NOISE TESTING AND ANALYSIS OF TWO WHEELERS

A Dissertation
Submitted in partial fulfillment of the requirements for the award of degree of

MASTER OF ENGINEERING
IN
CAD/CAM & ROBOTICS

BY
Karan Chitkara
(Roll No.-80781013)

Under the Guidance of

Dr. S.P Nigam
VISITING PROFESSOR
MECHANICAL ENGG. DEPTT
THAPAR UNIVERSITY, PATIALA

THAPAR UNIVERSITY
PATIALA-147004 (PUNJAB)
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CERTIFICATE

I hereby certify that the work which is being presented in this dissertation entitled as ***"Noise Testing and Analysis of Two Wheelers "*** in partial fulfillment of the requirement for the award of degree of ***Master of Engineering*** in ***CAD/CAM & ROBOTICS*** in the Mechanical Engineering Department, ***Thapar University, Patiala*** is an authentic record of my own work carried out under the supervision and guidance of ***Dr. S.P Nigam*** and refers other researcher's work which are duly listed in the reference section.

The matter embodied in this dissertation has not formed the basis for the award of any other degree, associate ship, fellowship or any other similar title to any other university or institute.

(KARAN CHITKARA)

This is to certify that above declaration made by the student concerned is correct to the best of my knowledge & belief.

15/7/09

(Dr. S.P. NIGAM)
Visiting Professor
Mechanical Engg. Department
Thapar University
Patiala, 147004

Countersigned by:

(Dr. S.K. MOHAPATRA)
Professor and Head,
Mechanical Engineering Department,
Thapar University,
Patiala, 147004.

(Dr. R.K. SHARMA)
Dean of Academic Affairs
Thapar University
Patiala, 147004.

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Date :

Place: PATIALA **(Karan Chitkara)**

ABSTRACT

The number of vehicles like motor-cycles, cars, trucks and scooters etc. are increasing day by day which create large amount of noise on highways and street systems. The purpose of this work is to study the fundamentals of noise and analysis of two wheeler noise which causes serious effects on human beings. So, it is necessary to study the Two Wheeler noise:

1) Present thesis work is completed using four basic methods of monitoring:
   a) Pass by test
   b) Parallelepiped Method for calculating acoustic power.
   c) Frequency analyzer
   d) Motorway noise predicting method.

First method has been used for the measurement of Sound Pressure Level at two operating conditions 3rd and 4th Gear.

Second method has been used for calculating acoustic power at two operating conditions Zero and Full Throttle.

Third method has been used to analyze the variation in Sound Pressure Level with frequency at two operating condition Zero and Full Throttle .

Fourth method has been used to analyzed predicted mean energy emission Level for 10 sec at different speeds.

This work also includes use of Capacitor Microphone to perform acoustical measurements in accordance with ISO standards and recommendations. Further the basic method for pass by test, sound power level measurement with sound pressure level, frequency analysis and motorway noise prediction model have been described with the experimental work.

This kind of present work on noise has been carried out for the first time in Mechanical Engineering Department, Thapar University, Patiala.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Description **Page No.**

CHAPTER – 1: Introduction

In the modern world noise presents an ever growing environmental pollution problem. One of the major reasons for noise pollution is internal combustion engines. Various types of automobiles such as two wheelers, cars and truck traffic operating on highways and street systems produce noise, as do aircraft flights due to jet noise, particularly supersonic-capable aircraft. Most intense noise is created by Rocket engines.

Noise affects the quality of life through a wide range of effects. To name a few, as annoyance, psychological strain, lack of communication, reduced efficiency at work, impairment of hearing, and even damage to physical health. Over the last forty years there has been a growing awareness of the harmful effects of noise and efforts have been made to reduce the noise pollution through improved design of equipment and adhoc noise control measures such as attenuation techniques.

1.1 Definitions [27]

Sound is produced as a result of some mechanical disturbance creating pressure variations in an environment such as air or water, or in fact any medium which can transmit a pressure wave. To be able to hear the sound there must always be air or other medium at the ear. The magnitude of the pressure variations (the amplitude of the pressure oscillation) is proportional to the loudness of the sound. The number of pressure cycles per second (the frequency of the sound pressure variations) determines whether we hear a sound of high pitch or of low pitch, the higher the frequency the higher the pitch. Human hearing responds to frequencies in the range approximately 20 cycles per second to 20,000 cycles per second or “Hertz”.

Noise is commonly defined as an unwanted sound**.** It is a fact of life that we all make noise and as none of us lives in a vacuum, our actions influence the lives of those around us. With no house or flat being totally soundproof, everyone can expect a degree of noise from their neighbours. However, excessive noise can be frustrating and cause unnecessary stress and suffering. It could be too loud, too intrusive, or just happen at the wrong time or without warning, for example, even melodious music played next door may be regarded as noise by someone trying hard to sleep. In a more specific sense, noise is a sound generally of random nature, the spectrum of which does not exhibit clearly defined frequency components. The severity of reaction to the unwanted sound is again a subjective matter and ranges from moderate annoyance to raised blood pressure, erratic heart beats and sometimes even permanent physical damage.

1.2 Sound Sources

(a) Point Source

If source dimensions are small in relation to the distance to the receiver and it radiates an equal amount of energy in all directions. Typical point sources are industrial plants, aircraft and individual road vehicles. The sound pressure level decreases 6 dB whenever the distance to a point source is doubled.

(b) Line Source

It may be continuous radiation, such as from a pipe carrying a turbulent fluid, or may be composed of a large number of point sources so closely spaced that their emission may be considered as emanating from a notional line connecting them. The sound pressure level decreases 3 dB, whenever the distance to a line source is doubled.

(c) Plane Source

If a piston source is constrained by hard walls to radiate all its power into an elemental tube to produce a plane wave, then the tube will contain a quantity of energy numerically equal to the power output of the source. In the ideal situation there will be no attenuation along the tube. Plane sources are very rare and only found in some systems like duct systems.

Addition of Sound Levels

When 2 sources radiate sound energy, they will both contribute to the sound pressure level at a distance away from the sources. If they radiate the same amount of energy and the distance from the point of measurement to the sources is the same, the level will increase by 3 dB compared with the level created by one source alone.

For example, if the measurement for one component is 55 dB and for another component is 52 dB, so there is a difference of 3 dB in it. So from addition curve, 1.7 dB of correction value is taken to get a corrected value. Then 1.7 dB is to be added in the larger value to get the corrected value. So the corrected sound pressure level is 56.7 dB as shown in **Fig. 1.1**.

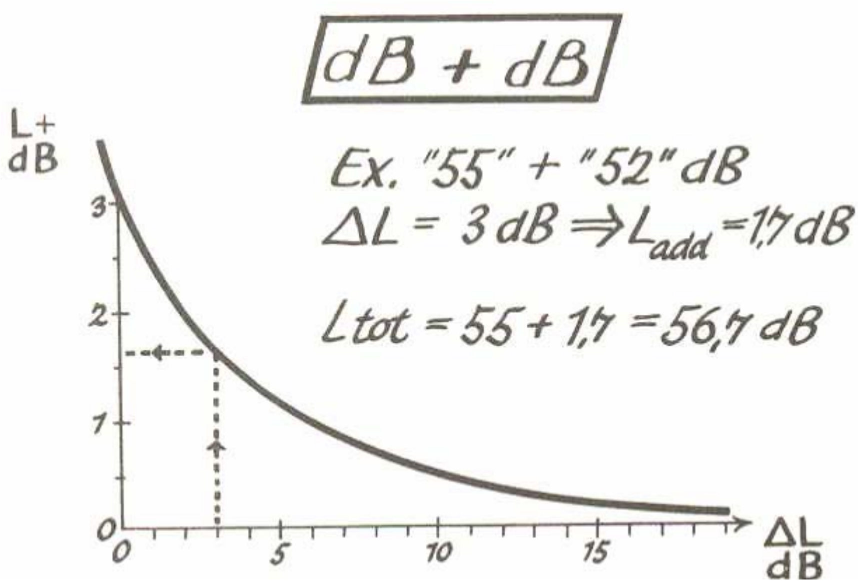

Fig. 1.1 Addition of sound levels

1.3 Sound Propagation

When sound is produced, a transfer of energy from the source to the surrounding air molecules takes place. This energy is transferred to other air molecules, and the energy spreads away from the source like rings in water.

1.3.1 Sound Power Level

Sound Power (W) is the amount of energy per unit time that radiates from a source in the form of an acoustic wave. The Sound Power Level (L_w), in decibels, is defined as:

$$L_w = 10\log_{10} (W/W_0) \quad \_\_\_\_\_\_\_\_\_\_\_\_\_ (1.1)$$

W=sound power in Watts

W_o = reference sound power (10^{-12} watts)

Doubling the sound power increases the sound power level by 3 decibels (dB).

Example:

W = 2 watts: $L_w = 10 \log (2/10^{-12}) = 123$ dB

W = 4 watts: $L_w = 10 \log (4/10^{-12}) = 126$ dB

In a free field (no reflections), the sound from a point source radiates equally in all directions in the form of a spherical wave. This distribution of sound power over the area of the propagating wave is designated as intensity and is measured in units of watts per square meter.

Sound power cannot be measured directly. It is possible to measure intensity, but the instruments are relatively expensive and must be used carefully. Under most conditions of sound radiation, sound intensity is proportional to the sound pressure. Sound pressure can be measured more easily, so sound measuring instruments are built to measure the sound pressure level in dB.

1.3.2 Sound Pressure Level (L_p)

Sound pressure is a pressure disturbance in the atmosphere whose intensity is influenced not only by the strength of the source, but also by the surroundings and the distance from the source to the receiver. Sound pressure is what our ears hear, what sound meters measure and what ultimately determines whether a design achieves quality sound.

The Sound Pressure Level (L_p), in decibels, is given by the following:

$$L_p = 20 \log_{10} (p/p_0) \qquad (1.2)$$

p = measured root-mean-square (rms) sound pressure

p_0 = reference rms sound pressure (20 micropascals (μPa))

The reference sound pressure of 20 micropascals approximates the normal threshold of human hearing at 1,000 Hz.

The multiplier above is 20 and not 10 (as in the case with sound power level). This is because the sound power is proportional to the square of sound pressure and $10 \log p^2 = 20 \log p$.

There is a significant advantage to using decibel notation rather than the wide range of pressure or power.

A change in sound pressure by a factor of 10 corresponds to a change in sound pressure level of 20 dB:

p = 40 μPa: $L_p = 20 \log (40/20) = 6$ dB

p = 400 μPa: $L_p = 20 \log (400/20) = 26$ dB

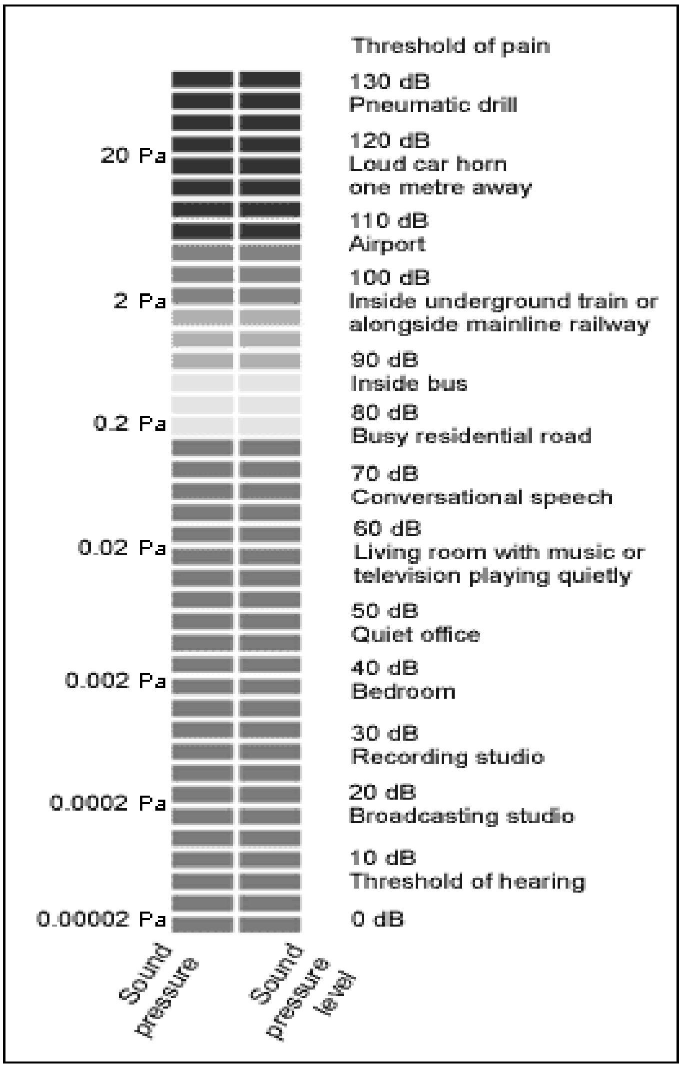

Fig. 1.2 Comparison between Sound Pressure and Pressure Level

1.3.3 Difference between Sound Pressure and Power Level

There is a common tendency to confuse sound power with sound pressure. Sound power is analogous to the power rating of a light bulb.

- A "weak" sound source will produce low sound levels, whereas a "stronger" sound source will produce higher sound levels.
  - Sound power level is independent of the environmental surroundings.
  - The magnitude of the sound pressure from a given sound source, however, depends on the distance from the source and the characteristics of the environmental surroundings.
- Sound pressure level is readily measured by instruments, but sound power cannot be measured directly.

1.4 Frequency Spectrum

If a sound has components at one frequency only, it is said to be a pure tone. Such sounds are not very common in nature, however, and the only common example of a pure tone is the sound of a tuning fork. Most usually, sounds have components at several frequencies and the character or timbre of a steady sound is determined by the pressure amplitudes at the different component frequencies. We can therefore describe a steady sound by a graph of frequency against amplitude, and such a graph is referred to as the Frequency Spectrum of the sound. Sound measuring instruments are usually constructed to measure the frequency spectrum, but for measurement convenience and simplicity of the instrument in practice we measure the energy content in a particular range of frequencies. Some examples of the frequency spectra of particular sounds are shown in **Fig. 1.3**.

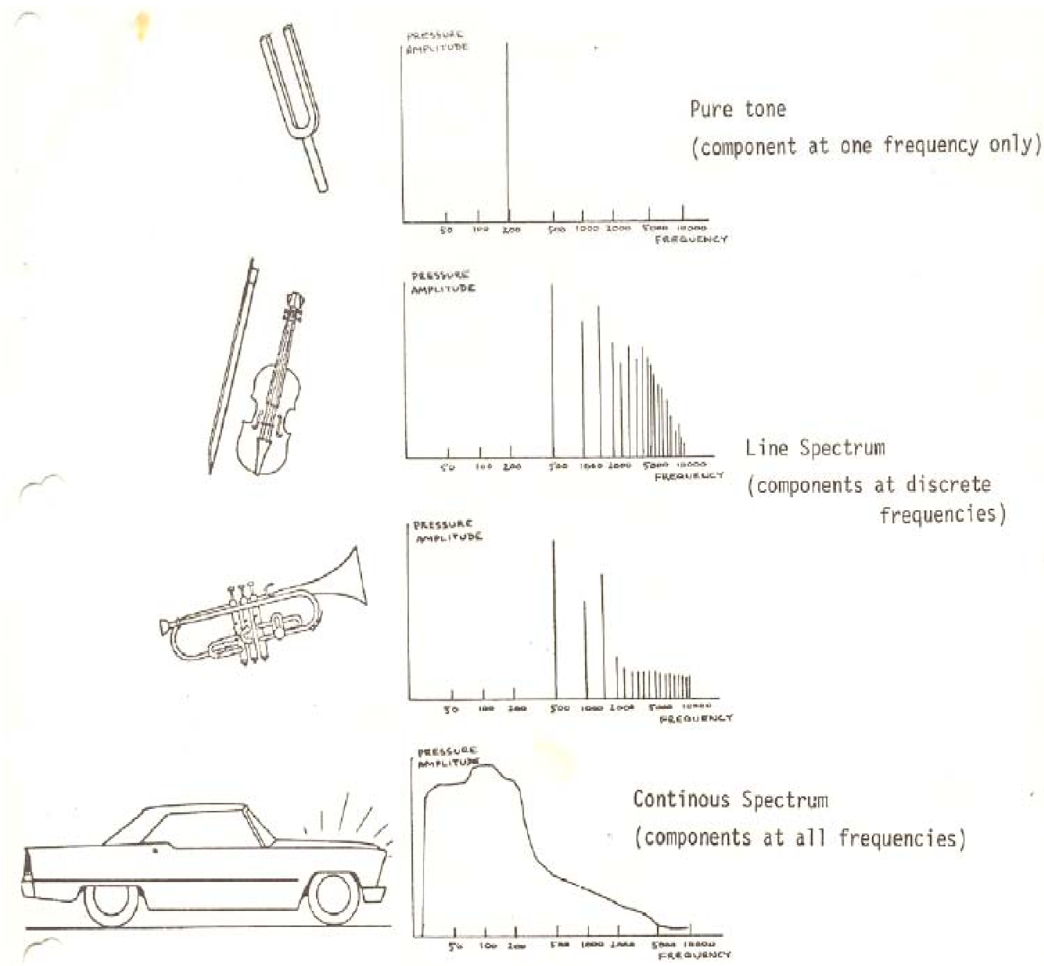

Fig. 1.3 Examples of frequency spectra

1.5 Frequency Analyzers

The spectra in **Fig. 1.3** are those which would be obtained from a narrow bandwidth analyzer, since the pure tone components appear as single lines of thickness equal to the frequency bandwidth of the analyzer. Such analyzers are not very common in practice because of the large number of frequency intervals which would be required to build up a complete spectrum and the consequent long time of analysis. For most purposes where resolution of the exact frequency of a pure tone is not important, the frequency spectrum is built up from larger frequency intervals, the most common bandwidths being 1-1 octave bands and third octave bands. Octave bands contain a range of frequencies the upper limit of which is double the frequency of the lower limit (or $f_{upper} = 2 f_{lower}$). The third octave band is defined by the limits

$$f_{upper} = 2^{1/3} f_{lower} \qquad \_\_\_\_\_\_\_\_\_\_(1.3)$$

All frequency bands are usually referred to a Centre Frequency which is the geometric mean frequency of the band;

$$(c_{entire} = \sqrt{\ } f_{upper} \sqrt{\ } f_{lower}) \qquad \_\_\_\_\_\_(1.4)$$

Frequency spectra such as those in Fig.2.1 take no account of variations with time and represent simply the average level of the sound over a particular interval.

1.6 Characteristics of Sound

2.6.1 Loudness

It is a perceptual intensity of sound. Loudness depends importantly on the physical intensity of sound, increasing when physical intensity increases and decreasing when physical intensity decreases. But loudness also depends on other physical properties of sound, such as frequency and duration. Much of the object of noise analysis and control is directed towards comfort for the human ear.

Increase in loudness for a corresponding increase in sound level depends upon frequency and on Sound Pressure Level as well which has been shown in **Fig. 1.4**.

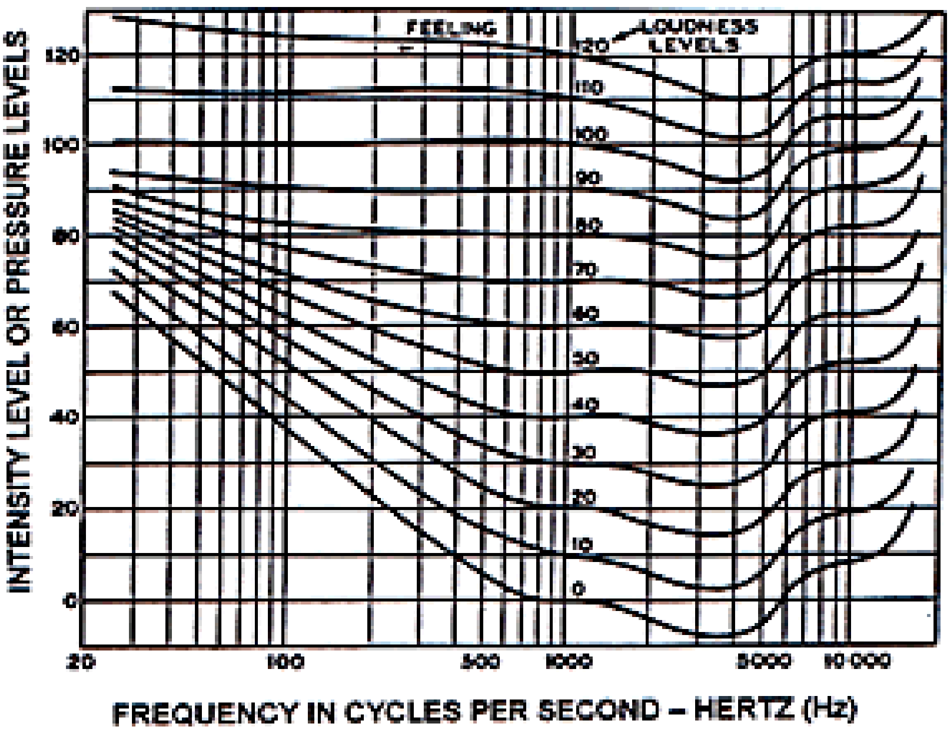

Fig. 1.4 Equal loudness curve

Non-linear response of ear

1000Hz of **40dB** is same loudness as **63Hz** tone of **58dB** or **4000Hz** of **31dB** similarly 1000Hz of 100dB has source loudness as 106dB tone at 63Hz or a 90dB tone at 4000Hz.

1.6.2 Frequency-Weighted Contours (dB(A), dB(B), and dB(C))

The non-linear response of the ear has lead to the introduction of weighting filters, making it possible to carry out measurements, correlate well with the response of the ear.

The most commonly used of these curves is the A-weighting curve, because it gives the best correlation between the measured values and the annoyance and harmfulness of the sound signal. It follows approximately the 40 dB curve in **Fig. 1.5**. The B-weighting and C-weighting curve follow more or less the 70 dB and the 100 dB curves. The D-weighting curve follows a contour of perceived noisiness, and is used for aircraft noise measurement. Weighting filters can easily be built into portable Sound Level Meters, and the sound level measured is then given in dB(A) in cases where an A-weighting filter has been used etc.

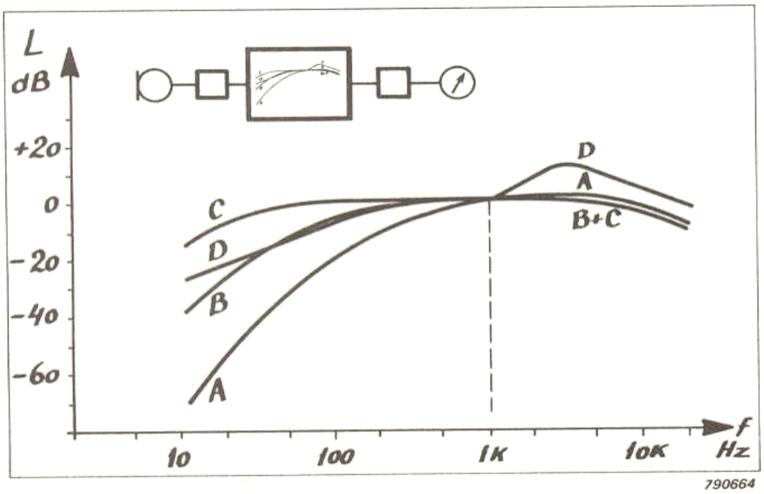

Fig. 1.5 Weighting curves

1.6.3 Background Noise

When sound measurement, on for instance a machine, is carried out, it is important that the background noise level is so low, that it does not have any influence on the result. This can be tested in the following manner. Measure the sound at the position where it should be measured with the source (machine) running. Switch off the machine and measure the sound level without the machine running.

If the difference is less than 3dB measurements should be stopped until the background noise has been reduced. If the difference is between 3 and 10 dB use the curve to correct the measured value. If the difference is more than 10 dB, the background noise may be ignored as shown in **Fig. 1.6**.

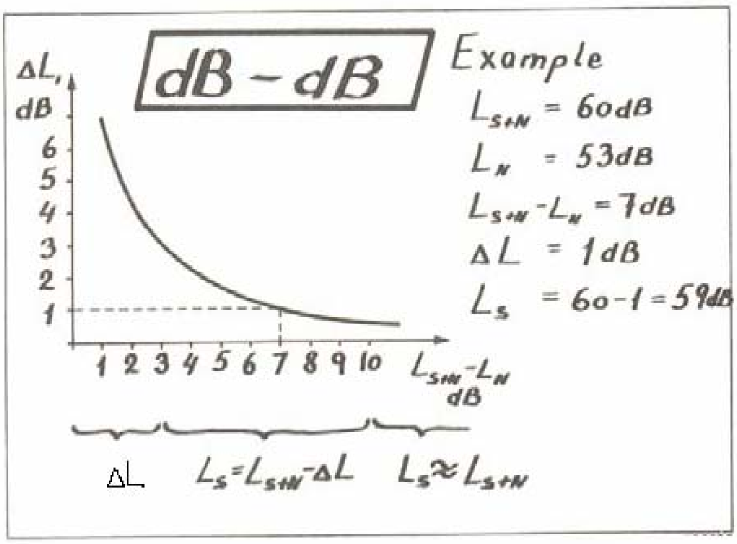

Fig. 1.6 Subtraction of background noise in dB

1.6.4 Equivalent Continuous Sound Level

L_{eq} is the A-weighted energy mean of the noise level averaged over the measurement period. It can be considered as the continuous noise which would have the same total A-weighted acoustic energy as the real fluctuating noise measured over the same period of time and is defined as

$$L_{eq} = 10 \log_{10} 1/T \int_0^T (p/p_{ref})^2 \, dt \qquad \text{---------------------(1.5)}$$

Where T is the total measurement time,

P(t) = A-weighted instantaneous acoustic pressure

P_{ref} = Reference acoustic pressure of 20 μPa

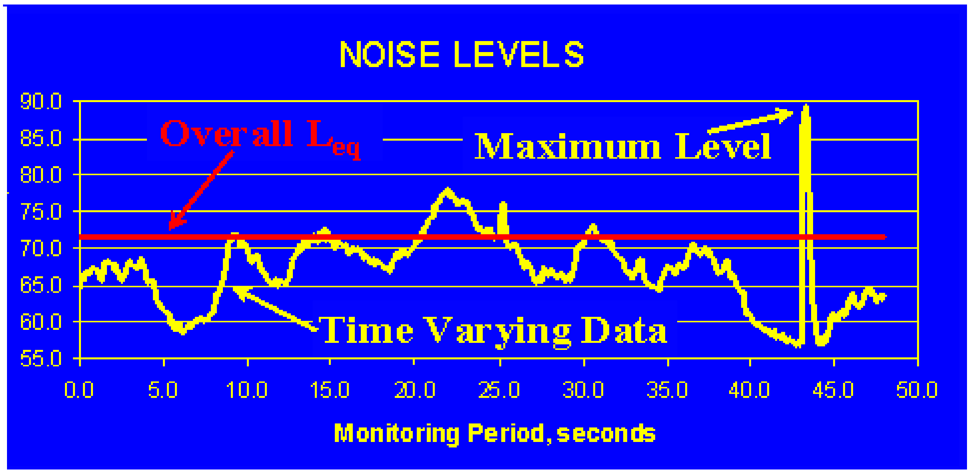

Fig. 1.7 Equivalent continuous sound level

1.6.5 Percent Noise Level (L_n)

To account for intermittent or fluctuating noise, another method to characterize noise is the Percent Noise Level (L_n). The Percent Noise Level is the level exceeded n% of the time during the measurement period. It is usually measured in dB(A), but can be expression of any noise rating scale. For example, L_{90} is the noise level exceeding 90 percent of the time, L_{50} is the level exceeding 50 percent of the time, and L_{10} is the level exceeding 10 percent of the time. L_{90} is generally regarded as the background sound level, L_{50} represents the median level, and L_{10} represents the peak or intrusive noise level. Percent noise level is commonly used in community noise ordinances that regulate noise from mechanical equipment, entertainment noise sources, etc.

1.6.6 Maximum Sound Pressure Level (L_{max})

The maximum Sound Pressure Level (dB) measured over a stated period, using a stated time period using an exponential time constant (fast, slow or impulse). When the exponential time constant is not provided, it is assumed that fast response has been used. Its measurement can only be obtained with a “maximum hold” feature, which serves to capture and store

L_{max} data. This metric is useful in exploring the maximum levels encountered in events which occur quickly such as slamming of a door or the noise emitted by passing Trucks. It also shows in **Fig. 1.7**.

Maximum Impulsive sound level shall be measured using the "fast response" setting.

Maximum Continuous sound level shall be measured using the "slow response" setting.

1.7 Harmful Effects of Noise on Human Beings

1. Reduces work efficiency.
2. Affects the speech communication.
3. May cause temporary threshold shift (TTS) / permanent threshold shift (PTS).
4. Induces loss of hearing ability.
5. Causes psychological strain and mental fatigue.
6. May damage the heart.
7. Increases the cholesterol level in the blood.
8. Dilates the blood vessels of the brain.
9. Upsets the chemical balance of the body.
10. Causes headache, nausea and general feeling of uneasiness.

1.8 Major Sources of Noise

1. Road Traffic Noise

In the city, the main sources of traffic noise are the motors and exhaust system of autos, smaller trucks, buses, and **two wheelers**.

2. Air Craft Noise

Now-a-days, the problem of low flying military aircraft has added a new dimension to community annoyance, as the nation seeks to improve its nap-of the-earth aircraft operations over national parks, wilderness areas, and other areas previously unaffected by aircraft noise has claimed national attention over recent years.

3. Noise from railroads

The noise from locomotive engines, horns, whistles, switching and shunting operation in rail yards can impact neighbouring communities and railroad workers. For example, rail car retarders can produce a high frequency, high level screech that can reach peak levels of 120 dB at a distance of 100 feet, which translates to level as high as 138 or 140 dB at the railroad worker's ear.

4. Construction Noise

The noise from the construction of highways, city streets and buildings is a major contributor to the urban scene. It includes pneumatic hammers, air compressors, bulldozers, loaders and dump trucks.

5. Noise in Industry

Although industrial noise is one of the less prevalent community; noise problems, neighbours of noisy manufacturing plants can be disturbed by sources such as fans, motors, and compressors mounted on the outside of buildings Interior noise can also be transmitted to the community through open windows and doors, and even through building walls. These interior noise sources have significant impacts on industrial workers, among whom noise- induced hearing loss is unfortunately common.

6. Noise in building

Apartment dwellers are often annoyed by noise in their homes, especially when the building is not well designed and constructed. In this case, internal building noise from plumbing, boilers, generators, air conditioners, and fans, can be audible and annoying. Improperly insulated walls and ceilings can reveal the sound of amplified music, voices, footfalls and noisy activities from neighbouring units. External noise from emergency vehicles, traffic, refuse collection, and other city noise can be a problem for urban residents, especially when windows are open or insufficiently glazed.

7. Noise from Consumer products

Certain household equipment, such as vacuum cleaners and some kitchen appliances have been and continue to be noisemakers, although their contribution to the daily noise dose is usually not very large.

1.9 Noise Measuring Instrument

Noise measuring devices typically use a sensor to receive the noise signals from a source. The sensor, however, not only detects the noise from the source, but also any ambient background noise. Thus, measuring the value of the detected noise is inaccurate, as it includes the ambient background noise.

The sound pressure level can be measured with a Sound Level Meter, which basically contains the following 5 blocks.

1. Microphone
2. Amplifier
3. Rectifier
4. Smoothing circuit
5. Meter

1.9.1 Capacitor Microphone

It is an electronic component which stores energy in the form of an electrostatic field and uses a capacitor to convert acoustical energy into electrical energy.

Condenser microphones require power from a battery or external source. The resulting audio signal is stronger signal than that from a dynamic. Condensers also tend to be more sensitive and responsive than dynamics, making them well-suited to capturing subtle nuances in a sound.

How Capacitor Microphones Works?

A capacitor has two plates with a voltage between them. In the condenser microphone, one of these plates is made of very light material and acts as the diaphragm. The diaphragm vibrates when struck by sound waves, changing the distance between the two plates and therefore changing the capacitance. Specifically, when the plates are closer together, capacitance increases and a charge current occurs. When the plates are further apart, capacitance decreases and a discharge current occurs.

A voltage is required across the capacitor for this to work. This voltage is supplied either by a battery in the microphone or by external phantom power.

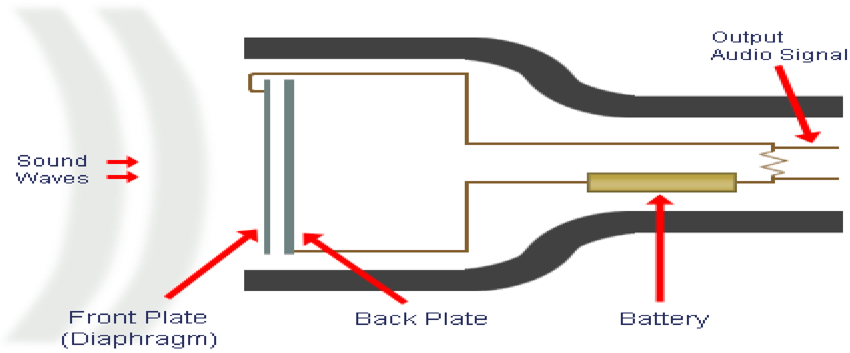

Fig. 1.8 Cross-Section of a typical Capacitor Microphone

1.9.2 Steps in Measurement of Noise

(a) Check the Sensitivity (calibration) of the Measurement System

Before and after each measurement.

It is a legal requirement.

(b) Measure the Acoustical Noise Level

Apply all Necessary Correction to the Observed Measurement

1. Correction for Back Ground Noise.
2. Correction for reflection of nearby surfaces
3. Correction for ambient pressure

1.9.3 Various Conditions which Creates an Error in Measurement

(a) Effect of the Instruments Case and of an Observer on the Measurement

The most convenient way to make acoustical measurement in the field is by use of hand-held instruments. The instruments case and the body of the observer holding the case may affect the measured data, particularly when the observer is close to microphone.

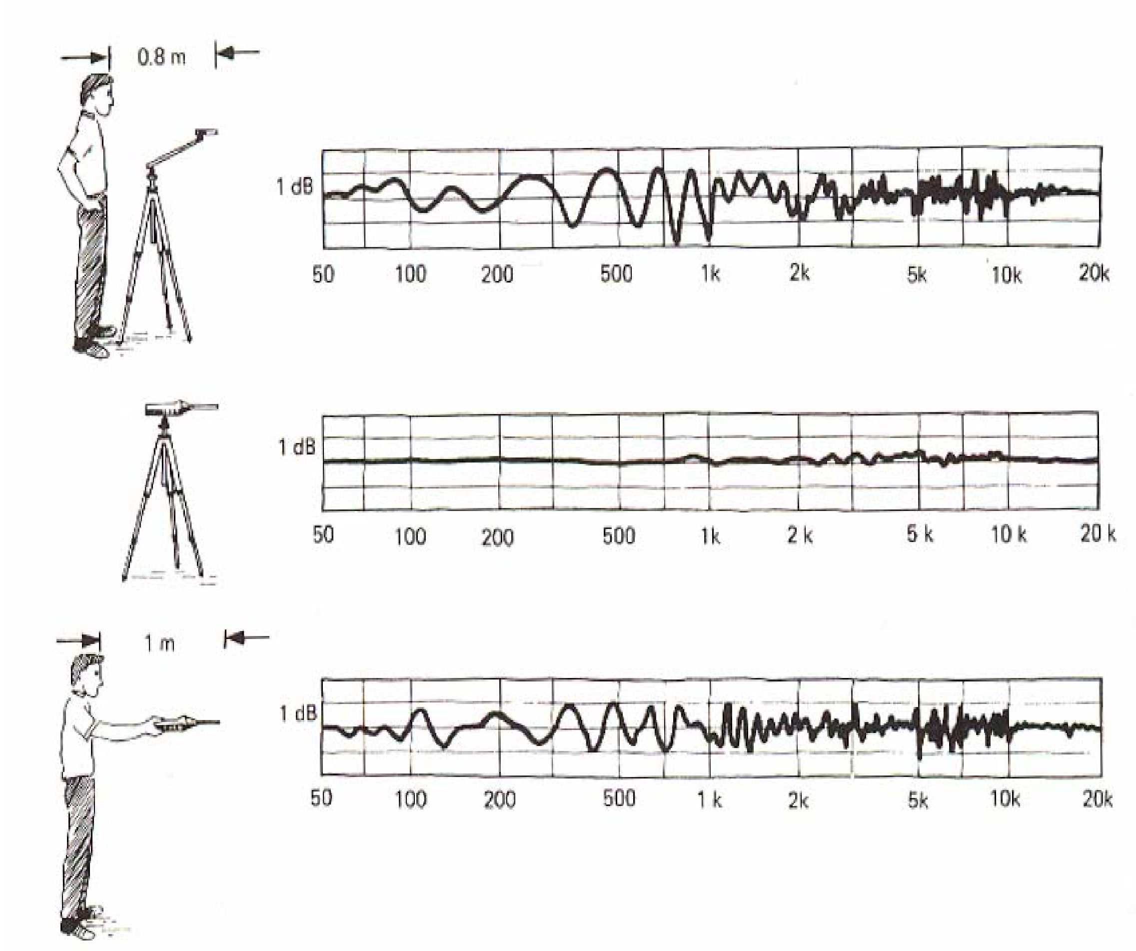

Fig. 1.9 Accurate SLM position

(b) Effect of Humidity

Humidity (Moisture) can have a serious effect on the operation of some type of measuring microphone, especially those of capacitor type.

For capacitor type microphone, high level, intermittent , internal noise may result at moderate--to-high humidity or condition where condensation occur at diaphragm due to microphone cooler than surrounding air.

(c) Effect of Temperature

If cold microphone is brought into warm air, or if the temperature decreases rapidly in the presence of high humidity, droplets of water may condense on the microphone leading to break down of electrical field between the diaphragm and the back plate and to the generation of high-level intermittent electrical noise.

