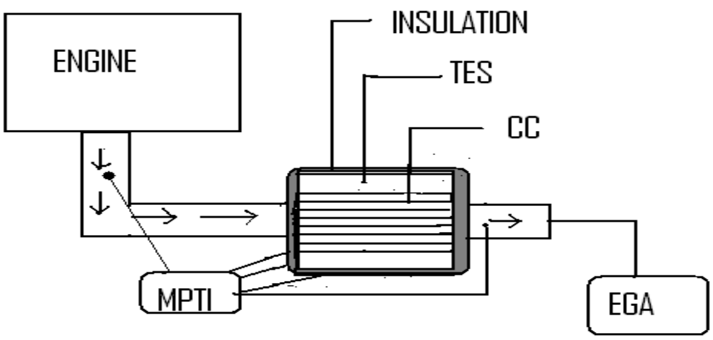

Fig. 2 Block diagram of setup

TES -- Thermal energy storage
CC -- Catalytic converter
MPTI – Multipoint temperature indicator
EGA -- Exhaust gas analyzer

C *Test procedure*:

1) Initially thermal jacket is filled with phase change material (PCM)-Paraffin wax. Then the jacket is allowed to cool. It takes two hours to solidify & to stabilize close to room temperature.

2) Next day morning, the silencer assembly of a Pulsar 150cm^3 DTSi motorcycle is replaced by the modified silencer assembly containing a Latent Heat Thermal Energy storage system.

ISSN: 2319-8753

nternational Journal of Innovative Research in Science, Engineering and Technology
Vol. 2, Issue 2, February 2013

3) Then all the thermocouples are connected to MPTI & then MPTI indicator is connected to a single phase alternate current supply.
4) During warm up (DW) condition, the engine is started & maintained in idling condition. With the help of exhaust gas analyser engine exhaust emission readings were recorded after different time intervals and then the engine is shut down. During engine shut down period, temperature readings of PCM thermal jacket (T3) & catalytic converter (T4) were recorded. It is found that for next half an hour, PCM thermal jacket (T3) is maintained constant due to proper glass wool & cotton rope insulation.
5) During next cold start (CS), after half an hour shut down of engine, the engine is started again & same procedure as that for warm up period is repeated. During engine shut down period, temperature readings of PCM thermal jacket (T3) & catalytic converter (T4) were recorded. It is found that for next half an hour, PCM thermal jacket temperature (T3) is maintained constant due to proper glass wool & cotton rope insulation.
6) During this period .it is found that catalyst of catalytic converter was unable to reach its light off temperature 180°C or 50% conversion efficiency temperature of catalyst.

IV RESULTS

1) From comparison of exhaust pipe surface temperature (T2) near the catalytic converter during engine Warm up period [charging]and during engine Cold start period [charging]of half an hour ,it is observed from Fig.3 that exhaust pipe surface temperature during Cold start is maintained higher which is useful to maintain the catalytic converter in hot condition.

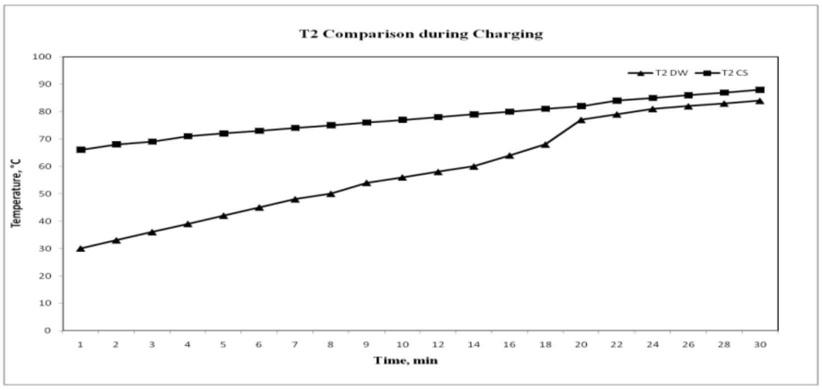

Fig. 3 T2 Comparaison

2) From comparison of temperature of PCM (T3) during engine Warm up period [charging]and during engine Cold start period [charging]of half an hour ,it is observed from Fig.4 that temperature of PCM during Cold start is maintained higher which is useful to maintain the catalytic converter in hot condition . During discharging period or engine shut down period after engine warm up & engine cold start periods, it is observed that T3 is maintained at constant temperature.

