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JUDUL: **NOISE SOURCE IDENTIFICATION OF ENGINE DYNAMOMETER**

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NOISE SOURCE IDENTIFICATION OF ENGINE DYNAMOMETER

AB RAHMAN BIN MOHD NOOH

A report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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To Beloved Mother and Father

HABIBAH BINTI IDRIS

MOHD NOOH BIN AB MAJID

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ABSTRACT

This project presents the effort taken to determine the major source of the noise and verify the frequency resonance and amplitudes for different engine speed of the engine dynamometer in automotive research laboratory of Universiti Malaysia Pahang (UMP).The research describes the experimental set-up and investigation of the mechanisms of engine dynamometer noise generation and the corresponding countermeasures employed during the engine performance tested. According to the analysis of acoustic signals and vibration signals measurement, an investigation of the noise source identification in a diesel engine is presented, and that the noise level of the diesel is comprehended. The experiment carried out with several altered parameters for flexibility investigation. With the sound intensity method, the results of the noise source of flywheel cover and exhaust were presented. The results of analysis showed that the 1250 Hz bands had the most significant contribution to the engine right noise. For the 1500rpm, 2000rpm and 2500rpm the sound power level are 86.42dB, 92.44 and 96.34dB respectively. These clearly show that higher rpm will increase the noise at the engine. Additionally mounting area noise for this engine also give significant effect with the value of 77.71dB for 1500rpm and 89.86db for 2500rpm due to the engine's structural vibration transfer and noise radiation behavior with respect to the excitation mechanism. The research also provides the reliable basis for the engineering practice to reduce noise level.

ABSTRAK

Projek ini menunjukkan usaha yang telah dijalankan untuk menentukan punca utama bunyi bising dan menguji frekuenci resonan dan amplitud pada kelajuan enjin yang berbeza pada enjin dynamometer yang terletak di makmal kajian automotif Universiti Malaysia Pahang (UMP). Kajian ini menerangkan kaedah eksperimen dan kajian mekanisma penyebab bunyi bising pada enjin dinamometer dan juga kaedah mengatasi semasa ujian prestasi enjin sedang dijalankan. Berdasarkan kepada pengukuran analisis isyarat bunyi dan isyarat getaran, penyelidikan untuk menentukan punca bunyi bising pada enjin diesel telah dijalankan, dan aras bunyi bising pada enjin diesel telah dapat dipastikan.Eksperimen ini juga dijalankan dengan menggunakan beberapa pemboleh ubah untuk melihat perubahan yang terjadi. Dengan menggunakan kaedah keamatan bunyi, punca bunyi bising pada permukaan luar sebelah kanan enjin dan juga ekzos telah dapat dikenalpasti. Pada Frekuensi 1250Hz adalah dikenalpasti terjadinya bunyi yang paling kuat. Pada kelajuan enjin 1500,2000 dan 2500 bunyi yang paling kuat dihasilkan ialah 86.42dB, 92.44 dan 96.34dB. Tambahan pula, semakin laju kelajuan enjin per minit semakin kuat bunyi bising yang dihasilkan pada bahagian pemegang enjin iaitu 77.71dB untuk 1500 dan 89.86dB untuk 2500 terutamanya yang disebabkan oleh mekanisma mekanikal di dalam enjin tersebut . Kajian ini juga menyediakan kaedah yang sesuai untuk mengurangkan bunyi bising.

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LIST OF ABBREVIATIONS

AC	Alternate Current
AISI	American Iron and Steel Society
BLDC	Brushless Direct Current
CPB	Constant Pressure Bandwidth
DC	Direct Current
DTU	Device Under Test
FFT	Fast Fourier Transform
ISO	International Standard Organization
rpm	Rotation per minute

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

In the sixties and early seventies racers raced mostly for fun and were not very sophisticated in figuring out how to make their race cars go faster. In those days everyone built their own engines, race cars, and even their own trailers and haulers for their racing efforts. It was always difficult to determine whether a given change in an engine or chassis was really better or not due to all the other variables present in the race car environment. As time marched on and everyone got more experience, more testing tools became available. Manually operated engine dynamometers were used to try and figure out how to build a better, more powerful engine and get a jump on the competition. The advent of personal computers and associated technology further advanced the process as well as vehicle data acquisition systems which became popular.

The main problem in engine test cell is the actual noise level nearly always exceeds the levels permitted by statues. The noise generated by engines causes annoyance to people as well to environment. For human being noise can affect physically, psychologically and socially. Apart from being annoyance, noise damages hearing, interferes with communication, cause tiredness and reduces efficiency. But noise level can not be directly eliminated, it can only be reduce.

The best way to address unwanted sound issues with a view to find out the noise contribution of different sources within the engine dynamometer to total noise. So, accurate measurements and noise analysis by using sound intensity techniques supported with the use of latest software is needed to reduce all the problems because in this project the engine dynamometer is installed in the automotive research laboratory where the surrounding area also involved with the other outdoor classes.

1.2 PROBLEM STATEMENT

There are various of engine dynamometer is fixed to the test-rig at definite level of height that have capability of test engine up to 200HP at the Universiti Malaysia Pahang(UMP) Automotive laboratory. Even when one of the engine performances is being test, it will produce more than the criteria of 65dB which is also the threshold where noise begins to intrude significantly into normal activities such as a conversation even in the close area such as office or home. Additionally there is a time when the engine test is performs; there are also other classes at the same area doing outdoor activities such as experiment; Automotive Technology and Power Plant. This will make the classes are considered "sensitive receivers" due to possible noise interference with instructional programs.

1.3 OBJECTIVES OF STUDY

Basically, the main purposes in accomplishing this task are as shown below:

a) To perform experiment and determine the major source of the noise at the engine dynamometer by using sound intensity method.
b) To investigate the frequency resonance and amplitudes of the system at different RPM

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SCOPES

There are several scopes of this project which are:

a) This research will conducted in different engine's rpm ranging from 1000 to 2500.

b) The types of engine use is single-cylinder, 4 strokes air-cooled diesel engine.

c) The noise that is produce will be detected by using sound intensity probe and then will be processed by using Pulse Labshop 11.1 software.

1.5 CHAPTER OUTLINE

Chapter 1 explains the introduction about this research where all the objectives and problems that lead to the implementation of this project are stated.

Chapter 2 explains the literature study regarding Noise Source Identification and Sound Intensity based on recent journals and papers. Most of the literature discuss about the advantages of Sound Intensity for its application in engineering fields.

Chapter 3 explains about the preparation and installation of the experiment setup. All apparatus used in the experiment are listed and displayed. Start from designing and fabrication process till the most important part in this chapter which is the procedures applied in implementing Sound Intensity using the Pulse Labshop software to simulate the data gained from the experiment.

Chapter 4 provides the results obtained from the experiment. The results are displayed together with the explanation and be compare with the journals that is similar to this project.

Chapter 5 contains conclusion and some recommendations for further research on the experimental of noise source identification using sound intensity method.

1.6 GANTT CHART

Gantt chart for Final Year Project 1 and Final Year Project 2 is enclosed at the appendix.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review of past research efforts regarding Noise Source Identification and Sound Intensity. A review of other relevant research studies is also provided. Most of the literature discuss about the advantages of Sound Intensity for its application in engineering fields especially that required the sound power data be gathered normally in-situ and give real time data from the sources.

2.2 DYNAMOMETER

2.2.1 Classification of Dynamometer

The ability to measure performance characteristics such as fuel flow, airflow, and blow-by, is the key to increase the understanding of the engine combination. The dynamometer also allows analyzing the shape of the torque and power curves and also as the final quality control check before the engine is shipped.