CHAPTER – 2: Literature Review

A wealth of literature exists in the area of noise and a lot of time and effort has been devoted to develop different methods for noise identification in Two Wheelers. From a long time, work is continued in this field. Some important works are as below:

C.H.G. Mills and D.T. Aspinall [1] discussed the various sources of the noise in I.C. engine commercial vehicle and methods of noise reduction by the use of high transmission-loss enclosures and sound-absorbent and panel-damping materials are described. Examples are given on the practical applications of acoustical treatments to the reduction of the noise within and emitted by typical road haulage vehicles. Useful reductions can achieve by palliative treatments but attention is drawn to the practical and economic difficulties associated with incorporation of sound reducing treatments in production vehicles.

Wonnacott E. J [2] proposed a work to analyze and build a series of efficient silencers for general vehicle and stationary engine use. The recommended design procedure has generally been found to be flexible in its application and the silencers thus designed appear to have distinct advantages over their current counterparts in relation to design simplicity, ease of manufacture and consistent attenuation performance throughout their useful life. The results of these trials are described together with details of the manufacturing and testing problems that have been experienced in building such units for each specific application.

Jha S.K [3] proposed a detailed study of the characteristics of noise and vibration in a motor car. The predominant frequency regions in which noise levels are high are established. It is shown that the major part of the sound energy lies within the frequency region below 20 Hz and is caused mainly by road excitation being transmitted through the wheel and suspension system. The predominant noise in the audible range lies within 30-300 Hz frequency band and is produced primarily by body resonances excited by various engine harmonics. The vibrational and acoustical behavior of the car body at some of these critical frequencies is also discussed. Finally it is shown that by structural modification a substantial noise reduction can be obtained.

W. D. Bryce and R. C. K. Stevens [4] identified and understand the noise sources that contribute to the exhaust noise of aircraft gas turbine engines, controlled experiments have been carried out to study the noise characteristics of a model turbo-jet exhaust system. The noise data have been related to measurements of the aerodynamic conditions in the model and, with the aid of specific diagnostic tests, the predominant noise mechanisms are considered to have been recognized. The noise radiation, above that of the jet, is attributed primarily to dipole sources generated by the turbine outlet struts, the transmission of this noise being modified by duct propagation and nozzle impedance effects.

Jayaram V. D. and Jarchow F [5] proposed a work for finding the effect of the operating speed and the imposed load on the noise characteristics of commercially available ball bearings was studied at different speeds and loads using various lubricants. The noise level significantly increases with the speed factor, a progressively higher load factor increases the noise level but to a minor extent. Higher viscosity lubricants were beneficial in diminishing the noise level.

Oguchi Tetsuru [6] studied the piston slap noise, which is generated by the sudden impact of the piston on the cylinder wall, is the most predominant mechanical noise emitted from the engine. It is studied here in terms of its transmission paths through the engine elements. Two engines with different cylinder liners types are tested in a non-running condition. The transmission paths are measured and evaluated in terms of the mechanical mobility, the ratio of the velocity response on the cylinder wall to the force applied to the external surface of the engine, which represents, by reciprocity, the ratio of the velocity response on the external surface of the engine to the force applied to the cylinder wall. The work concentrates on the major transmission paths of the piston slap noise and the factors which affect that transfer mobility in the frequency range of 1.5 to 4 kHz.

The major transmission path of the piston slap noise is experimentally determined to be the path through the cylinder wall and the upper deck of the cylinder block to the external surface of the cylinder block.

Slack James W [7] studied the piston slap, is typically the major source of noise and vibration in the I.C. Engine. An investigation of piston slap noise in an I.C. Engine is carried out. Vibration measurements are carried out at connecting rod, cylinder wall and block surface while monitoring. Drive point and transfer mobility measurements were made on non-running engine. The measured mobility's are used to construct a model of piston-cylinder wall interaction which predicts the excitation due to the piston slap. The measured transfer mobility's are used to predict vibration transfer to the block surface. Bending of the connecting rod is to play an important role in both the excitation and vibration and the transmission of vibration energy to the block surface.

Lim M. K. and Low S. C [8] proposed a work on an engine-cylinder-pressure-damping device has been designed to reduce engine noise by controlling the sharp pressure-rise excitation applied to the engine structure by the combustion process. The device is a small piston controlled by a spring-and-dashpot system connected to the engine cylinder by mounting it on top of the cylinder head. Laboratory tests showed that there was a significant reduction in engine surface vibration and noise radiated, particularly at high frequencies above 4000 Hz.

A least squares method is applied by **Desmons L et al [9]** to characterize an internal combustion engine considered as a noise source. It is shown that although extremely severe conditions exist "high sound pressure level high temperatures turbulent a linear theory can predict the noise level at the output of the exhaust systems with a surprisingly good accuracy when the transfer matrix is known". The measurements avoid the use of calibrated internal microphones only one external microphone and a set of calibrated loads are needed. An indirect validation of the linearity hypothesis is achieved and the predicted exhaust noise level is compared with experimental results in the case of a tube and in the case of a silencer composed of three expansion chambers.

Torben Astrup[10] gives an overview of observations from almost I.5 years of practical experience with acoustic intensity measurements. The often difficult working conditions of acoustic consultants mean that we tend to make demands on the measuring methods and the instrumentation that presently cannot easily be met.

Therefore the instrumentation should be improved in order to increase both the dynamic and the frequency range. Further development of ‘real-time’ control of measurement quality is also desirable, i.e. the possibility of surveying the quality of the result during or immediately after the measurement is performed.

The objectives combine the achievement of sound emission targets with the maintenance of optimum engine performance and fuel efficiency throughout a specified range of operating conditions. Practical experience demonstrates that the relevant technology includes a quantitative evaluation of those factors directly concerned with engine operation and breathing, those factors influencing the excitation and propagation of pressure waves through the relevant system and those factors controlling the emission of sound to the surrounding environment. A summary of previous and current developments in appropriate existing numerical codes for performing the detailed calculations and associated performance assessments with increasing realism is provided by **Davies P. O. A. L and Holland K. R [11]**

The main objective of this paper written by **Kim Y. S and Lee D. J [12]** is to identify the mechanism of generation, propagation and radiation of the intake noise. With a simple geometric model, it is found that one of the main noise sources for the intake stroke is the pressure surge, which is a compression wave due to the compressed air near the intake valve after closing. The pressure surge, which has the non-linear acoustic behavior, propagates and radiates with relatively large amplitude. In this paper, unsteady compressible Navier Stokes equations are employed for the intake stroke of axisymmetric model having a single moving piston and a single moving intake valve. To simulate the periodic motion of the piston and the valve, unsteady deforming mesh algorithm is employed. For the purpose of perfect closing of the intake valve, the numbers of mesh are changed using a Lagrange interpolation. In order to resolve the small amplitude waves at the radiation "field, essentially non-oscillatory (ENO) schemes are used. The source of the intake noise can be identified through the visualization of propagation in a finite duct and radiation to the far fields. Comparison with measured data is given for in-duct pressure showing a better agreement than the one-dimensional calculation data.

Single pipes used in a conventional vehicle exhaust system are not enough to reduce exhaust noise to a satisfactory level, especially at high frequencies. Double pipes are elective for reducing noise, but still not enough, and they are heavy. The new method developed by **Akama Hiroshi [13]** and Braided Wire Damper is an exhaust pipe partly wrapped with braided wire net. Proposed here is the use of & Braided Wire Damper and it is found to be very elective for reducing not only the noise but also the weight of the exhaust system.

Cho S.H et al [14] studied the concept of piston slap and model or estimate the impact forces using FEM. One of the major sources of noise and vibration in an internal combustion engine is the impact between piston and cylinder wall. The crank-slider mechanism of an internal combustion engine has very small clearance between piston and cylinder inner wall. The clearance is very small but large enough to induce the piston's secondary motion periodically and finally generates unwanted sound and vibration. This secondary motion across the clearance between piston and cylinder inner wall is caused by the side thrust force that changes its direction depending on its position. This side thrust force is induced by the connecting rod. As a result, the piston moves from one side to opposite side in the cylinder. Then eventually, the piston collides against the cylinder inner wall. These impact phenomena are called “piston slap".

There have been many attempts to model or estimate the impact forces and the side thrust force. These are a function of inertia force of piston and connecting rod and explosive force in internal combustion engine. There are also studies on the dynamics of planar crank-slider mechanism in order to investigate the influence of the clearance gap size, bearing friction, and crank speed on the response of the system. Finite Element Method (FEM) has been also applied in order to analyze the impact force. However, the models as well as FEM are not satisfactory to estimate the impact forces. This is because the basic mechanism associated with the piston slap is complicatedly related to the mechanical elements of engine block.

A model of highway traffic noise is formulated by **Pamanikabud Pichai and Vivitjinda Prakob [15]** based on vehicle types. The data were collected from local highways in Thailand with free-flow traffic conditions. First, data on vehicle noise was collected from individual vehicles using sound level meters placed at a reference distance. Simultaneously, measurements were made of vehicles_ spot speeds. Secondly, are data for building the highway traffic noise model. This consists of traffic noise levels, traffic volumes by vehicle classification, average spot speeds by vehicle type, and the geometric dimension of highway sections. The free-flow traffic noise model is generated from this database. A reference energy mean emission level (the basic noise) level for each type of vehicles is developed based on direct measurement of Leq (10 sec) from the real running condition of each type of vehicles. Modification of terms and parameters are used to make the model fit highway traffic characteristics and different types of vehicle.

It has been recently reported that smooth tires generate noise. This paper written by **Koizumi Takayuki et al [16]** investigates smooth tire vibration noise generated by rolling on roads. Because of difficulties in measuring exciting forces, we undertake an operational analysis to examine rolling tire vibration behavior. Rolling tire vibration is measured using a scanning laser Doppler vibrometer. In addition, we measured sound intensity to investigate the relation between vibration and sound radiation. Rolling tire sound radiation is estimated by applying the results of the operational analysis to the boundary element method, and the results of predicting sound intensity radiation show good agreement with experimented data.

Torregrosa A.J et al [17] discusses issues related to the estimation of flow noise emission from rear mufflers in IC engine exhaust systems, through the analysis of measurements performed in a steady cold flow bench. First, the net acoustic power transmitted along the outlet pipe is obtained from in-duct pressure measurements. The induct power is then compared with noise measurements carried out in a semi anechoic chamber, in order to distinguish between flow noise contributions associated with internal generation (muffler and tailpipe) and flow noise produced in the discharge process (interaction between the outgoing flow and the outside atmosphere). The ratio between the tailpipe in-duct acoustic power and the radiated acoustic power is analyzed as a function of the Strouhal number. The results provide some information about the relative importance of internal and external sources

.

Engine exhaust noise source is often described in frequency domain by the impedance and strength of an equivalent acoustic one-port source at a reference plane downstream of the exhaust manifold. These parameters can be measured by experimental methods, however, it is also desirable to develop methods for their prediction. A pre-requisite for the prediction of the equivalent one-port acoustic source parameters of an engine manifold is a linear mathematical model of the breathing noise generation mechanism at the valves. The present paper written by **Dokumaci E [18]** proposes new mathematical models for this source mechanism and the prediction of the one-port source characteristics of engine exhaust noise. The analysis is based on basic fluid dynamic equations for inviscid one-dimensional flow and encompasses both linear time-invariant, linear time variant and non-linear one-port source models. A systematic procedure is presented for the calculation of one-port source characteristics of engine manifolds, with an application to a 4 cylinder engine exhaust manifold.

Tansatcha M, Pamanikabud P, Brown A.L and Affum J.K [19] A model for motorway traffic noise has been obtained from measurements along the Bangkok–Chonburi motorway. The model_s parameters include traffic volume and combination, the average spot speed of each type of vehicle and the physical conditions of the motorway in terms of right-of-way width, number of lanes, lane width, shoulder width, and median width for both of the main carriageways and frontage roads. The noise level that is generated by each type of vehicle has been analyzed according to the propagation in the direction perpendicular to the center line of motorway_s carriageway. The total traffic noise is then analyzed from traffic volume of all vehicle types on both sides of carriageways and frontage roads. The basic noise levels used in the motorway traffic noise model are modified according to the effective ground effect along the propagation path. The final result of this study is that a motorway traffic noise model based on the perpendicular propagation analysis technique performs well in a statistical goodness-of-fit test against the field data, and therefore, can be used effectively in traffic noise prediction for related or similar motorway projects.

A Shrivastava, M Dang [20] studied a novel setup for measuring sound power emitted by an automobile engine has been designed and fabricated in this study. Sound pressure levels have been measured to compute sound power level as per ISO Standard 3744. A microphone traversing system has been designed and fabricated to measure sound pressure at various points on a spatial grid. Sound pressure level and spectra have been measured at these points for various operating conditions of throttle opening and speed. The setup seems to be a cost effective option for automobile engine industry for power level certification and for online silencer design.

The noise emission level associated with two types of speed reducers has been investigated by **Behzad M. et al [21]** both numerically and experimentally for different dimensions and different speeds of vehicle (20, 40 and 60 km/h) and zero acceleration. Numerical analysis has been performed using an FEM method in the ANSYS environment. The experiments show that for a bump of height 0.04 m, the peak noise level is increased by between 1 and 14 dB (A) whereas, for bump of height 0.055 m, the peak noise level increases by between 1 and 19 dB (A). There is an excellent agreement between the numerical and experimental results.

Yong Hao Zhi et al [22] proposed an independent component analysis was applied to analyze the acoustic signals from diesel engine. First the basic principle of independent component analysis (ICA) was reviewed. Diesel engine acoustic signal was decomposed into several independent components (ICs); Fourier transform and continuous wavelet transform (CWT) were applied to analyze the independent components. Different noise sources of the diesel engine were separated, based on the characteristics of different component in time-frequency domain.

The effects of vehicles and pavement surface types on noise have been investigated at the Korea Highway Corporation's Test Road along the southbound side of the Jungbu Inland Expressway, South Korea. The study was conducted in 2005 and 2006 by **Cho Dae Seung et al [23]** through field measurements at nine surface sections of asphalt concrete and Portland cement concrete pavements using eleven vehicles. For the road noise analysis, the sound power levels (PWLs) of combined noise (e.g., tire/pavement interaction noise and power-train noise together) and tire/pavement interaction noise using various vehicles were calculated based on the novel close proximity (NCPX) and pass-by methods. Then, the characteristics of the PWLs were evaluated according to surface type, vehicle type, and vehicle speed. The results show that the PWLs of vehicles are diversely affected by vehicle speed and the condition of the road surface.

Brake squeal noise has been under investigation by automotive manufacturers for decades due to consistent customer complaints and high warranty costs. J.D. Power surveys consistently show brake noise as being one of the most critical vehicle quality measurements. Furthermore, the development of methods to predict noise occurrence during the design of a brake system has been the target of many researchers in recent years. This paper written by **Junior Mario Triches et al [24]** summarizes the application of complex Eigen value analysis in a finite element model of a commercial brake system. The effect of the operational parameters (friction coefficient, braking pressure and brake temperature) and wear on the dynamic stability of the brake system is examined. After identifying unstable frequencies and the behavior of the brake system under different conditions, the performance of some control methods are tested. Changes in material properties and the application of brake noise insulators are presented and their effects discussed. The results show that the effect of brake temperature changes the coupling mechanisms between rotor and pad, which in some cases can be useful in order to reduce the instabilities and generated noise. Wear is an operational condition that has a strong effect on the system instability, since stiffness properties of brake pads are influenced by the changes on geometry and on the friction material, leading to high-frequency noise generation when the system is in the end of its lifetime. Application of brake insulators requires a detailed investigation of the system since, for some cases, an increase on the system damping does not balance changes on stiffness, leading the system to instability and noise.

It is very important to predict the radiated noise from the engine intake system for the effective noise control and virtual prototyping of in-cavity and outdoor noise of a vehicle. To this end, one should precisely measure the in-duct acoustic source parameters of the intake system, source strength and source impedance. Usually, the noise radiation characteristics need to be expressed as a function of engine speed. In this study done by **Ih Jeong-Guon et al [25]**, acoustic source parameters of an engine intake system under engine run up condition were measured by using the direct method. Direct method employed two external loudspeakers, turned on simultaneously, and three microphones for the separation of upstream and downstream wave components. It was noted that the frequency spectra of source impedance hardly changes with the increase of engine speed. Utilizing this fact, source strength under the engine run-up condition was calculated by assuming invariant source impedance. Predicted insertion loss and radiated sound pressure level using the measured source parameters were compared with those of measured data and predicted data using several idealized source models, which have been adopted for the calculations. A reasonably good agreement was observed between measured sound spectra at the intake orifice and predicted one using the measured source data. It was shown that the source data obtained by the present method yielded a far better prediction accuracy than those by the idealized source models.

CHAPTER – 3: Two-Wheeler Noise

Two-Wheelers are becoming increasingly prevalent both as a means of transportation. Because of the variety of vehicles intended uses, noise characteristics vary quite widely for this class of vehicles. Two-Wheeler covers a wide range of power to weight ratio so that even a typical operation may call for a wide range of available power output.

3.1 Sources of Two Wheeler Noise

In most motor vehicles the engine structure, intake and exhaust, transmission and differential, brakes, aerodynamic flow, and tyres are all important contributors, under various conditions, to total vehicle noise. The major sources of noise in the two-wheeler are tyre noise and engine noise which are discussed below.

3.2 Tyre Noise

At moderate to high speeds the noise from tyres typically dominates, provided the vehicle is equipped with a reasonably good exhaust muffler and is in a good state of repair. Tyre noise affects both the occupants of the vehicle and the community.

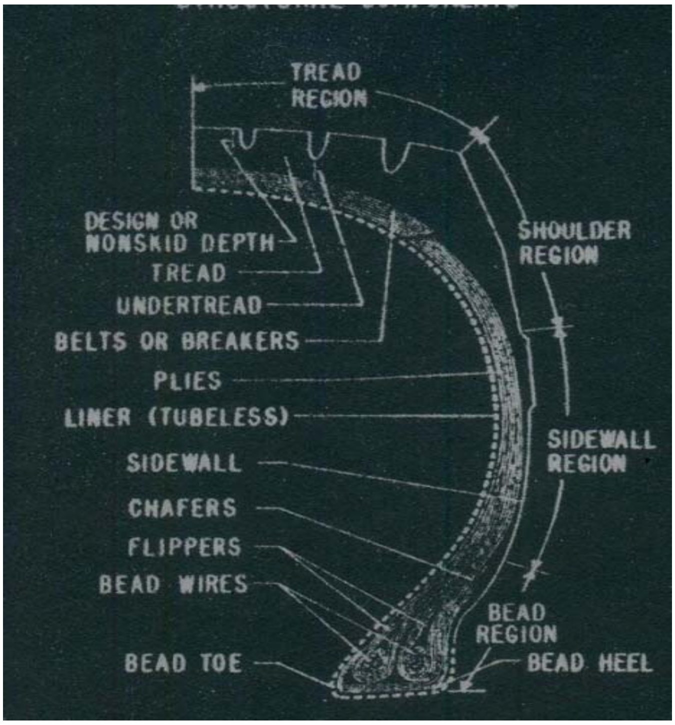

Fig. 3.1 Cross-sectional view of Tyre

3.2.1 Mechanism of Tyre Noise Generation

As a tyre rolls on a road surface it displaces macroscopic and microscopic volumes of air. The Macroscopic applies to volume displacement of the same order as the tyre itself, and microscopic applies to much smaller volumes. These air displacement generated pressure displacement disturbances in the surrounded air. Pressure disturbances in the audio frequency range and of sufficient amplitude are responsible for the production of noise along the road way.

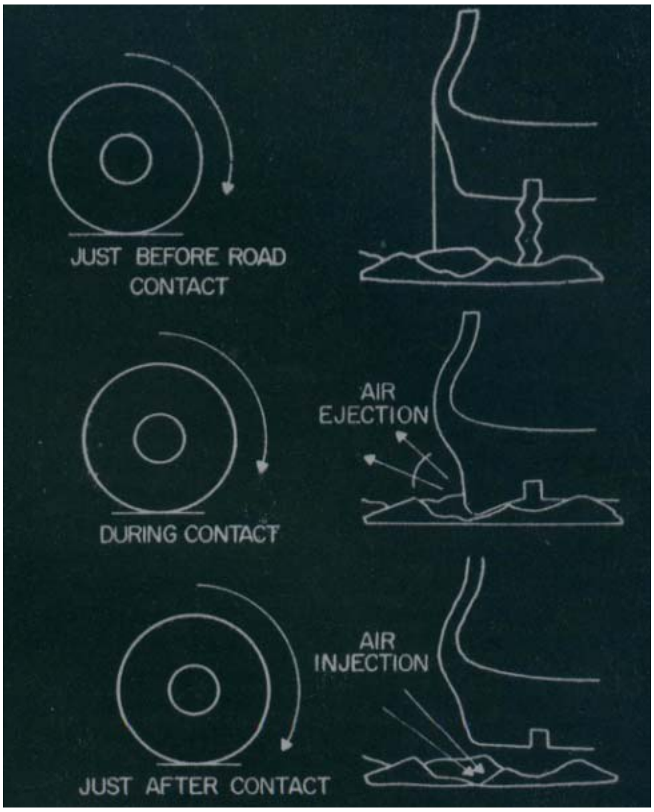

Fig. 3.2 Mechanism of tyre noise

3.2.2 Physical Mechanisms that have been Postulated to Tyre Noise

(a) Carcass & Tread Vibrations

Deformation that do change the tyres envelope as view from an inertial frame of reference moving with the tyre(but not rotating with it), are do to carcass & tread vibrations. For the purpose of analysis, it is convenient to restrict the definition of carcass and tread vibrations to encompass only repetitive, oscillatory deformation of carcass and tread surfaces. This excludes deformation that occurs once per tyre evolution when a particular portion of tire enters or leaves contact patch region. The deformations of tread voids in and near the contact patch for example are not considered to be tread vibration.

Three causes of carcass and tread vibrations that may produce audible sound, are

1. Tread pattern can produce load modulation that excite tread and carcass in the following way. When the tyre rolls the tread in the contact patch undergoes shear and circumferential compressions these strains are released discontinuously as tread elements exit contact patch and gripping as it let go. This excitation of the tread element is transmitted to the side walls. The resulting tread and carcass vibrations can then radiate sound. This excitation is primarily dependent on the tread pattern size and stiffness of the tread elements.

2. Road asperities can introduce carcass and tread vibration in a manner exactly analogous to the vibration produced by the tread pattern through load modulations. The amplitude of vibrations introduced by the road surface depend on the size and distribution of these asperities.

3. Tyre non-uniformities can also excite carcass and tread vibrations. The amplitudes of such vibrations would depend on the severity of the non-uniformities

(b) Air Pumping

It is the another source of air displacement which provides the major sound source and is associated with tread deformations which are not classified as tread or carcass vibrations. When a portion of the tread rolls into contact with the road surface, it is compressed radially, transversely and longitudinally. This compression forces air out of the tread voids as a volume of the voids are reduced. When the tread rolls out of contact, the compression is relieved and flows back into the expanding voids. This action of forcing air out of and into the tread voids is called **air pumping**.

3.2.3 Parameters Influencing Tyre Noise

(a) Effect of Speed

Sound level rise with increasing **speed** for all tyres, but at slightly different rates.

(b) Effect of Wet Road Surface

With the significant increase in sound level for the wet surface condition.

(c) Effect of Load

Load is an important parameter. In general, an increase in load results in an increase in the maximum A-weighted sound level.

(d) Effect of Tread Wear

Tread Wear is a variable that can greatly affect the sound level generated by tyres. The sound level generally increases as the tyre wears from new to a certain worn state, usually about 50 percent worn, with continued wear the sound level may drop again. The total increase is generally from 4-9 dB and depends on the type of the tyre.

(e) Effect of Temperature

There is no significant change in the overall sound level with changes in temperature over the range 25^{o}-125^{o} F.

3.3 Engine Noise

An **engine** is a mechanical device that produces some form of output from a given input and its purpose is to produce kinetic energy output from a fuel source is called a prime mover.

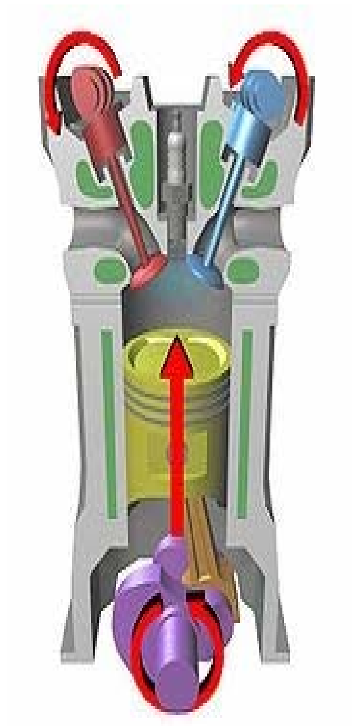

Fig. 3.3 Engine cross-sectional view

3.3.1 Noise Generation Process

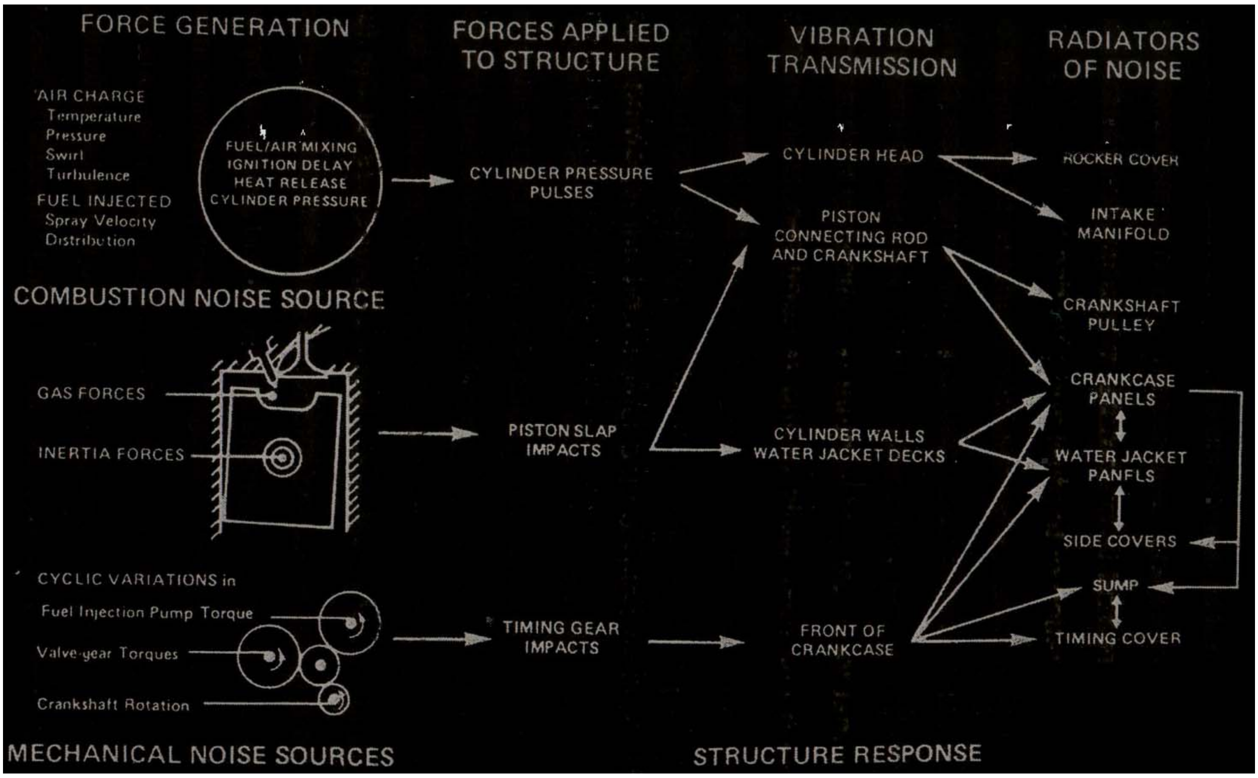

Fig. 3.4 Noise generation process in engine [28]

3.3.2 Types of Noise in Engine

(a) Exhaust Noise

An **exhaust system** is usually tubing used to guide waste exhaust gases away from a controlled combustion inside an engine or stove. The entire system conveys burnt gases from the engine and includes one or more **exhaust pipes.** This produces some amount of noise because of these pressurized gases. In most motorcycles all or most of the exhaust system is visible and may be chrome plated as a display feature. On a two-cylinder motorcycle, "siamese exhaust pipes" are where both cylinders blow into the same exhaust pipe or run parallel and connect with a crossover. This usage is derived from "Siamese twin".

Fig. 3.5 Exhaust noise component

(b) Combustion Noise

It is caused by the rapid pressure rise and high peak pressure in the combustion chamber during combustion. This occurs once per revolution per cylinder for two stroke engines and once per two revolutions per cylinder for four stroke engines.

It is produced because of unsteady combustion of fluid and is of two types: Turbulent combustion noise and periodic combustion oscillation.

The turbulent combustion noise or combustion roar has no specific frequency but is composed of broad-band frequency spectrum. This noise is amplified if the flame is enclosed with the system resonance frequencies dominating. The requirements for reduction of this noise tend to be opposition to those for efficient combustion.

Combustion oscillations involve a feedback cycle that converts chemical energy into oscillatory energy in the gas flow to the combustion region. The mechanism is such that the pressure waves generated are so phased to the velocity fluctuations. The noise spectrum involves one specific frequency and its harmonics and that frequency is related to the resonant modes of the combustion chamber.

Some of the possible cures are:

1. Modification of Combustion chamber geometry

2. Change of air-fuel ratio, burner type etc.

3. Change of burning rate

It should be noted that Combustion roar in reciprocating engines which has frequency of the firing rate is not related to the combustion noise, but is due to the gross fluctuation in the flow rate produced by periodic action.

(c) Bearing Noise

These are always replaced when rebuilding an engine because they are a wear component. Heat, pressure, chemical attack, abrasion and loss of lubrication can all contribute to deterioration of the bearings. The above features give rise to the noise. Some of the factors that causes bearing noise are as follows:

1. **Dirt:** Dirt contamination often causes premature bearing failure. When dirt or other abrasives find their way between the crankshaft journal and bearing, it can become embedded in the soft bearing material. The softer the bearing material, the greater the embed ability, which may or may not be a good thing depending on the size of the abrasive particles and the thickness of the bearing material.
2. **Heat:** Heat is another factor that accelerates bearing wear and may lead to failure if the bearings get hot enough. Bearings are primarily cooled by oil flow between the bearing and journal. Anything that disrupts or reduces the flow of oil not only raises bearing temperatures but also increases the risk of scoring or wiping the bearing.
3. **Misalignment:** Misalignment is another condition that can accelerate bearing wear. If the center main bearings are worn more than the ones towards either end of the crankshaft, the crankshaft may be bent or the main bores may be out of alignment.
4. **Disassembly:** Disassembly can be another cause of premature bearing failure. Common mistakes include installing the wrong sized bearings, installing the wrong half of a split bearing as an upper, getting too much or not enough crush because main and/or rod caps are too tight or loose, forgetting to tighten a main cap or rod bolt to specs, failing to clean parts thoroughly and getting dirt behind the bearing shell when the bearing is installed.
5. **Corrosion:** Corrosion can also play a role in bearing failure. Corrosion results when acids accumulate in the crankcase and attack the bearings causing pitting in the bearing surface. This is more of a problem with heavy-duty diesel engines that use high sulfur fuel rather than gasoline engines, but it can also happen in gasoline engines if the oil is not changed often enough and acids are allowed to accumulate in the crankcase.

(d) Piston Slap Noise

It is generated by the sudden impact of the piston to the cylinder wall is considered to be predominant due to the higher amount of energy released.

In the compression stroke, the connecting rod pushes the piston upwards overcoming the gas force. The force acting on the piston has a lateral component and the piston slides upwards on the minor thrust side of the cylinder wall. As the piston moves through T.D.C. the gas forces dominate the internal forces and keep the connecting rod in compression. Thus, as the crank pin passes through the cylinder center line, the lateral component of force on the piston pin changes direction, causing the piston to accelerate through the clearance and slap against the major thrust side of the cylinder wall.

There at least two piston slaps per revolution, but the major impact occurs at T.D.C. before the power stroke.

These simple models do not take into account others factors which may affect the piston motion such as:

1. Piston pin offset

2. Rocking motion of piston

3. Frictions at piston pin as well as piston's outer surface

4. Piston configuration, especially under operation

5. Pressure distribution around piston due to the squeezing motion of oil film

6. Compliance of cylinder liner wall

7. Cylinder liner deformation

(e) Knocking

It is also called **knock**, **detonation** or **spark knock**, **pinking** in UK English or **pinging** in US English in spark-ignition internal combustion engines occurs when combustion of the air/fuel mixture in the cylinder starts off correctly in response to ignition by the spark plug, but one or more pockets of air/fuel mixture explode outside the envelope of the normal combustion front. The fuel-air charge is meant to be ignited by the spark plug only, and at a precise time in the piston's stroke cycle. The peak of the combustion process no longer occurs at the optimum moment for the four-stroke cycle. The shock wave creates the characteristic metallic **"pinging" sound**, and cylinder pressure increases dramatically.

Main Factors affecting knocking are

1. **Compression Ratio:** Higher the compressor ratio increases the tendency of knocking because it increases the displacement volume.
2. **Cool Mixture:** If the moist air taken by the carburetor then it will decrease the tendency of knocking, because the temperature of the unburnt fuel becomes low.
3. **Lean Mixture:** If the lean mixture is supply then it will decrease the tendency of knocking.

(f) Mechanical Noise

It is generated by various impacts between the engine parts. This noise source is more important in the higher frequency range rather than in lower frequency range where combustion noise is important. There are lots of moving parts, for example, gear, valves, and rocker arms, piston and cylinder liner.

3.4 Noise Standards followed in Different Countries

<table>
<tr><th>Vehicle Category</th><th colspan="3">Max Permissible Sound Level in dB(A)</th></tr>
<tr><td></td><td>1992</td><td>1999</td><td>2002</td></tr>
<tr><td rowspan="3">Motorcycles</td><td rowspan="3">80</td><td rowspan="3">80</td><td>75 for < 125 cc</td></tr>
<tr><td>77 for 125-250 cc</td></tr>
<tr><td>80 for >250 cc</td></tr>
<tr><td>Scooter/Mopeds</td><td>80</td><td>80</td><td>77</td></tr>
</table>

Table - 3.1 Noise standard followed in India

<table>
<tr><th>Vehicle Category</th><th>Max Permissible Sound Level in dB(A)</th></tr>
<tr><td rowspan="2">Off-Road Motorcycles</td><td>80 for < 170 cc</td></tr>
<tr><td>82 for >170 cc</td></tr>
<tr><td>Street Motorcycles</td><td>80</td></tr>
<tr><td>Scooter/Mopeds</td><td>70</td></tr>
</table>

Table – 3.2 Noise standard followed in U.S.A

Vehicle Category	Max Permissible Sound Level in dB(A)
Motorcycles	73 for < 50 cc
	78 for 50-125 cc
	81 for 125-350 cc
	83 for >350 cc

Table – 3.3 Noise standard followed in Switzerland

Vehicle Category	Max Permissible Sound Level in dB(A)
Motorcycles	72 for >50 cc < 125 cc
	75 for >125 cc < 250 cc
	78 for > 250 cc
Scooter/Mopeds	72 for < 50 cc

Table – 3.4 Noise standard followed in Japan

CHAPTER – 4: General Procedure and Experimental set up

4.1. Nature of Noise Problem

In the modern world, noise is one of the major problems which affect human beings. The major contributions of the noise are industrial noise, community noise, air craft noise and traffic noise. One of the major reasons for noise pollution is Two Wheelers. The A-weighted noise level with respect to the time for different types of vehicles is shown in **Fig. 4.1**. It can easily be seen that Two Wheelers (motorcycle), aircraft over flight and car have much high noise level above the average level.

So, the aim is to study the noise of Two Wheeler under different ambient conditions and by changing different parameters i.e. Gear and Throttle in nine different cases with the help of different methods which has explained afterwards followed by diagram:

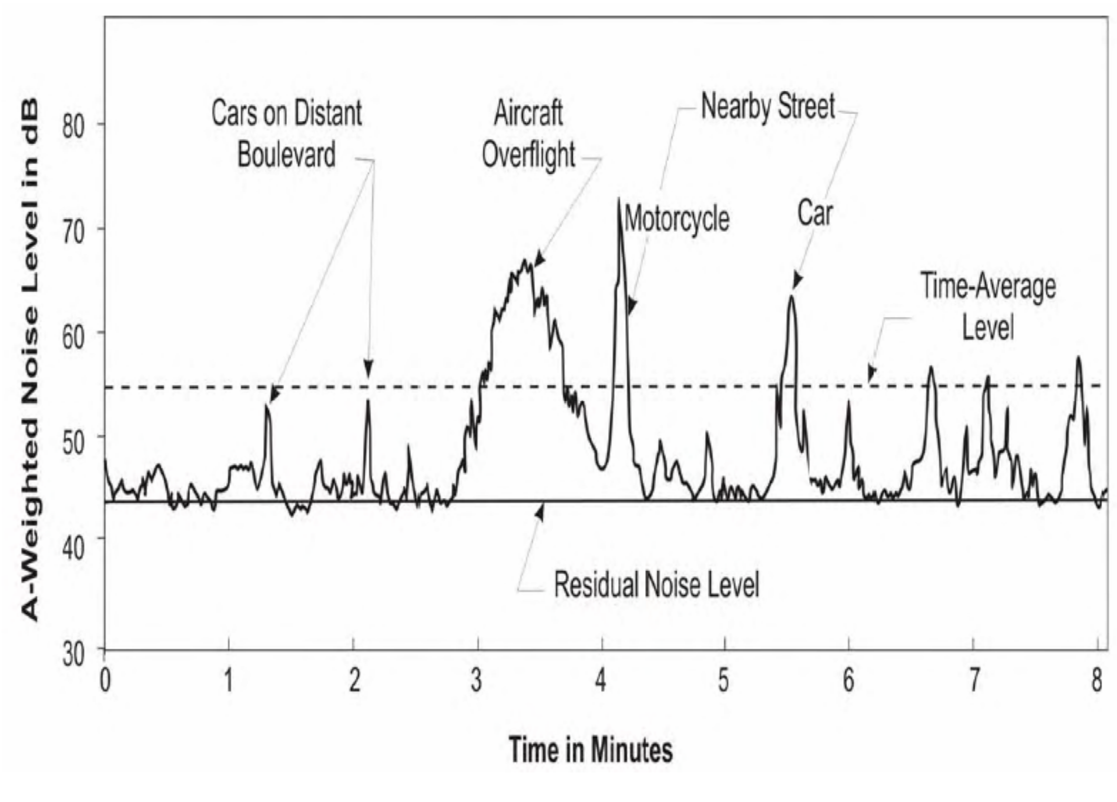

Fig. 4.1 A-weighted noise level with respect to the time

4.2 Measurement of different Noise parameters of Two Wheelers

To study the noise generated by Two Wheelers, the various parameters are required to study at different conditions. There are different types of procedure to find out different parameters which contributed noise are as follow:

1. Pass by Test method
2. Method to determine sound power level
3. Frequency Spectrum
4. Motorway noise prediction model

All the data is given in the Appendixes.

