Measuring Vehicle Performance on Road & on Dynamometer

Gurinder Singh Sekhon[1] Harpreet Singh[2]
[2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1]DIET, Mohali, India [2]Chandigarh University (Gharuan), Mohali, India

Abstract— Automobiles are the major source of atmospheric pollution international causing various health and environmental related risks. Regardless of the importance, the exhaust automotive emissions are inefficiently understood and enumerated. The increasing sizes of urban areas, increasing vehicle population and increased driving distances have led to serious pollution levels in many cities. With reduction in the emission limits the air quality, has not improved considerable as prophesied, mainly intended for NOx emissions. One of the main causes for the gap is the emission measurement under the legislative test cycles and their efficacy during the actual driving conditions. A vehicular emission needs to be modelled and derived from the actual driving conditions rather than the legislated drive cycle data. For commercial vehicles the main gap lies in the repeatedly used engine speeds that these falls outside the range presently experienced under the type approval testing. India follows a dual fuel policy and dieselization of India's automobile with subsidies for diesel fuel increasing the particulate matter emissions. Realistic exhaust emissions rests largely on elements such as dynamic driving pattern, atmospheric circumstances, fuel quality, road conditions, altitude variation and vehicle aging. Major pollutants like NO_X, CO, PM and VOC differ under dynamic condition than those under the steady state. India is following European emission standards, besides the road conditions and vehicle specifications are not up to those standards. This study aims to identify the emission gap on the base of evaluation and assessment of operating circumstances underneath legislative test cycles and the actual driving conditions in the normal traffic. The vehicle was equipped for logging of various engine and vehicle related parameters. The operating conditions were divided into three parts rural, urban and highway.

Key words: Air Pollution, Emission, Type Approval Test, Real Traffic Conditions & Nitrogen Oxide

I. Introduction

Increasing concern over the state of the environment has led to an increasing demand for lower automotive emissions. Diesel-powered vehicles have become the chief attributable cause of air pollution in most urban areas. Nizich S.V. et al. [1] stated that thoroughfare vehicles are the prime source of transport associated emissions and contribute one-third of the total nationwide emissions. Smith D. et al. [2] purposed a thorough understanding of the emissions producing characteristics of these vehicles must be determined, to decrease the amount of pollutants expelled by modern automobiles. For this reason, accurate measurements of the tailpipe emissions are required. The BS-IV emission standards are pertinent to 13 cities in India including NCR, can't successfully regulator the emissions level in these cities, as the commercial motor vehicles are not limited to a specific city/place and also drive elsewhere, and in those areas the fuel standards still follow the BS-III standards. Automotive emissions of hydrocarbons (HC), nitric oxides (NOx), carbon monoxide (CO), and particulate matter (PM) pose a threat to the environment at large. The development of diesel engines is focused to the reduction of tailpipe emissions, principally nitrogen oxides and particulate matter. The technologies followed these days to achieve the BS-IV emission standard are EGR (exhaust gas recirculation) for NOx emission and particulate filters to tackle particulates. The BS-IV emission norms are reduced by 30% for HC, NO_X and CO and 80% for particulate matter as compared to BS-III norms, which is achieved by introduction of electronic engine management. May, John et al. [3] conducted test on three diesel vehicles having different emission control technologies for NOx (LNT, SCR & EGR) to identify and understand the differences in emissions results between real world driving and chassis dynamometer tests. The hydrocarbon results of all three vehicles were within limits. The NOx results of on-road testing were 23% higher than Euro 5/6 limit compared to dynamometer cycles. Merkisz, Jerzy et al. [4] compared the Euro-III diesel truck on city and highway drives, with and without load conditions. The exhaust NO_X and CO_2 during city as well as highway drive indicate that the emission grows almost twice. Heinz Steven [5] enlightened the faintness of the European stationary and transient test cycles. He suggested to replace current cycles with normalised stationary and transient test cycle. Shortcomings associated with dynamometer tests normally suffer from non-representativeness of actual driving conditions. These tests are not adequate for the EF development however used for validation and certification international [6-7]. The on road testing of Euro-3 light duty vehicle showed that the nitrogen oxides (NO_X) substantially surpass the legislative emissions standards [8-9]. Joumard, R. [10] premeditated outdated conducts for assessing on bed exhaust emission, particularly of new vehicles. Similarly, Andersson J. et al. [11] evaluated two Euro 6 diesel cars, on the road and over chassis dynamometer. The on-road recorded emissions results exceeds Type-Approval limits, which indicates that real-world operating conditions requires robust control strategies over those needed to satisfy existing legislation.

II. Design Methodology

Commercial vehicle (above 3.5T GVW) is approved for use by testing its engine on an engine dynamometer to measure the emissions. Currently in India, ESC test cycle is used for emission measurements in steady state for BS-III and BS-IV norms. During this test the engine is operated at different steady speeds (A, B and C) and loads, the emission values are measured on each operating point. Furthermore, NO_X should be measured at three random points inside the control zone. This confirms the efficiency of the engine NO_X emission control inside the typical functional range. This is relatively easy to test, and does not give a true impression of the emissions from the engine under the typical on road operating conditions. The benefits of the current method of testing are that the engine manufacturer needs only to design and calibrate within the control area. Once the engine is homologated it can be sold this to many vehicle builders for use in any suitable vehicle without regard to the actual real world emissions. The higher speed n_{hi} is determined by calculating 70 % of the declared maximum net power. The highest engine speed where this power value occurs (i.e. above the rated speed) on the power curve is defined as n_{hi} and n_{lo} as 50% of declared maximum net power. The lowest engine speed where this power value occurs (i.e. below the rated speed) on the power curve is defined as n_{lo}. [12].