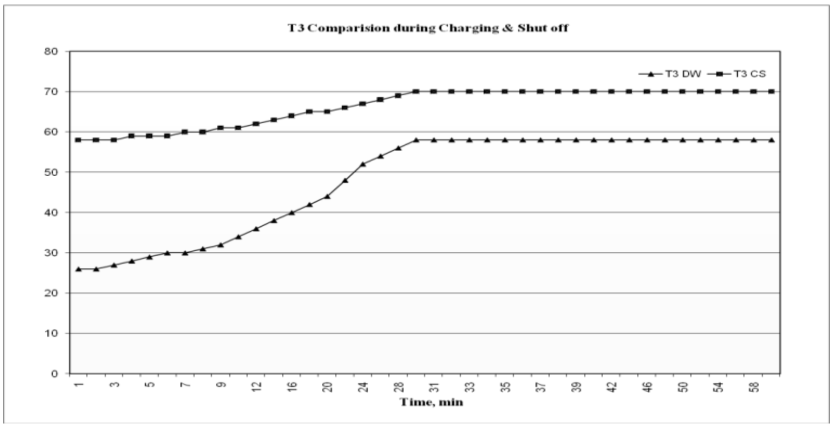

Fig. 4 T3 Comparison during charging and engine shut off period.

3) From comparison of %CO emissions during engine Warm up period [charging] and during engine Cold start period [charging], it is observed from Fig. 5 that it is observed on an average **23 %** reduction in **%CO** emissions occurred during cold start condition of engine.

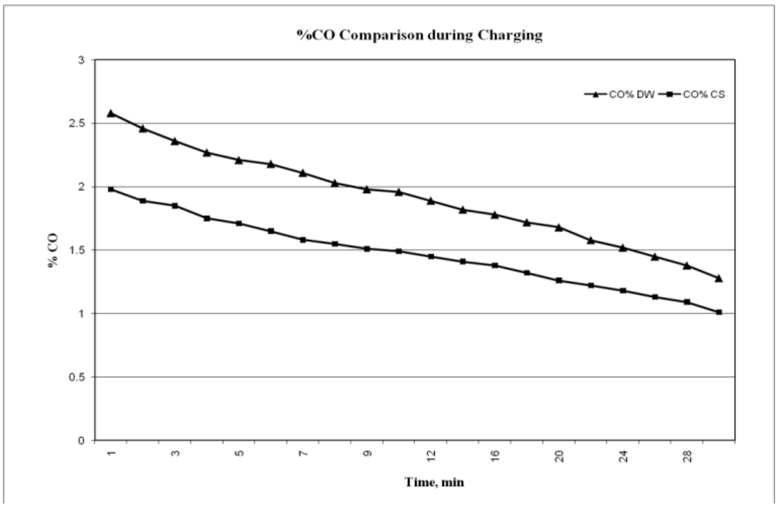

Fig.5 % CO Comparison

4) From comparison of HC ppm emissions during engine Warm up period [charging] and during engine Cold start period [charging],it is observed from Fig.6 that it is observed on an average **21%** reduction in HC ppm emissions occurred during cold start condition of engine.

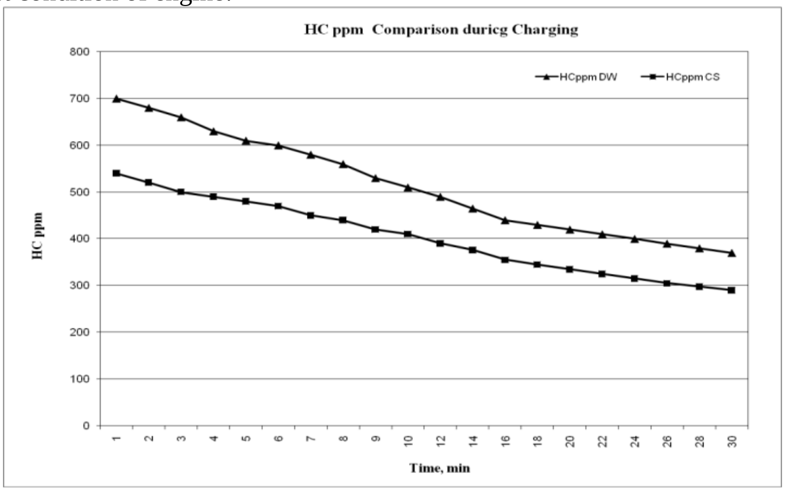

Fig. 6 HC ppm Comparison

V CONCLUSION

We conclude that cold start emissions of the S.I. engine are reduced as compared to emissions of the engine during warm up period by using PCM based catalytic converter.

1) On an average, 23% reduction in cold start emissions of %CO is achieved.
2) On an average, 21% reduction in cold start emissions of HC ppm is achieved.
3) The performance of TES system improves as the number of starting of motorcycle increases.
4) As charging period increases, the performance of TES system also improves

ACKNOWLEDGMENT

The authors acknowledge the support rendered by the staff of department of Mechanical engineering, AISSMS's College of Engineering, Pune 411001.

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