Basically, the dynamometers can be divided into two types. There are engine dynamometer and chassis dynamometer. Both of them have similar functions and aim, but it is quite different of structure or machine due to the objective of research and power output obtain. These two types of dynamometer is developed by a few ways and they are different each other due to the types. The common types of them are hydraulic and electric. For electric dynamometer, it contains three types; DC Dyno, AC Dyno and Eddy Current Dyno [1] [2].

2.2.2 Types of dynamometers

In addition to classify as absorption, motoring or universal as described above, dynamometers can be classified in other ways. A dynamometer that is coupled directly to an engine is known as an engine dyno. A dynamometer that can measure torque and power delivered by the power train of a vehicle without removing the engine from the frame of the vehicle is known as a chassis dynamometer. The tree chart of the types of dynamometer can be viewed as in Figure 2.1.

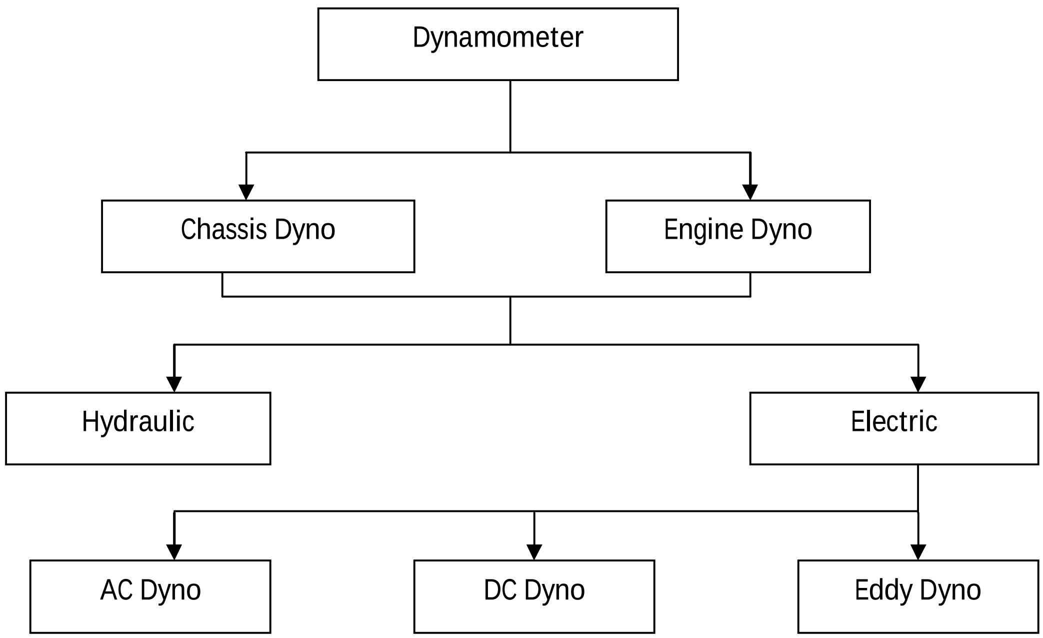

Figure 2.1: The Tree Chart of Automotive Dynamometers

Dynamometers can also be classified by the type of absorption unit or absorber/driver that they use. Some units that are capable of absorption only can be combined with a motor to construct an absorber/driver or universal dynamometer.

2.2.3 Theory of Absorption Dynamometer

Absorption provides a load using a brake to slow the acceleration of the rolling road, the braking force applied must be varied depending on the current speed of the engine and the actual braking force applied must be known so it can be taken into account in the mathematics. Typical brakes used are water brake absorbers, Eddy current absorbers, friction brake, AC and DC motor generators [1].

2.3 DIESEL ENGINE

Mechanically, 4-stroke diesel engines work identically to four-stroke petrol engines in terms of piston movement and crank rotation. It is in the combustion cycle where the differences come through. First, during the intake cycle, the engine only sucks air into the combustion chamber through the intake valve. Second, there is no spark plug. Diesel engines work on self-ignition, or detonation. At the top of the compression stroke, the air is highly compressed about 40 bar compared to 14 bar in the gasoline engine. The fuel is injected directly into that environment and because of the heat and pressure, it spontaneously combusts .This gives the characteristic knocking sound that diesel engines make and is also why pre-igniting petrol engines are sometimes referred to as 'dieseling' [3].

2.4 NOISE

Sounds that are unpleasant or unwanted are called noise. Noise and vibration problems are common in industrial and domestic applications. Noise will produce when one system is subjected to vibrations. Any piece of machinery that vibrates radiates acoustical energy. Noise is linearly dependent on the vibrations that have been introduced. The noise level is sometime almost unbearable [4].

Noise in the working environment frequently occurs as a result of dynamic motion. With proper machined design for example improved stiffness of the machines structure the problem of relative dynamic motion at the engine dynamometer may be reduce.

2.5 SOUND INTENSITY

In order to reduce noise, the amount of noise that being radiated by the component in the machine is needed to know. Therefore the sound power of the machines can be known by measuring sound intensity. Sound intensity describes the rate of energy flow through a unit area. When locating the source of sound, sound intensity is very useful because it gives a measure of direction as well as magnitude.

Therefore the radiation patterns is of complex vibrating machinery can be studied in situ and measurement on individual machines or individual component can be made even when all the other are radiating noise, because steady background noise makes no contribution to the sound power determined when measuring intensity. A sound intensity analyzing system consists of a probe and an analyzer. The probe simply measures the pressure at the two microphones. The analyzer such as Constant Percentage Bandwidth (CPB) analyzer does the integration and calculations necessary to find the sound intensity [5].

Figure 2.2 : Instrumentation For Sound Intensity

2.6 CPB ANALYZER

Figure 2.4: CPB Analyzer

CPB is capable of taking a real world, time-varying signal and splitting it into components, each with amplitude, a phase, and a frequency. By associating the frequencies with machine characteristics, and looking at the amplitudes, it is possible to identify troubles very accurately .

Depending on user requirements or analysis and the native units of the raw signal, the signals from sensor can either be processed directly or routed to mathematical integrators for conversion to other units of vibration measurement.

The signals that obtained from the source of noise can be displayed as either a velocity waveform (time domain) or a velocity spectrum (frequency domain). A velocity spectrum is derived from a velocity waveform by means of a mathematical calculation known as the Fast Fourier Transform (FFT) which is calculated by FFT Analyzer [5].

2.7 SPECTRUM ANALYSIS

Spectrum analysis is defined as the transformation of a signal from a time-domain representation into a frequency-domain representation. Spectrum that obtained from the analyzer can be analyzed to know the noise that produce on machine. The velocity spectrum of a noise components tell the frequencies at which the components vibrating and at what speeds. A spectrum displays vital information that is hard to extract from a waveform. Waveform does not clearly display the individual frequencies at which vibration occurs. A waveform instead displays only the overall effect [4].

2.8 PAPER REVIEW

Noise generated by computer hard disk drives was measured with a view to find out the noise contribution of different sources within the drives to total noise. Sound power levels, rather than sound pressure levels were measured. Sound power is a measure of the amount of sound energy a sound source produces per unit time, independent of its surroundings. It is essentially a physical property of a sound source and an important absolute parameter that is widely used for rating and comparing sound sources. Sound power can be calculated from measured values of sound pressure or intensity levels. Sound power has a number of useful applications. It can be used to calculate the approximate sound pressure level at a given distance from a machine operating in a specified environment. It can compare the noise radiated by machines of the same or different type. In engineering work, it can assist in developing quiet machinery and equipment. It can help determine whether a machine complies with noise specification standards. It is a useful parameter in identifying major noise sources in machines for noise control work [6].

