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Modal analysis of real-time, real world vehicular exhaust emissions under heterogeneous traffic conditions

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ABSTRACT

This study presents the characteristics of real world, real time, on-road vehicular exhaust emission namely, carbon monoxide (CO), nitric oxide (NO), hydrocarbons (HC), and carbon dioxide (CO_2) emitted under heterogeneous traffic conditions. Field experiments were performed on major category of vehicles in developing countries, i.e. two-wheelers, auto-rickshaws, cars and buses. The on-board monitoring was carried out on different corridors with varying road geometry. Results revealed that the driving cycle was dependent on the road geometry, with two lane mixed flow corridor having lot of short term events compared to that of arterial road. Vehicular emissions during idling and cruising were generally low compared to emissions during acceleration. It was also found that emissions were significantly dependent on short term events such as rapid acceleration and braking during a trip. Also, the standard emission models like COPERT and CMEM under predicted the real world emissions by 30–200% depending upon different driving modes. The on-road emissions measurements were able to capture the emission characteristics during the micro events of real world driving scenarios which were not represented by standard vehicle emission measured at laboratory conditions.

1. Introduction

The human interaction with vehicles dates back to the invention of wheel during pre-historic age. With the invention of internal combustion engines, road transport has expanded exponentially in the last century. In India, the automobile industry is blooming with improvement in per capita income over the past years. The road infrastructure has also improved leaps and bounds both in terms of quality of roads and to the total length of the road from 0.4 million km in 1951 to about 4.24 million km in 2008 (Nesamani and Subramanian, 2011). Masked behind all the great things achieved with the help of road infrastructure there is the growing problem of air pollution due to traffic congestion. The road density, in the urban areas has increased with a compound annual growth rate of 3.3%. The number of vehicles registered per year is also increasing over the years.

Although stringent emission norms are established for the vehicles, the ambient air pollution in the major cities continues to increase over the recent years (Faiz and Sturm, 2002). The key pollutants from the vehicular exhaust such as oxides of nitrogen (NOx), carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HCs) and particulate matter (PM) are reported to be very high at the urban corridors (CPCB, 2010; Lipfert and Wyzga, 2008; Palmgren et al., 1999). Even the secondary pollutant like ozone (O_3) is also prevalent in the urban areas because of the persistent nature of the vehicular pollutants (USEPA, 2011).

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1.1. Vehicular exhaust emission standards

In order to control vehicular air pollution, regulatory agencies like United States Environmental Protection Agency (EPA) and Automotive Research Association of India (ARAI) have developed vehicular exhaust emission standards (ARAI, 2016). These standards were derived from various tests conducted in the chassis dynamometer studies. These studies were made in controlled laboratory conditions where the test vehicle is mounted on a roller and the driver was advised to operate according to a fixed driving cycle. These standard driving cycles are not reflecting the present real world driving behavior. The Indian Driving Cycle (IDC) used for emission standards was not reflective of complex behavior associated with heterogeneous traffic (i.e., different types of vehicles such as auto-rickshaws, two-wheelers, cars, jeeps, vans, buses, light commercial vehicles and trucks uses the same lane) conditions of the Indian roads as shown in Fig. 1 (Kamble et al., 2009).

The evolution of emission standards for different category of vehicles in India is shown in Fig. 2 (ARAI, 2016). Although stringent norms were established by the regulatory agencies, the contribution of the transportation sector, including on-road and non-road vehicles, contributes 47% of HC emissions, 55% of NO_X emissions, 77% of CO emissions, and 25% of PM emissions to the ambient environment (Kioutsioukis et al., 2004). The contribution of on-road motor vehicle emissions to local emission inventories of urban areas, may be higher than the national average values. This has shown the need for emission standards under real world conditions.

1.2. Vehicular exhaust emission prediction

Emissions models like COPERT, MOVES, PHEM, and EMFAC have been widely used by various regulatory agencies to estimate emissions and to make control strategies (Sturm et al., 1998). In most of these models the emissions were measured in laboratory conditions using dynamometer by following a schedule according to different driving cycles. These driving cycles are not usually reflecting the driving behavior of the real world conditions thereby adding considerable error into the emission estimation. Most of these model results are further integrated into dispersion models for the prediction of air quality in urban areas. The dispersion model predictions were also used in framing various policy decisions (Hagemann et al., 2014; Sturm et al., 1998; West et al., 1997). In general emissions reported by these models are several times lower than the real world emissions. Hence, the policy developed based on model predictions showed only marginal improvement in local air quality. Therefore, the knowledge on real world emission characteristics is essential for the design of effective exhaust emission control strategies and better traffic management at intersections and busy corridors where vehicular emissions are significant.

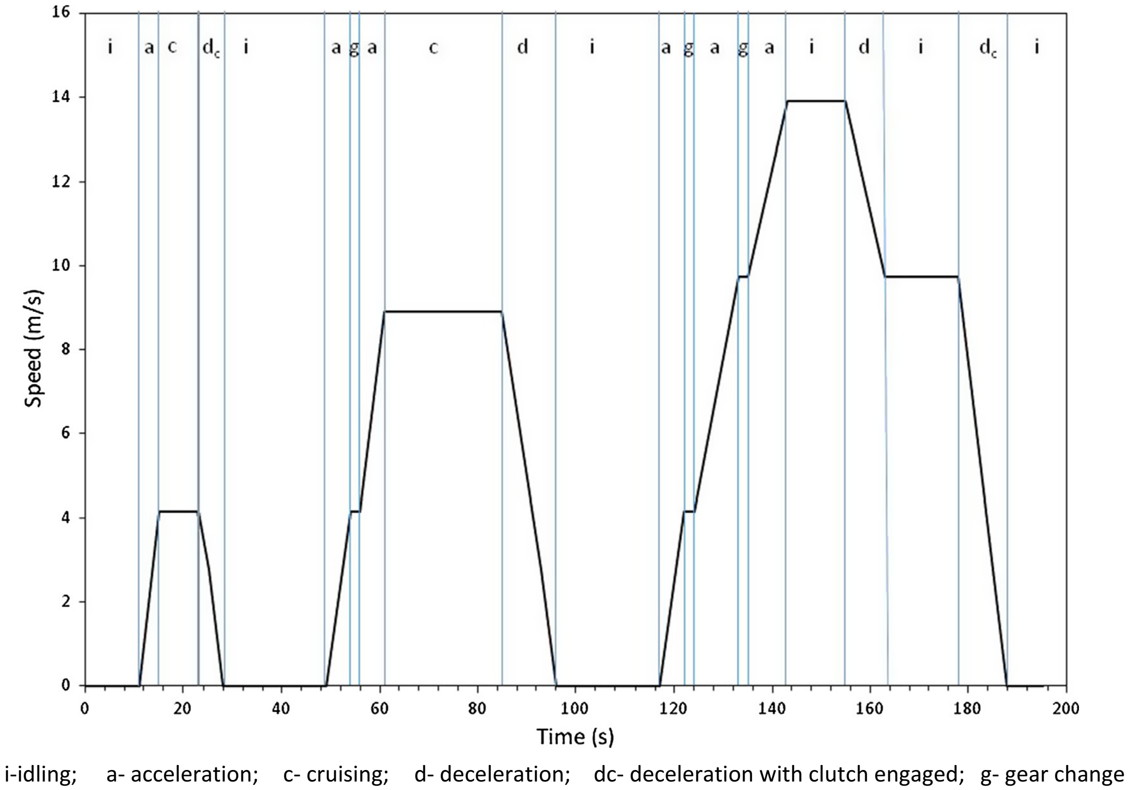

Fig. 1. Indian standard driving cycle.