Tail Pipe Emissions of a Passenger Car on Different Driving Modes

Devika S.
Former MTech Student
Rajiv Gandhi Institute of Technology
Kottayam, Kerala

Bino I. Koshy
Professor
Rajiv Gandhi Institute of Technology
Kottayam, Kerala

Bindhu B.K.
Associate Professor
Rajiv Gandhi Institute of Technology
Kottayam, Kerala

***Abstract*— Motor vehicles are one of the major contributors to greenhouse gas emission. Inadequate public transport facility in urban areas increased the number of personal vehicles for their travel needs. As a result the vehicular population in urban cities has increased tremendously in recent years. Among this passenger cars make a major portion of traffic fleets on urban roads mainly in developing countries like India. Previous studies have revealed that queuing of vehicles, changes of traffic signals, various driving modes, and frequent interruptions cause a significant amount of fuel lose and increased emissions from vehicles. This paper deals with the study on vehicular tail pipe emissions from a diesel passenger car on different driving modes by using a portable gas analyzer. Results from the study show that vehicle emissions are higher during acceleration mode and lowest during idle. Vehicle emission can be controlled to a certain extent by driving the vehicle at a constant speed.**

Keywords—tail pipe emission; driving mode; vehicle speed

I. INTRODUCTION

According to 2011 census result, estimated population in India is 1.21 billion. Such increase in urban population has resulted in unplanned urban development and higher demand for transport energy and other infrastructure. The expansion in vehicle population, consumption of fuel and pollutant problems is now becoming a critical issue. The share of passenger cars in urban roads is high in developing countries. The number of trips in urban centers is also high in comparison to other personalized vehicles due to the inadequate public transport facilities [1]. As a result congestion increases the interaction between vehicles and vehicles and between vehicles and people which reduces the overall speed of vehicles. The frequent stop and go, queuing of vehicles, and delay increase the emission and fuel consumption of vehicles. Pollutants emitted from vehicular exhausts are Carbon monoxide (CO), hydrocarbon (HC), oxides of nitrogen (NOx) and fine particulate matter (PM). These are generally associated with vehicle types and fuels used. Besides, road traffic also contributes to greenhouse gases such as carbon dioxide (CO_2).

In this study vehicle emission data are collected under real world conditions which differ from laboratory-based measurements because they have more realistic potential to predict the range of variability typically encountered in real-world driving, including variability in driver behavior, interactions with other road users, and interactions with highway infrastructure, all of which have significant effect to influence exhaust emissions from vehicles [2]. Road vehicles generally exhibit significantly different emission behavior in actual situations compared to standard test conditions.

A number of researches have been conducted based on the current topic, but most studies are done on laboratory based emission measurements. These methods don't give actual driving dynamics.

Road geometry, the numbers of acceleration/ deceleration cycles and time spent in idling have significant impacts on fuel consumption and exhaust emissions [3]. The emission levels depend heavily on traffic-flow characteristics, such as average flow speed, the frequency and intensity of vehicle acceleration and deceleration, the number of stops, and vehicle operating mode.

Wang et al. (2011) conducted a study to determine the influencing factors and characteristics of vehicle emission on urban road intersections [4]. A typical urban road intersection at Changchun city was selected as an example and the instantaneous mass emission of Jetta Gix 1.6 L car and Jinbin EFI 2.4L bus were tested by using the OEM-2100 Emission tester. NOx, HC and CO was taken as the main pollutants. The relation between emission rate and driving mode, the emission status at different time periods and the influence of speed and acceleration on emission rate were all analyzed and compared.

By using traffic simulation model VISSIM and vehicle specific power (VSP) of vehicle an emission model is developed by Bing et al. (2014) to analyze the traffic emissions under different lane configuration designs [5]. The result shows that the existence of exclusive lane set indicates a significantly effect on the characteristics of the traffic flow and emissions at intersections. The comparisons between different lane configurations scenarios provided a suggestion that an exclusive signal phase or waiting area for left turn exclusive a right turn exclusive lane is always useful.