4.2.1 Pass by Test

It is a method of measuring the noise of two-wheelers given by **ISO/R 362** [29]. It was developed to yield noise from two-wheelers under operating conditions which represent the maximum conditions to which a two-wheeler is most likely to be subjected during its operation on roads.

(a) General Procedure

This test incorporates vehicle operating conditions which are realistic which give the highest noise level consistent with normal driving and which enable the noise emission to be reproducible. The test is, therefore based on accelerating the vehicle at full throttle from a started running condition.

The test is carried out in a wide open space of about 50 m radius, the central 20 m of which is covered with concrete, asphalt or a similar material. Careful consideration should be given to possible sources of error such as the sound absorption by the ground, reflections from nearby objects, unevenness of the ground and the wind.

The vehicle approaches the line AA along the line CC in **Fig 4.2.** When the front of the vehicle crosses the line AA, the throttle is opened as rapidly as practicable and held open until the rear of the vehicle passes over the line BB. During this transit, the maximum sound pressure level is measured using a sound level meter possessing and A-weighting network and a “fast” response time at the positions indicated in **Fig 4.2.** The microphone should be located 1.2 m above the ground. At least two measurements should be made on each side of the vehicle, as it passes the measuring position.

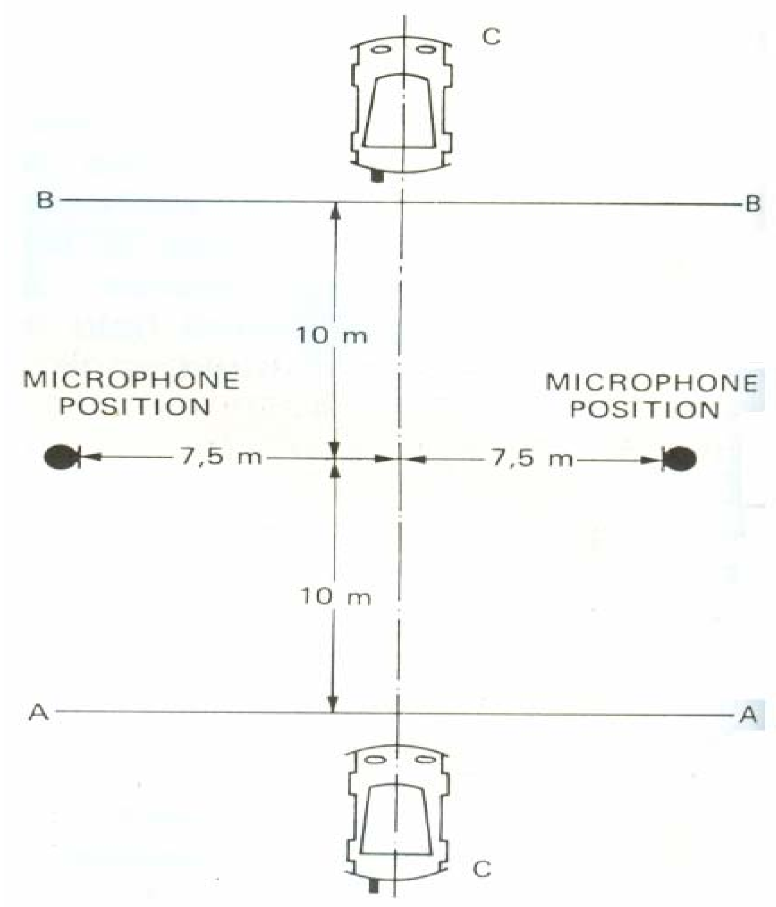

Fig. 4.2 Diagrammatical view of Pass by Test Method

(b) Experimentation

The above procedure used for measuring A-Weighted fast response Sound level for different moving nine Two Wheelers at two operating conditions **(a) 3rd Gear (b) 4th Gear** at **full throttle** just to find out how much noise is contributed to the environment with varieties of Two Wheelers followed one having defective silencer. So for this process site was the major need which will fulfill the basic requirement and the site at **Army Helipad Aviation Club** at Sangrur road, Patiala was suitable for this process as recommended by **ISO R/362.** The site view has shown in **Fig. 4.3.** This procedure have followed ffive times from left to right and right to left for all two wheelers. The result and discussion are given in chapter 5.

Fig. 4.3 Experimental Site for Pass by Test Method

4.2.2 Method to determine Sound Power Level

It is a method of measuring the sound power of two-wheelers given by ISO/R 3744. It was developed to yield noise from two-wheelers under operating conditions which represent the maximum conditions to which a two-wheeler is most likely to be subjected during its operation. [27]

(a) Sound Power Level Measurement with Sound Pressure Level

The sound power level of noise sources can be measure with the help of sound pressure level with following steps:-

1. Surround the source with hypothetical surface of area S (either a hemisphere or a rectangular parallelepiped).

2. Calculate the area of this hypothetical surface if it is hemisphere, S is given by $\mathbf{2\pi r^2}$ where r is radius of the hemisphere.

3. If it is rectangular, S is given by **ab+2(ac + bc)**, where a, b, c are its length, width and height.

4. Measure the sound pressure level at designated point on the hypothetical surface.

5. Obtain the average Lp of sound pressure level measured in the step 3.

6. Finally calculate the sound power level from the following equation.

$$Lw=Lp+10\log10(S/So) \quad \text{--------------(4.1)}$$

So = reference area

S = hypothetical surface area

(b) Additional Aspect of Measurement which are Numbered to Correspond to the Steps in the above Procedure

1. For the small sources those whose largest dimension is significantly less than one meter. It is usually more convenient to use hemisphere the rectangular parallelepiped as a hypothetical measurement surface for large rectangular sources the rectangular parallelepiped surface is usually preferred.

2. The radius of hypothetical hemisphere should be equal to or greater than twice the major source dimension and not less than 1m for the rectangular parallelepiped, the measurement distance “d “, the perpendicular distance between the source and the measurement surface has a preferred value of 1m.

3. For hemisphere the designated point of the microphone locations are shown in **Fig. 4.4**. The corresponding point for the rectangular parallelepiped is shown in **Fig. 4.5**. The sound pressure level at designated point is measured with A-weighting or in octave or in one-third octave bands.

4. The average sound pressure level over the measurement surface, Lp is calculated from the measured sound pressure level Lpi, after correction for background noise.

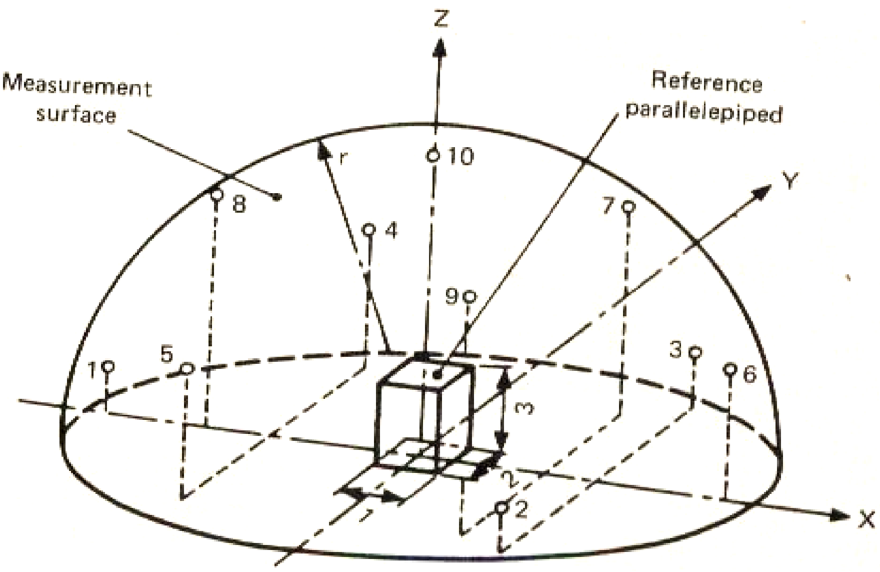

Fig. 4.4 Graphical representation of microphone positions on an imaginary hemispherical surface surrounding a source.

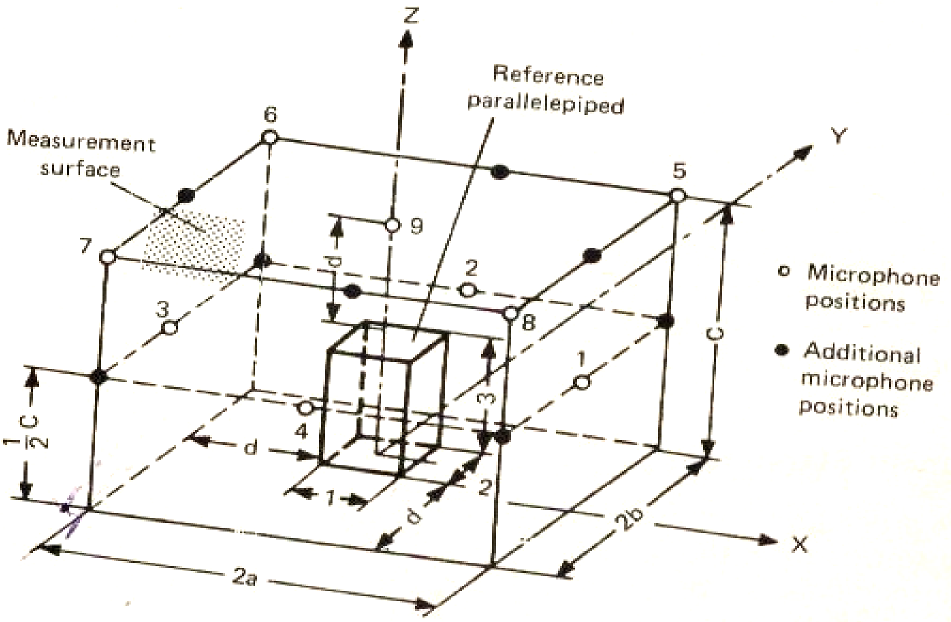

Fig. 4.5 Array of microphone positions on an imaginary parallelepiped surface surrounding a source whose sound power is to be measured.

(c) Most Appropriate Method of Measurement Depends on

1. Mobility and location of the noise sources.
2. Nature and the configuration of the test environment.

(d) Measurement of Sound Power Level

1. Calculating the sound pressure level at a given distance from a machine.
2. Comparing the noise radiated by machines of the same type and size.
3. Comparing the noise radiated by machines of different types and sizes.
4. Determine whether a machine compiles with a specified upper limit of sound emission.
5. Determine the amount of noise reduction required under certain circumstances.
6. Developing quite machinery and equipment.

(e) Experimentation

The procedure which has already been explained in the article **4.2.2**. The parallelepiped method for calculating Acoustic Power has been used for nine different stationary Two Wheelers at two operating condition **(a) Zero Throttle (b) Full Throttle** because the largest dimension of the source is greater than 1 m. In this experiment the first step is to make the arrangement for 17 Grid Points in the rectangular parallelepiped of dimension **Length 3.9 m, Breadth 2.8 m, Height 2 m** for the case of Motorcycles and **3.8 m, 2.7 m, 2 m** for Scooters as modeled in ProE shown in **Fig, 4.6(a)** and **(b)** and was made with the help of bamboos and aluminium wires which is shown in **Fig. 4.7(a)** and **(b).** Now it's necessary to place the microphone at every grid points to take the readings at different conditions. This procedure was followed three times for all two wheelers. The result and discussion are shown in chapter 5.

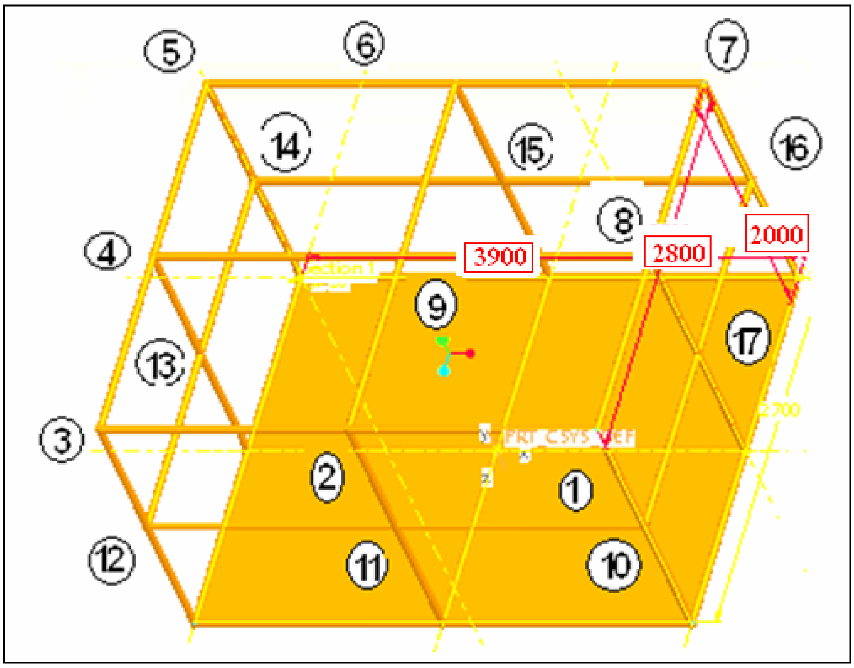

Fig. 4.6(a) Rectangular Parallelepiped with dimension for Motorcycle

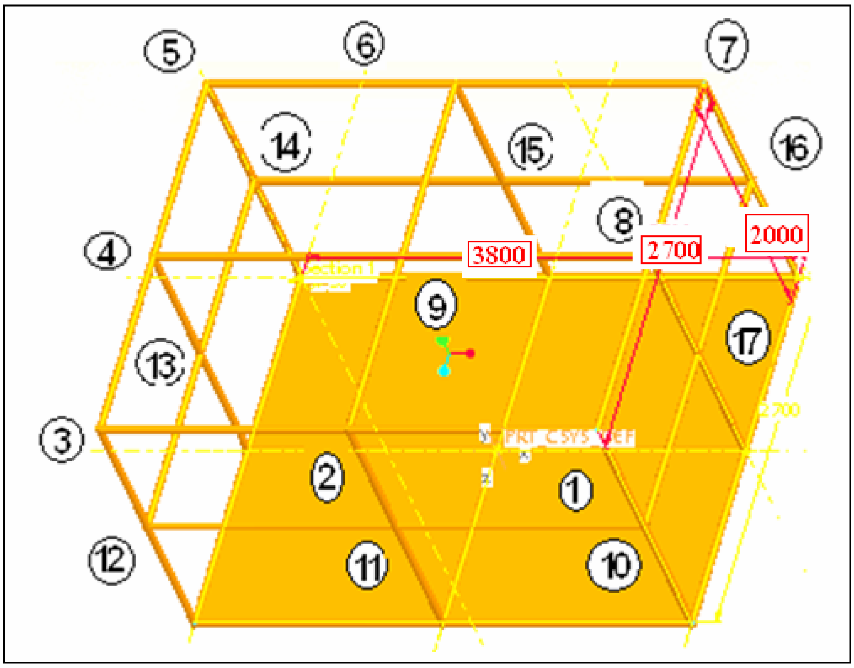

Fig. 4.6(b) Rectangular Parallelepiped with dimension for Scooters

Fig. 4.7(a) Experimental set up for calculating Acoustic Power

Fig. 4.7(b) Two Wheeler standing inside Rectangular Parallelepiped

4.2.3 Measurement of Sound Pressure Level in frequency spectrum

The measurement of Sound Pressure Level has been done with the help of CESVA ACOUSTIC INSTRUMENT which has been shown in **Fig 4.8(a)** at 1-1 octave band frequency spectrum mode which gives an idea of the maximum and minimum value of sound level at different frequencies. In this process the four locations has selected been marked **A, B, C,** and **D** at distance of **1m** and a height of **0.5 m** from the source at each side which has been shown in **Fig. 4.8(b)** at two different operating conditions **(a) Zero Throttle (b) Full Throttle** for 5 sec just to find out which part creates more noise at different frequencies. The instrument gives the data of SPL in all frequencies by the software "CESVA CAPTURE STUDIO". The result and discussion has been shown in chapter 5.

Fig. 4.8(a) CESVA Acoustic Instrument

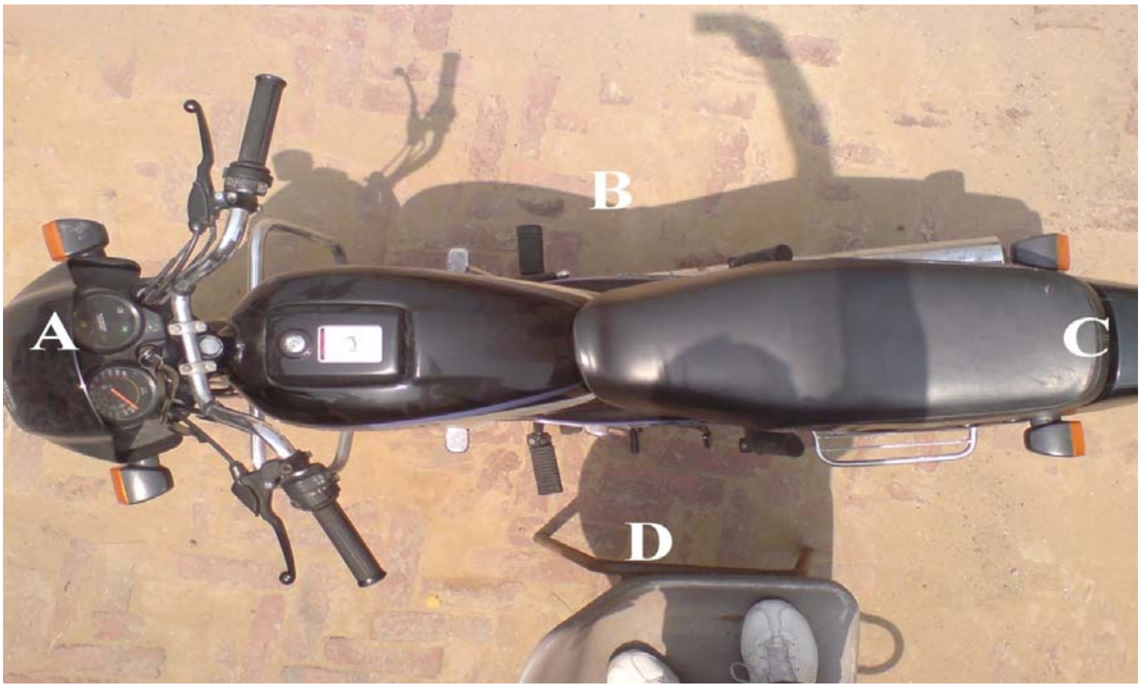

Fig. 4.8(b) Showing locations A, B, C and D

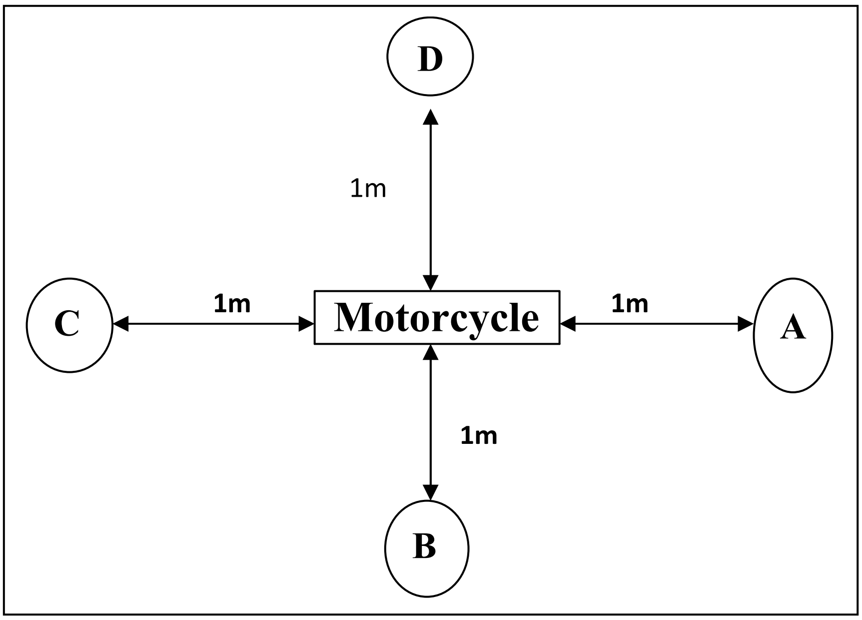

Fig. 4.8(c) Shows sketch view of Fig. 4.8(b)

4.2.4 Motorway noise prediction model

(a) General Procedure

The basic noise level model is used as the first prediction of traffic noise from an individual type of motor vehicle on the roadway. The noise data on individual vehicles passing by the noise level meter is collected simultaneously with the spot speed of that particular vehicle for each type of vehicles. The noise level meter is placed at the reference distance of 15 m perpendicular to the centerline of the traffic lane with the meter height of 1.20 m from ground surface. In this study, vehicles on the motorway are classified into eight types, namely, automobile, light truck, medium truck, heavy truck, semi-trailer, full-trailer, bus, and motorcycle.

The index for this noise measurement is $\mathbf{L_{eq}}$ (equivalent sound level), which is the energy mean emission level in the period of measurement. This study uses a measurement period of 10 sec – $\mathbf{L_{eq}}$ dB(A), which is the time that can cover a representative period of noise generated from an individual vehicle passing by the noise meter as shown in **Fig. 4.9**. This type of noise measurement is the real time measurement of a running vehicle using the model's forecasting index of $\mathbf{L_{eq}}$, i.e., it is based on the measurement of mean energy emission from a passing by vehicle during the 10 sec period. The advantages of this index are **(1)** it minimizes the error created by multi sources of noise from vehicle especially the long body vehicles, i.e., truck, semi-trailer truck, and bus, and **(2)** the 10 sec measuring time period can cover almost all of the pass-by sound pressure level profiles of vehicles in this study. Regression analysis was used to analyze the **reference energy mean emission level** (predicated $\mathbf{L_{eq}}$) equation in terms of $\mathbf{L_{eq}}$ (dB(A)) for 10 sec in relation to spot speed for each vehicle type over the different speed range.

The 15 m location of the reference point used in this study is based on the reference distances that have been used in USA and Thailand. [15] and [19].

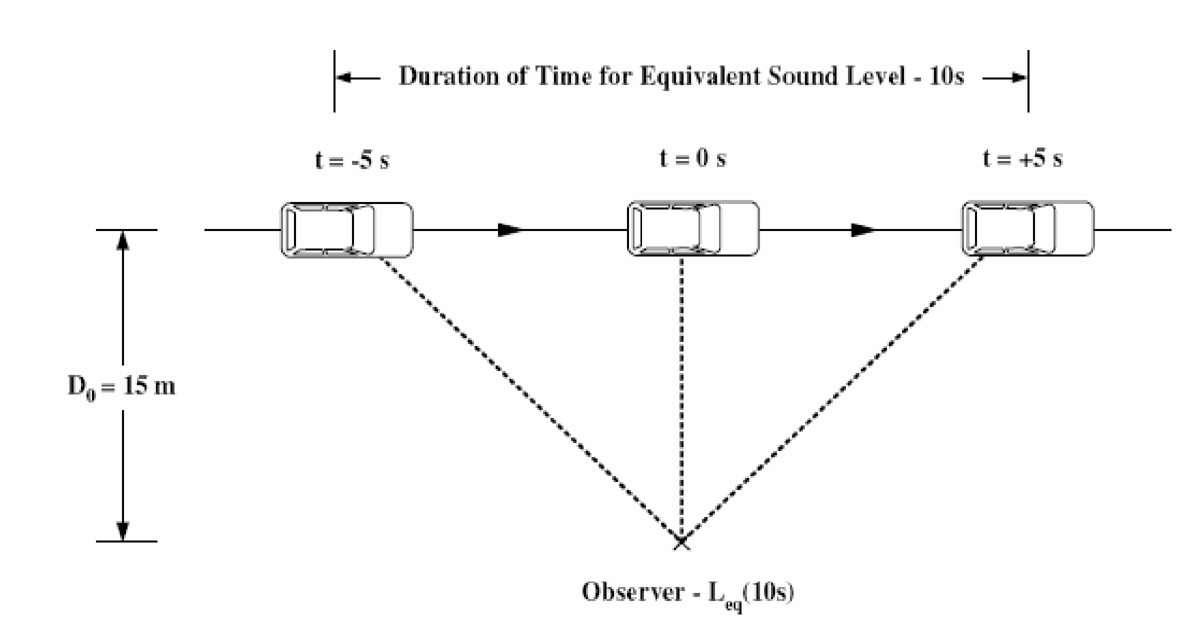

Fig. 4.9 Individual Pass-by vehicle noise measurements

(b) Experimentation

This above procedure has been used for calculating **reference mean energy emission level** for Two Wheelers. First step is to measure $\mathbf{L_{eq}}$ (db(A)) for 10 sec of different seven Two Wheelers at different speeds i.e 30, 40, 50 and 60 km/hr with the help of CESVA Acoustic Instrument then with the help of regression analysis reference mean energy emission level has calculated. The result and discussion has shown in chapter 5.

CHAPTER – 5: Results and Discussions

The noise measurements have been made for the four types of descriptors as explained in chapter 4. Results are discussed in the following paragraphs.

5.1 Measurements

As discussed in chapter 4, measurements for SPL with the Pass by Test Method, Acoustic Power, Frequency Spectrum and Reference Mean Energy Emission Level have been taken and analyzed.

5.1.1. Measurement of Sound Pressure Level

The comparison of different Motorcycles followed with Scooters for sound pressure level at fast response at two operating conditions **3rd** and **4th** Gear with the help of Pass by Test at Full Throttle is shown with reference to **Appendix A**, where the observation table is shown.

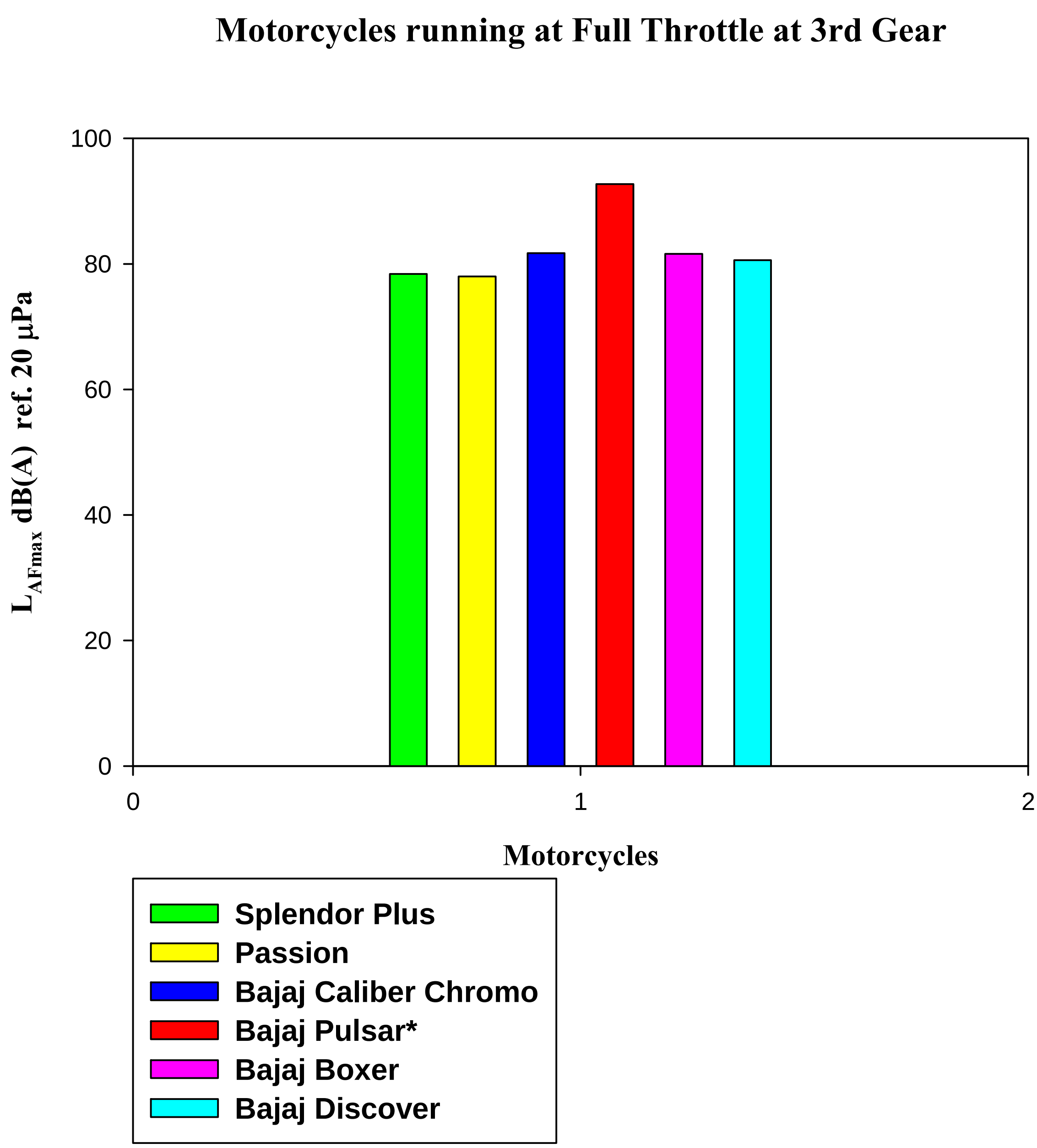

Fig. 5.1 Comparison of Sound Pressure Level of different Motorcycles at 3rd Gear Appendix A1

Comparison between different Motorcycles with their average L_{AFmax} which varies from 78 to 92.7 dB(A) at 3rd Gear. It seems to be motorcycle with defective silencer has almost 10-15 dB(A) difference in sound compared with others. It's found that Bajaj Caliber Chromo has maximum noise amongst with others at 3rd Gear.

"*" shows silencer is defective.

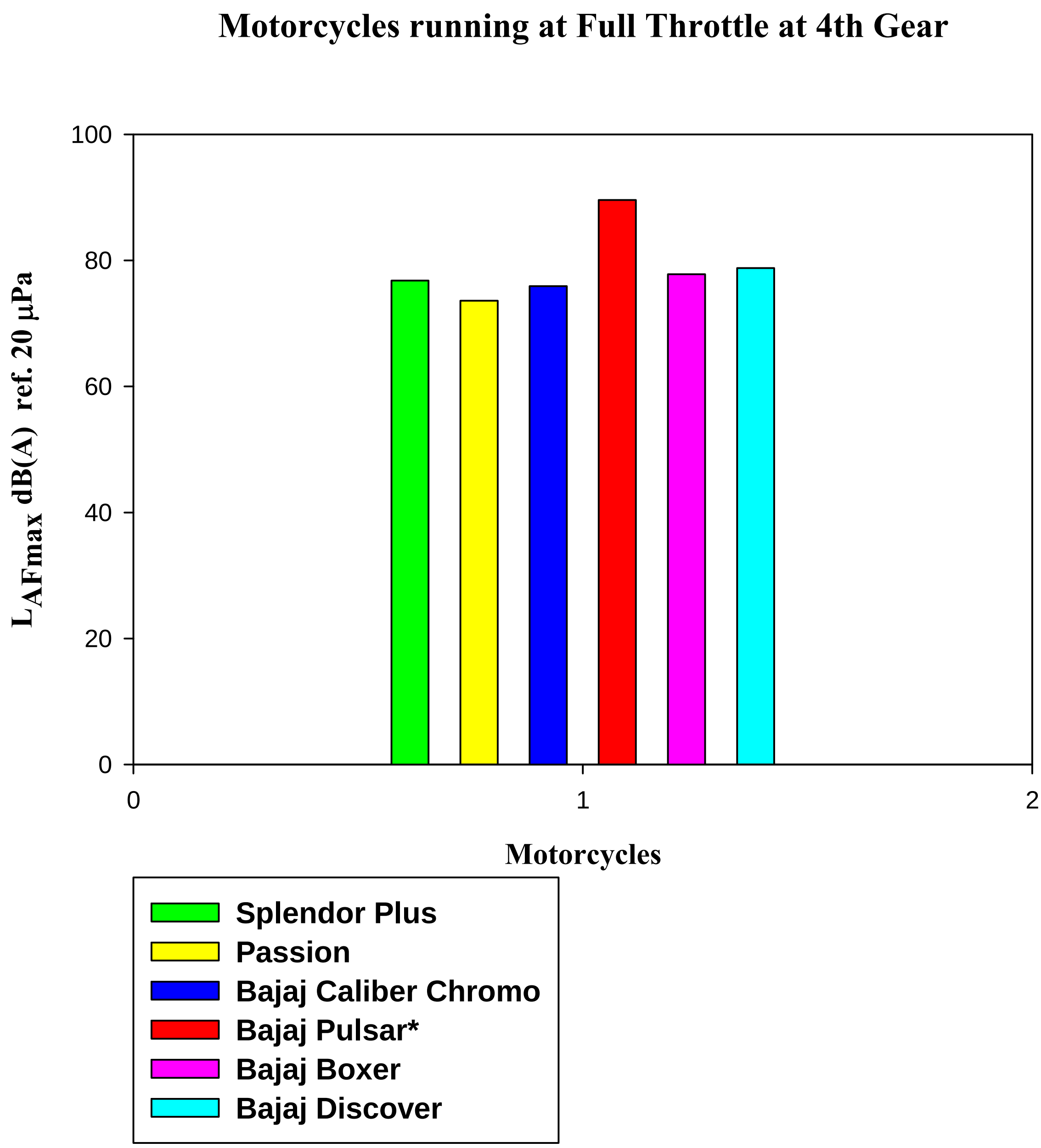

Fig. 5.2 Comparison of Sound Pressure Level of different Motorcycles at 4th Gear Appendix A2

Comparison between different Motorcycles with their average L_{AFmax} which varies from 73.6 to 89.6 dB(A) at 4th Gear. It seems to be motorcycle with defective silencer has almost 10-16 dB(A) difference in sound compared with others. It's found that Bajaj Discover has maximum noise amongst with others at 4th Gear.

"*" shows silencer is defective.

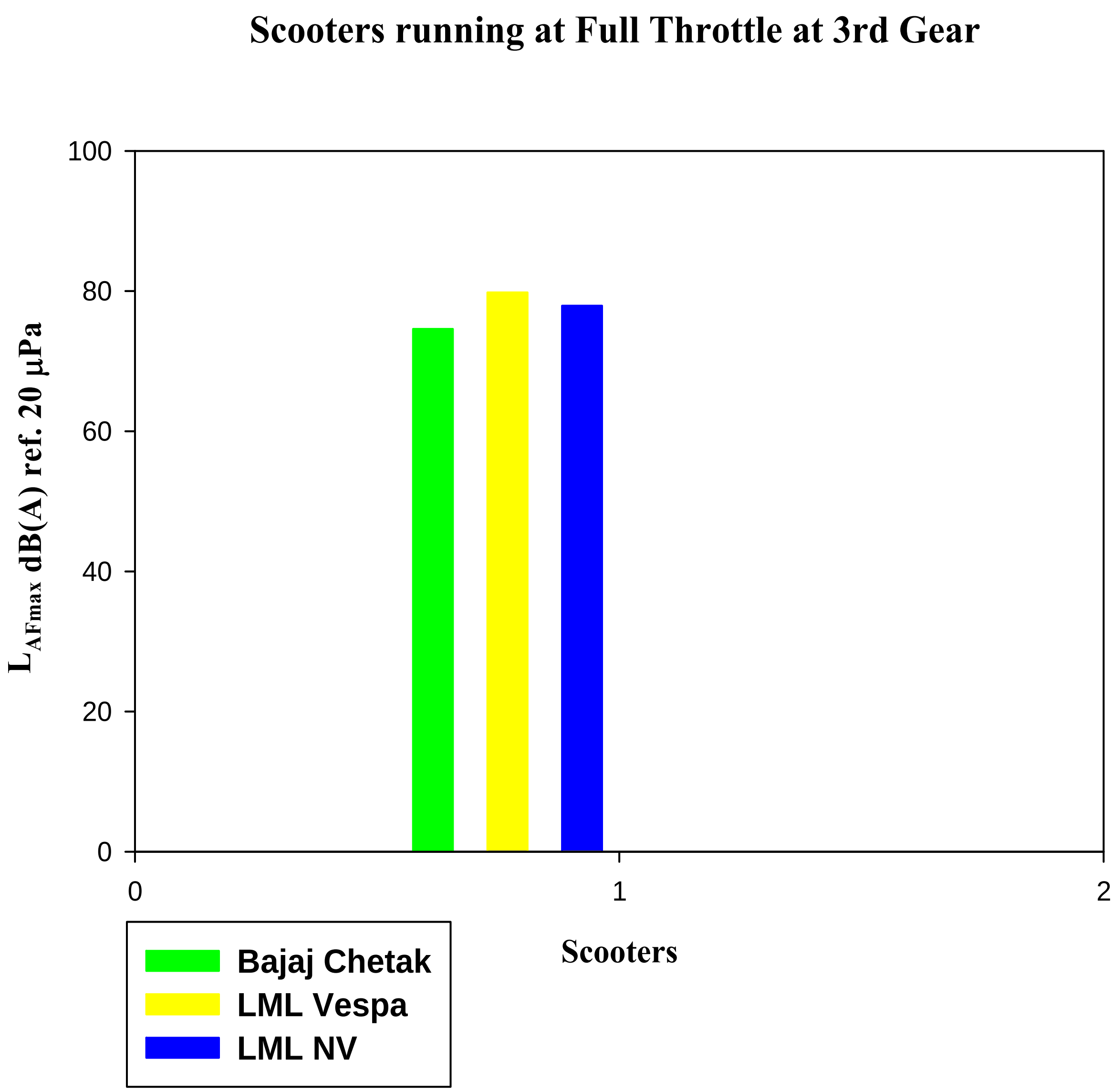

Fig. 5.3 Comparison of Sound Pressure Level of different Scooters at 3rd Gear from Appendix A3

Comparison between different Scooters with their average L_{Afmax} which varies from 74.6 to 79.8 dB(A) at 3rd Gear. It seems to be LML Vespa has maximum sound amongst with others at 3rd Gear.