The most important Noise, Vibration and Harshness (NVH) relevant excitations in a passenger car engine can be identified as follows: combustion force; main bearing reaction forces including mass forces damper function and flywheel whirling, modified by the front-end damper; piston side forces including secondary motion; camshaft bearing reaction forces including mass forces, opening and closing impacts and bearing impacts; valve opening and closing impacts; valve train forces caused by chain/belt movement or gear drive; gear train forces inside the transmission; drive train reaction forces and moments [7].

Consideration of all of these important excitation mechanisms requires a very complex simulation model. However, in principle, such a procedure is conceivable but, depending on the design status, it can be difficult to acquire the necessary input data. Therefore, early in the design stage, assumptions and practical simplifications must be made when analyzing and optimizing engine components regarding NVH. Despite this, in order to ensure acceptable accuracy of the predictive NVH calculations, it is important to investigate the behavior of the entire engine with all accessories, taking into accounts all of the pertinent excitation mechanisms. Calculation of the excitation mechanisms presupposes a simulation model that considers the dynamic behavior of all of the rotating components (cranktrain, valvetrain, timing drive, transmission shafts and gears) as well as the dynamic behaviour of the housing (engine, transmission) [8].

This paper presents a practical approach for identifying the source of excessive noise in the small fan-motor system for household refrigerators. The source is presumed to a mechanical resonance excited by torque ripple of the BLDC motor. By using finite element analysis, natural frequencies and mode shapes of the rotating part of the system are obtained and they are compared with experimental mode shapes obtained by electronic torsional excitation test which uses BLDC motor itself as an exciter. Two experimental validations are carried out to confirm the reduction of excessive noise [9].

This paper describes the investigation of the mechanisms of engine front noise generation and the corresponding countermeasures employed in the development of a diesel engine. According to the analysis of acoustic signals and vibration signals measurement, an investigation of the noise source identification in a diesel engine is presented, and that the noise level of the diesel is comprehended. With the sound intensity method, the major sources of the exterior radiation noise of the engine front are surveyed. The research provides the reliable basis for the engineering practice to reduce vehicle noise level. Furthermore, the measuring data of the acoustic signals are compared by measuring noise from surface vibration, and the results are valid [10].

This paper presents the results of experimental studies of the noise of a residential split system air-conditioner unit. The compressor and condenser and associated fans were removed from the unit and did not form part of the studies. Care was taken with the unit to separate the inlet and exhaust noise from the noise radiated from the cabinet. The measurements were made with a two-microphone sound intensity probe and these resulted in sound power level data. The sound power levels produced by radiation from the inlet, exhaust and cabinet were obtained for five different volume flow rates. The effect on the sound power generated by removing the coil was investigated. Measurements and subjective studies show that the low frequency sound is predominantly radiated from the exhaust and inlet. At high frequency, the cabinet noise dominates [11].

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CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Generally this project involved in designing, fabricating the rig and experimental analysis. In order reduce the error while taking the data, noise mapping are use. The model of Intensity Mesh which was used in noise and sound intensity measurement were defined. Virtually the drawing process is designed by SolidWork. To fabricate it, the dimension of the material has been measured. The process of fabrication involves of cutting material, machining part and assembly all the part. Finally, the analysis of the noise using Pulse LabShop software also enclosed in report writing. In 3.2 below, it showed the methodology process.

3.2 PROJECT METHODOLOGY

To determine the major source of the noise and to verify the behaviors of frequency and amplitudes of the engine dynamometer during operation at different RPM, these phases must be done.

- Phase 1 – Literature study
- Phase 2 – Fabricate noise intensity rig.
- Phase 3 – Experimental analysis of engine dynamometer
- Phase 4 – Data collection by using averages reading.

From the Figure 3.1, the flow chart of this project showed how the phase was made:

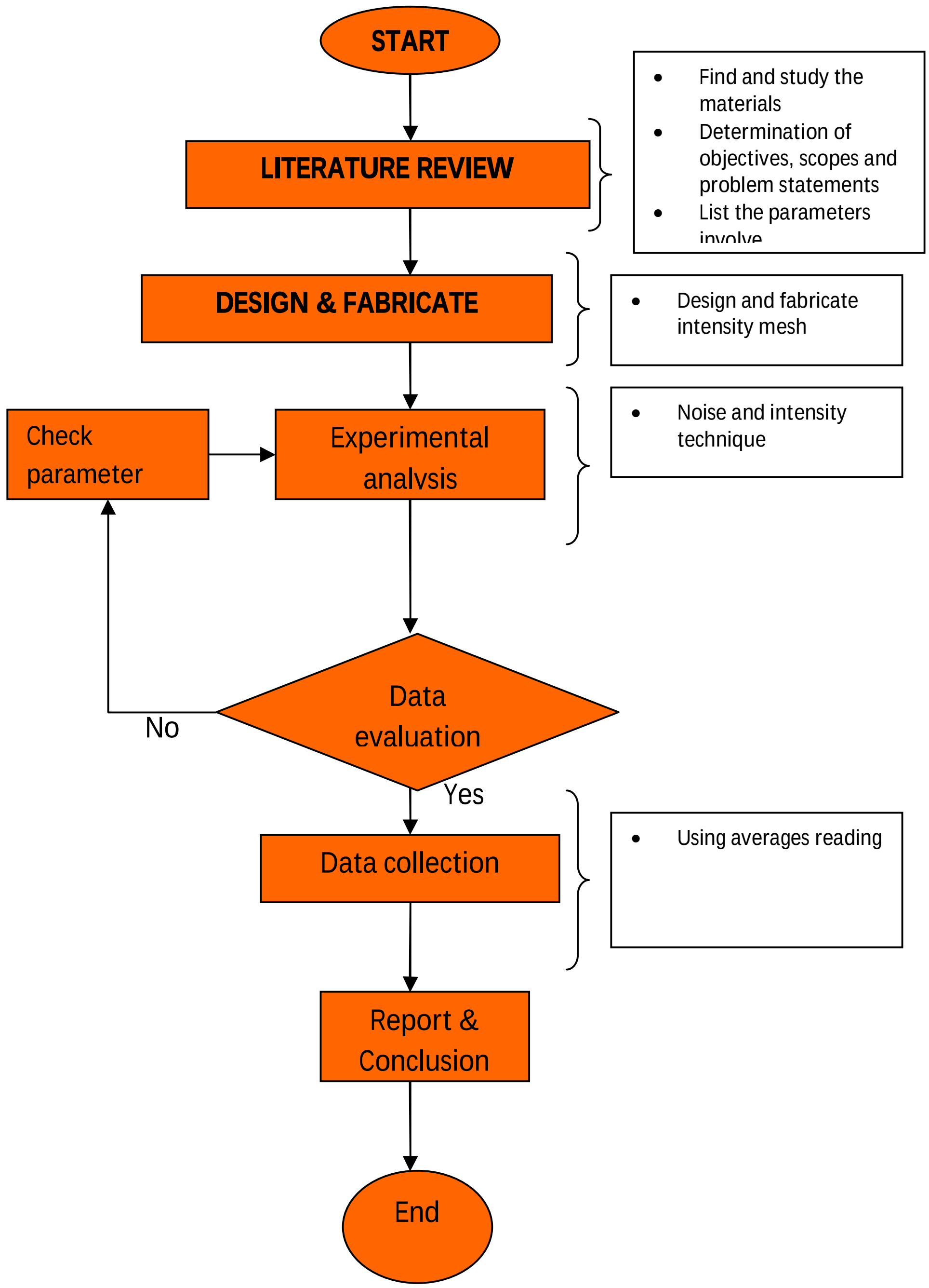


Figure 3.1: The Project Flow Chart

3.2.1 Design and Fabricate of Noise Intensity Rig

After the title confirmation achieved and literature review were done, the designing process was started. First of all, the review of noise intensity mapping which used in the literature reviews was in Figure 3.2 [16].

