OPJIT International Journal of Innovation & Research
Vol. - 03, No.-01, Page-48-52, Year-2014

SIMULATING OUTDOOR PASS BY NOISE TEST OF A PASSENGER CAR IN LABORATORY

L. R. Bhandarkar[1], Mahesh Bhiwapurkar[2], S. S. Chakrabarti[3], P. Nageswara Rao[4]

[1]*Assistant Professor, Mechanical Engineering Department, O.P. Institute of Technology, Chhattisgarh, India,* ***laxminarayan@opjit.edu.in***

[2]*Professor, Mechanical Engineering Department, O.P. Institute of Technology, Chhattisgarh, India,* ***mahesh.bhiwapurkar@opjit.edu.in***

[3]*Associate Professor, Mechanical Engineering Department, O.P. Institute of Technology, Chhattisgarh, India,* ***sidharth.chakrabarti@opjit.edu.in***

[4]*Associate Professor, Mechanical Engineering Department, O.P. Institute of Technology, Chhattisgarh, India,* ***nageswara.rao@opjit.edu.in***

Abstract

Technological advancements had reached up to such level in room acoustics that with the aid of vehicle dynamometer simulation and digital signal processing, it is possible to conduct vehicle exterior noise measurements in Laboratory with a high degree of accuracy. Testing conducted at various laboratories has shown good correlation to similar tests performed at a conventional open-air test site. Conducting testing, in a laboratory environment eliminates constraints due to ambient conditions such as weather and background noise. In addition, laboratory testing can provide significant time savings during vehicle development programs in which many iterative tests are performed.

Paper deals with method for Simulating Exterior Pass-by Noise test in Laboratory with the help of vehicle chassis dynamometer and digital signal processing. Tests with three cases, viz., add-on silencer, engine bonnet open and air intake resonator disconnected are conducted along with Baseline condition. The method used is Microphone array method, array of microphones are kept in laboratory and vehicle is made to run on chassis dynamometer with rear wheels fixed under the two test conditions. The time data from each of the microphones are sequenced over time, based on the speed of the vehicle and its simulated position along the test track. Through the process of combining these signals, a virtual sweep is made of the microphone array to represent the movement of the vehicle past a single microphone. These data is analyzed to get the sound pressure levels during the course of the Indoor test in laboratory and then compared with the results obtained in Exterior Pass by Noise test performed on track.

Index Terms: *Digital Signal Processing, Dynamometer, Indoor, Outdoor, Pass-by-noise*

---------- *** ----------

1. INTRODUCTION

Community Noise regulations put stringent requirements on road vehicle exterior noise emission. Outdoor Pass by Noise [PBN] test is mandatory for passenger cars.

The outdoor Pass by Noise test has the following constraints:

- Effect of ambient conditions such as whether, background noise does not give consistent results.
- It is difficult to make development changes in the vehicle while being tested on track.
- The driving style is typical of road tests, which causes uncertainties that lead to errors.
- Complexity of handling instrumentation requirements for data acquisition.

Indoor Pass by Noise test has some benefits over outdoor test, which are

- The indoor test eliminates restrictions due to weather and background noise, especially in areas where rain, snow and wind conditions result in significant time loss.
- Significant time is saved in the development of vehicle components and sub- systems where iterative testing is required.
- A more controlled driving can be implemented in case of indoor test.
- Indoor method offers good repeatability, flexibility, and is easy to use.

The objective of this paper is to co-relate sound pressure levels measured during outdoor tests conducted on test track with sound pressure level measured indoor's in a

OPJIT International Journal of Innovation & Research
Vol.- 03, No.-01, Page-48-52, Year-2015

semi-anechoic chamber and to study the effect of different parameters on the sound pressure levels measured during the tests.

2. TEST SET-UP & PROCEDURE

2.1 Outdoor Pass-by Noise, Wide Open Throttle (WOT) Test set-up and Procedure

2.1.1 Test Set-up

Currently, the Outdoor Pass-by noise level during acceleration is the only legal limit in vehicle acoustics [1]. Test set-up for Outdoor Pass-by Noise test is shown in Fig. 1. Set-up consists of specific track of length 20 m from AA' line to BB' line. PP' line is center line in between AA' line and BB' line. Three photocells are placed to record the positions of the vehicle along the track. Two microphones are placed on PP' line, one on RHS and other on LHS to record the sound pressure level during the test. Engine speed is measured via Telemetry which is kept in vehicle. Following are the test conditions specified in the standard ISO 362-1:2007 [1] for the Pass by Noise test.