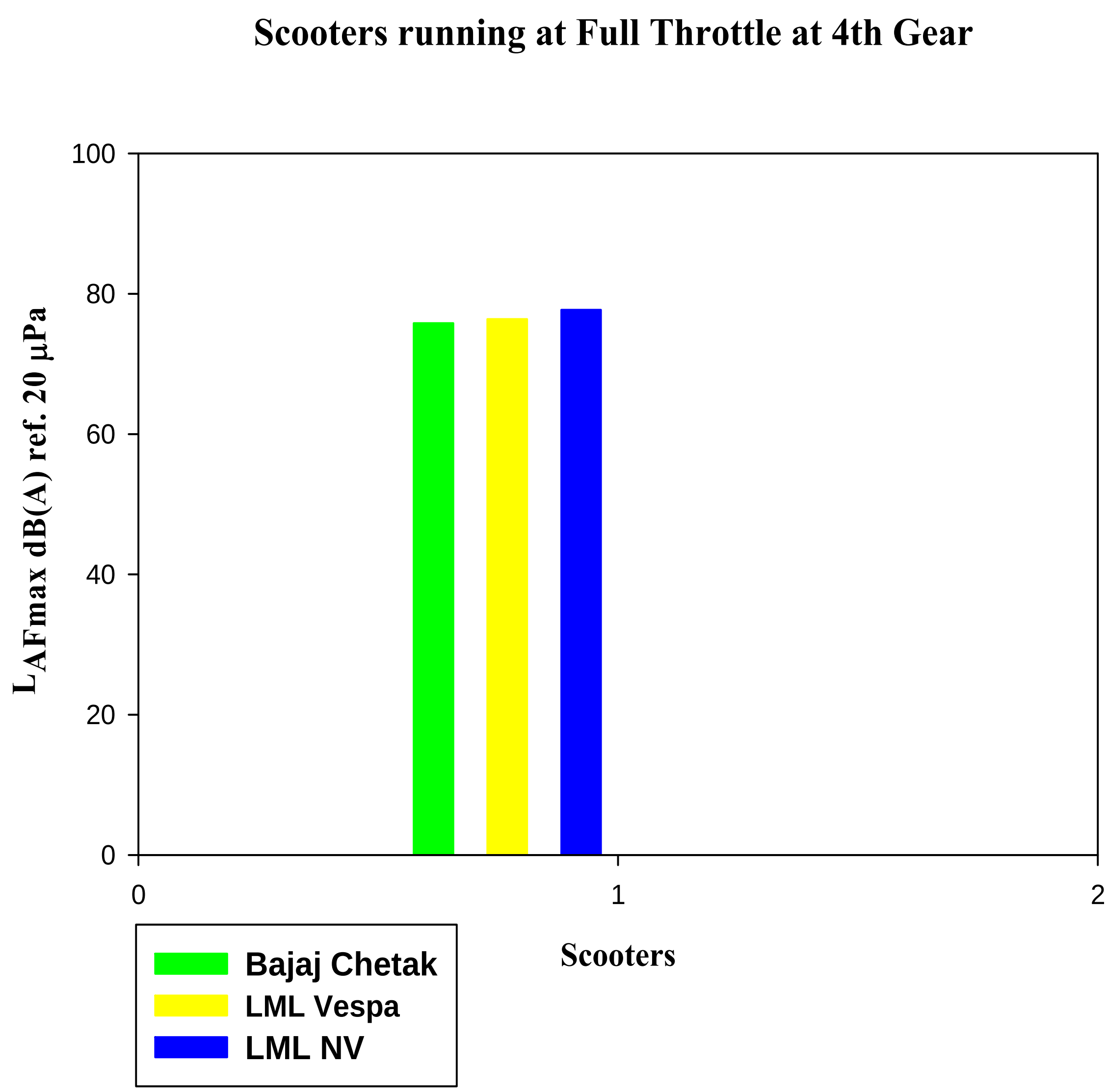

Fig. 5.4 Comparison of Sound Pressure Level of different Scooters at 4th Gear from Appendix A4

Comparison between different Scooters with their average L_{AFmax} which varies from 75.8 to 77.7 dB(A) at 4th Gear. It seems to be LML NV has maximum noise amongst with others at 4th Gear.

5.1.2. Measurement of Sound Power

The comparison of Acoustic power has evaluated after measurement of Sound Pressure Level at 17 different Grid Points for different Two Wheelers at two operating conditions **Zero and Full Throttle** is shown with reference to **Appendix B**, where the observation table is shown.

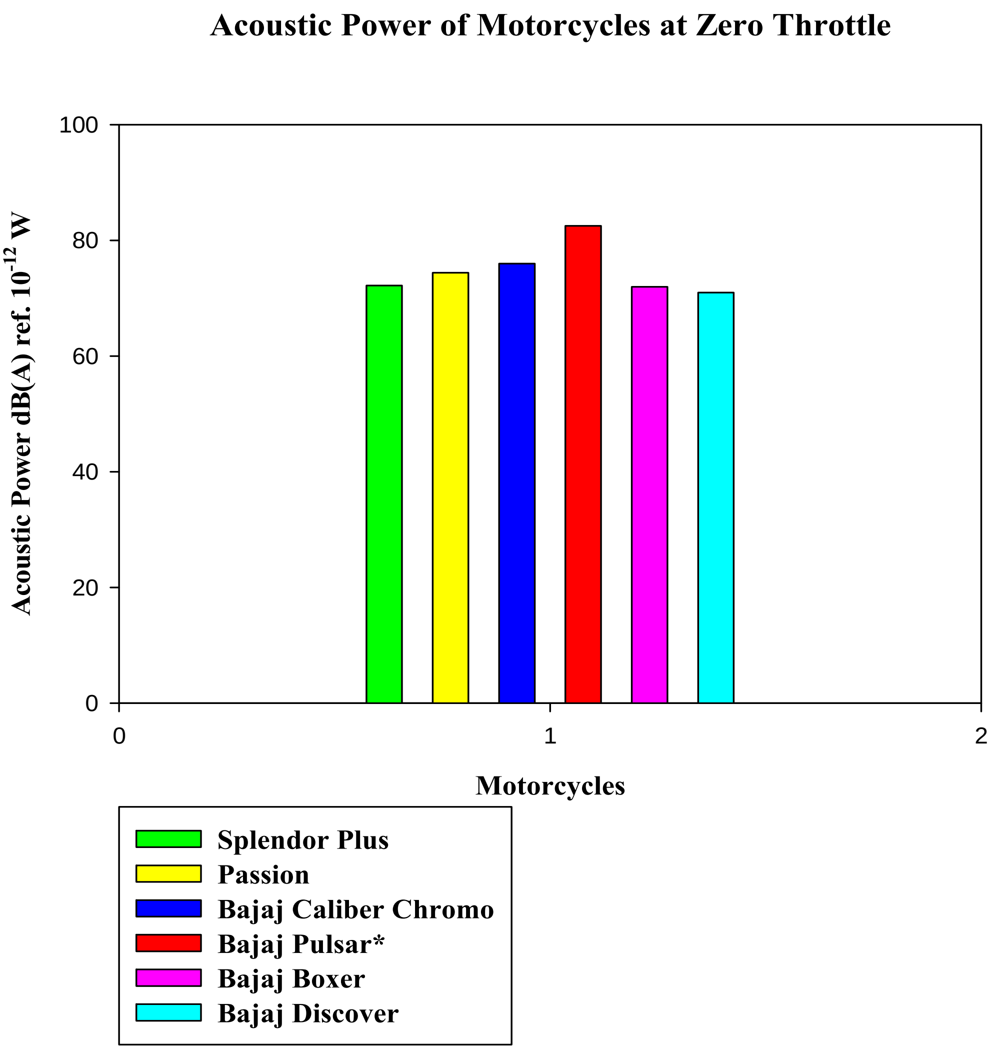

Fig. 5.5 Comparison of Sound Power Level of different Motorcycles at Zero Throttle from Appendix B1-B6

Value of Acoustic power varies from 71.0 to 82.5 dB(A) (ref. 10^{-12} W) at Zero Throttle, it seems that Motorcycle with defective silencer has maximum Acoustic Power. Amongst others Passion has maximum and Bajaj Boxer has minimum Acoustic Power.

"*" shows silencer is defective.

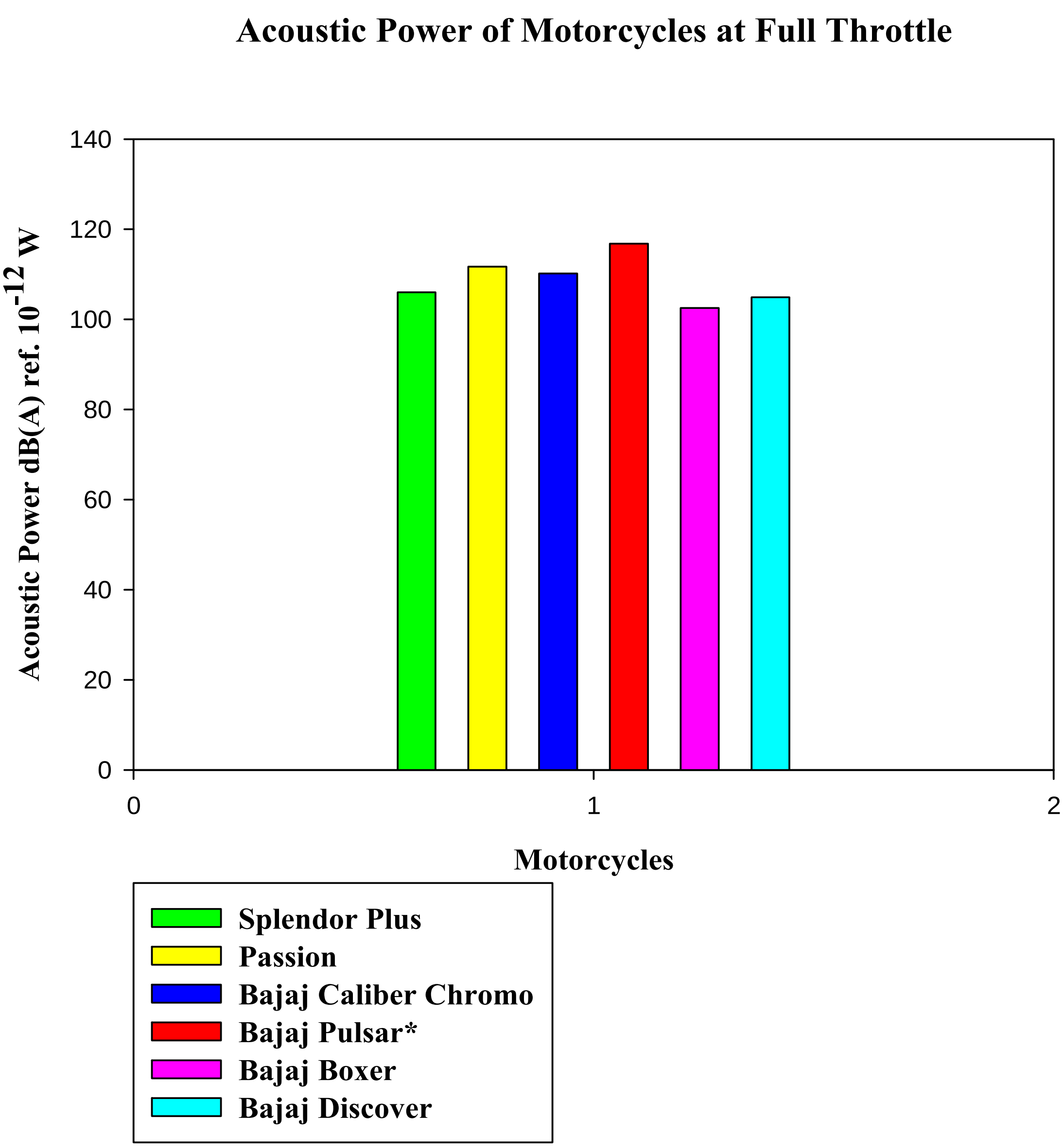

FIG. 5.6 Comparison of Sound Power Level of different Motorcycles at Full Throttle from Appendix B7-B12

Value of Acoustic power varies from 102.5 to 116.8 dB(A) (ref. 10^{-12} W) at Full Throttle, it seems that Motorcycle with defective silencer has maximum Acoustic Power. Amongst others Passion has maximum and Bajaj Boxer has minimum Acoustic Power.

"*" shows silencer is defective.

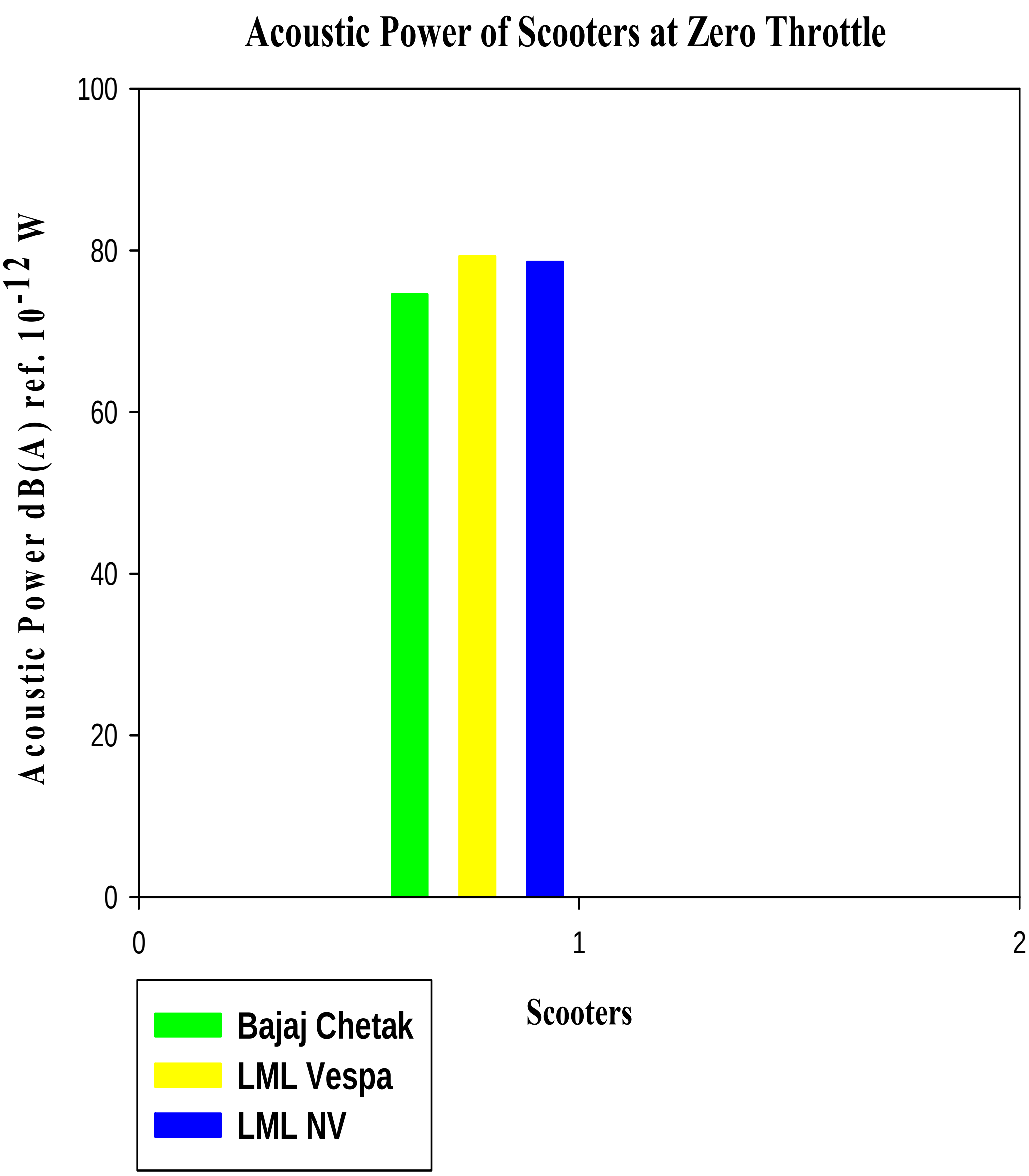

FIG. 5.7 Comparison of Sound Power Level of different Scooters at Zero Throttle from Appendix B13-B15

Value of Acoustic power varies from 74.6 to 79.8 dB(A) (ref. 10^{-12} W) at Zero Throttle. It seems to be LML Vespa has maximum and Bajaj Chetak has minimum Acoustic Power amongst other.

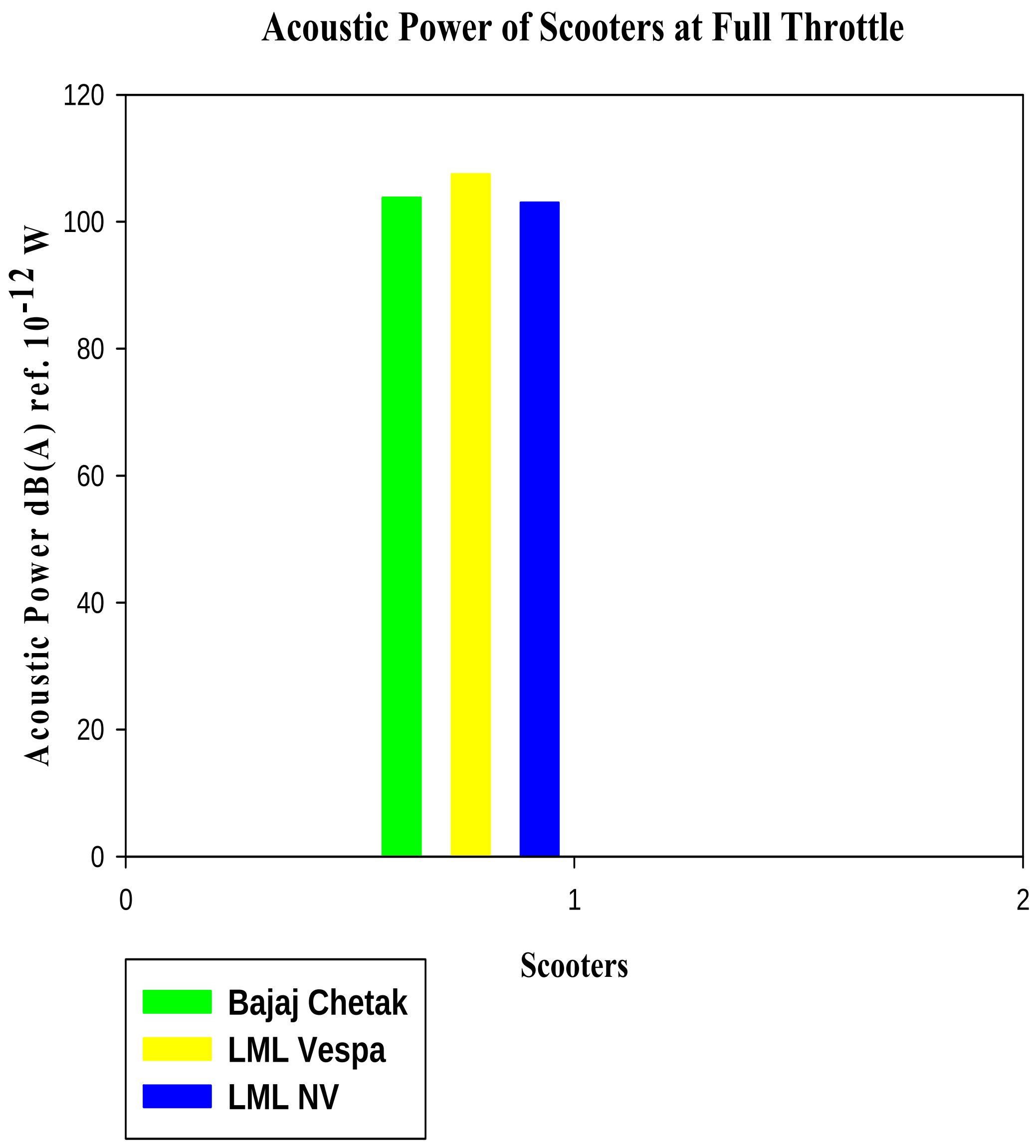

FIG. 5.8 Comparison of Sound Power Level of different Scooters at Full Throttle from Appendix B16-B18

Value of Acoustic power varies from 102.5 to 116.8 dB(A) (ref. 10^{-12} W) at Full Throttle. It seems to be LML Vespa has maximum and LML NV has minimum Acoustic Power amongst other.

5.1.3 Frequency Spectrum

This graph shows sound pressure level with respect to frequency at four different locations A, B, C and D at two operating conditions **Zero and Full Throttle** of Two Wheelers with reference to the **Appendix C** where the observation table is shown.

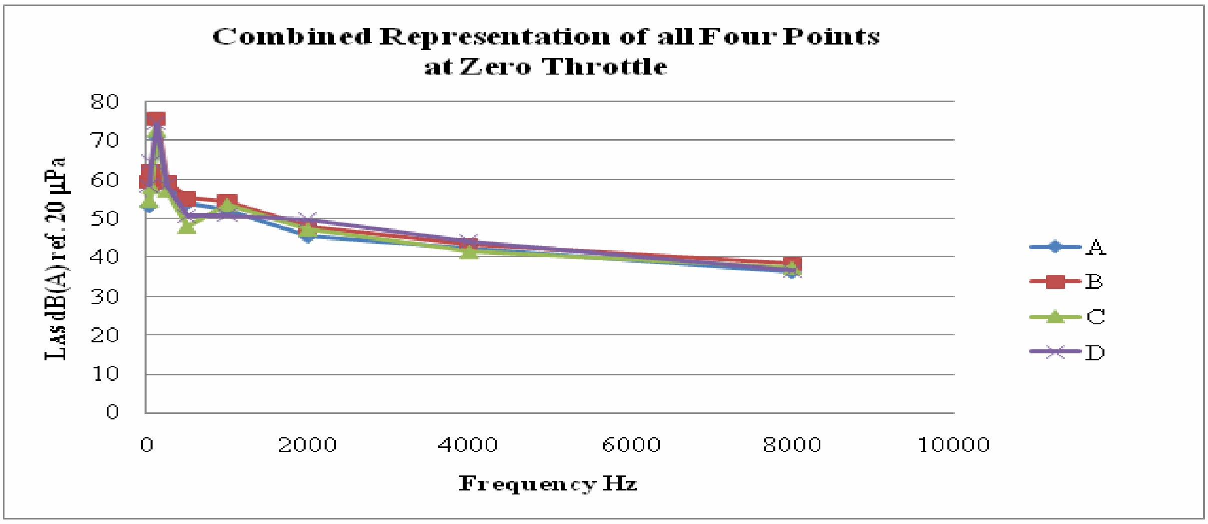

Fig. 5.9(a) Comparison between L_{AS} vs frequency at all four locations for Splendor Plus Zero Throttle from Appendix C1

The value of SPL in frequency spectrum varies from 36.2 to 75.7 dB(A) for Splendor Plus. It's found that maximum peak is at location B at 125 Hz which is in front of an engine and minimum at location A at 8000 Hz which is at the front end of Motorcycle.

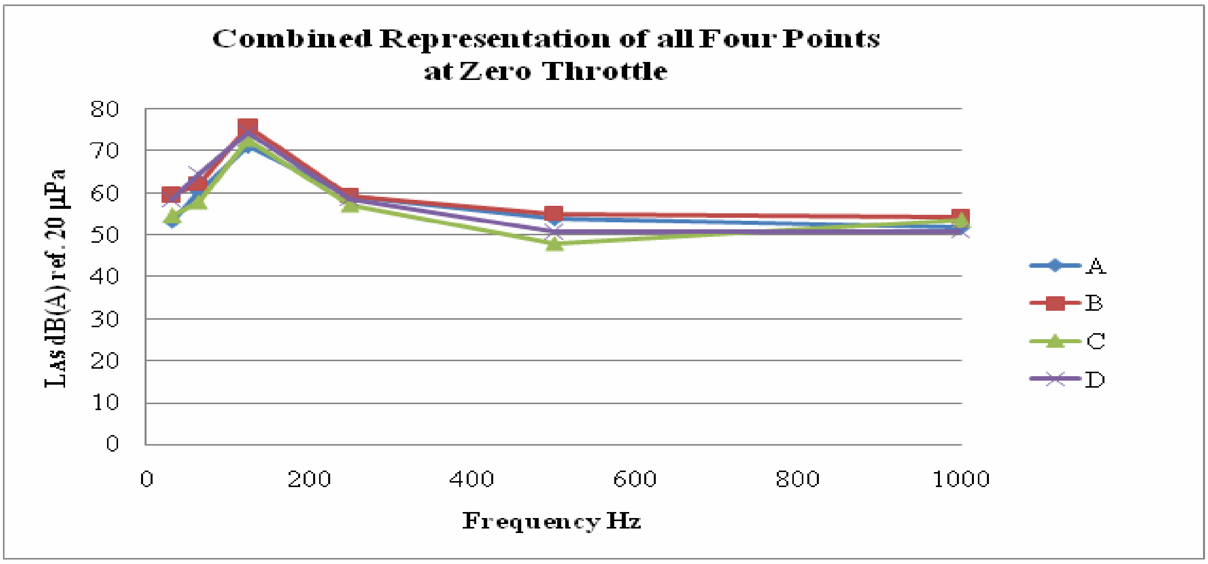

Fig. 5.9(b) Enlarged view of above Fig. 5.9(a)

It seems to be Sound Pressure Level dominates at lower frequency 125 Hz at location B. First it inceases upto dominating frequency and then decreases linearly with the increase in frequency.

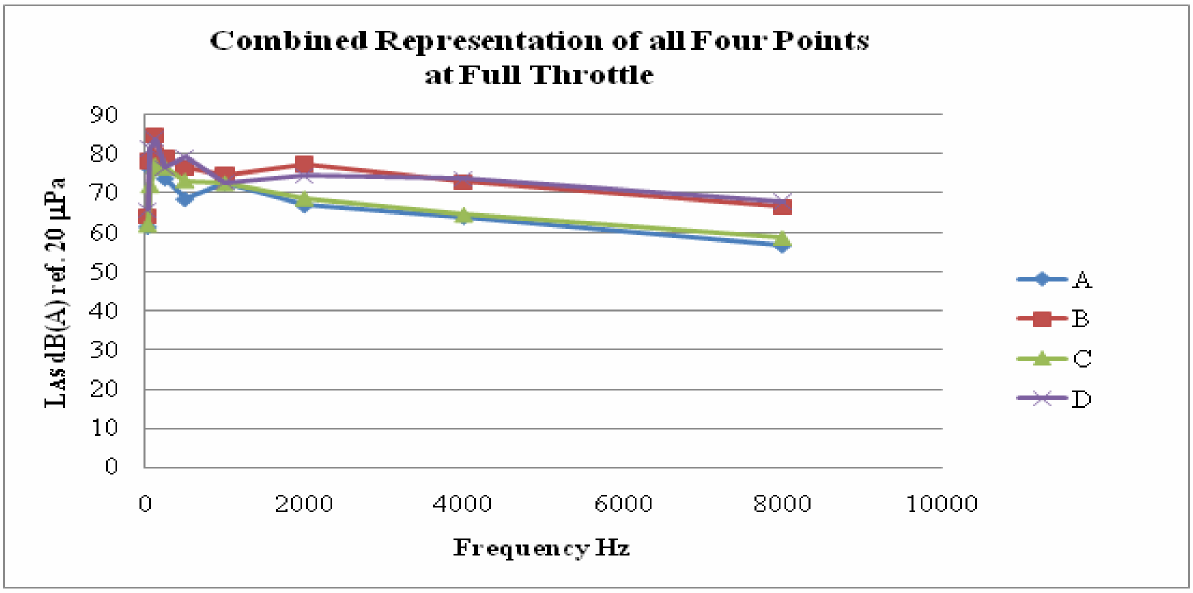

Fig. 5.10(a) Comparison between L_{AS} vs frequency at all four locations for Splendor Plus at Full Throttle from Appendix C1

The value of SPL in frequency spectrum varies from 56.7 to 84.5 dB(A) for Splendor Plus. It seems that maximum peak is at location B at frequency 125 Hz which is in front of an engine and minimum at location A at frequency 8000 Hz which is at the front end of Motorcycle.

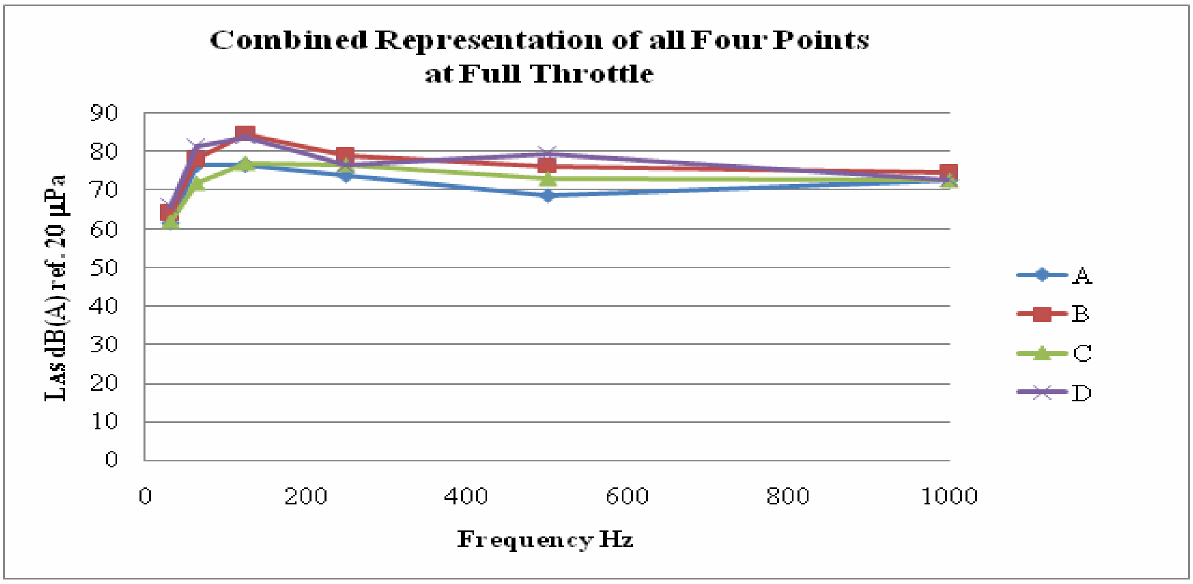

Fig. 5.10(b) Enlarged view of above Fig. 5.10(a)

It seems to be Sound Pressure Level dominates at lower frequency 125 Hz at location B. First it increases upto dominating frequency and then fluctuates with the increase in frequency .

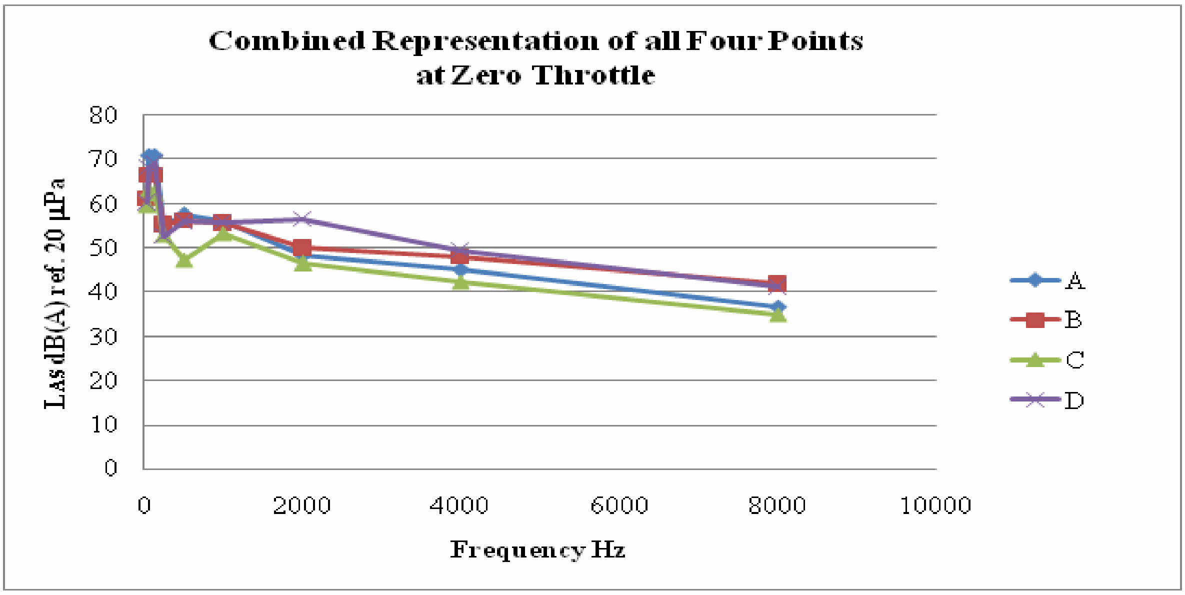

Fig. 5.11(a) Comparison between L_{AS} vs frequency at all four locations for Passion at Zero Throttle from Appendix C2

The value of SPL in frequency spectrum varies from 34.9 to 71.0 dB(A) for Passion. It seems that maximum peak at frequency 125 Hz at location A in which is in front of an engine and minimum peak at frequency 8000 Hz at location C which is at the front end of Motorcycle.

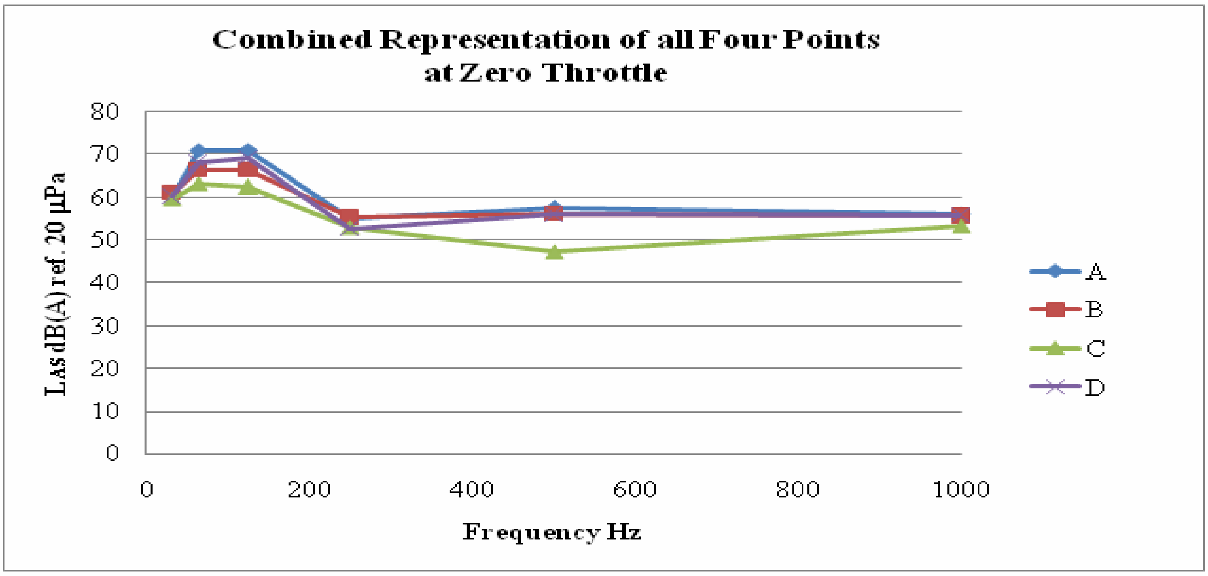

Fig. 5.11(b) Enlarged view of Fig. 5.11(a)

It seems to be Sound Pressure Level dominates at lower frequency 125 Hz at location A. First it increases upto dominating frequency and then fluctuates with the increase in frequency.

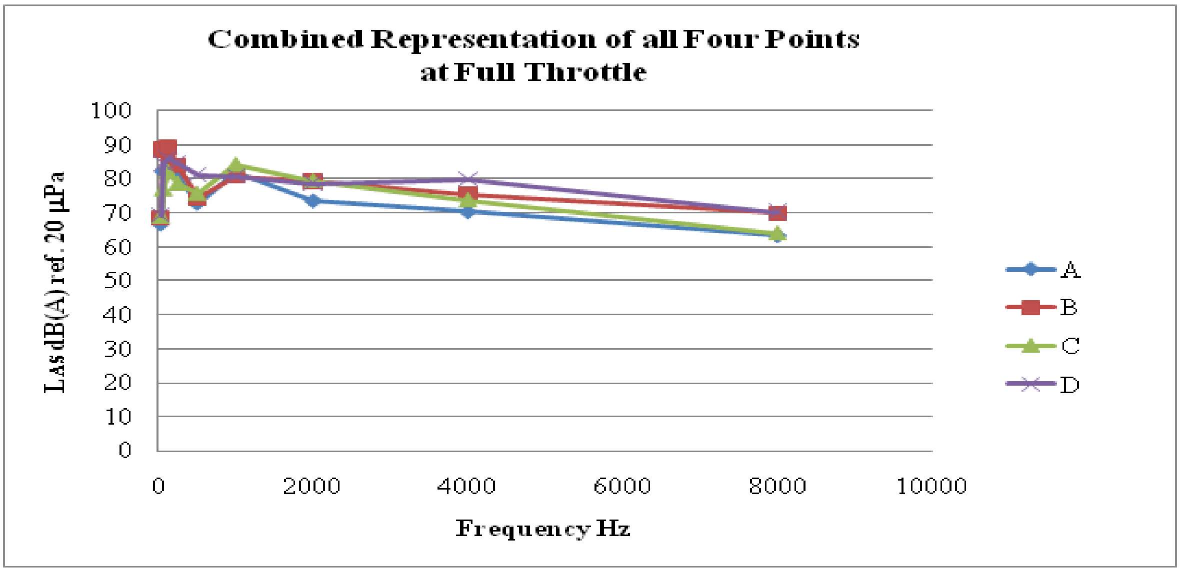

Fig. 5.12(a) Comparison between L_{AS} vs frequency at all four locations for Passion at Full Throttle from Appendix C2

The value of SPL in frequency spectrum varies from 64.0 to 89.2 dB(A) for Passion. It seems that maximum peak at frequency 125 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location A which is at the front end of Motorcycle.