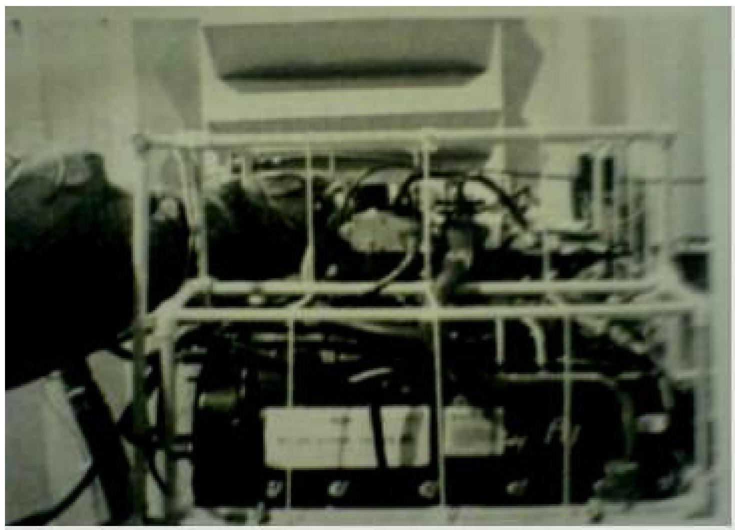


Figure 3.2: Intensity Mesh of the Engine side
Source: Vehicle Noise and Vibration, SAE 2003

After having a concept design, the design of intensity mesh rig is created by using SolidWorks 2006 software. To make it simpler the design of the intensity mesh has been changed without affecting the functionality as the intensity rig. The dimension of the rig is 135cm x 100cm. The dimension of this rig is more than enough to the longest side of the engine dynamometer which is the right and left side of the engine dynamometer. In order to conduct the tests, as far as possible, in accordance to the draft International Standard ISO/DIS 9614-1 each section of the rectangular for the mapping is 10cm x 10cm. Each small rectangular act as a discrete point in order to determine the sound power levels of noise sources using sound intensity. To make sure the rig is capable to be used at the each side without being affected by the test bed structure, the stand of the rig is using bolt and nuts.

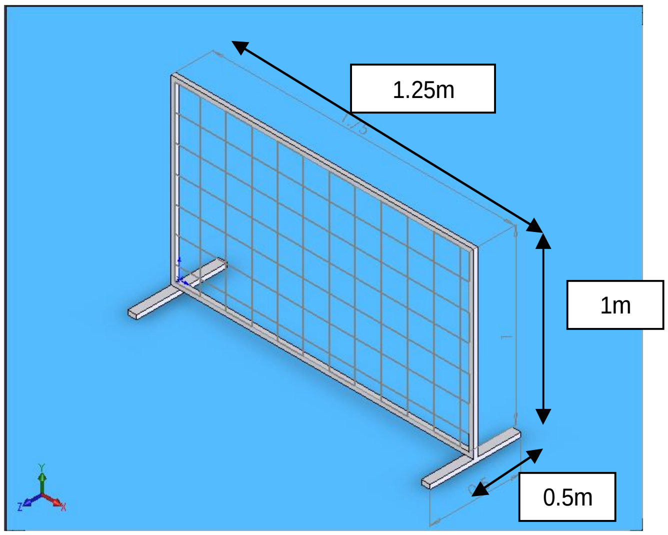


Figure 3.3: Design of Intensity Mesh

To fabricate this structure, devices such as Metal Inert Gas (MIG) welder, cutter and hand grinder are used to assist in the fabrication. The steel will be cut according to dimension and welded according to shape. To make each small rectangular wire is used, prior to that the hole is made by using hand drill vertically and horizontally. To complete the fabrication process the wire is tied by using each hole as a reference point to get 10cm x 10cm cross section.

Figure 3.4: Welding process to make the Intensity Mesh

3.2.2 Selecting Materials

To make the main structure of the intensity mesh, the material must have high strength and cannot easily crack and fail. The best material available in laboratory is Carbon Steel AISI 1020 which used for common industrial products. Carbon Steel AISI 1020 is used because of it has a very high ultimate tensile strength 448 MPa, Yield Strength 346 MPa and the Hardness is 143MPa. The type of the material use is hollow rectangular with the size of 1 inch x 1 inch. For the stand of this rig, L shape 1.5 inch x 1.5 inch steel is used.

3.2.3 Testing Procedure

The determination of the true source ranking of each situation is an important stage to achieve in this project. The most effective route to good results is found by dealing with the most significant sources first .This applies to both practical and predicted results, since both are equally prone to errors. Sometimes this is not possible, but decisions to deal with a range of source should be made by using knowledge rather than guesswork [16].

The noise on engine dynamometer needs proper setup before the experiment can be done. The parameters for the experiment and how the experiment will be conduct need to be clarify and set in order to make sure that the result obtained is accurate result. When the rig frame is fabricated successfully, the experiment is now ready to be implemented. All the apparatus associated with experimental are gathered and identified. There are laptop, Bruej and Kjaer intensity probe, calibrator and front end analyzer. Figure 3.5 shows the apparatus setup used in the experiment. After that the rig is located 1m at the side of engine dynamometer that wants to be test as shown in Figure 3.6.

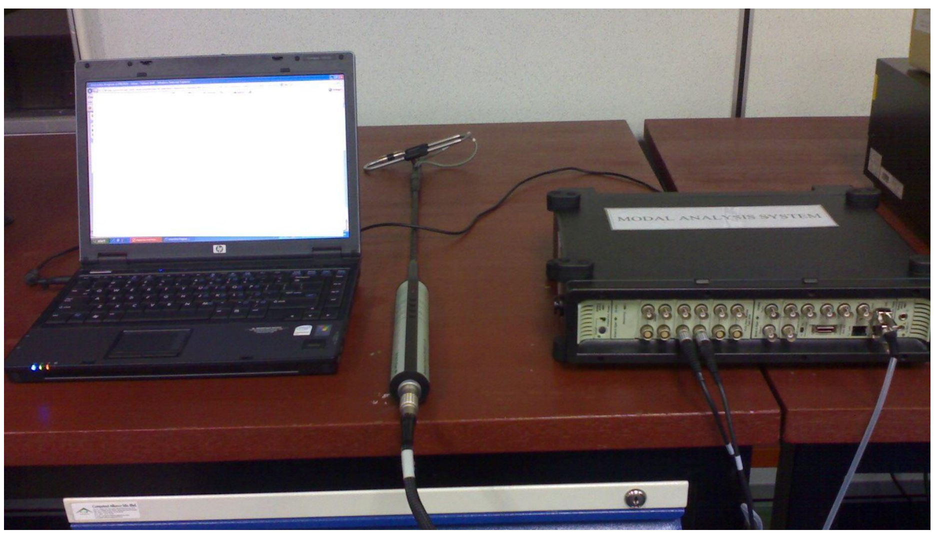


Figure 3.5: Arrangement of the apparatus

Figure 3.6: Noise sound identification setup using sound intensity method

Main technical for engine and dynamometer data are summarized in Table 3.1:

Table 3.1: Main technical engine data

Engine model:	CF 186F /Diesel Engine
Type:	Single cylinder, vertical 4 cycle air cooled
Displacement:	0.406L
Compression ratio:	19.3
Max power:	7.4kW

Table 3.2: Main technical engine dynamometer data

Dynamometer model:	Eddy Current dynamometer
Model:	ECB- 15kW
SR. No:	615
W (PAN) MAX:	12kg

Figure 3.7: Engine dynamometer used for this project

3.2.4 List Of Apparatus

Below are the lists of apparatus or devices used in the experiment of this project:

No	Apparatus	Function
1.	Laptop with PULSE-LabShop software Version 11.1 Figure 3.8	Used to display the response signal from the test. It also used to simulate data from the analyzer.
2.	Intensity Probe Figure 3.9	Measures the response signal transferred to the analyzer. Consists of: 2 closely phase matched microphones, preamplifiers with tight phase match, low noise cables
3.	Sound Intensity Calibrator 4297 Figure 3.10	Verify sound power level and particle velocity

4.	Analyzer Model : PULSE Type 3560 C Figure 3.11	Used to analyze data sent by the load cell attached with the intensity probe. It converts them to the frequency domain and sent the data to be displayed in laptop. Ability to estimate sound intensity directly.

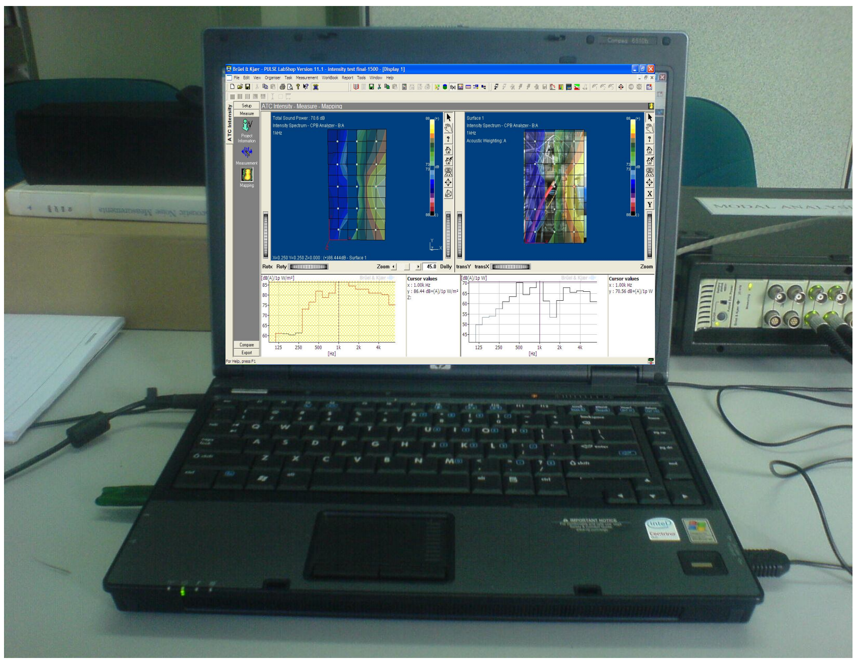


Figure 3.8: Laptop with PULSE-LabShop software Version 11.1

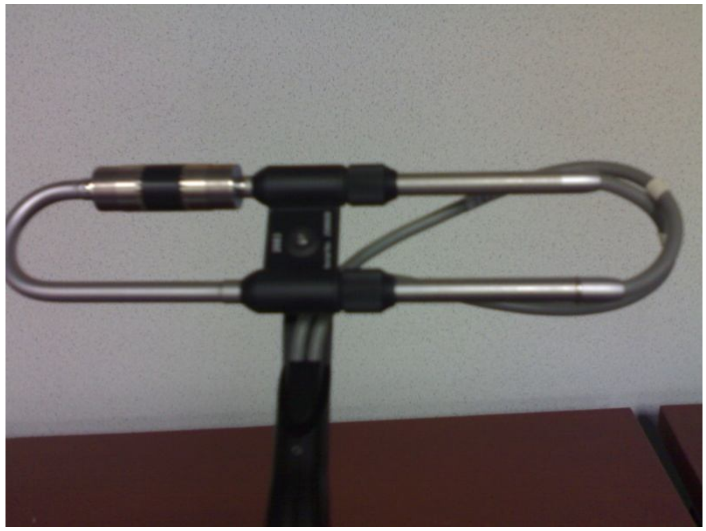


Figure 3.9: Intensity Probe

Figure 3.10: 4297 Sound Intensity Calibrator

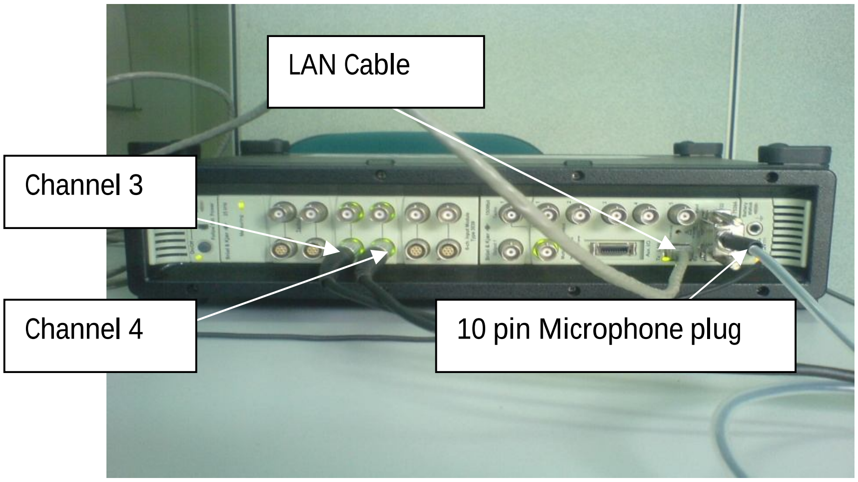


Figure 3.11: Analyzer

The laptop with Pulse LabShop software will be connected to the analyzer using LAN cable. From the analyzer it will be connected to the probe with the preferred port that has been determined in the setting. For this experiment the microphone is connected to the port 3 and port 4. Make sure that the indicator lamp at the port is illuminated.

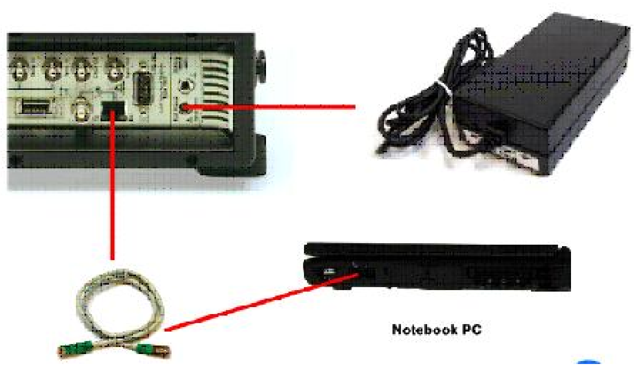


Figure 3.12: Connecting the Front-end

3.2.5 Microphone Setting

The complexity of this sound problem required that several experimental techniques be utilized to identify the noise source and quantify its value. To identify the overall sound power of the engine dynamometer, the sound intensity method was utilized. This method also provided the ranking of different component within the engine dynamometer and the engine as well as identified the source of the noise. The mesh around the engine dynamometer was made in a way to obtain the intensity for different components such as the front, top and rear of the engine valley, valve covers, front cover and oil pan [2].