Frey et al. (2003) measured the tailpipe emissions of individual vehicles using onboard instrumentation [6]. They considered episodic nature of vehicular emission. They used OEM 1000 (a five gas analyzer) to collect emission data and engine diagnostic scanner to collect engine data like speed, engine rpm, etc. at a busy arterial with signalized intersection. Authors concluded that there is a significant variation in emission of vehicles during temporary events like acceleration, deceleration and cruising. Variation of vehicular emissions with time was found to be sensitive to short term episodes like acceleration and deceleration

Unal et al. (2004) quantified emissions at hot spots (spots where emissions are significantly high) on highway corridor using onboard emission measurement instrument. They observed that other methods of emission measurement such as chassis dynamometer, remote sensing, etc. have limitations in recording field conditions of emissions. Authors concluded that variables such as average speed, average acceleration and standard deviation of speed, percent of time spent in cruising minimum speed, maximum acceleration and maximum power have significant impact on vehicle tailpipe emissions.

The above literature indicates that the emission from vehicles can be well quantified using on road measurements. Also literature reveals that not much emission related studies have been conducted in developing countries like India. The vehicle characteristics, road features and driver habits are different in heterogeneous traffic condition. Hence this study aims to determine the effect of various driving modes and speed of vehicles on exhaust emission on heterogeneous traffic condition. Only emission level of HC, CO and NO are quantified in this study.

This paper focuses on the collection of emission from vehicles under real world conditions which is an actual representative of actual traffic condition and driving pattern. Variations in vehicular tail-pipe emissions of a passenger car under different driving mode and traffic conditions are studied to evaluate the influence of various traffic parameters such as speed and accelerations on tailpipe emission. The outcome may be used to develop a strategic plan to reduce the amount of pollutants emissions and to reduce the environmental cost to a minimum.

II. METHODOLOGY

On-road data collection is very flexible in terms of site selection and vehicle selection compared to other measurement methods. Selection of sites for on road data collection depends on the objectives of the study. Test car used in this study is a diesel powered TATA INDICA 2011 model. The specification of test vehicle is given in Table I

Table I. Specification of test vehicle:

Make	TATA INDICA
Fuel type	Diesel
Year of manufacture	2011 March
No. of cylinder	4
Weight	1240 Kg
Maximum power	55.3 kW @ 4000 rpm
Engine displacement (cc)	1248

A. Selection of Study Area

Based on the objectives, suitable study areas are selected for quantifying emission on different driving modes. Due to the difficulty in considering all these factors, study areas with specific criteria are selected for the study. Hence road stretch with following properties is chosen:

- It should have free flow traffic
- Road geometry should be fairly straight since effect of gradient is not considered.
- Road surface should be in good condition

B. Instrument Used

For the measurement of tail pipe emission of vehicles an exhaust gas analyzer (Kane Automotive 5-1 Series) is used. The equipment is capable of measuring the vehicular tail pipe emission of vehicle at frequent interval of time. Equipment measures HC and NO (ppm of volume) and CO (% of volume). Also a GPS is used for continuous record of speed profile and direction of travel.

C. Experimental Procedure

The exhaust gas analyzer was placed on the back seat of the test car. The emission recording probe was inserted into the tailpipe of the car and connecting pipe was attached to the device. After zero calibration of the instrument the time interval was set to collect the concentration of pollutants. The test vehicle was made ready for on road data collection. All the readings were taken after stabilized condition of the vehicle. Then the vehicle was accelerated to a desired speed at which the driver feel safe, based on the traffic condition within a minimum time and later the vehicle decelerate in order to quantify the emission in these modes.

At the same time speed profile of the vehicle was recorded. The same procedure was repeated on another selected 4.5 km undivided road to determine the effect of speed of vehicle on emission. The emission data were saved on a laptop. About 10 such test runs were conducted for each mode on a fair weather condition during May 2016.