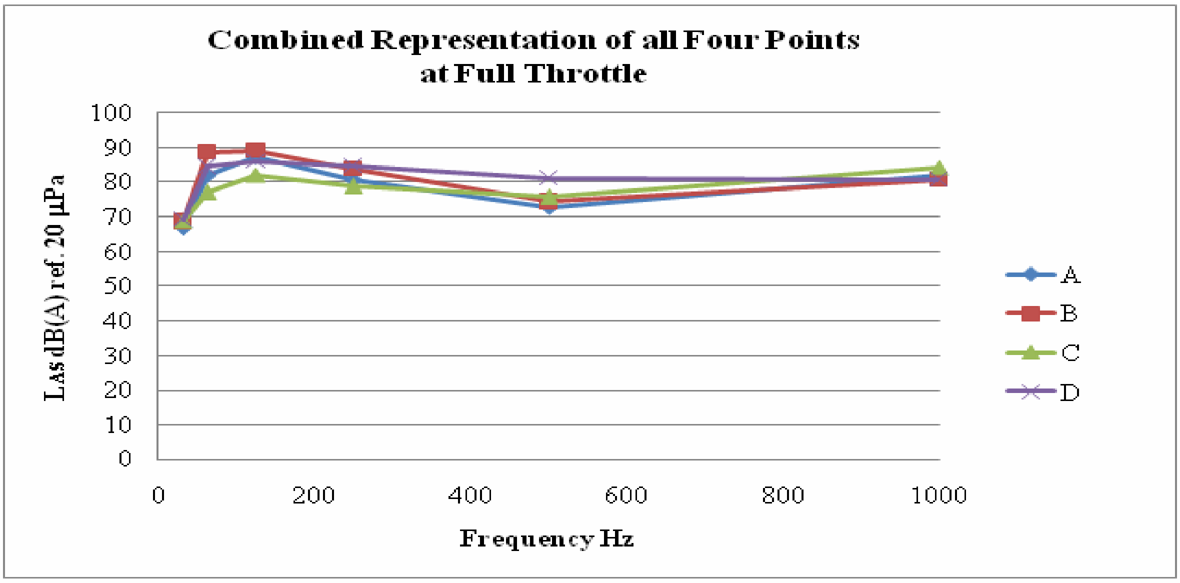

Fig. 5.12(b) Enlarged view of Fig. 5.12(a)

It seems to be Sound Pressure Level dominates at lower frequency 125 Hz at location B. First it increases upto dominating frequency and then fluctuates with the increase in frequency.

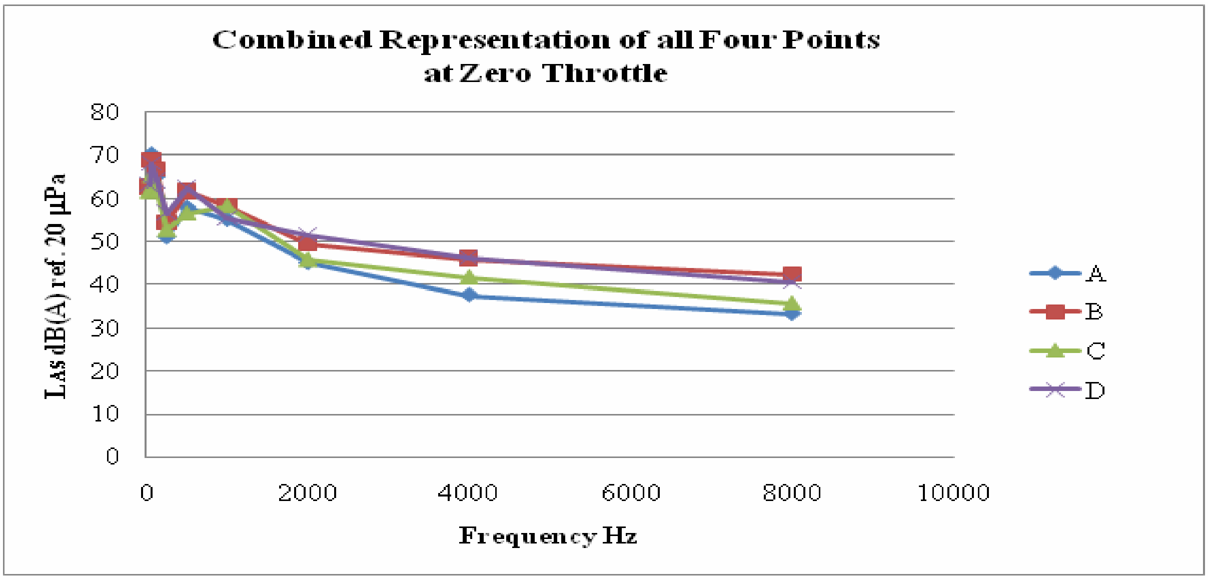

Fig. 5.13(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Caliber Chromo at Zero Throttle from Appendix C3

The value of SPL in frequency spectrum varies from 33.2 to 70.3 dB(A) for Caliber Chromo. It seems that maximum peak at frequency 63 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location A which is at the front end of Motorcycle.

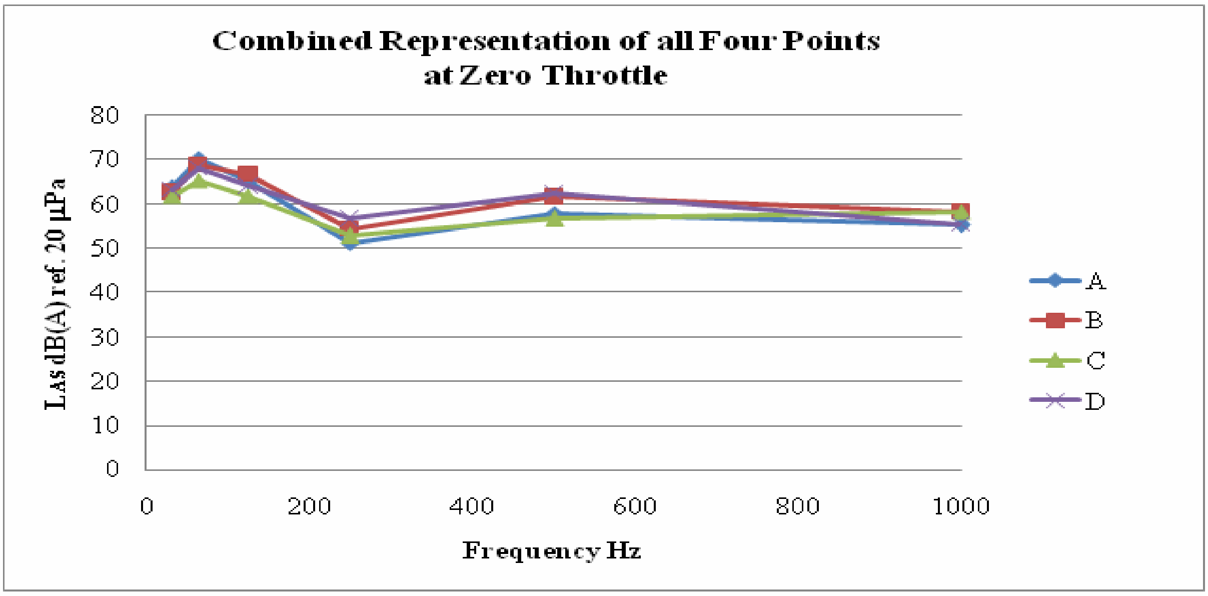

Fig. 5.13(b) Enlarged view of Fig. 5.13(a)

It seems to be Sound Pressure Level dominates at lower frequency 63 Hz at location B. First it increases upto dominating frequency and then fluctuates with the increase in frequency.

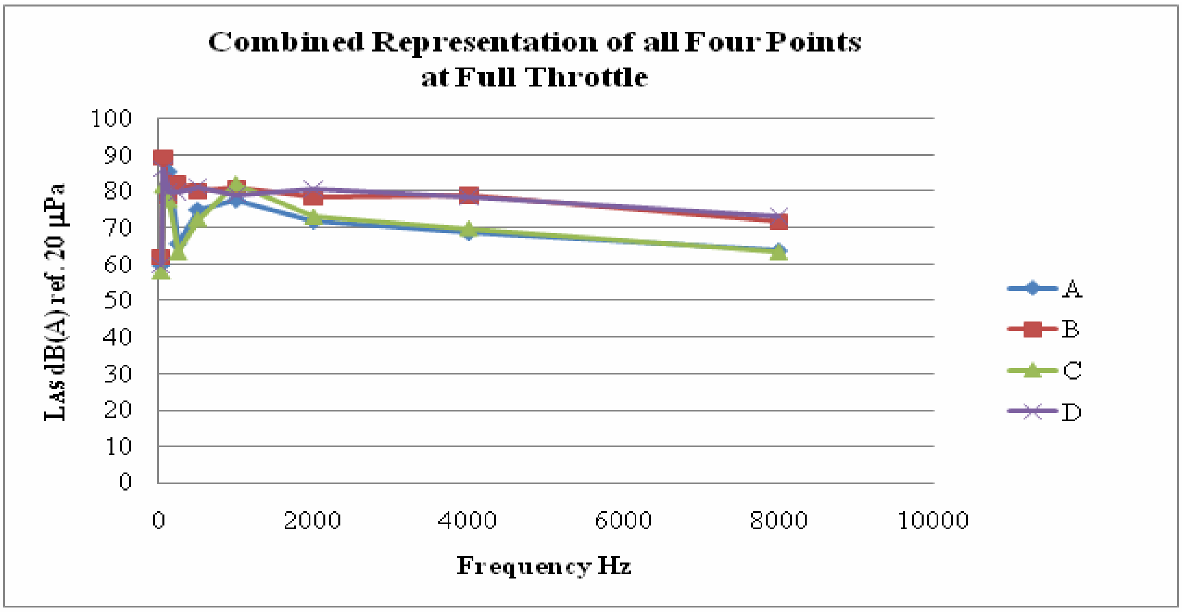

Fig. 5.14(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Caliber Chromo at Full Throttle from Appendix C3

The value of SPL in frequency spectrum varies from 63.8 to 89.4 dB(A) for Caliber Chromo. It seems that maximum peak at frequency 63 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location A which is at the front end of Motorcycle.

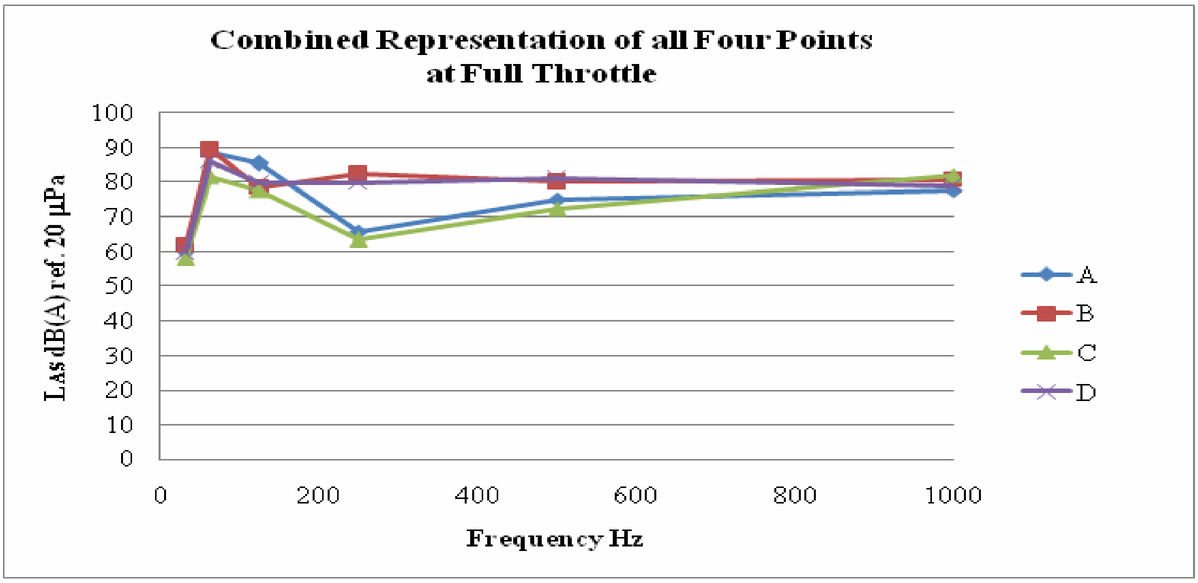

Fig. 5.14(b) Enlarged view of Fig. 5.14(a)

It seems to be Sound Pressure Level dominates at lower frequency 63 Hz at location B. First it increases upto dominting frequency and then fluctuates with the increase in frequency.

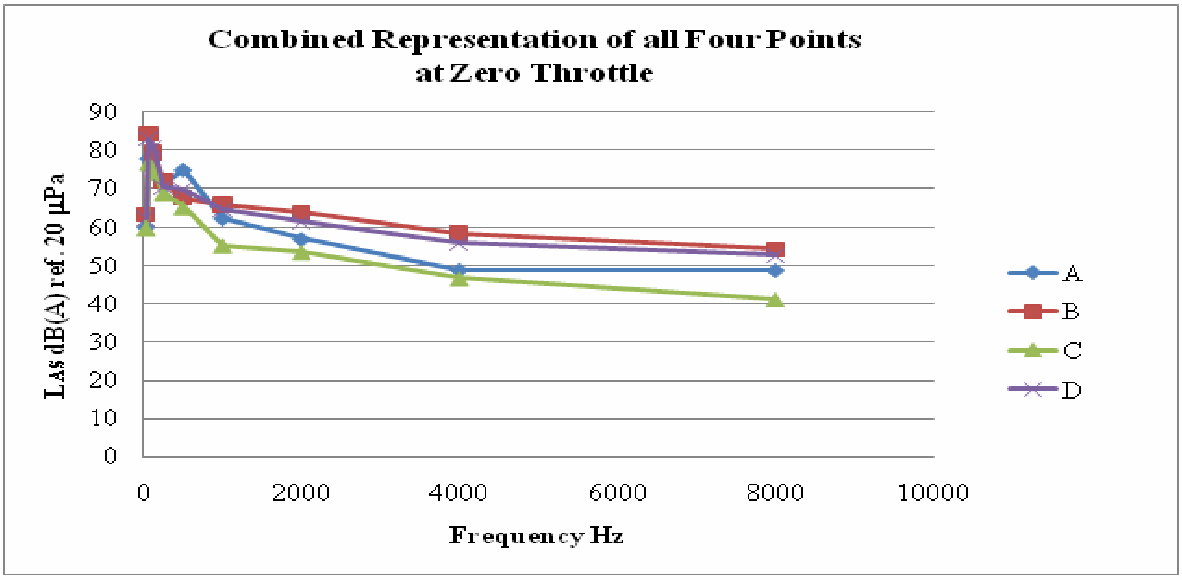

Fig. 5.15(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Pulsar* at Zero Throttle from Appendix C4

The value of SPL in frequency spectrum varies from 41.1 to 84.2 dB(A) for Bajaj Pulsar. It seems that maximum peak at frequency 125 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location C which is at the rear end of Motorcycle.

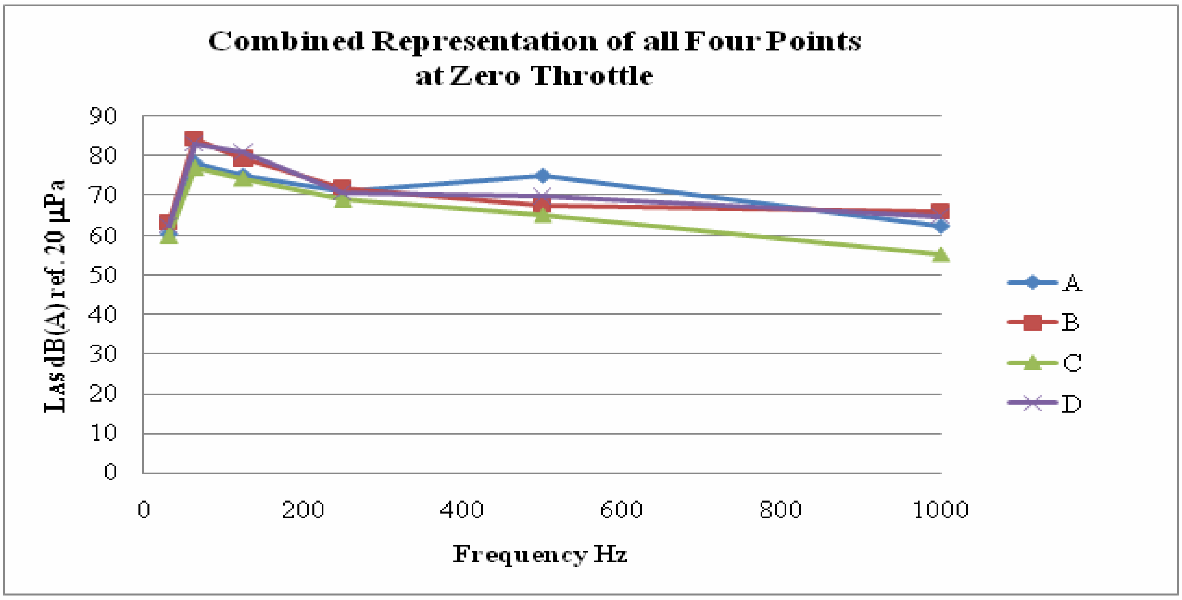

Fig. 5.15(b) Enlarged view of Fig. 5.15(a)

It seems to be Sound Pressure Level dominates at lower frequency 125 Hz at location B. First it increases upto dominating frequency and then fluctuates with the increase in frequency.

"*" shows silencer is defective.

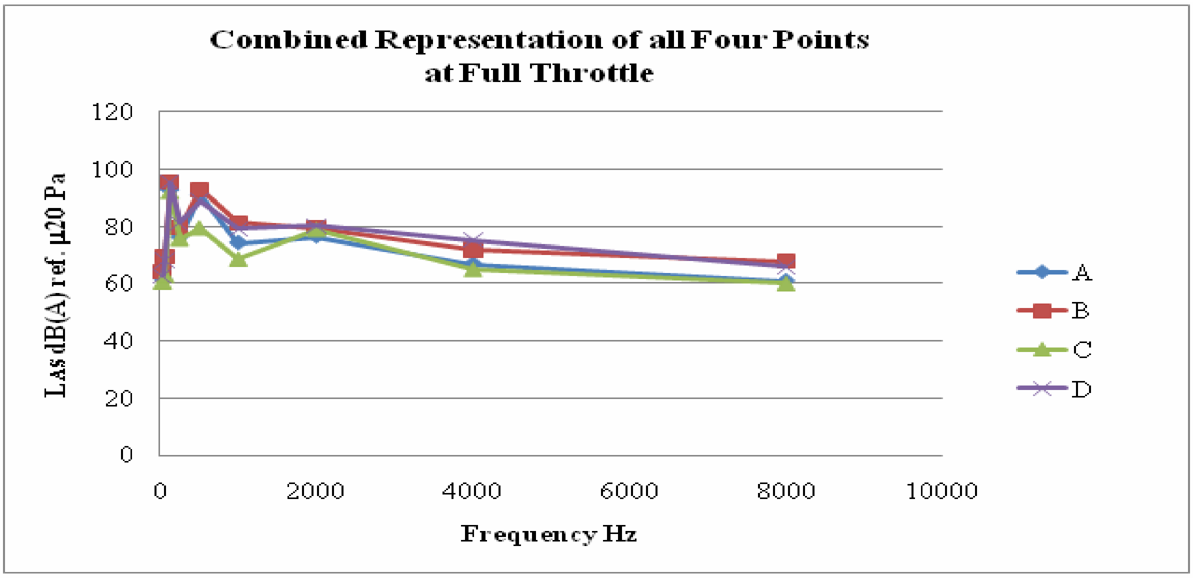

Fig. 5.16(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Pulsar* at Full Throttle from Appendix C4

The value of SPL in frequency spectrum varies from 60.2 to 95.6 dB(A) for Bajaj Pulsar. It seems that maximum peak at frequency 125 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location C which is at the rear end of Motorcycle.

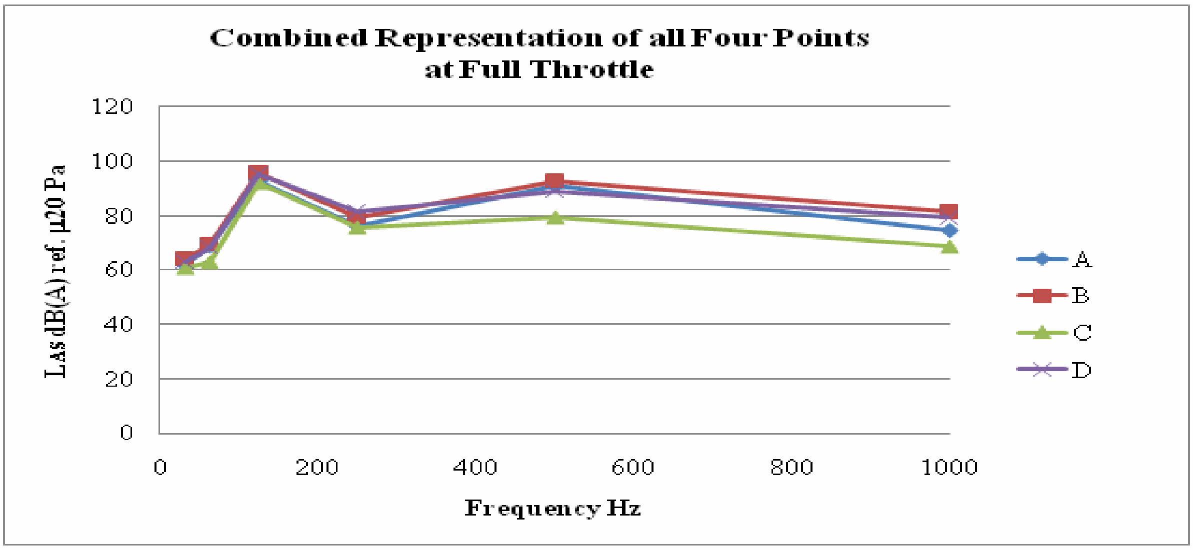

Fig. 5.16(b) Enlarged view of Fig. 5.16(a)

It seems to be Sound Pressure Level dominates at lower frequency 125 Hz at location B. First it increases upto dominating frequency and then fluctuates with the increase in frequency.

"*" shows silencer is defective.

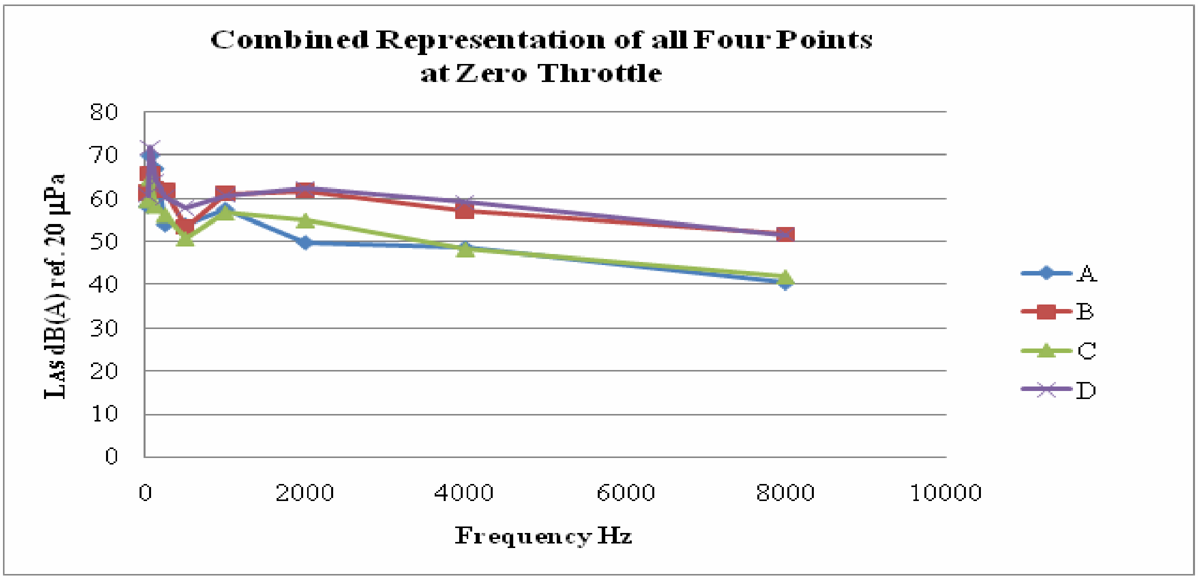

Fig. 5.17(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Boxer at Zero Throttle from Appendix C5

The value of SPL in frequency spectrum varies from 40.4 to 71.9 dB(A) for Bajaj Boxer. It seems that maximum peak at frequency 63 Hz at location D in which is in front of an engine and minimum peak at frequency 8000 Hz at location A which is at the front end of Motorcycle.

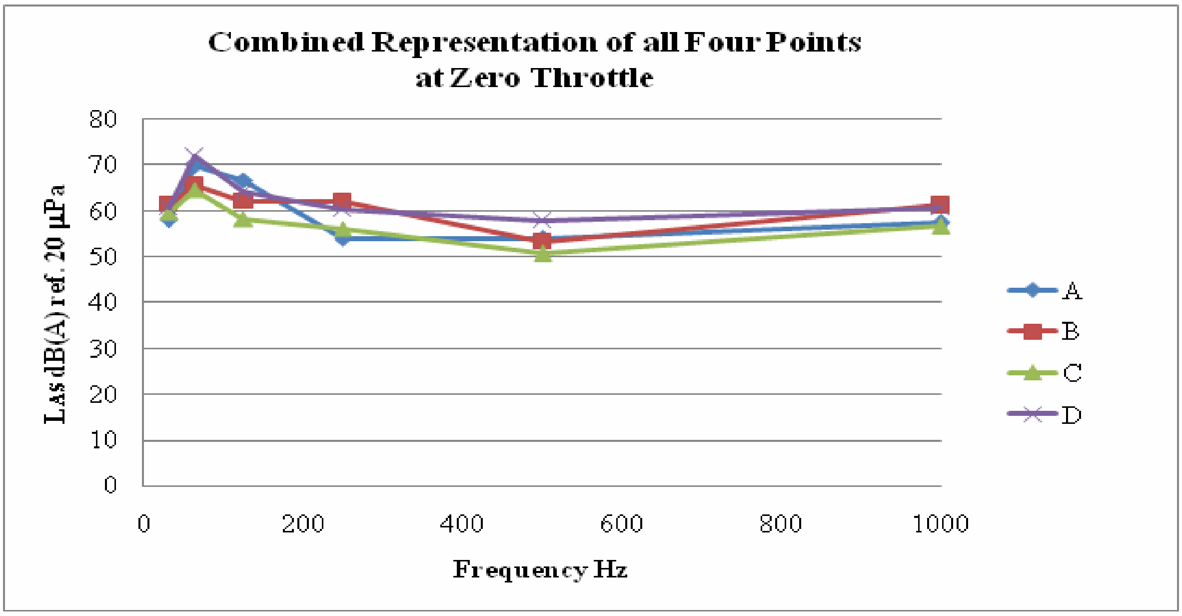

Fig. 5.17(b) Enlarged view of Fig. 5.17(a)

It seems to be Sound Pressure Level dominates at lower frequency 63 Hz at location D. First it increases upto dominating frequency and then fluctuates with the increase in frequency.

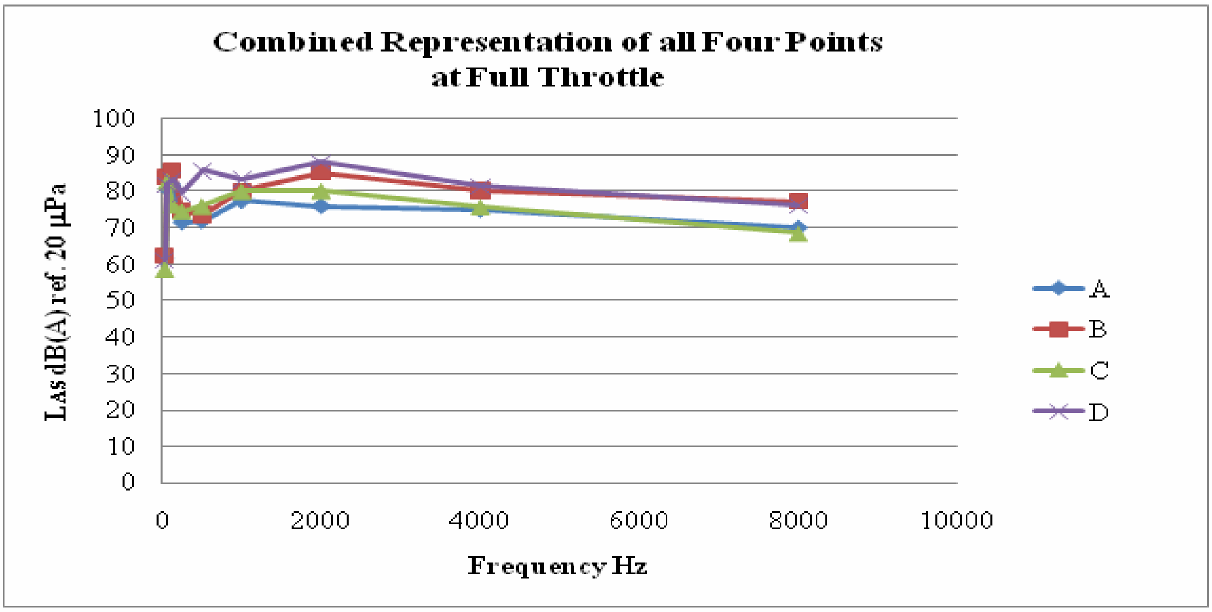

Fig. 5.18(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Boxer at Full Throttle from Appendix C5

The value of SPL in frequency spectrum varies from 61.3 to 88.0 dB(A) for Bajaj Boxer. It seems that maximum peak at frequency 2000 Hz at location D in which is in front of an engine and minimum peak at frequency 31.5 Hz at location C which is at the rear end of Motorcycle.

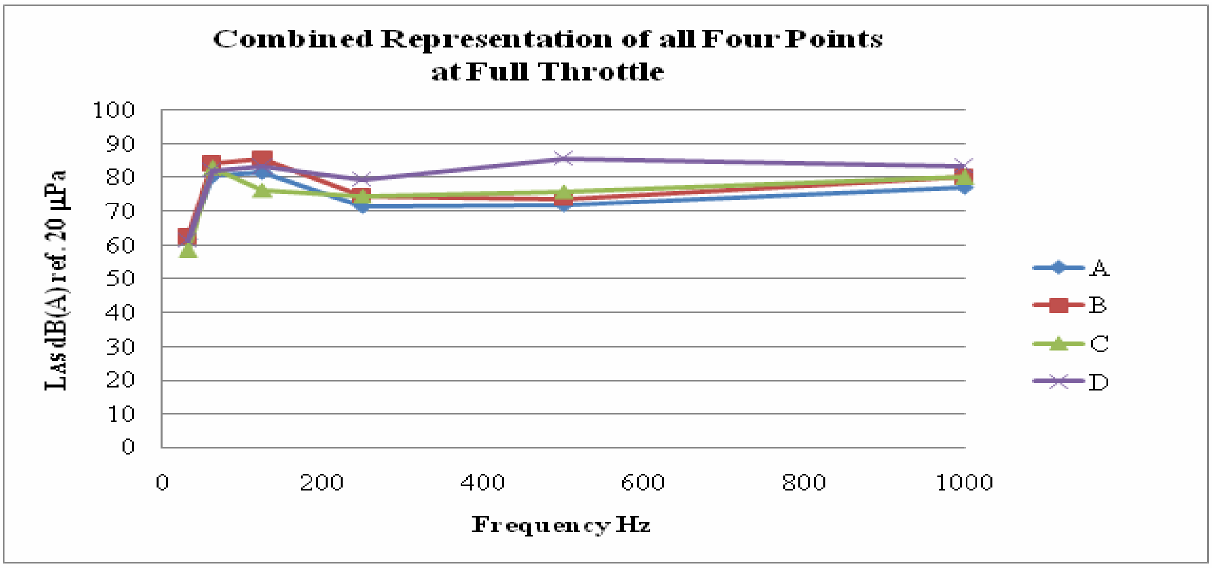

Fig. 5.18(b) Enlarged view of Fig. 5.18(a)

It seems to be Sound Pressure Level dominates at higher frequency 2000 Hz at location D. First it fluctuates upto dominating frequency and then decreases with the increase in frequency.

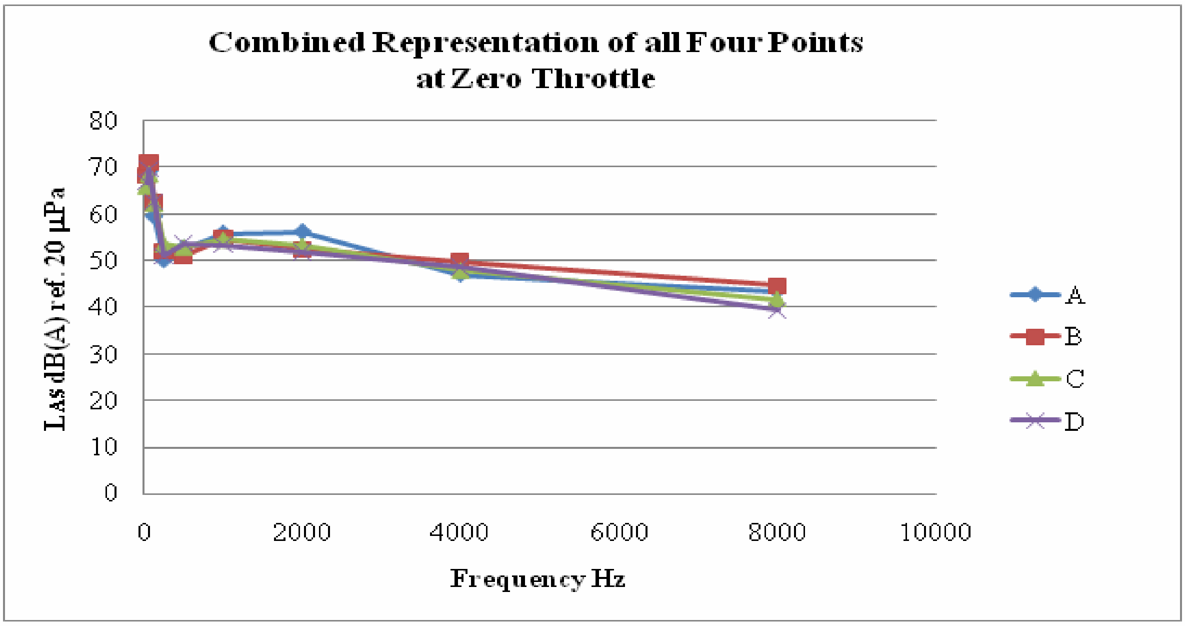

Fig. 5.19(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Discover at Zero Throttle from Appendix C6

The value of SPL in frequency spectrum varies from 39.9 to 71.0 dB(A) for Bajaj Discover. It seems that maximum peak at frequency 63 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location D which is behind engine of Motorcycle.

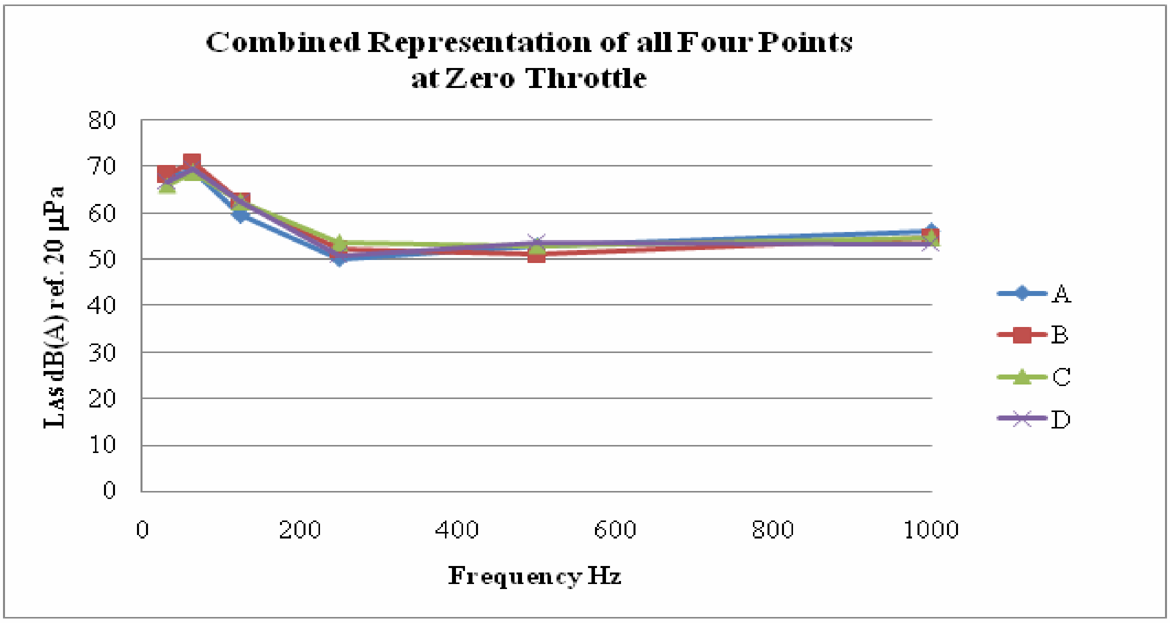

Fig. 5.19(b) Enlarged view of Fig. 5.19(a)

It seems to be Sound Pressure Level dominates at lower frequency 63 Hz at location B. First it increases upto dominating frequency and then moves linearly with the increase in frequency.