Microphone is used to detect noise that produce when the research is conducted. The microphone that is used is type 4197. One more important factor that can influence the reading that should not be neglected especially in the free field condition is the size of spacer use. To measure at high frequency short spacer is used and to measure at low frequency larger spacer is used. In this project 12mm spacer is used instead of 6mm and 50mm because the frequency range lay on the midrange frequency. To determine the noise that produce while the engine is running, coordinate system is used based on the rig that have been designed. By using this method, error due to the human factor while setting the microphone can be eliminated.

3.2.6 Data Analysis

Initially, an investigation took place to see the difference between the 70, 96 and 150 averages. Although there were some difference among the intensity measurement for these averages, due to the engine condition and location, 96 averages were chosen as a set point for the left and right side of the engine dynamometer as a set point for the rest of the testing. For the front and rear side of the engine dynamometer 15 averages were used in order to make easier detection of the part that making noise.

After the intensity mapping at the engine dynamometer has been done, the experiment is continued to the part that contribute significant noise source. After several tests had been conducted, it shows the engine itself is the significant source of vibration and noise in the engine test cell. Therefore the scope of the research is smaller and will be focused to the engine part only. For the engine part, a set of point for each surface is 15 point in a way to obtain the intensity different components such as the intake and exhaust manifold, the left, right and also left of the engine valley.

By using Pulse Labshop 11.1 the noise analysis can be interpreted by looking at the color of the contour graph to know which part that produces major source of noise. In order to get the component or part that contribute significant noise source the plots of amplitudes versus frequency are required to analyze and determine the major source. Then the data is interpreted by looking at the colors of the graph base on the frequency that produce higher level of the decibels reading.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This is the section where all results are displayed and interpreted. The results elaborated in this section using PULSE LABSHOP 11.1, a commercial software that recorded all intensity information in all cases in a narrow-band frequency range. After finish with the implementation of the experiment or taking data by experiment, all the data has been transferred for further analysis and observation. Each data gained by the experiment are compared with the other data from several trials. After comparison, the results are interpreted. Interpretation is important because it explain the results that are displayed.

4.2 RESULT

4.2.1 Noise Analysis of Engine Dynamometer

As explained in the previous chapter, investigations that were carried out using Sound Intensity technique for each side of engine dynamometer had been made. Thus, in this section the results of the experiment are showed.

The A-weighted one-third octave band sound power levels radiated by different parts of the unit were determined from sound intensity measurements made on different parts of the DUT and for different rpm.

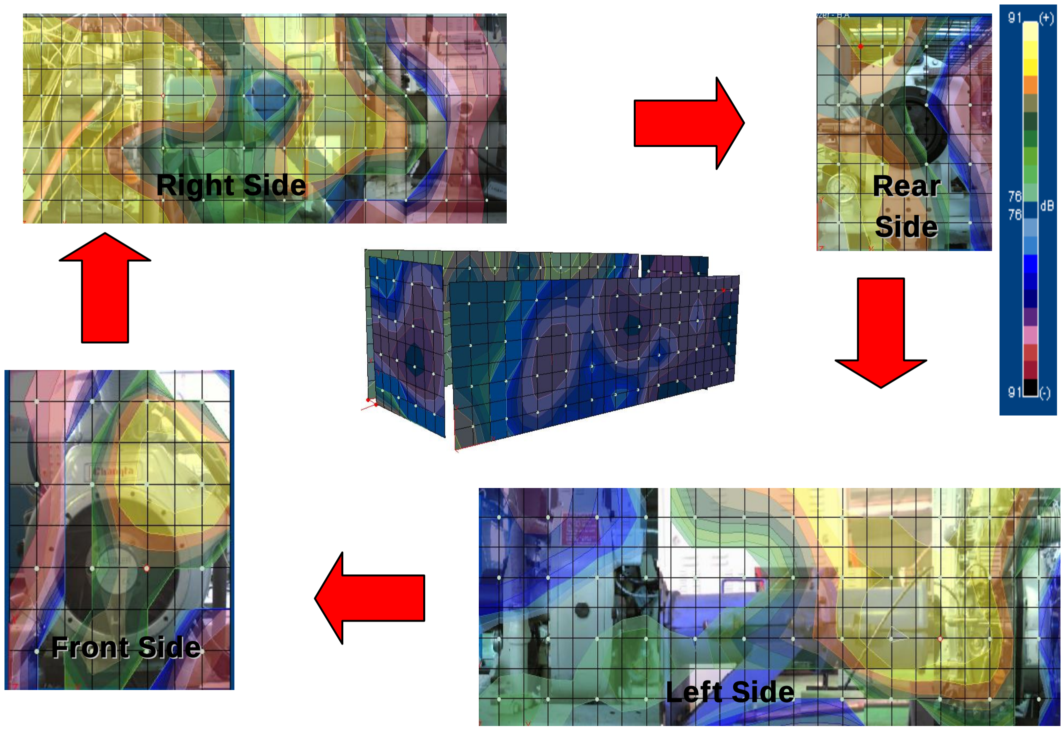


Figure 4.1: Investigations that were carried out using Sound Intensity technique for each side of engine dynamometer

The noise measurements were carried out at the front, rear and at the both side of the engine according to the SAE recommendation for microphone positions. The noise measurement were made at 1000, 1500, 2000, 2500 rpm at full load. Fig 4.1 shows the investigations that were carried out using Sound Intensity technique for each side of engine dynamometer.

In order to analyzed and interpreted the results produced by CPB analyzer that presented on the screen of a sound intensity analyzer, sound power level also can be determined by looking at the color of the contour graph to know the part that produces major source of noise. As shown by the color indicator at the right side of the picture, sound power level that produced ranging from 75dBa to 91dBa. Instead of positive values, negative values also take as account in these discussion where the negatives intensity showed that the sound coming from the back of the probe.

4.2.2 Result of Noise Analysis at Engine Dynamometer

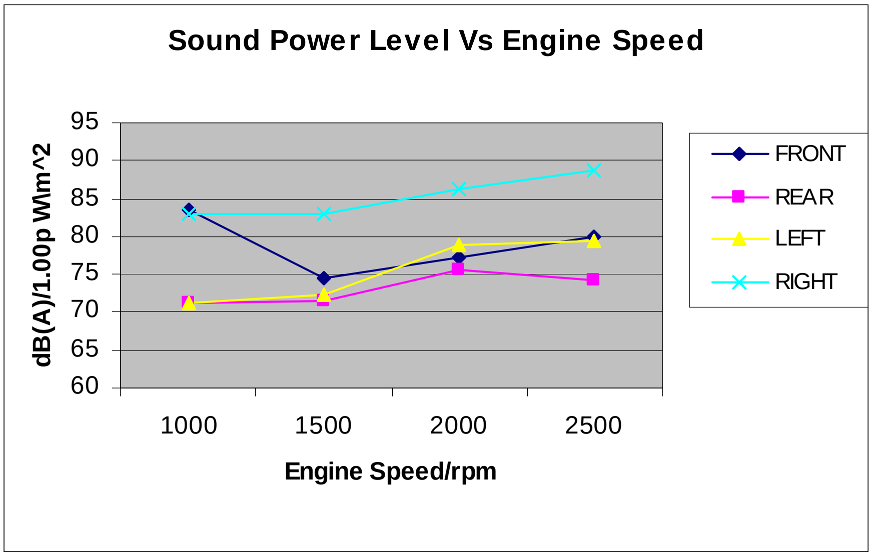


Figure 4.2: Sound Power Level Vs Engine Speed

Table 4.1: Sound power level for each side of the Engine Dynamometer

RPM	Location of Sound Power Level			
	FRONT(dBA)	REAR(dBA)	LEFT(dBA)	RIGHT(dBA)
1000	83.58	71.10	71.30	82.90
1500	74.40	71.60	72.40	83.00
2000	77.20	75.50	79.00	86.30
2500	80.00	74.20	79.50	88.60

. As indicated in this Figure 4.2 the noise level at right side of the engine dynamometer at 2500rpm was the highest average sound power produced with the value of 88.6dBa. For the front, rear and left side the value is 80dBa, 74.2dBa and 79.5dBa respectively. From the Table 4.1 also the right side of the engine at different rpm still show the highest value compare to other side of the engine dynamometer. Therefore, in terms of overall engine dynamometer noise detection an effective way in identifying major noise sources in the engine dynamometer right side during operation was essential.