- The vehicle approach the line AA' at a steady approach speed, ¾th of maximum engine speed with 2nd gear engaged. When the front end of the vehicle reaches the line AA', the accelerator throttle is fully operated as rapidly and smoothly as possible and held in the fully opened position until the rear of the vehicle reaches the line BB'. As the vehicle rear end reaches line BB', accelerator control is released as quickly as possible.
- The vehicle approach the line AA' at a steady approach speed of 50 kmph with 3rd gear engaged. When the front end of the vehicle reaches the line AA', the accelerator throttle is fully operated as rapidly and smoothly as possible and held in the fully opened position until the rear of the vehicle reaches the line BB'. As the vehicle rear end reaches line BB', accelerator control is released as quickly as possible.

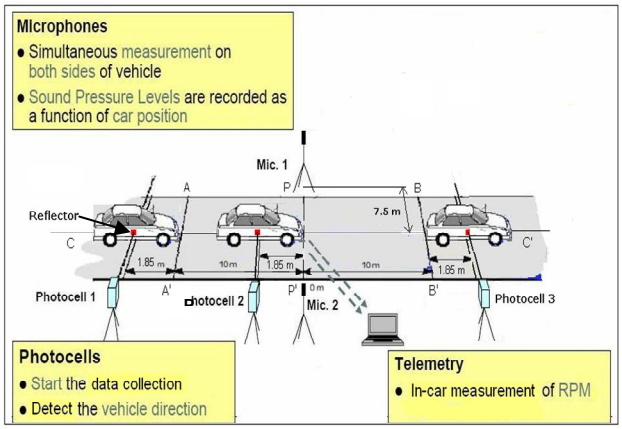

Fig-1: Outdoor Pass-by Noise Test Set-up

2.1.2 Test Procedure

For all measurements, the vehicle is driven in a straight line over the acceleration section in such a way that the median longitudinal plane of the vehicle is as close as possible to the line CC' (refer Fig. 1). The vehicle is made to run under two test conditions as specified in section 2.1.1. When the front end of vehicle reaches the AA' line, PP' line and as the rear end of the vehicle reaches the BB' line, positions of the vehicle at these reference lines are detected by the respective photocells. During the course of the test engine speed is recorded. Position recording is important in order to find out engine speed at AA', PP' and BB' line and also to record the exact time at the corresponding positions of vehicle. Microphones placed at both sides of the vehicle records the acoustical data. The data, when the vehicle is accelerated and then decelerated is of special interest for 20 m length of track plus vehicle length. This data is then analyzed to obtain the overall noise levels during the test.

2.2 Test set-up and Procedure

Indoor acoustics had reached such a technological advancement that with vehicle dynamometer simulation and digital signal processing available now days; it is possible to perform vehicle outdoor noise tests indoors with high degree of accuracy. Test set-up for Indoor Pass-by Noise test is shown in Fig. 2, Fig. 3. Microphones, 14 in number are placed in a line on either one side or both sides of the vehicle (refer Fig. 2). The microphone array is placed at a distance of 7.5 m from the longitudinal centreline of the vehicle. The array is evenly spaced along the line with the array extending from 4 m in front of the vehicle to 10 m behind the front end of the vehicle. Due to limitation of length of the chamber only 14 microphones could be placed instead of 20 microphones.

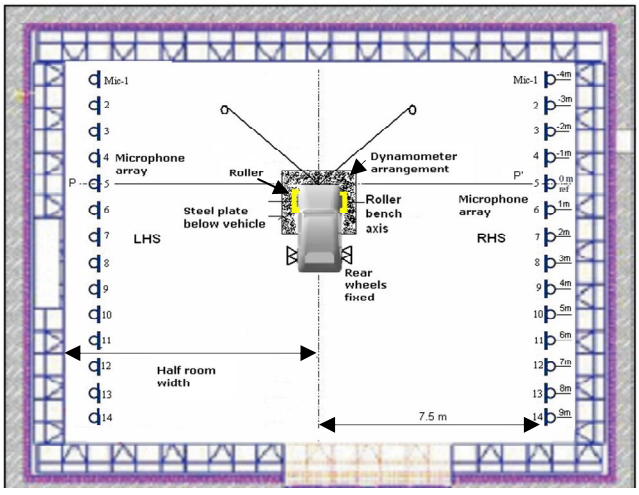

Fig-2: Floor plan of Indoor Pass-by noise test set-up

OPJIT International Journal of Innovation & Research
Vol.- 03, No.-01, Page-48-52, Year-2015