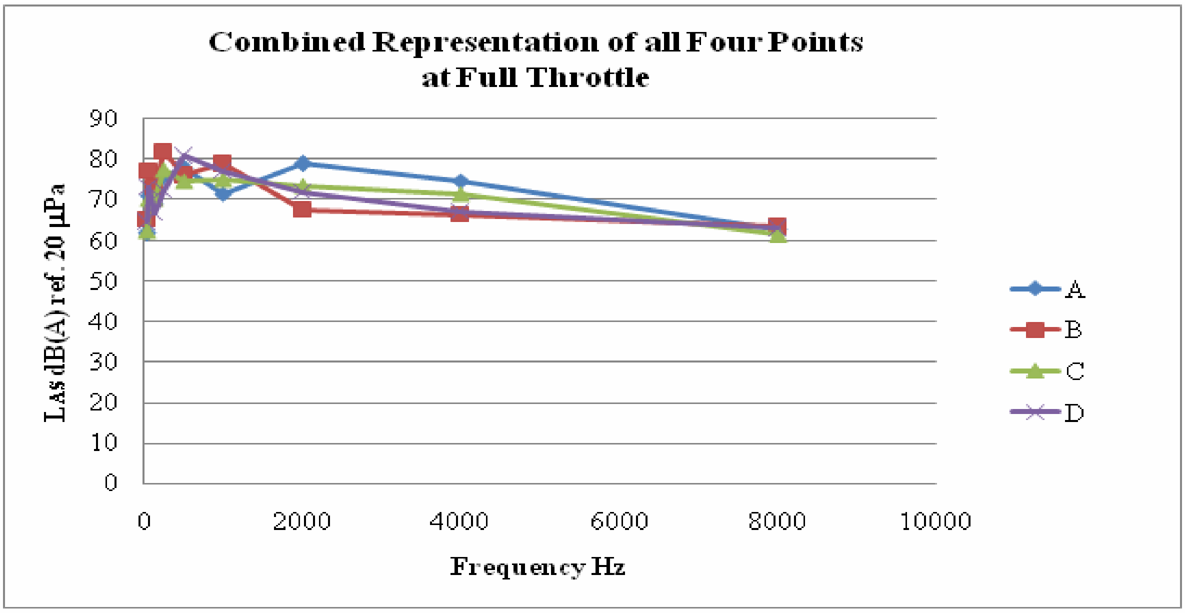

Fig. 5.20(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Discover at Full Throtle from Appendix C6

The value of SPL in frequency spectrum varies from 61.4 to 81.9 dB(A) for Bajaj Discover. It seems that maximum peak at frequency 250 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location C which is at the rare end of Motorcycle.

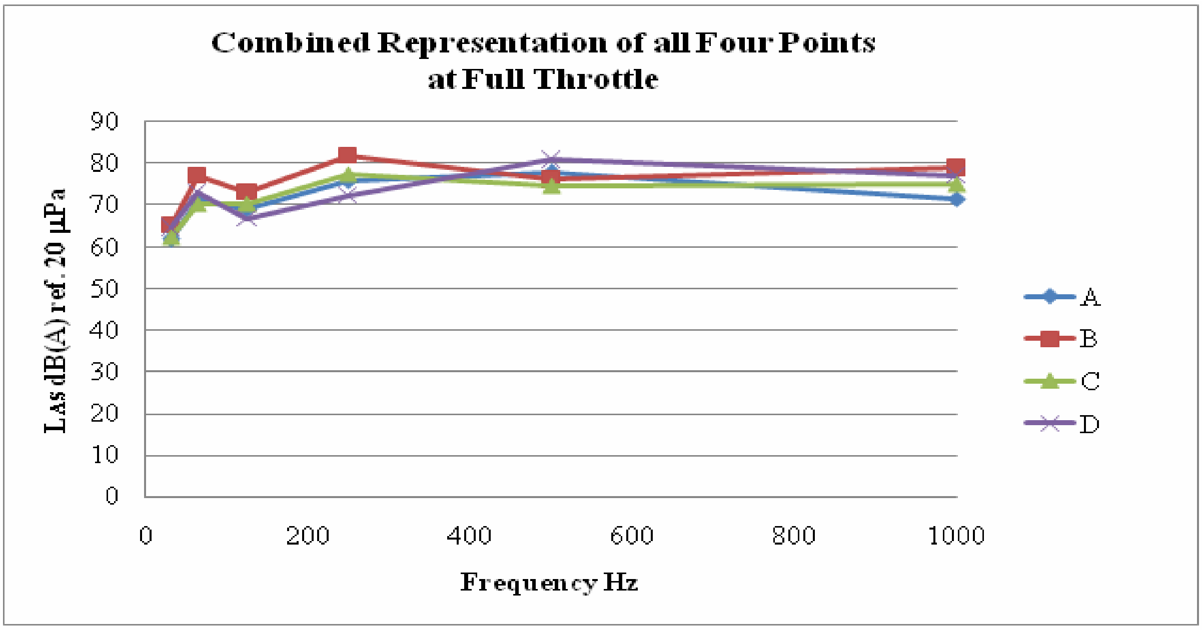

Fig. 5.20(b) Enlarged view of Fig. 5.20(a)

It seems to be Sound Pressure Level dominates at lower frequency 250 Hz at location B. First it increases upto dominating frequency and then fluctuates with the increase in frequency.

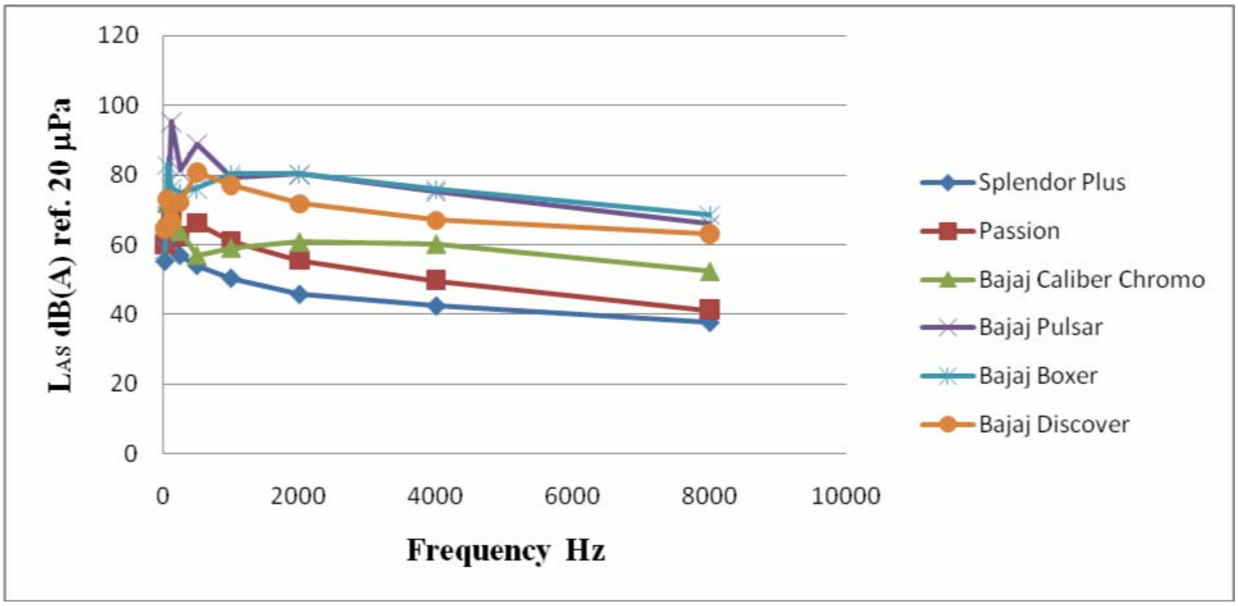

Fig. 5.21 Comparison between L_{AS} vs frequency at location A at Zero Throttle for all Motorcycles from Appendix C1-C6

It seems that Bajaj Caliber Chromo would be better amongst all available Motorcycle at location B at Zero Throttle.

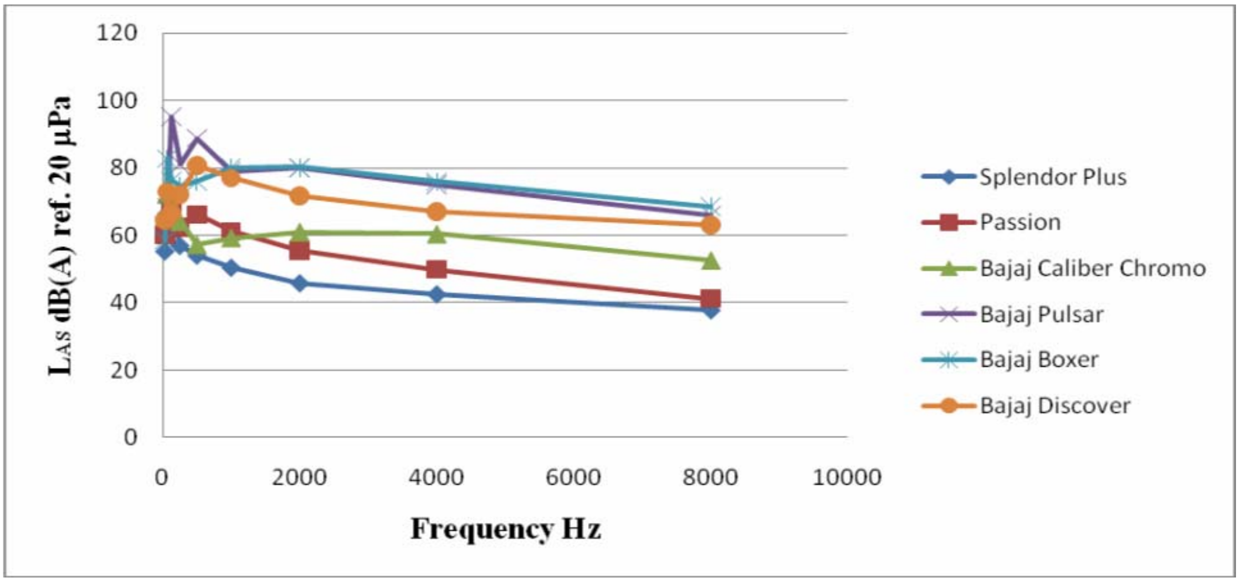

Fig. 5.22 Comparison between L_{AS} vs frequency at location B at Zero Throttle for all Motorcycles from Appendix C1-C6

It seems that Splendor Plus would be better amongst all available Motorcycle at location B at Zero Throttle. The engine noise of this motorcycle is seems to be less as compared with others.

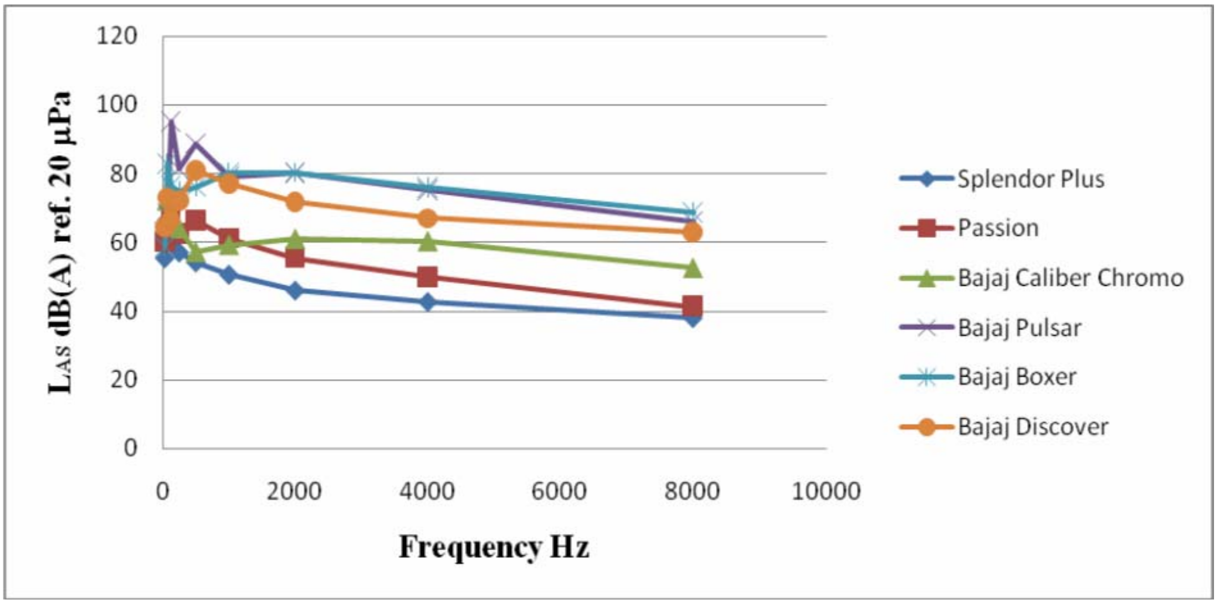

Fig. 5.23 Comparison between L_{AS} vs frequency at location C at Zero Throttle for all Motorcycles from Appendix C1-C6

It seems that Passion would be better motorcycle amongst all available Motorcycle at location C at Zero Throttle. The exhaust noise of this motorcycle is seems to be less than the others.

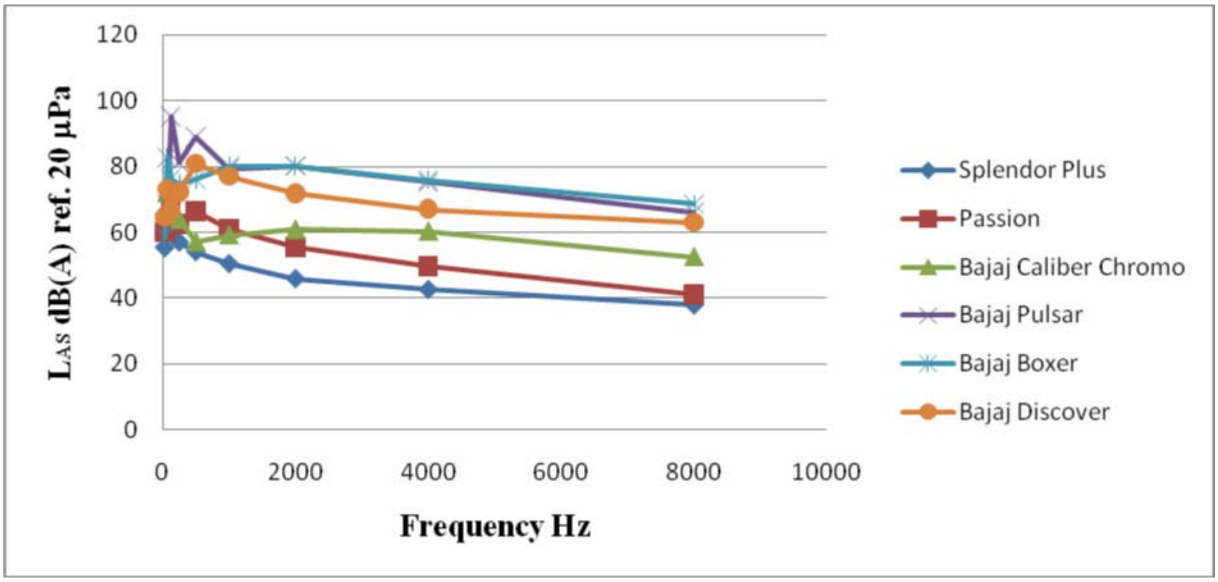

Fig. 5.24 Comparison between L_{AS} vs frequency at location D at Zero Throttle for all Motorcycles from Appendix C1-C6

It seems that Splendor Plus would be better amongst all available Motorcycle at location D at Zero Throttle.

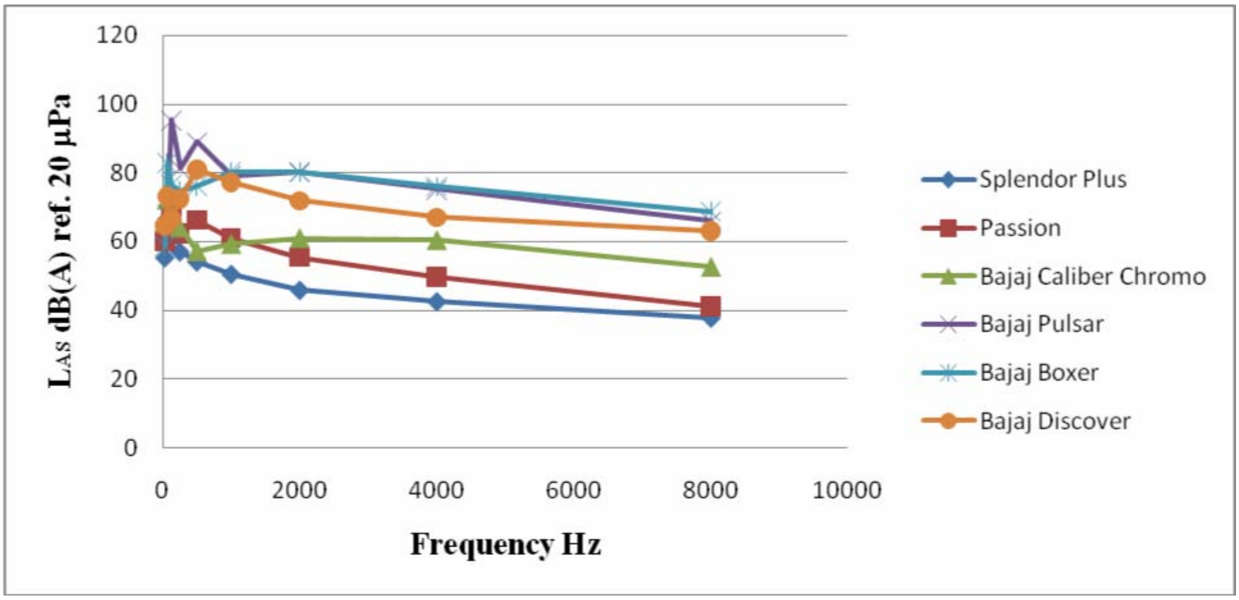

Fig. 5.25 Comparison between L_{AS} vs frequency at location A at Full Throttle for all Motorcycles from Appendix C1-C6

It seems that Splendor Plus would be better amongst all available Motorcycle at location A at Full Throttle.

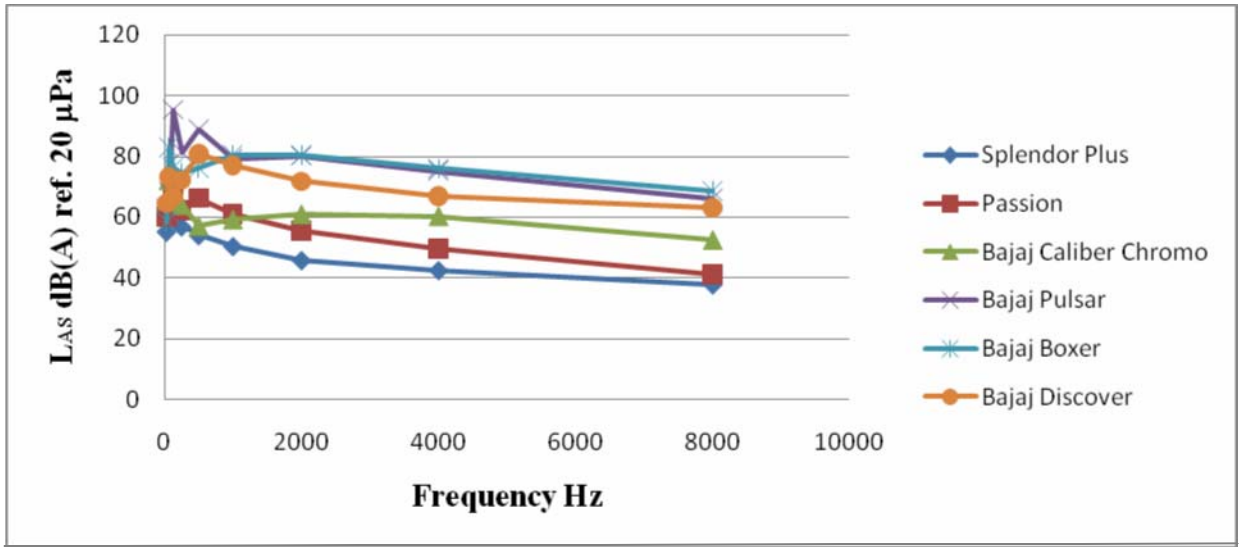

Fig. 5.26 Comparison between L_{AS} vs frequency at location B at Full Throttle for all Motorcycles from Appendix C1-C6

It seems that Bajaj Discover would be better amongst all available Motorcycle at location B at Full Throttle. The engine noise of this motorcycle is seems to be less as compared with others.

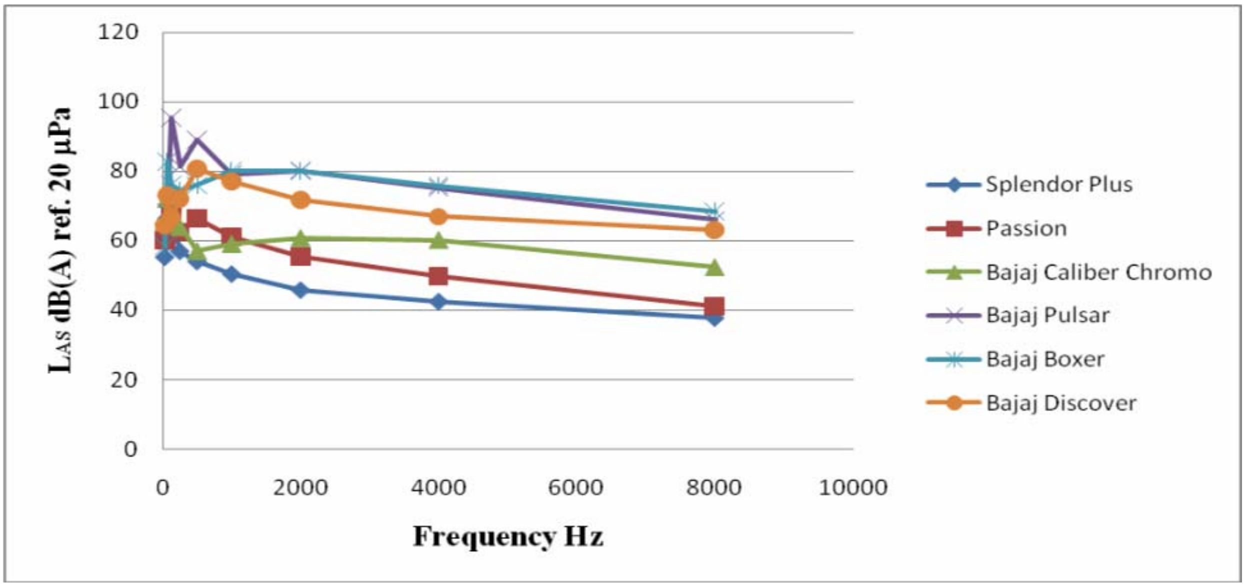

Fig. 5.27 Comparison between L_{AS} vs frequency at location C at Full Throttle for all Motorcycles from C1-C6

It seems that Splendor Plus would be better amongst all available Motorcycle at location C at Full Throttle.

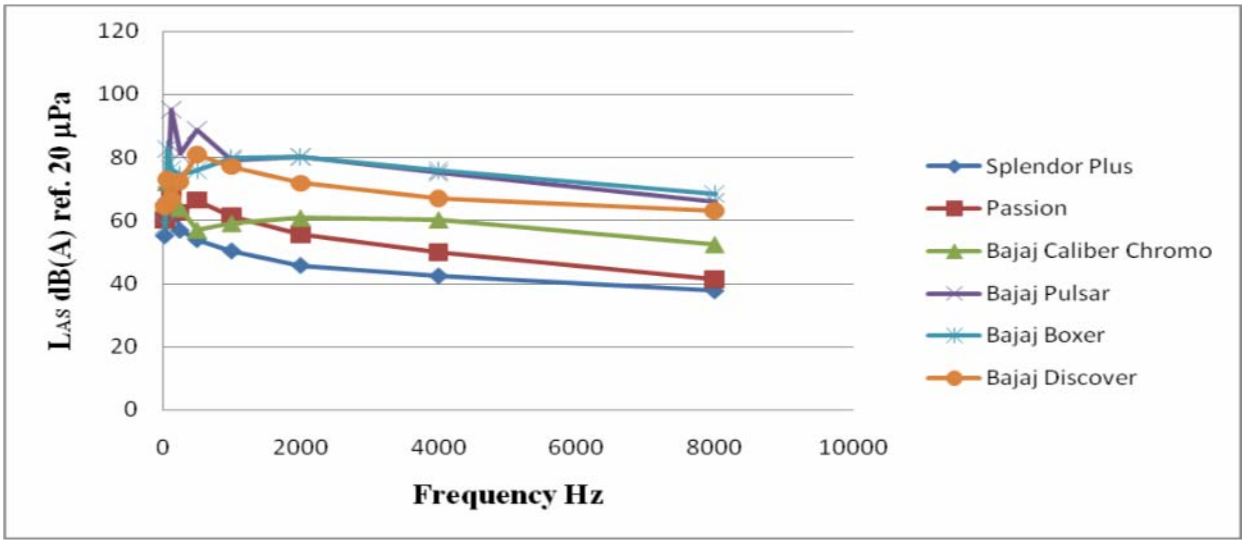

Fig. 5.28 Comparison between L_{AS} vs frequency at location D at Full Throttle for all Motorcycles from Appendix C1-C6

It seems that Bajaj Discover would be better amongst all available Motorcycle at location D at Full Throttle.

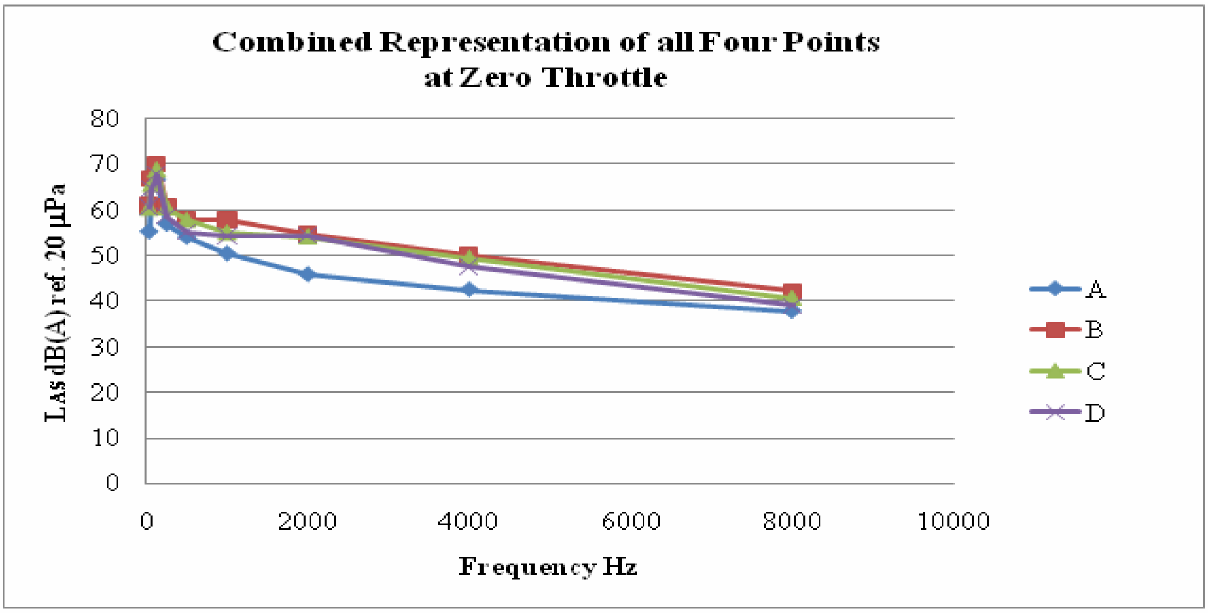

Fig. 5.29(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Chetak from Appendix C7

The value of SPL in frequency spectrum varies from 37.9 to 69.9 dB(A) for Bajaj Chetak. It seems that maximum peak at frequency 125 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location A which is at the front end of Scooter.

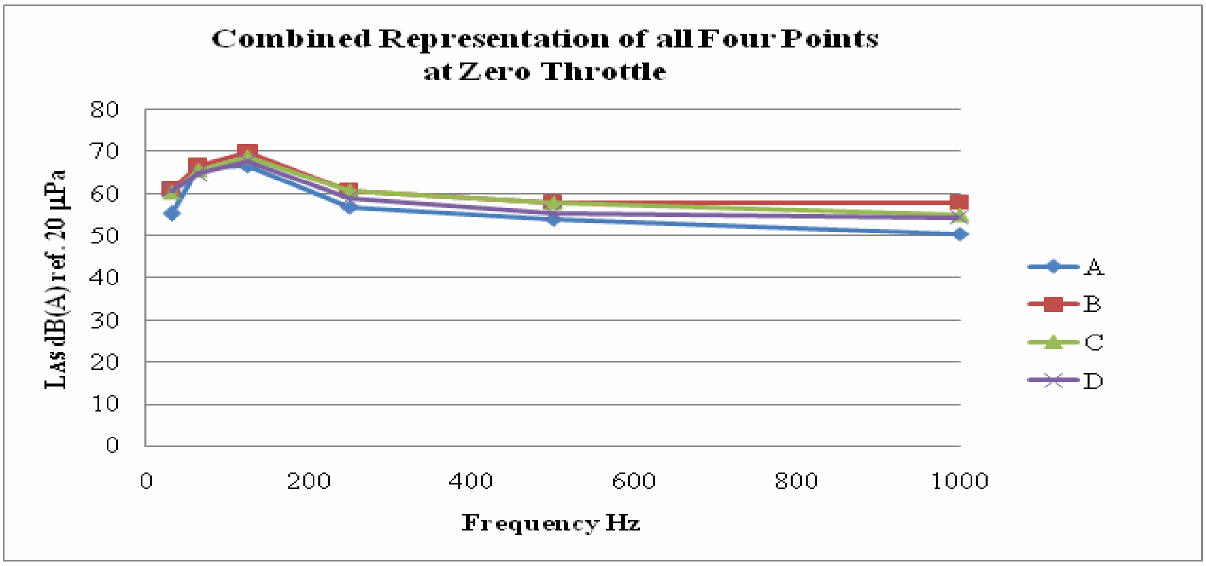

Fig. 5.29(b) Enlarged view of Fig. 5.29(a)

It seems to be Sound Pressure Level dominates at lower frequency 125 Hz at location B. First it increases upto dominating frequenncy and then become almost linear with the increase in frequency. The variation though, is not very large, it is nearly constant.

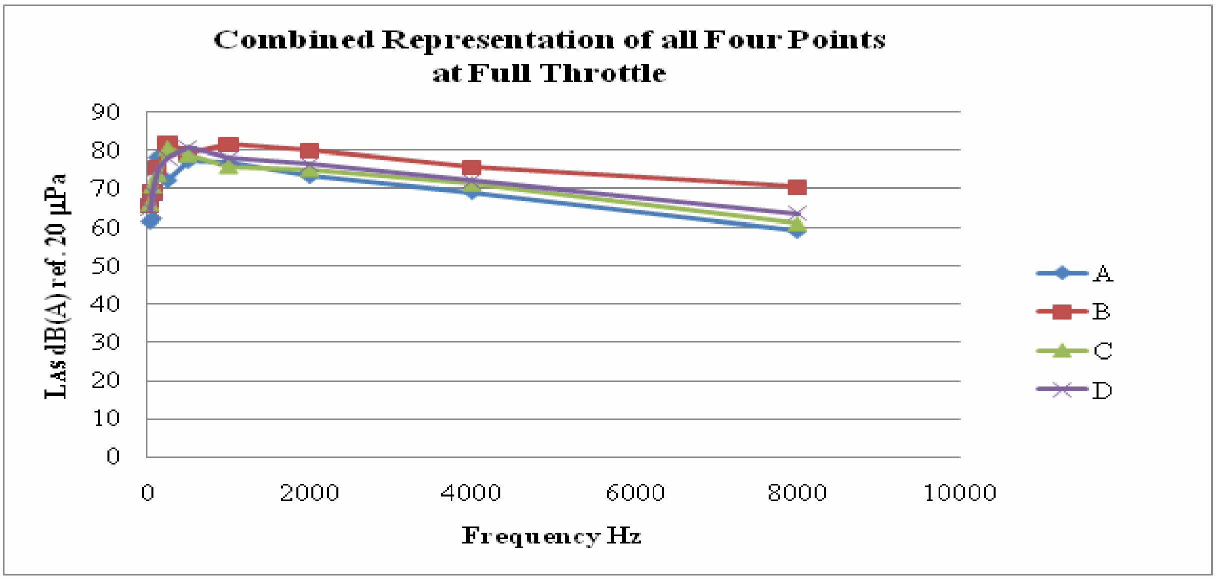

Fig. 5.30(a) Comparison between L_{AS} vs frequency at all four locations for Bajaj Chetak from Appendix C7

The value of SPL in frequency spectrum varies from 59.0 to 82.0 dB(A) for Bajaj Chetak. It seems that maximum peak at frequency 250 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location A which is at the front end of Scooter.

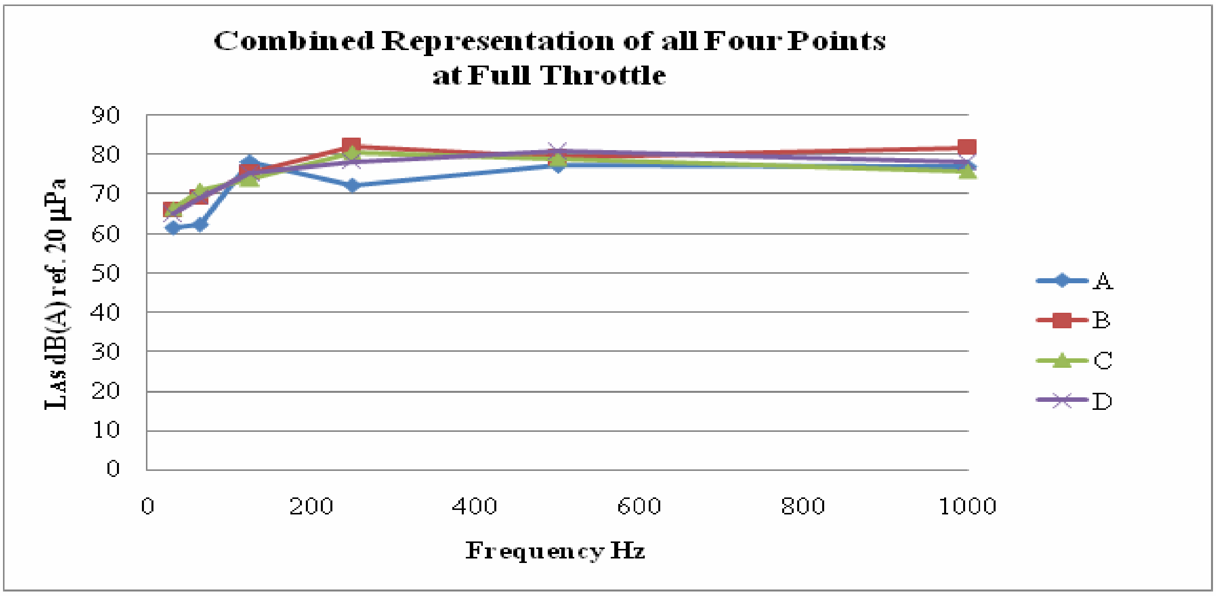

Fig. 5.30(b) Enlarged view of Fig. 5.30(a)

It seems to be Sound Pressure Level dominates at lower frequency 250 Hz at location B. First it increases upto dominating frequency and then become almost linear with the increase in frequency. The variation though, is not large, it is nearly constant.

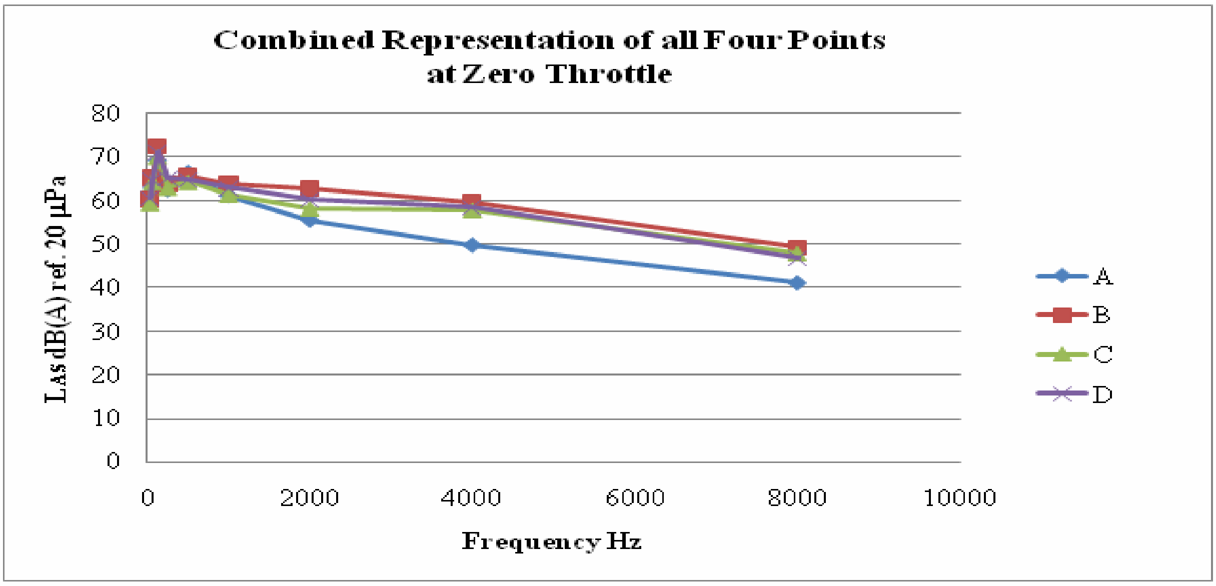

Fig. 5.31(a) Comparison between L_{AS} vs frequency at all four locations for LML Vespa from Appendix C8

The value of SPL in frequency spectrum varies from 41.2 to 72.4 dB(A) for LML Vespa. It seems that maximum peak at frequency 125 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location A which is at the front end of Scooter.