For the right side of the engine dynamometer, red arrow show the location of the highest sound power produce during the test have been conducted which is 78.551dB and lowest values at point 14 (67.922dBa) , while the red oval shape indicates that engine part at the engine dynamometer is the significant source of noise based on the contour color produced.

Figure 4.3: the location of the highest sound power level produced.

Table 4.2: Value for each point power level produced

NO.	dB	NO.	dB	NO.	dB	NO.	dB	NO.	dB
1	77.380	5	77.054	9	74.025	13	73.728	17	76.057
2	76.970	6	78.551	10	78.359	14	67.922	18	71.290
3	78.535	7	74.816	11	72.772	15	70.692	19	75.599
4	79.232	8	77.729	12	72.100	16	69.840	20	72.080

To validate that the part that contribute most noise during the performance test of the engine have been conducted, contour plot of the left side of the engine dynamometer also presents(Figure 4.3). Same procedures were used like the right hand side condition which is at 2500rpm to make sure that the error during the data taken can be minimized. As a result, engine part is still the main noise source.

For the left side of the engine dynamometer, red arrow show the location of the highest values of sound power produce (71.723dBa), while the oval shape indicates that, engine area is the part that contributes to the most noise based on the color contour plotted (Figure 4.4).

Figure 4.4: the location of the highest sound power level produced.

Table 4.3: Value for each point power level produced

NO.	dB	NO.	dB	NO.	dB	NO.	dB	NO.	dB	NO.	dB
1	64.99	5	63.598	9	64.095	13	66.837	17	71.494	21	69.904
2	64.642	6	58.679	10	51.252	14	62.947	18	70.131	22	68.462
3	54.249	7	58.365	11	57.815	15	66.201	19	71.723	23	70.373
4	59.745	8	58.038	12	48.522	16	61.537	20	65.362	24	67.332

From the results, it shows the engine itself is the only significant source of vibration and noise in the engine test cell [11]. Secondary sources such as the ventilation system, pumps and circulation system systems of the engine dynamometer are usually swamped by the effects of the engine.

Therefore the scope of the research is smaller and will be focused to the engine part only. For the engine part, a set of point for each surface is 15 point in a way to obtain the intensity different components such as the intake and exhaust manifold, the left, right and also left of the engine valley.

4.2.3 Result of Noise Analysis at Engine

Figure 4.5: The Diesel engine used in this experiment

Noise generated by the engine was measured with a view to find out the noise contribution of different sources within the drives to total noise. Sound power levels, rather than sound pressure levels were measured. Sound power is a measured of the amount of a sound source produces per unit time, independent of its surrounding. It is essentially a physical property of a sound sources and an important absolute parameter that is widely used for rating and comparing sound sources. Sound power can be calculated from measured values of sound pressures or intensity levels. Sound power has number of useful applications. It can be used to calculate the approximate sound pressure level at given distance from a machine operating in a specified environment. Besides that it can compared the noise radiated by machines of the same or different type.

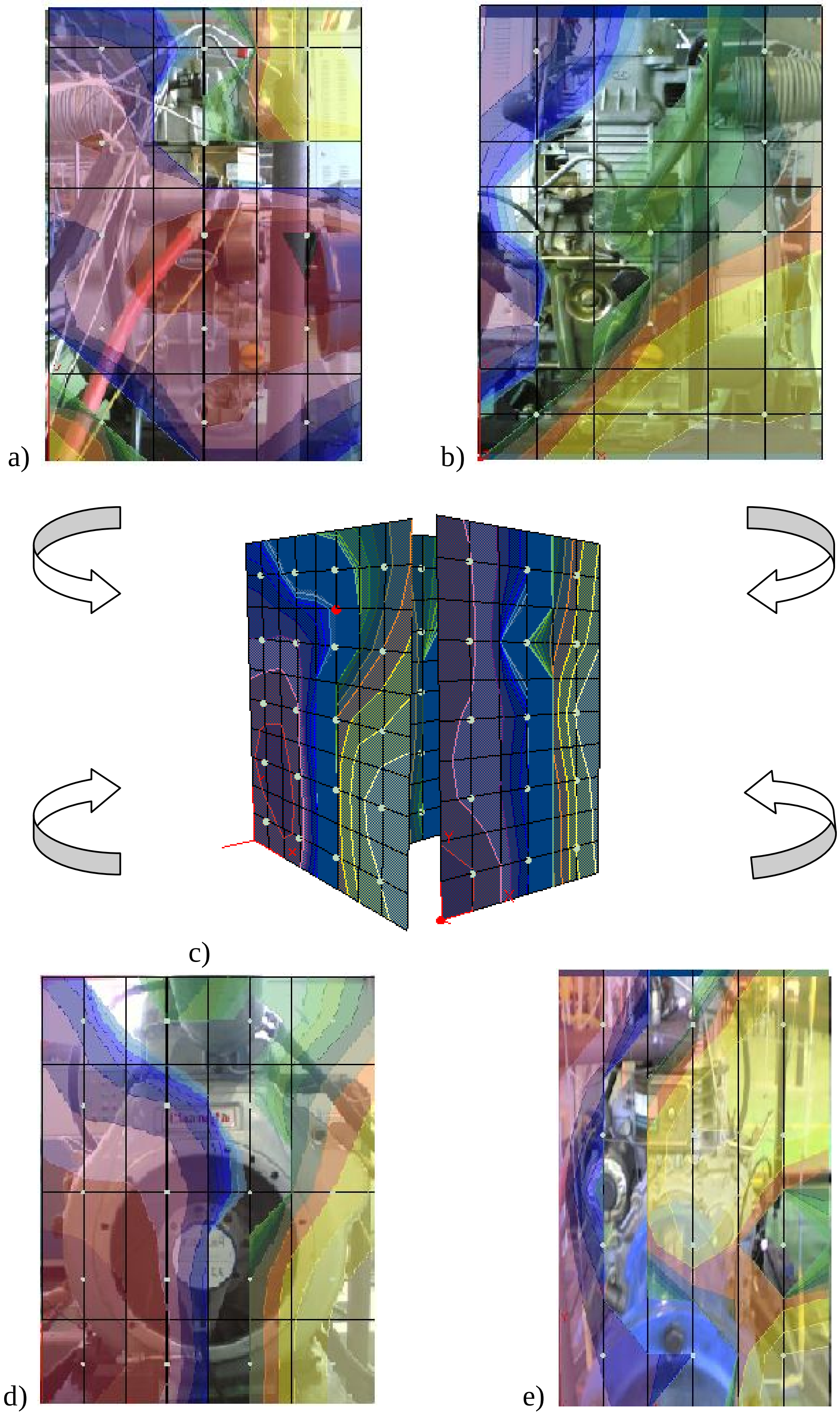


Figure 4.6: Investigations that were carried out using Sound Intensity technique for each side of engine

To identify the noise source, an investigation was carried out using the Sound Intensity (SI) techniques, the results of which is shown in Figure 4.6. The SI measurements were made at 2500 rpm at full load. Tests have been conducted in accordance to the draft International Standard ISO/DIS 9614-1, where the determination of sound power levels of noise sources using sound intensity is measure at the discrete points in order to increase repeatability point taken.