Test set-up for Indoor Pass by Noise Test is shown in Fig. 2. The vehicle is made to run under same two test conditions (2GWOT and 3GWOT) as for Outdoor Pass by noise test as mentioned in section 2.1.1. Acoustic data from each of the measuring microphones is recorded. At the same time, data is acquired to quantify engine speed during the test. These various sources of information are combined, based on a triggered engine speed at AA' line and BB ' line, which are used as reference from outdoor test. The real time data from each of the microphones are sequenced over time, based on the speed of the vehicle and its simulated position along the test track. Through the process of combining these signals, a virtual sweep is made of the microphone array to represent the movement of the vehicle past a single microphone. This data is analyzed to get the overall noise levels during the course of test.

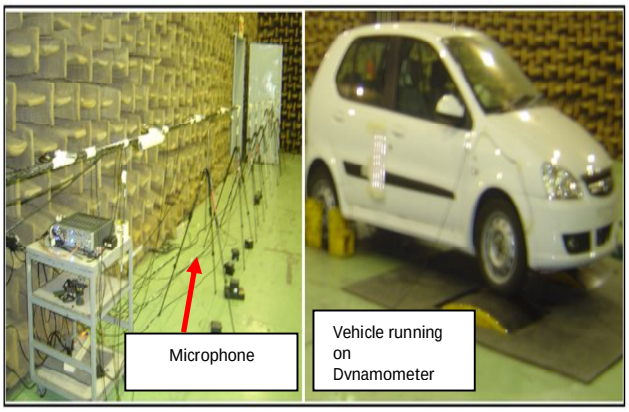

Fig-3: Indoor Pass by Noise, Wide Open Throttle test set-up

2.3 Pass-by Noise, Wide Open Throttle (WOT) Test with Acoustical Treatment on Dynamometer

Fig-4: Schematic of Indoor Pass-by noise Test set-up with Acoustical treatments

This test is conducted to see the effect of Acoustical treatments being provided on Dynamometer roller arrangement (refer Fig. 4). Test set-up used is same as that used for Acceleration test (refer Fig. 2). Acoustical treatments are tried and test results are compared with the baseline condition (without acoustical treatment). Tests are also conducted with three cases, viz., add-on silencer, engine bonnet open and air intake resonator disconnected are conducted along with Baseline condition [3].

3. RESULTS & DISCUSSION

3.1 Pass by Noise, wide open throttle Test

Initially Pass-by noise test is conducted outdoor on the test track then indoor in the semi-anechoic chamber, with the set-up available without any modifications. Analysis is done to compare sound pressure levels with respect to engine speed, between AA' line and BB' line. The results obtained are plotted in Fig. 5, for the case of vehicle running in 2nd gear with wide open throttle and noise measurement being done at left hand side.

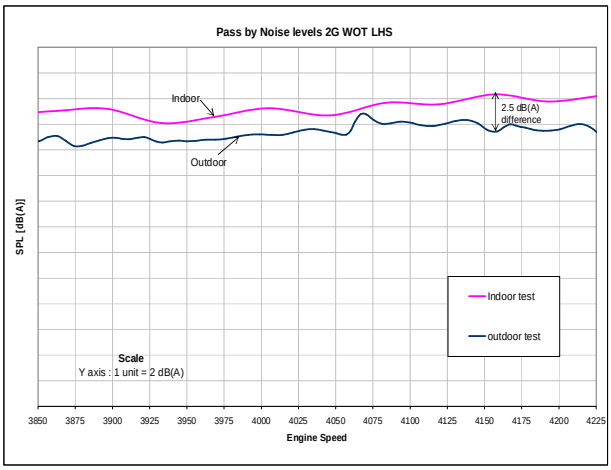

Fig-5: Pass by Noise test, 2GWOT on LHS under Baseline condition

It is observed that, the Sound Pressure Level (SPL) measured in case of indoor test is higher than that measured during outdoor test as seen in Fig. 5. As the engine speed increases sound pressure level increases. The difference in SPL measured is 2.5 dB(A) for 2GWOT. For 2GWOT and 3GWOT tests on LHS, noise levels in case of Indoor test are always on higher side nearly 2.5 dB(A). There could be 4 factors responsible for this difference