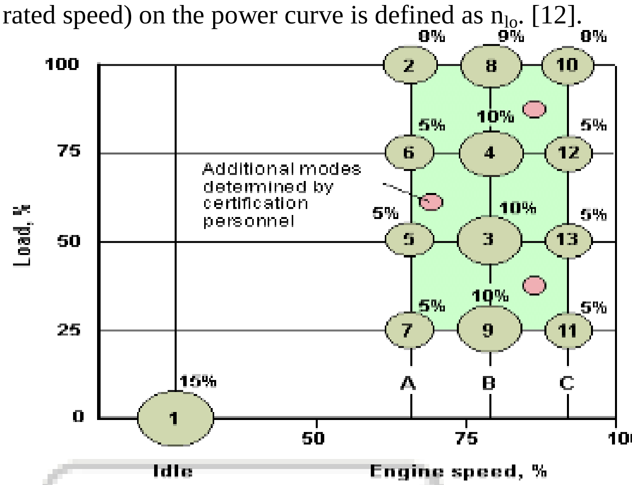

Fig. 1: European Stationary Cycle (ESC)

The engine speeds A, B and C shall be calculated as follows:

Speed A = $n_{lo} + 0.25*(n_{hi} - n_{lo})$

Speed B = $nl_o + 0.50*(n_{hi} - n_{lo})$

Speed C = $n_{lo} + 0.75*(n_{hi} - n_{lo})$

The 13-mode ESC test cycle followed on dynamometer for engine testing

Mode Number	Engine Speed	Percentage Load	Weighting factor	Mode length
1	Idle	--	15%	240 s
2	A	100	8%	120 s
3	B	50	10%	120 s
4	B	75	10%	120 s
5	A	50	5%	120 s
6	A	75	5%	120 s
7	A	25	5%	120 s
8	B	100	9%	120 s
9	B	25	10%	120 s
10	C	100	8%	120 s
11	C	25	5%	120 s
12	C	75	5%	120 s
13	C	50	5%	120 s

Table 1: ESC modes [12]

A. Input to Robustness Analysis

The experimental work is done on a truck of GVW 10250 kgs. The vehicle was operated on the different road conditions. The tests route consist of sections equating to urban, rural and motorway driving. The vehicle was instrumented for logging of various engine and vehicle parameters such as speed, torque, vehicle speed, acceleration pedal position, air flow, fuel flow, distance covered, map values, coolant temperature. Figure 2 represents the actual in use engine speed and load points recorded on the vehicle in different conditions, along with power and torque curve. Only positive power outputs are considered for the analysis. The points are plotted in term of specific power. The normalized engine speed (0% as idle and 100% as rated speed) and power (100% as rated power) are used for the graph and calculation work.

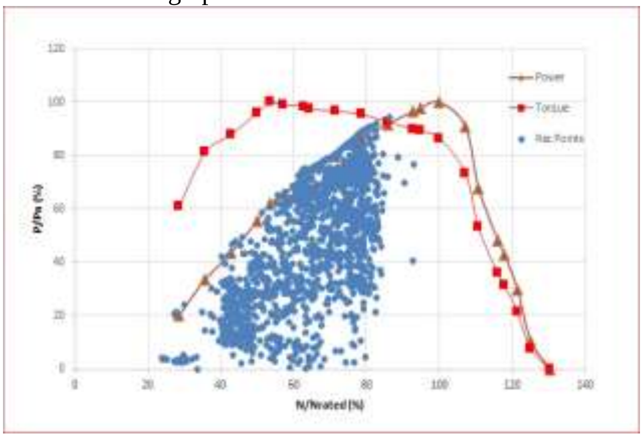

Fig. 2: Engine speed and load points recorded during vehicle operation along with power and torque curve.

III. RESULTS

As the vehicle is operated in different conditions, the engine is not focused to specified engine rpm and load points, it is broadly feast from engine idle to 85% of rated engine speed whereas the load is varying from zero to 100%. It is clear from figure 2 that the frequent operating zone falls below the speed A. Operating points underneath test speed A are not concealed for evaluation by the test cycles. Normally there is turbocharger lag at the lower operating zone and higher emission values. Rated speed of engine is not achieved during the trial run. According to the Indian road and vehicle conditions a large section of engine operation are not encountered during the type approval test. This non encountered part will lead to the pollution beyond the manufacturing norms of the vehicles. This creates the contradiction in the laboratory test environment and the actual vehicle operating environments.

IV. CONCLUSION

The discrepancy of having a gap between the exhaust emissions during legislative type approval and the real traffic conditions is the major source of pollution. There is a need for the study of the driving behavior on Indian road conditions for the better view of the operating zone. The lower operating region to be studied carefully and calibrations needs to be done accordingly. In case of overloading of vehicles there is further decrease in the vehicle speed, which will result in speed range shifting. Moreover, the smoke values at the low engine speeds are higher, targeting for efficient optimization of PM (Particulate matter). This will result in extra vigorous procedure in contrast to speed range shifting. Hence, automotive emission and its environmental threats can be reduced.

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