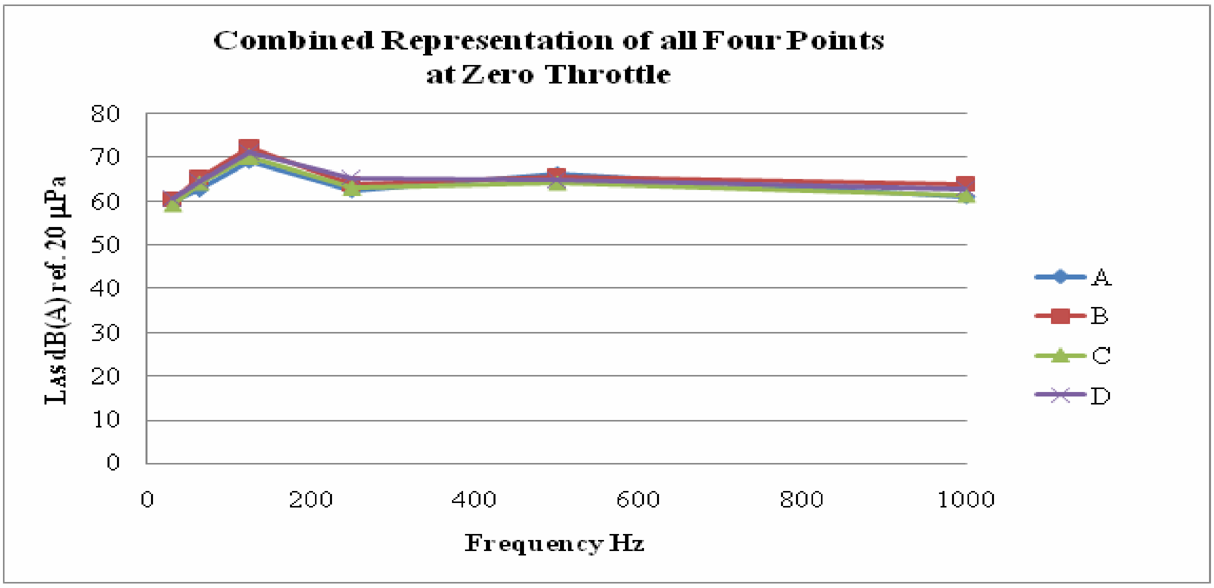

Fig. 5.31(b) Enlarged view of Fig. 5.31(a)

It seems to be Sound Pressure Level dominates at lower frequency 125 Hz at location B. First it increases upto dominating frequency and then become almost linear with the increase in frequency. The variation though, very small, it nearly constant.

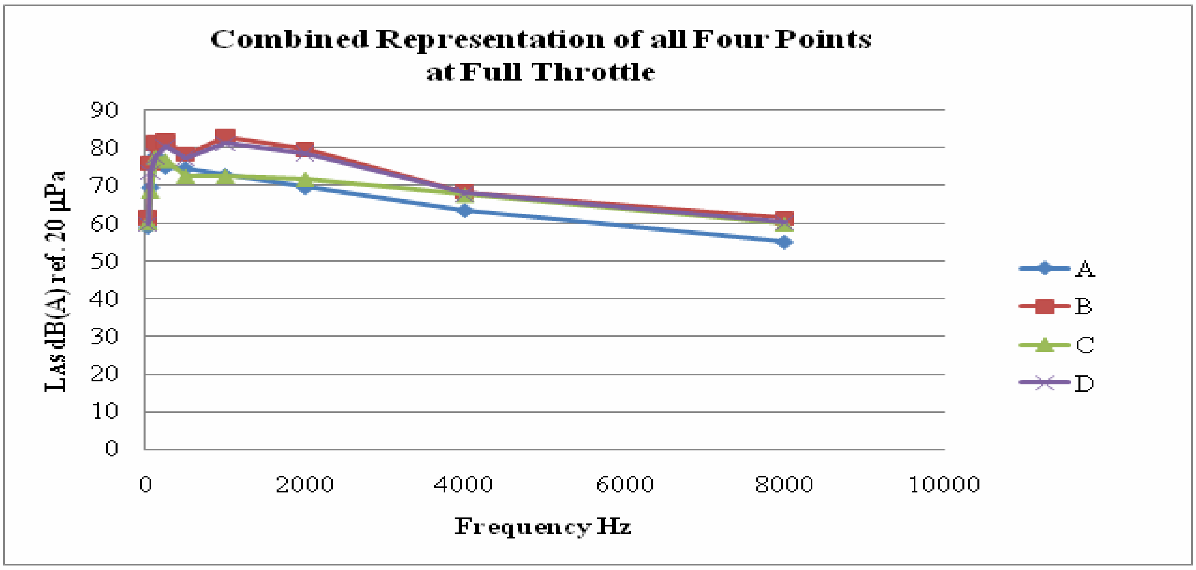

Fig. 5.32(a) Comparison between L_{AS} vs frequency at all four locations for LML Vespa from Appendix C8

The value of SPL in frequency spectrum varies from 55.0 to 81.8 dB(A) for LML Vespa. It seems that maximum peak at frequency 250 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location A which is at the front end of Scooter.

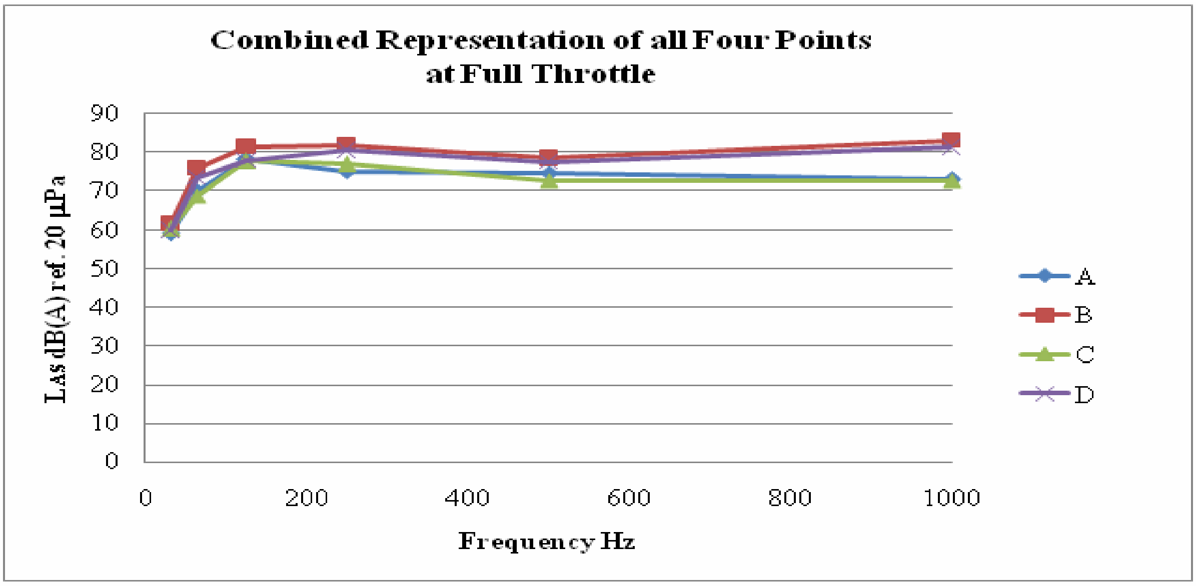

Fig. 5.32(b) Enlarged view of Fig. 5.32(a)

It seems to be Sound Pressure Level dominates at lower frequency 250 Hz at location B. First it increases upto dominating frequency and then fluctuates with the increase in frequency.

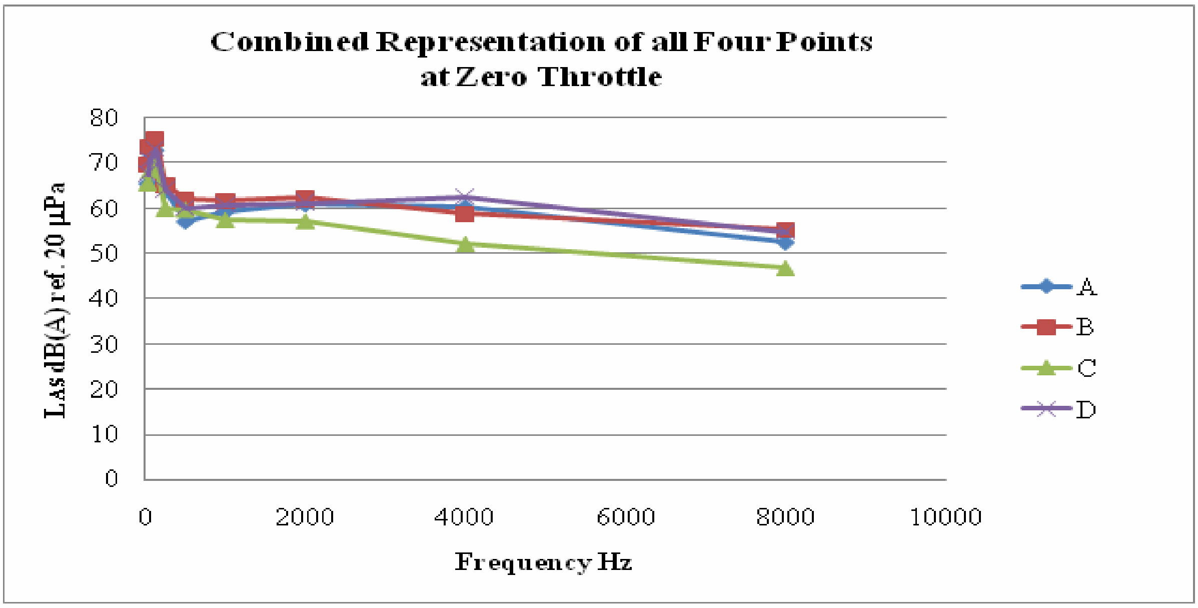

Fig. 5.33(a) Comparison between L_{AS} vs frequency at all locations for LML NV from Appendix C9

The value of SPL in frequency spectrum varies from 52.5 to 75.4 dB(A) for LML NV. It seems that maximum peak at frequency 125 Hz at location B in which is in front of an engine and minimum peak at frequency 8000 Hz at location C which is at the rear end of Scooter.

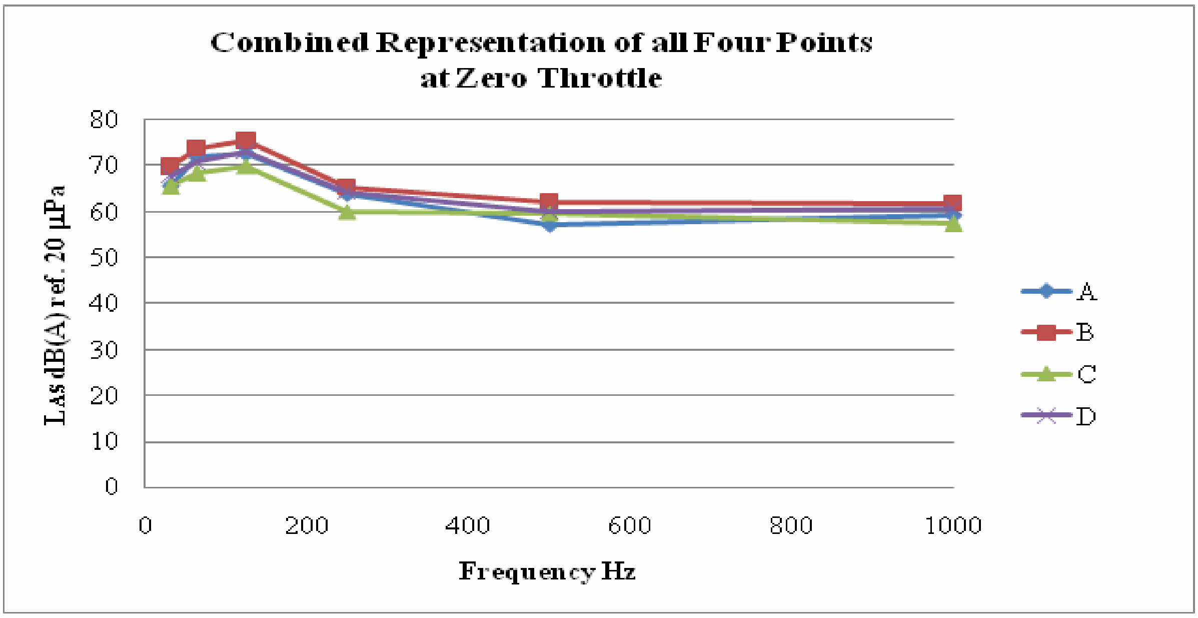

Fig. 5.33(b) Enlarged view of Fig. 5.33(a)

It seems to be Sound Pressure Level dominates at lower frequency 125 Hz at location B. First it inceases upto dominating frequency and then decreases with the increase in frequency.

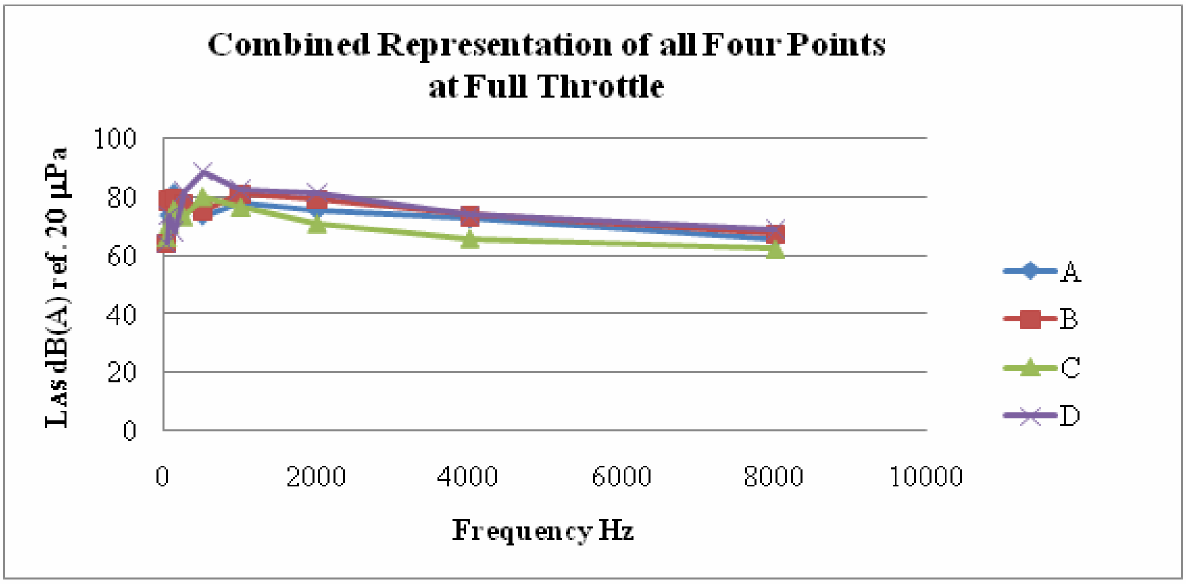

Fig. 5.34(a) Comparison between L_{AS} vs frequency at all locations for LML NV from Appendix C9

The value of SPL in frequency spectrum varies from 62.5 to 88.5 dB(A) for LML NV. It seems that maximum peak at frequency 500 Hz at location D in which is behind the engine and minimum peak at frequency 8000 Hz at location C which is at the rear end of Scooter.

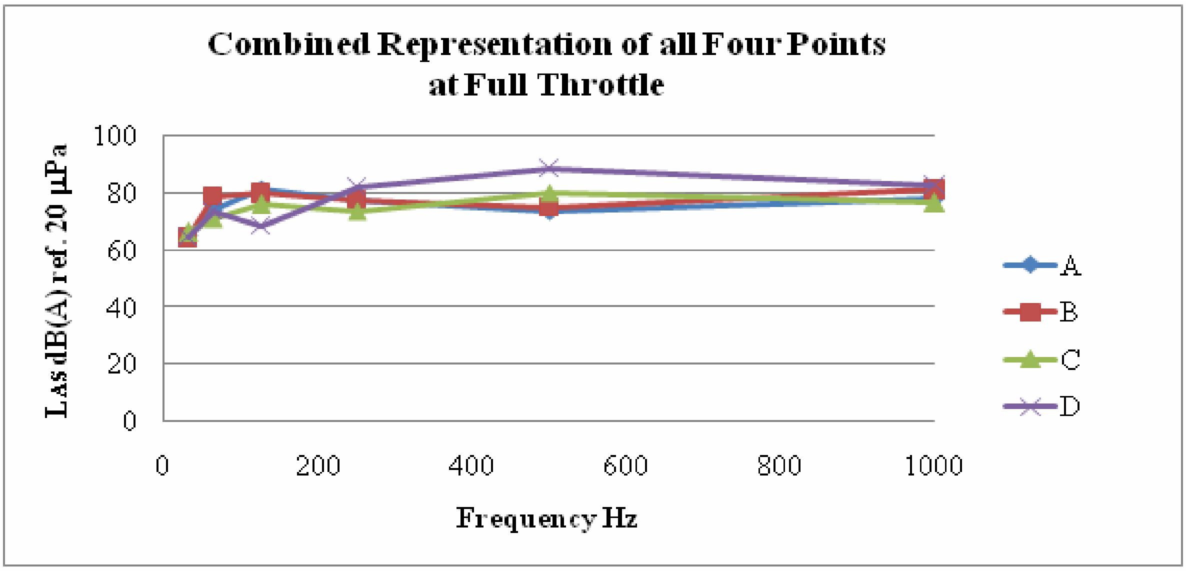

Fig. 5.34(b) Enlarged view of Fig. 5.34(a)

It seems to be Sound Pressure Level dominates at lower frequency 500 Hz at location D. First it fluctuates upto dominating frequency and then decreases with the increase in frequency.

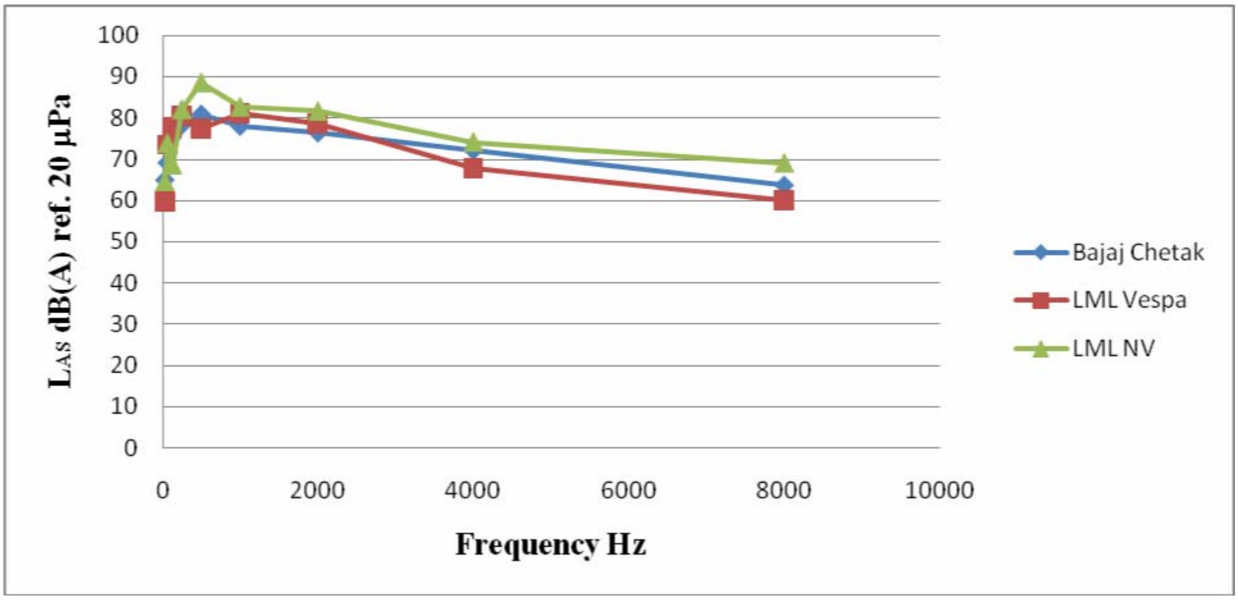

Fig. 5.35 Comparison between L_{AS} vs frequency at location A at Zero Throttle for all Scooters from Appendix C7-C9

It seems that Bajaj LML Vespa would be better amongst all available scooters at location A at Zero Throttle.

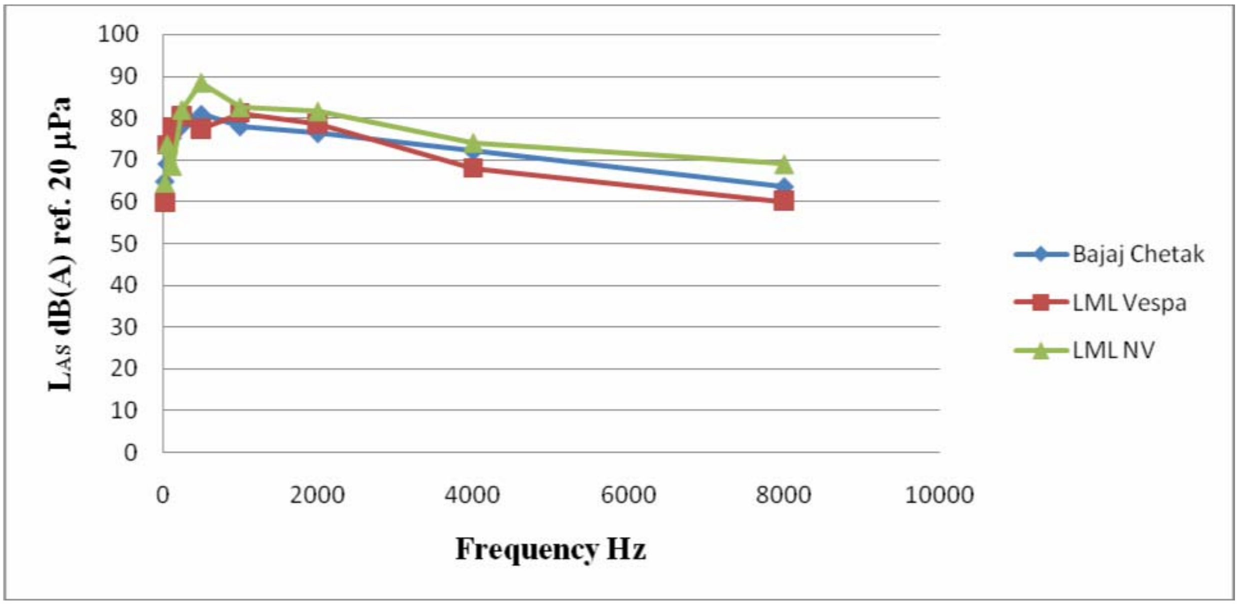

Fig. 5.36 Comparison between L_{AS} vs frequency at location B at Zero Throttle for all Scooters from Appendix C7-C9

It seems that Bajaj LML Vespa would be better amongst all available scooters at location B at Zero Throttle.

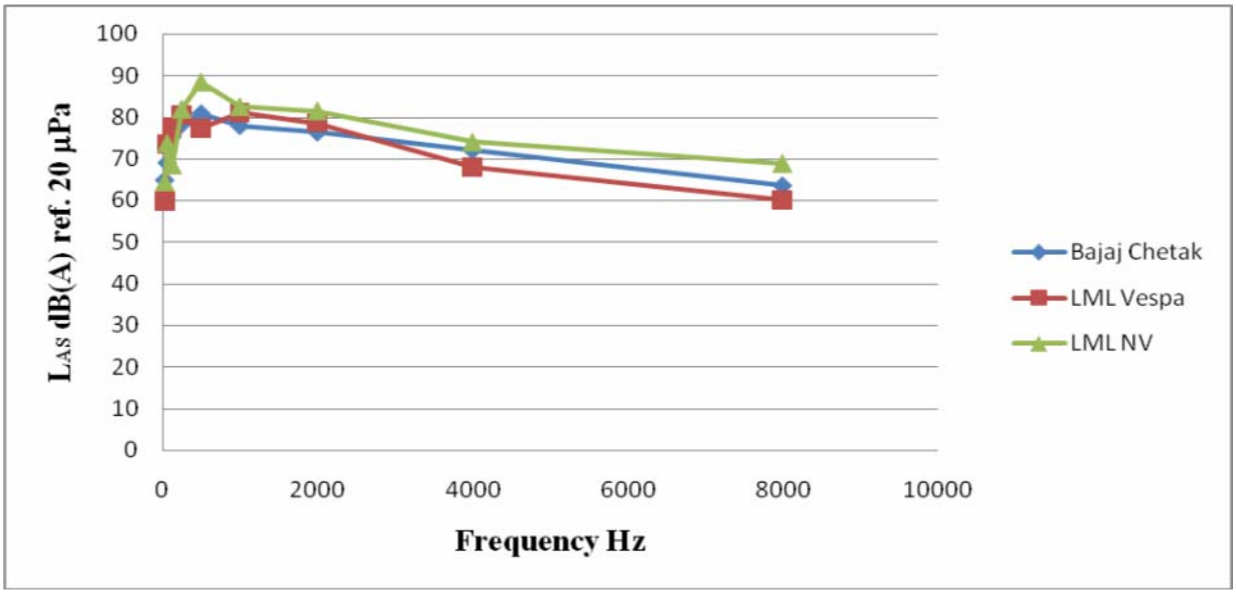

Fig. 5.37 Comparison between L_{AS} vs frequency at location C at Zero Throttle for all Scooters from Appendix C7-C9

It seems that Bajaj LML Vespa would be better amongst all available scooters at location C at Zero Throttle.

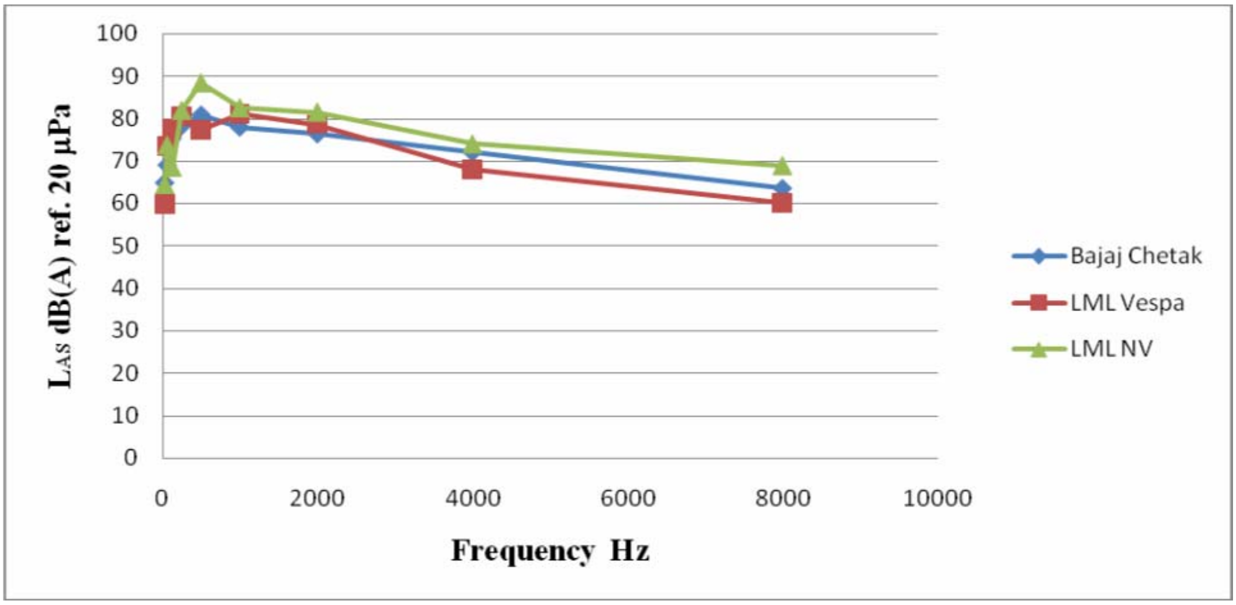

Fig. 5.38 Comparison between L_{AS} vs frequency at location D at Zero Throttle for all Scooters from Appendix C7-C9

It shows that Bajaj LML Vespa would be better amongst all available scooters at location D at Zero Throttle.

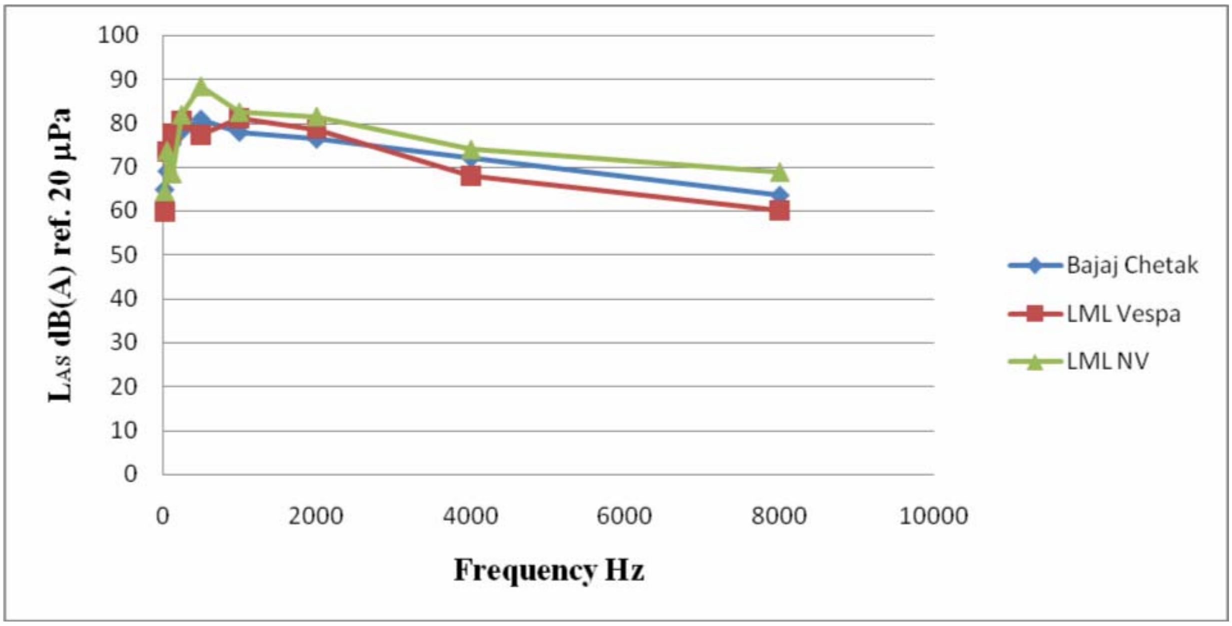

Fig. 5.39 Comparison between L_{AS} vs frequency at location A at Full Throttle for all Scooters from Appendix C7-C9

It seems that Bajaj LML Vespa would be better amongst all available scooters at location A at Full Throttle.

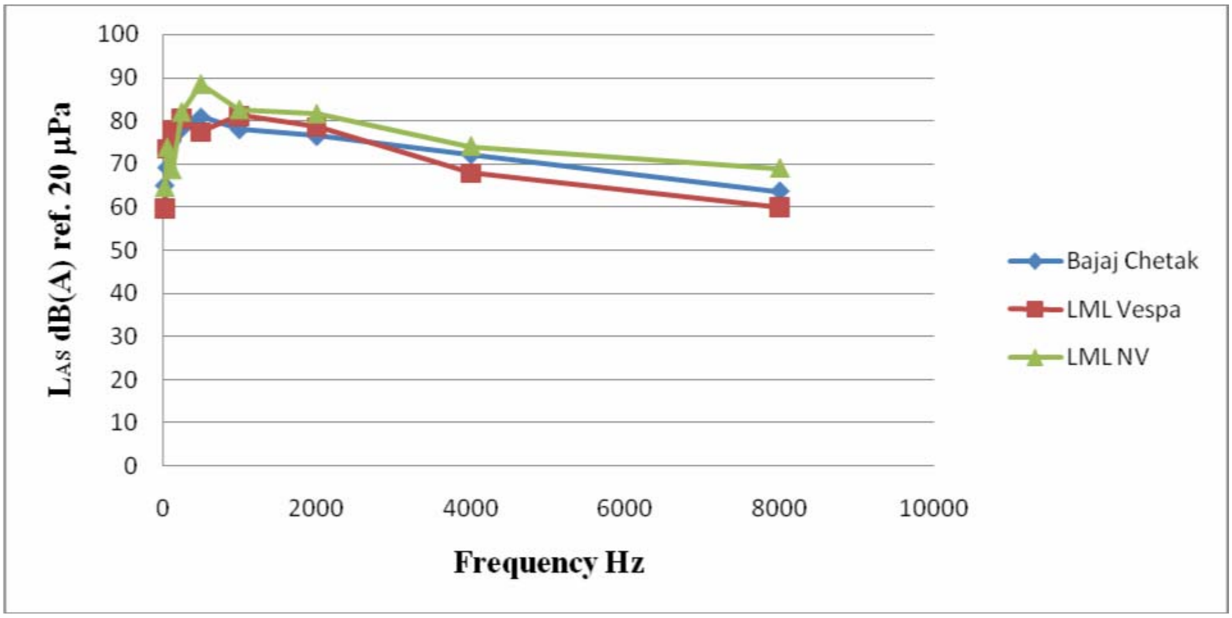

Fig. 5.40 Comparison between L_{AS} vs frequency at location B at Full Throttle for all Scooters from Appendix C7-C9

It seems that Bajaj LML Vespa would be better amongst all available scooters at location B at Full Throttle.

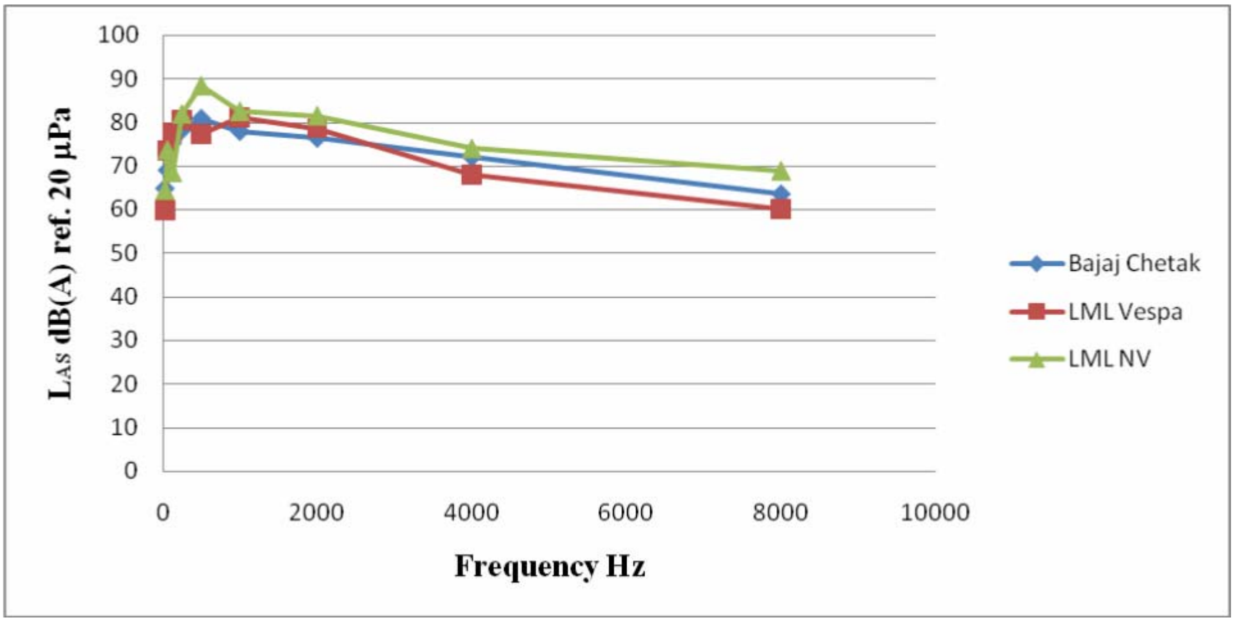

Fig. 5.41 Comparison between L_{AS} vs frequency at location C at Full Throttle for all Scooters from Appendix C7-C9

It seems that Bajaj LML Vespa would be better amongst all available scooters at location C at Full Throttle.

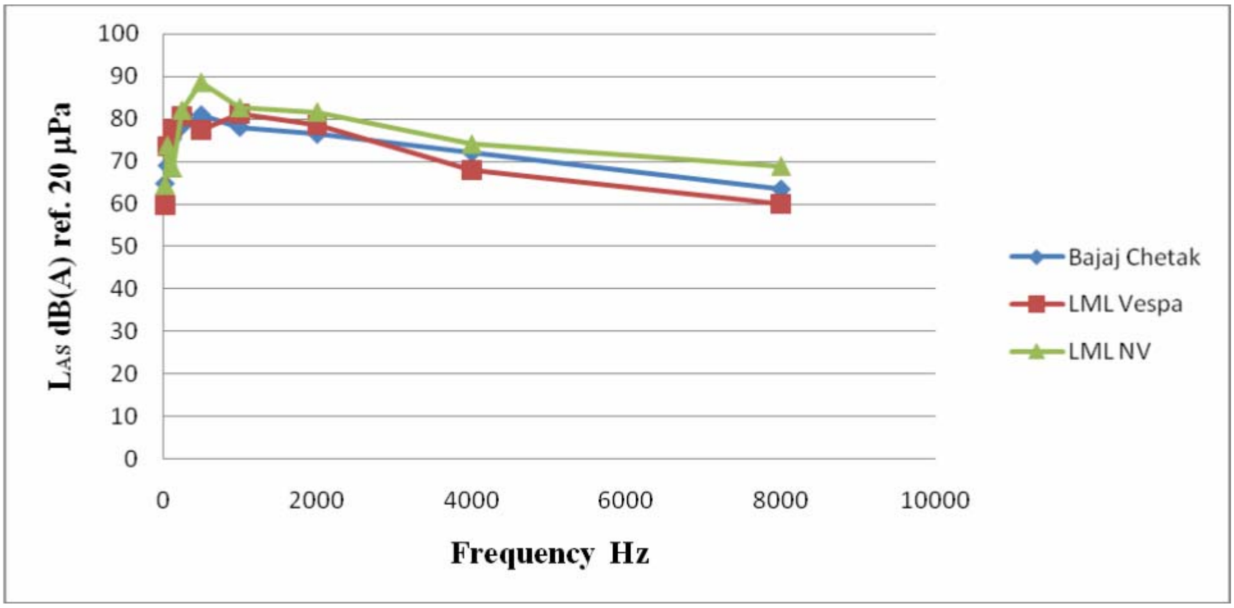

Fig. 5.42 Comparison between L_{AS} vs frequency at location D at Full Throttle for all Scooters from Appendix C7-C9

It seems that Bajaj LML Vespa would be better amongst all available scooters at location D at Full Throttle.