- These higher noise levels are due to high frequency dynamometer-roller noise above 1200 Hz.
- Rotation of dynamometer rollers generates noise in the dynamometer room.
- Due to high speed rotation of dynamometer rollers, there is a possibility that the steel plate below the vehicle can have sound radiation due to high frequency vibrations.
- Ground clearance of the vehicle is higher in case of indoor test as compared to outdoor test, since roller height is 100 mm above the floor level of the Chamber.

OPJIT International Journal of Innovation & Research
Vol.- 03, No.-01, Page-48-52, Year-2015

3.2 Pass by Noise, wide open throttle Test

In this case of indoor test, acoustical modifications are done on dynamometer arrangement. Noise analysis is done to compare sound pressure level with respect to engine speed or distance in meter moved by the vehicle. Fig. 6 shows pass by noise levels for baseline condition, 2GWOT-LHS.

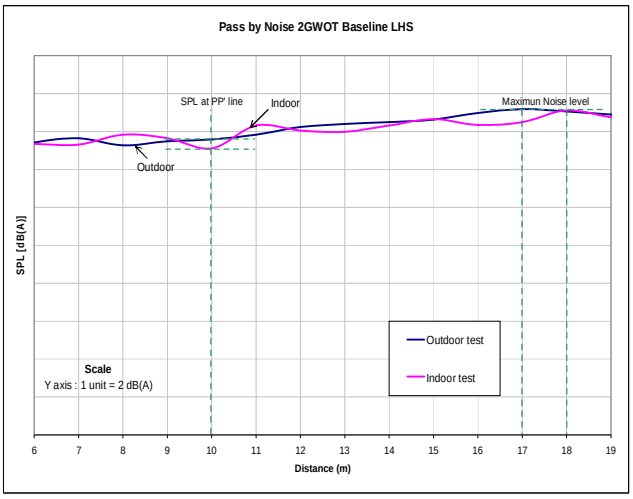

Fig-6: Pass by Noise test for Baseline, 2GWOT – LHS

Table 1 and Table 2 show differences in Maximum Sound Pressure Levels outdoor and indoor under different conditions on LHS and RHS respectively. Frequency analysis at a particular instant is done, where maximum sound pressure level is recorded.

Table-1: Difference in Maximum Sound Pressure Levels on LHS

Test	Condition	Difference in Max. Noise Levels between outdoor and indoor test [dB(A)]
2GWOT-LHS	Baseline	0.12
	Exhaust Noise suppressed	0.05
	Engine Noise Increased	0.26
	Air Intake system modified	0.18
3GWOT-LHS	Baseline	0.30
	Exhaust Noise suppressed	0.08
	Engine Noise Increased	0.16
	Air Intake system modified	0.38

Table-2: Difference in Maximum Sound Pressure Levels on RHS

Test	Condition	Difference in Maximum Noise Levels between outdoor and indoor test [dB(A)]
2GWOT-RHS	Baseline	0.10
	Exhaust Noise suppressed	0.90
	Engine Noise Increased	0.40
	Air Intake system modified	0.20
3GWOT-RHS	Baseline	0.70
	Exhaust Noise suppressed	0.10
	Engine Noise Increased	0.10
	Air Intake system modified	0.10

3.3 Frequency Analysis for Pass by Noise, wide open throttle Test with Acoustical treatment

Results for 1/3 octave noise levels for 2GWOT Pass by Noise test on LHS at maximum sound pressure level is shown in Fig. 6. The various peaks observed are due to different orders of engine firing along with tire acoustical modes. Noise sources like exhaust, air intake, structure, aerodynamic, etc., along the transfer path contributes to the overall noise levels. Similar nature for 1/3 octave analysis is observed in both 2GWOT – LHS and 3GWOT – LHS.