III. RESULTS AND DISCUSSION

A. Effect of Acceleration on Tail Pipe Emission

It is observed that total emission levels of all the pollutants are high during acceleration as compared to other driving modes. From the graph it is observed that the emission level of CO and HC are very high at initial stage and then goes on decreasing. This is because during acceleration the vehicle engine consumes more power and hence the fuel consumption is high as a result the tailpipe emission increases. The increase in emission level of HC and CO are due to the fact that, during acceleration the fuel inflow is high and also it is rich mixture so air to fuel ratio is very low and hence complete combustion of fuel doesn’t occur. Hence produce unburnt HC and CO.

B. Effect of Deceleration and Idling on Tail Pipe Emission

There is not much variation in pollutant level observed during the deceleration event. One possible reason is that the deceleration of vehicles is achieved using application of brakes, at this time engine is disconnected from vehicle and hence doesn’t participate in the process of deceleration. Thus, tailpipe emission is unchanged by deceleration. Idling mode is the low emission mode of the driving cycle.

Variations in HC, CO and NO are given in Figures 1, 2 and 3 respectively.

C. Effect of Speed on Tail Pipe Emission

The speeds encountered during each test run of vehicle are consolidated and corresponding emission levels are tabulated. Table II shows the various speed range and corresponding emission levels.

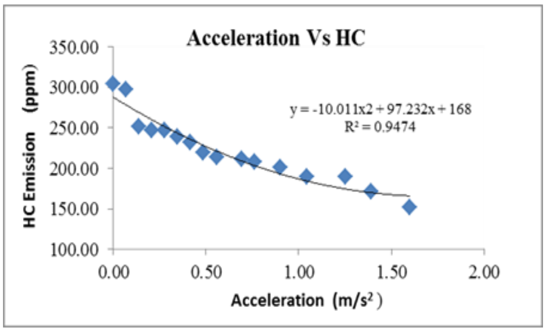

Figure 1 Variation of HC on Acceleration

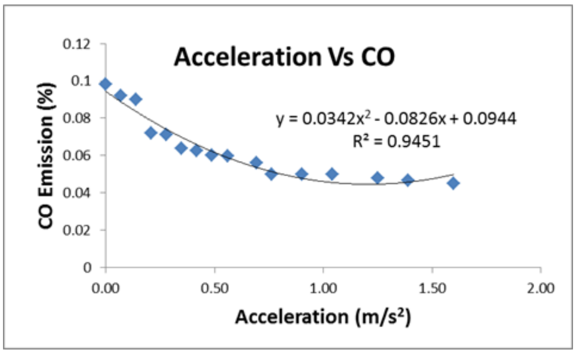

Figure 2 Variation of CO on Acceleration

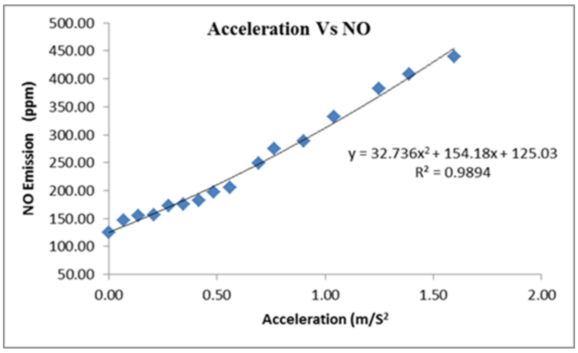

Figure 3 Variation of NO on Acceleration

The emission in each speed range is taken as the mean value of the observation. The maximum speed range of the vehicle during the test run is up to 70km/hr. From Table II it is seen that there is a significant variation in tailpipe emission rate with different speed range. It is observed that the tail pipe emission of vehicle is higher during lower speed range ie below 20km/hr which decreases with increase in the speed of vehicle. Later with further increase in speed, tailpipe emission again increases. A similar trend in emission level is observed for all pollutant like HC NO and CO. The result shows that during lower speed range the vehicle engine exerts more power and consumes more fuel as a result the emission increases. As the vehicle moves on the power requirement for the engine reduces and hence fuel consumption decreases. Graphs are plotted between emission levels on different speed range (Figure 4 & 5). However with further increase in speed ie above 70km/hr engine consumes more fuel for running the vehicle which again increases the vehicle emission.