5.1.4 Analysis of Reference Mean Energy Emission Level

An attempt has been made to do a regression analysis and obtain a mathemtical relationship connecting Reference Mean Energy Emission level with reference to **Appendix D**, where the observation table is given at various speeds for 10 sec for all the seven vehicles considering as one category of vehicles.

This equation would help in predicting Mean Energy Emission Level at various speeds for any of the two wheeler belonging to this category. The analytical expression is given below which has been obtained:

Equation: Predicted L_{eq}= 52.8929 + 0.1359* S…………………………(5.1)

S = Speed

Regression Output:

R square	**0.6299**
Std. Error	**0.9409**
Constant	**52.8929**
Indep. 1	**0.1350**

The predicted values with the help of this equation are:

Two Wheelers	**Measured L_{eq} (dB(A)) at Different Speeds**			
	30 km/hr	**40 km/hr**	**50 km/hr**	**60 km/hr**
	56.9	**58.3**	**59.6**	**61.0**

Table 5.1 Predicted L_{eq} (dB(A)) at different speeds

It is seen that the error between the predicted values obtained from this equation and actual value measured for different class of vehicles at different speed range between **± 2 to ± 3** dB(A). This seems to be fairly good estimate and can be used for input data for the prediction of traffic noise through modeling technique, with the variation in speeds.

CHAPTER-6: Conclusion and Future Scope

6.1 Conclusion

In the present work conclusions are made based on the collected data on Noise parameters:

a) It seems that Sound Pressure Level of Passion and Bajaj Chetak is the minimum amongst all available motorcycles and scooters tested with the help of Pass by Test method at both 3rd and 4th Gear respectively.

b) It has been found that Sound Power Level of Bajaj Discover is the minimum amongst all available motorcycles at Zero Throttle.

   It has been analyzed that Sound Power Level of Bajaj Boxer is the minimum amongst all available motorcycles at Full Throttle.

   It seems that Sound Power Level of Bajaj Chetak is the minimum amongst all available scooters at Zero Throttle.

   It has been analyzed that Sound Power Level of LML NV is the minimum amongst all available scooters at Full Throttle.

c) It seems that maximum Sound Pressure Level analyzed in front of the engine at location B with the help of frequency spectrum. All the motorcycles/scooters noise are low frequency dominant, so all the source identification to control the noise could be taken at low frequency only.

d) Noise monitoring used in motorway noise predicting method for measuring reference and predicted energy mean emission level concluded that the sound produced at a distance of 15m is much below the permissible level.

6.2. Future Scope

1) The present work can be used to find out the source of noise. This work can be extended to various fields of application such as noise monitoring of automobiles like Three Wheelers, Four Wheelers, buses etc.

2) Present thesis work is completed using four basic method of monitoring:

a) Pass by test

b) Parallelepiped Method for calculating acoustic power.

c) Frequency analysis

d) Motorway noise predicting method.

First method found its application in the field of Automobiles such as Three Wheelers, Four Wheelers, Buses etc with the use same procedure which has explained in **article 4.2.1.** This can be used to track the source of maximum noise in an moving object.

Second method generally deals with problems on stationary object having some rotary elements. This method found its application in the field of Automobiles as well as different Machines with the help of same procedure which explained in **article 4.2.2.**

Third method gives a wide range of application in the field of all Machineries as it gives a clear cut idea of which part is creating more noise with the help of procedure already explained in **article 4.2.3.** It can also be further analyzed with the help of 1-3rd frequency spectrum and at different heights.

Fourth method finds its application to measure all individual Traffic vehicular reference energy emission level and then calculate predicted reference energy emission level as the method explained in the **article 4.2.4**, so that individual effect of noise for all the vehicles to the environment can be analyzed.

3) Different noise source identification can also be done with the help of **Intensity Probe** in the future**.**

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APPENDIXES

Appendix A

A1: Pass by Test Data at 3rd Gear for Motorcycles

Level in dB(A) ref. 20 μPa

Gear	3rd						
Motor Cycles		Splendor Plus	Passion	Caliber Chromo	Bajaj* Pulsar	Bajaj Boxer	Bajaj Discover
	Observations (L_{AFmax})						
Vehicle moving from left to right	Obs. 1	79.1	78.9	82.6	93.9	80.7	80.4
	Obs. 2	80.1	78.0	83.5	92.9	81.7	81.6
	Obs. 3	76.4	78.1	83.4	96.1	83.5	81.7
	Obs. 4	79.9	78.1	81.8	94.6	83.2	80.5
	Obs. 5	78.4	78.4	81.7	91.0	81.9	81.7
Vehicle moving from right to left	Obs. 1	82.4	79.3	78.6	92.6	79.9	79.5
	Obs. 2	75.7	76.0	82.9	90.2	81.4	77.7
	Obs. 3	77.9	78.0	82.1	90.9	81.3	81.1
	Obs. 4	77.9	77.9	82.3	89.7	83.7	81.4
	Obs. 5	75.9	77.1	78.2	95.0	78.7	80.4
Average (L_{AFmax})		78.4	78.0	81.7	92.7	81.6	80.6

"*" shows silencer is defective.

A2: Pass by Test Data at 4th Gear for Motorcycles

Level in dB(A) ref. 20 μPa

Gear		4th					
Motor Cycles		Splendor Plus	Passion	Caliber Chromo	Bajaj* Pulsar	Bajaj Boxer	Bajaj Discover
	Observations (L_{AFmax})						
Vehicle moving from left to right	Obs. 1	77.7	75.8	72.3	92.4	80.0	77.5
	Obs. 2	76.2	72.5	75.3	85.5	79.9	79.6
	Obs. 3	79.1	75.1	77.2	91.1	77.3	78.9
	Obs. 4	76.9	71.7	78.5	86.2	77.8	78.7
	Obs. 5	75.9	75.3	74.6	96.4	77.5	78.6
Vehicle moving from right to left	Obs. 1	75.5	73.6	76.2	87.2	76.7	79.2
	Obs. 2	77.9	74.7	76.1	85.3	75.8	78.9
	Obs. 3	77.6	71.1	72.1	87.6	77.7	79.4
	Obs. 4	75.3	74.5	78.2	91.8	78.6	78.8
	Obs. 5	76.1	71.4	78.5	92.5	76.6	78.4
Average (L_{AFmax})		76.8	73.6	75.9	89.6	77.8	78.8

"*" shows silencer is defective.

A3: Pass by Test Data at 3rd Gear for Scooters

Level in dB(A) ref. 20 μPa

Gear	3rd			
Scooters		Bajaj Chetak	LML Vespa	LML NV
	Observations (L_{AFmax})			
Vehicle moving from left to right	Obs. 1	72.0	78.6	73.7
	Obs. 2	75.9	80.7	78.1
	Obs. 3	76.8	79.8	77.7
	Obs. 4	77.3	81.4	78.9
	Obs. 5	74.7	82.8	81.0
Vehicle moving from right to left	Obs. 1	74.0	78.3	77.3
	Obs. 2	74.4	79.9	77.4
	Obs. 3	72.5	79.6	77.9
	Obs. 4	74.5	77.0	79.5
	Obs. 5	74.3	79.9	77.7
Average (L_{AFmax})		74.6	79.8	77.9

A4: Pass by Test Data at 4th Gear for Scooters

Level in dB(A) ref. 20 μPa

Gear		4th		
Scooters		Bajaj Chetak	LML Vespa	LML NV
	Observations (L_{AFmax})			
Vehicle moving from left to right	Obs. 1	76.5	77.9	78.5
	Obs. 2	75.8	76.1	78.6
	Obs. 3	76.0	75.6	78.4
	Obs. 4	76.2	76.4	78.3
	Obs. 5	75.4	75.8	78.6
Vehicle moving from right to left	Obs. 1	75.2	76.2	76.4
	Obs. 2	74.7	76.2	76.9
	Obs. 3	74.9	76.9	77.1
	Obs. 4	76.7	77.4	77.4
	Obs. 5	77.0	75.5	76.8
Average (L_{AFmax})		75.8	76.4	77.7

Appendix B

B1: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Splendor Plus

Zero Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	60.0	60.8	60.3	60.4
2nd	59.8	60.2	59.9	60.0
3rd	58.4	59.7	59.2	59.1
4th	57.8	57.9	58.3	58.0
5th	63.9	61.5	60.8	62.1
6th	61.2	60.3	61.0	60.8
7th	59.3	59.5	61.1	60.0
8th	60.9	61.2	60.1	60.7
9th	58.0	57.4	59.1	58.2
10th	60.3	59.7	59.5	59.8
11th	58.8	59.2	58.9	59.0
12th	62.7	60.1	59.7	60.8
13th	61.3	60.2	60.4	60.6
14th	60.0	59.4	60.1	59.8
15th	60.2	60.3	59.9	60.1
16th	61.0	61.0	61.2	61.1
17th	62.2	61.4	60.5	61.4
Average L_{AS}				**60.1**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = $1m^2$

Acoustic Power = 72.2 dB(A) (ref. 10^{-12} W)

B2: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Passion

Zero Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1^{st}	67.1	62.3	63.2	64.2
2^{nd}	59.1	60.6	60.1	59.9
3^{rd}	67.4	60.0	63.2	63.4
4^{th}	59.9	61.5	62.2	61.2
5^{th}	60.9	62.9	63.4	62.4
6^{th}	58.5	66.1	62.3	62.3
7^{th}	58.1	59.6	60.2	59.3
8^{th}	59.9	60.6	59.4	60.0
9^{th}	60.0	61.0	60.6	60.5
10^{th}	59.9	61.2	60.4	60.5
11^{th}	64.1	61.0	62.3	62.5
12^{th}	59.9	62.4	61.2	61.2
13^{th}	63.7	65.0	64.2	64.3
14^{th}	63.6	68.3	65.2	65.7
15^{th}	62.4	65.8	63.7	64.0
16^{th}	66.6	61.9	63.2	63.9
17^{th}	66.4	63.6	62.3	64.1
Average L_{AS}				62.3

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = $1m^2$

Acoustic Power = 74.4 dB(A) (ref. 10^{-12} W)

B3: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Caliber Chromo

Zero Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1^{st}	62.2	63.3	62.7	62.7
2^{nd}	67.7	67.8	67.2	67.6
3^{rd}	62.4	63.2	64.1	63.2
4^{th}	63.0	63.1	63.7	63.3
5^{th}	61.8	62.4	62.7	62.3
6^{th}	62.1	62.9	62.5	62.5
7^{th}	60.6	60.2	61.1	60.6
8^{th}	62.8	62.9	61.4	62.4
9^{th}	65.1	65.4	65.9	65.5
10^{th}	61.0	61.4	62.2	61.5
11^{th}	65.8	64.9	65.3	65.3
12^{th}	65.3	65.8	65.2	65.4
13^{th}	66.5	67.2	66.1	66.6
14^{th}	62.0	62.6	62.1	62.2
15^{th}	65.0	65.8	64.7	65.2
16^{th}	64.7	63.8	63.9	64.1
17^{th}	66.0	66.2	66.8	66.3
Average L_{AS}				**63.9**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 76.0 dB(A) (ref. 10^{-12} W)

B4: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Pulsar*

Zero Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	66.3	67.0	66.7	66.7
2nd	66.5	67.4	67.5	67.1
3rd	67.8	68.9	68.5	68.4
4th	70.8	69.6	70.2	70.2
5th	71.9	70.9	72.1	71.6
6th	70.3	70.6	70.4	70.4
7th	69.0	70.1	69.8	69.6
8th	69.4	69.9	69.7	69.7
9th	71.4	72.0	72.1	71.8
10th	68.5	69.3	69.1	69.0
11th	69.4	70.5	71.2	70.4
12th	69.9	70.8	71.4	70.7
13th	74.0	71.2	71.5	72.2
14th	71.4	72.6	71.8	71.9
15th	73.4	74.6	72.8	73.6
16th	71.6	71.1	71.4	71.4
17th	71.7	71.7	72.2	71.9
Average L_{AS}				**70.4**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = $1m^2$

Acoustic Power = 82.5 dB(A) (ref. 10^{-12} W)

"*" shows silencer is defective.

B5: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Boxer

Zero Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	60.6	58.9	60.3	59.9
2nd	58.9	57.9	59.4	58.7
3rd	63.0	59.7	60.6	61.1
4th	59.2	59.1	59.9	59.4
5th	60.3	58.4	59.1	59.3
6th	59.6	58.4	59.2	59.1
7th	61.0	58.6	59.3	59.6
8th	60.7	59.0	59.8	59.8
9th	61.2	59.2	60.8	60.4
10th	58.4	57.5	57.6	57.8
11th	58.3	57.6	58.9	58.3
12th	59.1	60.3	59.5	59.6
13th	62.2	62.8	61.6	62.2
14th	60.3	61.2	60.8	60.8
15th	61.1	60.4	60.7	60.7
16th	60.0	59.3	58.4	59.2
17th	62.0	62.4	60.8	61.7
Average L_{AS}				**59.9**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 72.0 dB(A) (ref. 10^{-12} W)

B6: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Discover

Zero Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	61.0	56.6	56.2	57.9
2nd	56.5	56.7	56.0	56.4
3rd	56.5	57.3	56.2	56.7
4th	59.8	58.6	58.9	59.1
5th	58.3	56.5	56.6	57.1
6th	61.6	58.5	57.4	59.2
7th	57.7	57.1	59.3	58.1
8th	59.8	58.6	60.6	59.7
9th	60.3	59.1	61.0	60.1
10th	59.1	58.8	56.9	58.3
11th	59.2	57.4	57.6	58.1
12th	58.0	59.4	61.1	59.5
13th	61.3	61.2	61.7	61.4
14th	59.0	59.4	59.9	59.4
15th	59.3	59.2	59.3	59.3
16th	59.3	59.4	58.3	59.0
17th	61.0	61.4	61.2	61.2
Average L_{AS}				**58.9**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 71.0 dB(A) (ref. 10^{-12} W)

B7: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Splendor Plus

Full Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1^{st}	94.2	93.9	94.7	94.3
2^{nd}	91.0	91.9	90.7	91.2
3^{rd}	90.0	89.8	91.4	90.4
4^{th}	92.5	92.1	91.9	92.2
5^{th}	94.0	94.3	92.8	93.7
6^{th}	92.3	92.6	93.0	92.6
7^{th}	92.4	92.5	92.1	92.3
8^{th}	96.5	95.8	94.9	95.7
9^{th}	95.4	95.6	96.2	95.7
10^{th}	94.8	94.4	95.3	94.8
11^{th}	95.5	95.3	94.8	95.2
12^{th}	89.9	91.8	94.6	92.1
13^{th}	96.8	95.5	96.2	96.2
14^{th}	93.8	95.0	93.9	94.2
15^{th}	91.2	94.1	93.2	92.8
16^{th}	96.4	97.8	95.2	96.5
17^{th}	97.2	96.4	98.1	97.2
Average L_{AS}				**93.9**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 106.0 dB(A) (ref. 10^{-12} W)

B8: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Passion

Full Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	96.1	97.3	95.6	96.3
2nd	97.2	96.8	97.5	97.2
3rd	96.4	96.7	97.1	96.7
4th	98.0	98.8	97.6	98.1
5th	95.7	94.9	96.5	95.7
6th	96.3	95.3	96.1	95.9
7th	97.5	97.8	98.5	97.9
8th	99.9	98.8	100.5	99.7
9th	102.1	101.0	101.4	101.5
10th	99.3	101.1	100.1	100.2
11th	102.8	102.5	101.8	102.4
12th	103.7	102.8	103.2	103.2
13th	103.8	101.9	103.2	103.0
14th	101.0	101.5	100.5	101.0
15th	98.7	99.5	98.9	99.0
16th	100.6	101.3	100.2	100.7
17th	104.8	103.7	104.3	104.3
Average L_{AS}				**99.6**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 111.7 dB(A) (ref. 10^{-12} W)

B9: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Caliber Chromo

Full Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	96.8	96.3	96.9	96.7
2nd	94.4	96.2	96.3	95.6
3rd	93.9	94.2	93.2	93.8
4th	97.4	98.3	97.8	97.8
5th	99.5	99.1	99.7	99.4
6th	96.7	97.2	96.1	96.7
7th	98.0	97.1	97.5	97.5
8th	96.8	96.2	96.9	96.6
9th	98.4	99.2	99.6	99.1
10th	98.7	98.1	98.5	98.4
11th	98.3	98.9	98.6	98.6
12th	97.8	97.2	98.3	97.8
13th	101.8	100.5	99.6	100.6
14th	98.3	99.1	99.3	98.9
15th	98.9	99.4	98.6	99.0
16th	99.1	100.2	99.5	99.6
17th	102.3	101.7	99.8	101.3
Average L_{AS}				98.1

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = $1m^2$

Acoustic Power = 110.2 dB(A) (ref. 10^{-12} W)

B10: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Pulsar*

Full Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	99.4	102.3	101.9	101.2
2nd	99.1	101.7	101.2	101.0
3rd	100.9	103.4	101.9	102.1
4th	105.2	103.8	104.7	104.3
5th	107.0	104.3	103.5	105.0
6th	104.5	105.7	102.8	104.3
7th	106.2	104.1	104.9	105.1
8th	104.4	106.3	104.5	105.1
9th	103.3	105.6	104.8	104.6
10th	98.9	102.8	101.1	101.0
11th	101.3	103.6	102.3	102.4
12th	101.4	102.7	102.9	102.3
13th	109.2	105.9	106.8	107.3
14th	109.1	107.8	106.5	107.8
15th	111.9	110.1	108.6	110.2
16th	108.0	111.2	107.8	109.0
17th	106.9	105.9	110.1	107.6
Average L_{AS}				**104.7**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 116.8 dB(A) (ref. 10^{-12} W)

“*” shows silencer is defective.

B11: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Boxer

Full Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	**88.1**	**88.5**	**88.7**	**88.4**
2nd	**88.8**	**88.4**	**88.2**	**88.5**
3rd	**87.0**	**88.2**	**87.6**	**87.6**
4th	**89.3**	**89.7**	**88.1**	**89.1**
5th	**93.3**	**94.2**	**94.4**	**94.0**
6th	**93.0**	**93.4**	**92.2**	**92.9**
7th	**91.8**	**90.2**	**91.6**	**91.2**
8th	**91.6**	**91.2**	**91.9**	**91.6**
9th	**93.0**	**92.2**	**92.7**	**92.6**
10th	**91.3**	**91.8**	**91.7**	**91.6**
11th	**91.0**	**92.2**	**91.6**	**91.6**
12th	**90.6**	**90.8**	**90.9**	**90.8**
13th	**90.7**	**90.2**	**88.4**	**89.8**
14th	**90.1**	**90.5**	**89.4**	**90.0**
15th	**89.1**	**88.2**	**89.7**	**89.0**
16th	**89.4**	**89.1**	**90.1**	**89.5**
17th	**89.9**	**89.2**	**88.4**	**89.2**
Average L_{AS}				**90.4**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = $1m^2$

Acoustic Power = 102.5 dB(A) (ref. 10^{-12} W)

B12: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Discover

Full Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	88.2	90.2	91.1	89.8
2nd	89.4	92.7	90.4	90.8
3rd	89.1	90.0	89.8	89.6
4th	93.3	94.5	94.1	94.0
5th	89.2	91.7	91.9	91.0
6th	90.4	92.4	91.6	91.5
7th	88.5	90.3	91.2	90.0
8th	95.5	93.2	92.8	93.8
9th	94.1	94.5	94.2	94.3
10th	91.9	92.8	91.7	92.1
11th	91.3	93.2	92.8	92.4
12th	92.1	91.4	93.7	92.4
13th	97.3	94.5	95.8	95.9
14th	93.6	92.8	94.2	93.5
15th	95.2	93.8	96.7	95.2
16th	94.7	95.6	94.1	94.8
17th	96.9	95.7	96.1	96.2
Average L_{AS}				**92.8**

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 16.13 m^2
a = Length = 1.95 m
b = Width = 1.4 m
c = Height = 2 m
S_0 = Reference Area = $1m^2$

Acoustic Power = 104.9 dB(A) (ref. 10^{-12} W)

B13: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Chetak

Zero Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	62.2	61.5	62.8	62.2
2nd	61.6	62.3	62.4	62.1
3rd	61.1	61.0	61.9	61.3
4th	64.8	62.9	63.3	63.7
5th	65.2	64.7	64.0	64.6
6th	62.5	62.8	62.2	62.5
7th	63.6	64.1	63.0	63.6
8th	61.7	63.2	62.3	62.4
9th	64.4	63.8	64.9	64.4
10th	62.6	62.5	61.8	62.3
11th	62.1	62.0	62.3	62.1
12th	62.9	63.5	62.7	63.1
13th	67.1	66.5	67.4	67.0
14th	65.8	65.0	66.2	65.7
15th	64.9	64.1	63.6	64.2
16th	64.6	63.9	62.1	63.5
17th	65.1	64.3	63.7	64.4
Average L_{AS}				63.5

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 13.0 m^2
a = Length = 1.9 m
b = Width = 1.35 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 74.6 dB(A) (ref. 10^{-12} W)

B14: Measurement of Sound Pressure Level to Evaluate Acoustic Power for LML Vespa

Zero Throttle L_{AS} (dB(A))				
Grid Points	Obs. 1	Obs. 2	Obs. 3	Average
1st	65.7	66.5	66.1	66.1
2nd	64.3	64.9	65.1	64.8
3rd	67.2	66.8	66.5	66.8
4th	70.0	70.2	70.3	70.2
5th	68.1	68.4	68.6	68.4
6th	66.5	66.8	66.4	66.6
7th	66.0	66.9	66.7	66.5
8th	66.9	67.3	67.5	67.2
9th	66.8	67.4	67.3	67.2
10th	65.6	66.2	65.9	65.9
11th	66.6	67.7	67.1	67.1
12th	69.0	69.4	68.8	69.1
13th	73.1	73.6	72.9	73.2
14th	71.4	70.4	71.1	71.0
15th	70.1	69.8	70.3	70.1
16th	69.7	70.0	69.8	69.8
17th	69.3	69.3	69.5	69.4
Average L_{AS}				68.2

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 9.065 m^2
a = Length = 1.9 m
b = Width = 1.35 m
c = Height = 2 m
S_0 = Reference Area = $1m^2$

Acoustic Power = 79.3 dB(A) (ref. 10^{-12} W)

B15: Measurement of Sound Pressure Level to Evaluate Acoustic Power for LML NV

Zero Throttle L_{AS} (dB(A))				
Grid Points	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Average**
1st	68.2	67.1	67.8	67.7
2nd	66.0	66.4	66.6	66.3
3rd	65.8	66.3	65.9	66.0
4th	68.0	67.7	67.4	67.7
5th	66.7	66.2	66.8	66.6
6th	65.8	65.7	66.2	65.9
7th	66.2	67.1	66.8	66.7
8th	66.1	66.3	66.6	66.3
9th	65.6	65.9	66.1	65.9
10th	65.8	67.3	66.5	66.5
11th	65.1	66.5	65.8	65.8
12th	66.7	67.2	67.0	67.0
13th	70.7	70.3	70.7	70.6
14th	69.5	70.0	70.2	69.9
15th	69.1	69.8	68.9	69.2
16th	70.1	69.1	68.7	69.3
17th	69.6	69.3	69.5	69.5
Average L_{AS}				67.5

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 9.065 m^2
a = Length = 1.9 m
b = Width = 1.35 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 78.6 dB(A) (ref. 10^{-12} W)

B16: Measurement of Sound Pressure Level to Evaluate Acoustic Power for Bajaj Chetak

Full Throttle L_{AS} (dB(A))				
Grid Points	Obs. 1	Obs. 2	Obs. 3	Average
1^{st}	92.0	90.8	91.2	91.3
2^{nd}	90.3	91.1	90.7	90.7
3^{rd}	91.9	91.0	91.8	91.6
4^{th}	92.6	92.9	93.2	92.9
5^{th}	91.9	91.5	91.2	91.5
6^{th}	92.8	93.2	92.1	92.7
7^{th}	91.6	91.7	92.3	91.9
8^{th}	91.6	90.6	91.8	91.3
9^{th}	94.0	94.8	95.5	94.8
10^{th}	91.9	91.8	92.0	91.9
11^{th}	90.2	91.3	91.1	90.9
12^{th}	91.1	91.7	92.4	91.7
13^{th}	96.4	95.6	95.9	96.0
14^{th}	94.6	95.8	95.2	95.2
15^{th}	93.9	94.5	93.8	94.1
16^{th}	94.9	94.1	94.4	94.5
17^{th}	93.5	92.8	94.1	93.5
Average L_{AS}				92.7

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 13.0 m^2
a = Length = 1.9 m
b = Width = 1.35 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 103.8 dB(A) (ref. 10^{-12} W)

B17: Measurement of Sound Pressure Level to Evaluate Acoustic Power for LML Vespa

Full Throttle L_{AS} (dB(A))				
Grid Points	Obs. 1	Obs. 2	Obs. 3	Average
1st	94.6	95.1	95.4	95.1
2nd	93.7	94.8	95.3	94.6
3rd	94.8	96.1	96.7	95.9
4th	95.6	98.7	97.4	97.2
5th	94.3	95.6	94.7	94.9
6th	95.5	94.9	95.1	95.1
7th	94.8	94.6	94.8	94.7
8th	96.8	95.7	96.2	96.2
9th	95.7	94.5	94.6	94.9
10th	94.9	93.6	94.0	94.2
11th	97.7	94.1	94.9	95.6
12th	95.3	94.3	94.5	94.7
13th	99.3	101.4	98.5	99.7
14th	101.1	99.4	100.7	100.4
15th	96.0	97.8	96.7	96.8
16th	98.8	99.2	98.3	98.8
17th	98.4	100.4	101.0	99.9
Average L_{AS}				96.4

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 13.0 m^2
a = Length = 1.9 m
b = Width = 1.35 m
c = Height = 2 m
S_0 = Reference Area = $1m^2$

Acoustic Power = 107.5 dB(A) (ref. 10^{-12} W)

B18: Measurement of Sound Pressure Level to Evaluate Acoustic Power for LML NV

Full Throttle L_{AS} (dB(A))				
Grid Points	Obs. 1	Obs. 2	Obs. 3	Average
1st	88.6	90.7	91.9	90.4
2nd	89.5	91.5	92.1	91.1
3rd	89.9	92.7	92.3	91.6
4th	92.4	93.8	94.7	93.6
5th	88.2	89.9	90.4	89.5
6th	88.6	89.1	89.4	89.1
7th	88.7	91.2	90.9	90.3
8th	91.7	90.2	90.7	90.9
9th	90.8	92.3	91.8	91.6
10th	89.7	91.3	89.7	90.2
11th	88.9	90.1	90.5	89.8
12th	88.8	91.5	90.0	90.1
13th	95.9	96.8	96.3	96.3
14th	96.6	94.1	94.7	95.1
15th	93.9	92.9	93.0	93.3
16th	93.6	94.2	92.8	93.5
17th	95.8	95.9	94.8	95.5
Average L_{AS}				91.9

$L_W = L_P + 10\log_{10}(S/S_0)$

L_W = Acoustic Power
L_P = Average L_{AS}
S = Surface area = ab + 2(bc +ca) = 9.065 m^2
a = Length = 1.9 m
b = Width = 1.35 m
c = Height = 2 m
S_0 = Reference Area = 1m^2

Acoustic Power = 103.0 dB(A) (ref. 10^{-12} W)

Appendix C

C1: 1-1 Octave Band Frequency Spectrum Data for Splendor Plus

Frequency (Hz)	L_{AS} dB(A)							
	Zero Throttle				Full Throttle			
	Location A	Location B	Location C	Location D	Location A	Location B	Location C	Location D
31.5	53.2	59.5	54.5	58.4	61.5	64.1	62.0	65.9
63.0	60.4	62.1	58.0	64.6	76.4	78.0	72.0	81.3
125.0	71.1	75.7	72.7	74.6	76.5	84.5	77.1	83.7
250.0	59.1	59.3	57.1	58.6	73.9	79.0	76.6	76.4
500.0	53.8	55.1	47.9	50.7	68.6	76.3	73.2	79.2
1000.0	52.0	54.3	53.5	50.9	72.7	74.6	72.6	72.8
2000.0	45.4	47.9	47.2	49.7	67.0	77.2	68.7	74.5
4000.0	42.3	43.3	41.5	44.0	64.0	72.8	64.5	73.7
8000.0	36.2	38.3	37.3	36.5	56.7	66.3	58.6	67.9

C2: 1-1 Octave Band Frequency Spectrum Data for Passion

Frequency (Hz)	L_{AS} dB(A)							
	Zero Throttle				Full Throttle			
	Location A	Location B	Location C	Location D	Location A	Location B	Location C	Location D
31.5	60.1	61.1	59.6	60.2	66.8	68.6	68.9	69.3
63.0	71.0	66.4	63.2	68.1	82.2	88.6	77.0	84.5
125.0	71.0	66.3	62.3	69.3	87.4	89.2	82.2	86.0
250.0	55.1	55.3	53.0	52.6	80.7	83.9	78.7	84.7
500.0	57.4	56.1	47.4	56.0	72.9	74.3	75.7	81.3
1000.0	56.1	55.6	53.2	55.7	82.0	80.9	84.3	80.9
2000.0	48.3	49.9	46.4	56.5	73.6	79.3	79.6	78.7
4000.0	45.1	48.1	42.4	49.4	70.4	75.5	73.8	80.0
8000.0	36.7	41.8	34.9	41.1	63.4	69.9	64.0	70.3

C3: 1-1 Octave Band Frequency Spectrum Data for Bajaj Caliber Chromo

Frequency (Hz)	L_{AS} dB(A)							
	Zero Throttle				Full Throttle			
	Location A	Location B	Location C	Location D	Location A	Location B	Location C	Location D
31.5	63.8	62.7	61.7	63.3	59.9	61.8	58.0	59.8
63.0	70.3	68.8	65.3	68.1	88.7	89.4	81.7	86.2
125.0	65.1	66.7	61.8	64.1	85.4	78.6	77.7	79.9
250.0	51.1	54.3	52.8	56.6	65.7	82.4	63.3	79.9
500.0	58.0	61.6	56.6	62.5	75.0	80.1	72.4	81.3
1000.0	55.2	58.2	58.3	55.4	77.6	80.9	82.1	79.1
2000.0	45.1	49.3	45.8	51.6	71.8	78.3	73.0	80.7
4000.0	37.6	46.0	41.8	46.3	68.7	79.0	69.8	78.6
8000.0	33.2	42.4	35.7	40.6	63.8	71.7	63.4	73.2

C4: 1-1 Octave Band Frequency Spectrum Data for Bajaj Pulsar*

Frequency (Hz)	L_{AS} dB(A)							
	Zero Throttle				Full Throttle			
	Location A	Location B	Location C	Location D	Location A	Location B	Location C	Location D
31.5	60.1	63.2	59.7	62.4	61.6	64.2	60.8	62.8
63.0	78.0	84.2	76.9	83.1	68.8	69.4	63.0	68.3
125.0	75.0	79.3	74.2	80.8	92.7	95.6	92.0	95.3
250.0	70.9	71.9	68.9	70.6	76.2	79.5	75.8	81.3
500.0	75.0	67.6	65.2	69.7	90.9	92.8	79.4	88.9
1000.0	62.3	65.9	55.2	64.6	74.3	81.3	68.7	79.2
2000.0	56.9	63.8	53.4	61.4	76.5	79.5	78.9	80.2
4000.0	48.9	58.4	46.5	55.7	66.9	71.9	65.1	75.2
8000.0	48.8	54.3	41.1	52.7	60.9	67.7	60.2	66.0

"*" shows silencer is defective.

C5: 1-1 Octave Band Frequency Spectrum Data for Bajaj Boxer

Frequency (Hz)	L_{AS} dB(A)							
	Zero Throttle				Full Throttle			
	Location A	Location B	Location C	Location D	Location A	Location B	Location C	Location D
31.5	58.1	61.4	59.6	60.8	61.6	62.4	58.5	61.3
63.0	69.8	65.7	64.7	71.9	80.6	84.1	82.8	82.0
125.0	66.8	62.2	58.3	64.1	81.5	85.7	76.3	83.2
250.0	53.9	61.9	56.2	60.3	71.5	74.6	74.6	79.5
500.0	53.8	53.3	50.7	57.8	71.8	73.6	76.0	85.6
1000.0	57.4	61.2	56.7	60.8	77.3	80.1	80.1	83.4
2000.0	49.7	61.9	54.9	62.3	75.9	85.4	80.2	88.0
4000.0	48.5	57.1	48.2	59.2	74.8	80.3	75.9	81.6
8000.0	40.4	51.7	41.8	51.6	70.0	77.4	68.5	76.2

C6: 1-1 Octave Band Frequency Spectrum Data for Bajaj Discover

Frequency (Hz)	L_{AS} dB(A)							
	Zero Throttle				Full Throttle			
	Location A	Location B	Location C	Location D	Location A	Location B	Location C	Location D
31.5	68.0	68.3	66.1	66.8	61.8	65.2	62.3	64.5
63.0	69.2	71.0	68.7	69.5	71.2	77.0	70.3	73.1
125.0	59.5	62.5	62.3	62.5	69.1	73.1	70.4	66.6
250.0	50.1	52.1	53.5	50.9	75.8	81.9	77.5	72.2
500.0	52.8	51.0	52.9	53.6	77.7	76.1	74.6	80.9
1000.0	55.9	54.8	54.5	53.3	71.5	78.8	75.2	77.1
2000.0	56.2	52.5	53.2	51.8	78.9	67.4	73.6	71.8
4000.0	47.0	49.8	47.9	48.6	74.8	66.2	71.5	67.0
8000.0	43.5	44.8	41.7	39.3	62.6	63.4	61.4	63.0

C7: 1-1 Octave Band Frequency Spectrum Data for Bajaj Chetak

Frequency (Hz)	L_{AS} dB(A)							
	Zero Throttle				Full Throttle			
	Location A	Location B	Location C	Location D	Location A	Location B	Location C	Location D
31.5	55.2	61.0	60.4	60.7	61.5	65.8	66.3	64.9
63.0	66.3	66.8	65.6	64.8	62.3	69.1	71.0	69.1
125.0	66.7	69.9	68.8	67.9	78.3	75.6	73.9	75.3
250.0	56.9	60.7	60.5	58.8	72.2	82.0	80.7	78.3
500.0	54.0	57.9	57.8	55.2	77.3	79.3	79.0	80.9
1000.0	50.4	57.8	55.0	54.3	77.0	81.8	76.0	78.0
2000.0	45.8	54.6	54.1	54.4	73.3	80.0	75.2	76.4
4000.0	42.5	50.0	49.5	47.6	69.2	75.6	71.5	72.1
8000.0	37.8	42.2	40.6	39.0	59.0	70.5	61.1	63.6

C8: 1-1 Octave Band Frequency Spectrum Data for LML Vespa

Frequency (Hz)	L_{AS} dB(A)							
	Zero Throttle				Full Throttle			
	Location A	Location B	Location C	Location D	Location A	Location B	Location C	Location D
31.5	60.1	60.3	59.4	60.6	59.0	61.5	60.1	59.7
63.0	62.7	65.2	64.3	64.7	69.7	75.9	68.6	73.6
125.0	69.1	72.4	70.1	71.2	78.1	81.4	77.7	77.8
250.0	62.4	63.8	63.0	65.3	75.1	81.8	76.8	80.5
500.0	66.3	65.6	64.3	64.8	74.7	78.4	72.6	77.4
1000.0	61.1	64.0	61.4	62.9	72.9	83.1	72.6	81.2
2000.0	55.5	62.8	58.2	60.3	69.7	79.7	71.8	78.6
4000.0	49.8	59.6	57.9	58.5	63.5	68.4	67.6	67.9
8000.0	41.2	49.3	47.9	46.7	55.0	61.4	59.7	60.1

C9: 1-1 Octave Band Frequency Spectrum Data for LML NV

Frequency (Hz)	L_{AS} dB(A)							
	Zero Throttle				Full Throttle			
	Location A	Location B	Location C	Location D	Location A	Location B	Location C	Location D
31.5	65.5	69.7	65.5	67.7	65.2	64.2	66.2	64.5
63.0	72.1	73.8	68.3	70.8	74.0	78.9	70.9	73.8
125.0	72.8	75.4	69.9	73.2	81.4	79.8	75.9	68.6
250.0	64.0	65.2	59.9	64.2	77.3	77.8	73.6	82.0
500.0	57.1	62.1	59.7	60.0	73.8	75.2	80.2	88.5
1000.0	59.2	61.7	57.4	60.7	77.9	81.1	76.7	82.6
2000.0	60.9	62.2	57.1	61.3	75.5	79.2	71.1	81.6
4000.0	60.3	58.9	52.1	62.5	72.7	73.7	66.0	74.1
8000.0	52.5	55.3	46.8	54.8	66.1	67.5	62.5	69.0

Appendix D

D1: Reference Energy Mean Emission Level Data for 10 sec at different speeds for Two Wheelers

Motorcycles	Measured L_{eq} (dB(A)) at Different Speeds			
	30 km/hr	40 km/hr	50 km/hr	60 km/hr
Splender Plus	56.6	57.4	59.1	59.9
Passion	56.9	57.5	59.6	61.9
Caliber Chromo	57.4	58.3	60.7	62.2
Bajaj Discover	55.0	57.1	57.8	58.4
Bajaj Chetak	56.7	57.8	59.5	60.3
LML Vespa	59.0	59.7	60.7	61.3
LML NV	57.9	58.2	61.5	62.7