OPJIT International Journal of Innovation & Research
Vol.- 03, No.-01, Page-48-52, Year-2015

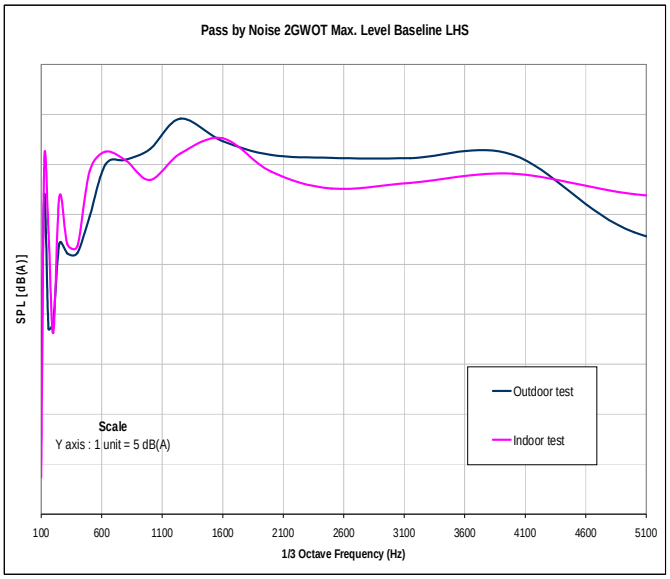

Fig-7: 1/3 Octave levels for Pass by Noise at Max. SPL Baseline, 2GWOT – LHS

4. CONCLUSION

- Variation in Sound pressure levels observed for Pass by Noise, wide open throttle test during outdoor test on a test track and indoor test in a semi-anechoic chamber shows a difference of less than 1 dB(A).
- The difference of less than 1 dB (A) exist with add-on silencer, engine bonnet open and with air intake resonator disconnected cases.
- There is necessity of providing isolation to the dynamometer roller noise in order to obtain better realistic vehicle noise measurement.
- Different peaks observed during the 1/3 Octave frequency analysis are due to different sources of noise mainly engine firing frequency, tire acoustical modes.
- It is possible to reduce number of outdoor tests by conducting indoor test. Since both the tests give noise level within ± 1 dB (A). But for the purpose of mandatory certification measuring Sound pressure level in outdoor test is necessary. The indoor test can reduce the total development duration.
- The variation in the noise levels (i.e., noise in case of outdoor test and in indoor test) are different for left hand side and right hand side of the vehicle, which need to be investigated further.

ACKNOWLEDGEMENT

Authors are thankful to their colleagues, Mr Suhas Dolse, Mr Amol Shewale, Mr Balasaheb Satkar and Mr Umesh for their valuable contributions.

REFERENCES

[1]. International standard ISO 362-1 First edition 2007-07-01, Measurement of noise emitted by accelerating road vehicles — Engineering method-Part 1: M and N categories.
[2]. Indian Standard IS 3028: 1998, “Automotive vehicles-Noise emitted by moving vehicles-method and measurement”.
[3]. Matthew Harrision, “Vehicle refinement Controlling Noise and Vibration in Road Vehicles”, 1st Edition – 2004, SAE International.
[4]. Malcolm J. Crocker, Handbook of “Noise and vibration control”, 2007 John Wiley & Sons, Inc.
[5]. Roberto Cicalo and Leonardo Trozzi, “A Procedure to Simulate the Pass-by Noise Test of a Two-Wheel Vehicle Inside a Semi-Anechoic Chamber”, SAE paper no. 2009-26-044.
[6]. S.H. Park, Y.H. Kim and B.S. Ko, “Method of Pass-by Noise Prediction in a Semi- Anechoic Chamber”, SAE paper no. 971989.
[7]. Klaus Genuit, Sandro Guidati and Roland Sottek, “Progresses in Pass-by Simulation Techniques”, SAE paper no. 2005-01-226 .
[8]. Tim Boland, Jeff Huang, and Walker Flint, “Vehicle Pass-By Exterior Noise In-Cell Simulation Test Method”, SAE paper no. 951358.
[9]. Sung-Ping Cheng, David Griffiths and P. Perry Gu, “Chassis Dynamometer Simulation of Road Noise”, SAE paper no. 971893.
[10]. Yunseon Ryu and Soren, “The Design and Validation of Simulated Indoor Pass-by Noise Measurement System”, SAE paper no. 2007-26-033.

Date of submission: Dec. 2013
Date of acceptance: June 2014