Table II. Average tailpipe emission rate at different speed ranges

Speed (km/hr)	HC (ppm)	CO (%)	NO (%)
0-10	418.23	0.31	285.05
10-20	389.15	0.25	296.12
20-30	310.63	0.15	318.03
30-40	285.47	0.09	345.26
40-50	209	0.09	385.32
50-60	152.91	0.07	323.17
60-70	190.12	0.08	393.01
70-80	252.27	0.14	452.28

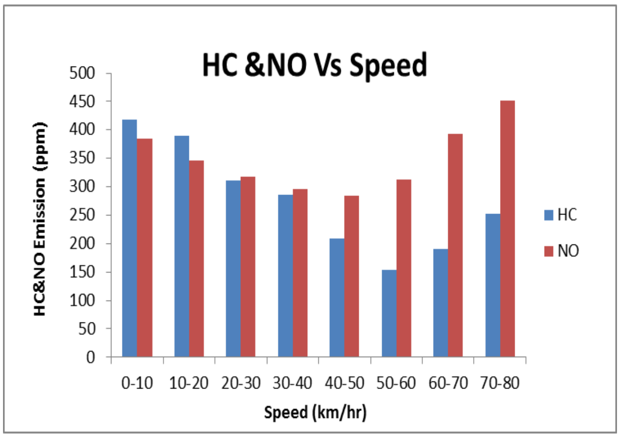

Figure 4 Effect of Speed on Emission of HC and NO

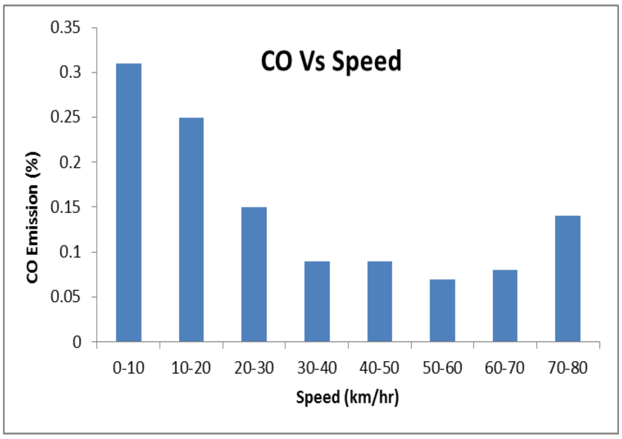

Figure 5 Effect of Speed on Emission of CO

Since the test vehicle is a diesel car due to the high combustion of fuel in high speed and also increases in temperature and pressure produces high amount of NO. So the emission level of unburnt hydrocarbon and CO decreases with increase in speed. From Figure 4 and Figure 5, it is observed that a speed range of about 50-60, which is an optimum speed range of the test vehicle which produces low emission level during the test runs.

IV. CONCLUSIONS

The purpose of this research was to study the variation of exhaust pollutants from single passenger car under different driving mode also to evaluate the influence of traffic parameters such as Acceleration, Speed on tailpipe emission. The following are the conclusions are drawn from the study:

- Among the different driving mode it is observed that the acceleration of the vehicles generate high amount of emission and idling of vehicles which produces low emissions rate, since no power or speed requirement by the engine during idling.
- The effect of vehicle speed on tail pipe emission was also evaluated, low speed range produce high emission; also as the as the vehicle reaches to an intermediate speed range between 50 to 60 km/hr the emission decreases. And emission again increases at higher speed ranges, ie above 80km/hr.
- Main conclusions are vehicles should be run at approximately a constant speed range and reduce sudden acceleration as far as possible to result in lower emissions.

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