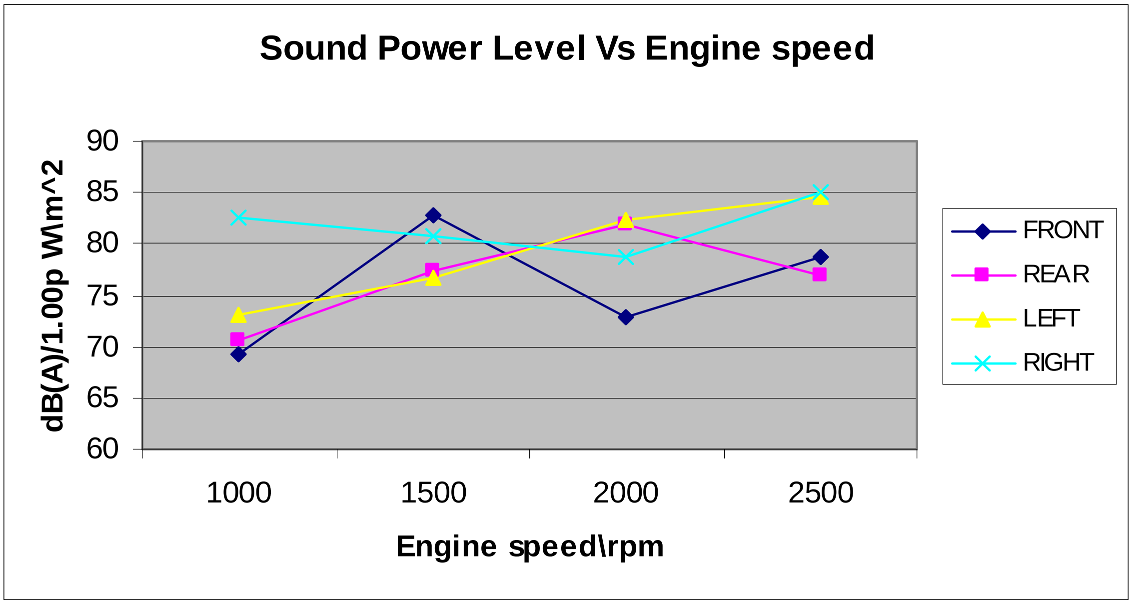


Figure 4.7: Sound Power Level Vs Engine Speed

Table 4.4: Sound power level for each side of the Engine

RPM	Location Sound Power Level			
	FRONT(dBA)	REAR(dBA)	LEFT(dBA)	RIGHT(dBA)
1000	69.20	70.50	73.00	82.60
1500	82.80	77.40	76.70	80.80
2000	72.90	81.90	82.00	78.70
2500	78.70	77.00	84.60	85.10

From the graph (Figure 4.7) and the average value from the Table 4.4, the results still show the right side of the engine is the area that contributes to major source of noise. The highest value is 85.1 dBA at the engine speed equal to 2500 rpm. For the front, rear and left side the value is 78.7dBA, 77dBA, and 84.6dBA. From the Figure 4.7 also, for the front side it showed that at the engine speed 1500rpm there is fluctuation of the sound power produce due to the condition of that day test.

The test has been conducted during night and at the same time it was a rainy day. Therefore the humidity of the environment is believed have influence the data taken on that day.

The determination of the true source ranking of each situation is an important stage to achieve in this project. The most effective route to good results is found by dealing with the most significant sources first. Therefore for each rpm the most significant sources is determined by using the highest magnitude that get from the certain frequencies. For the 1500 rpm, the Figure 4.8 shows the frequencies at 1250 kHz is the highest sound power produced with the value 81.68dBA.

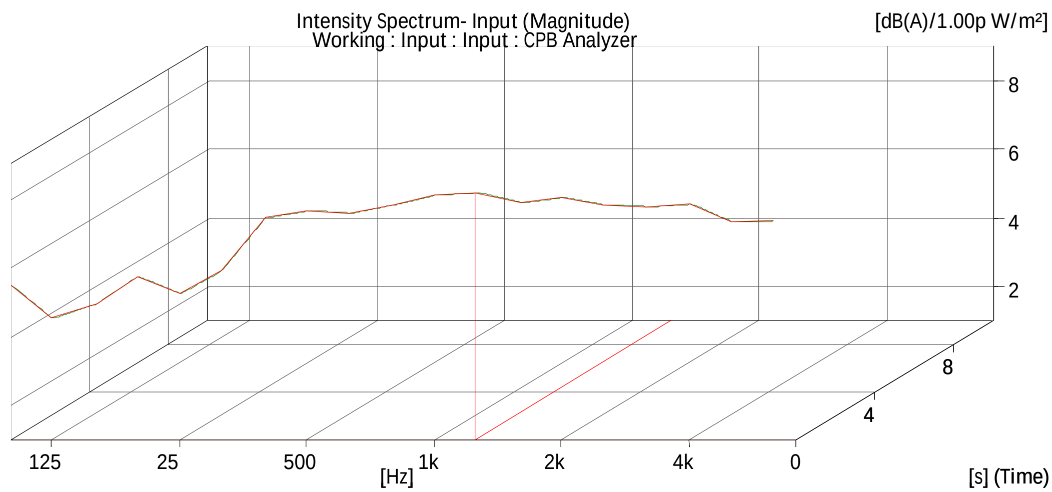


Figure 4.8: The right side magnitude of the engine at the 1250Hz with the value 81.68dB (A)/ 1.00p W/m^2

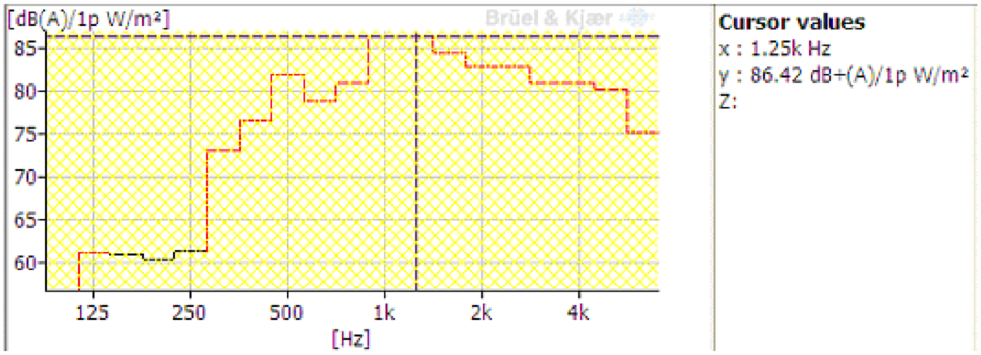


Figure 4.9: 1/3 octave CPB analysis for 1500rpm

The highest value of the sound power produced is determined by placing the cursor at the frequency(Figure 4.9) that had been firm earlier which is 1.25 kHz and the sound power value is 86.42dB(A). Only then, the spectrum color showed is the highest value of sound power produces same as Figure 4.10 with the red highlight.

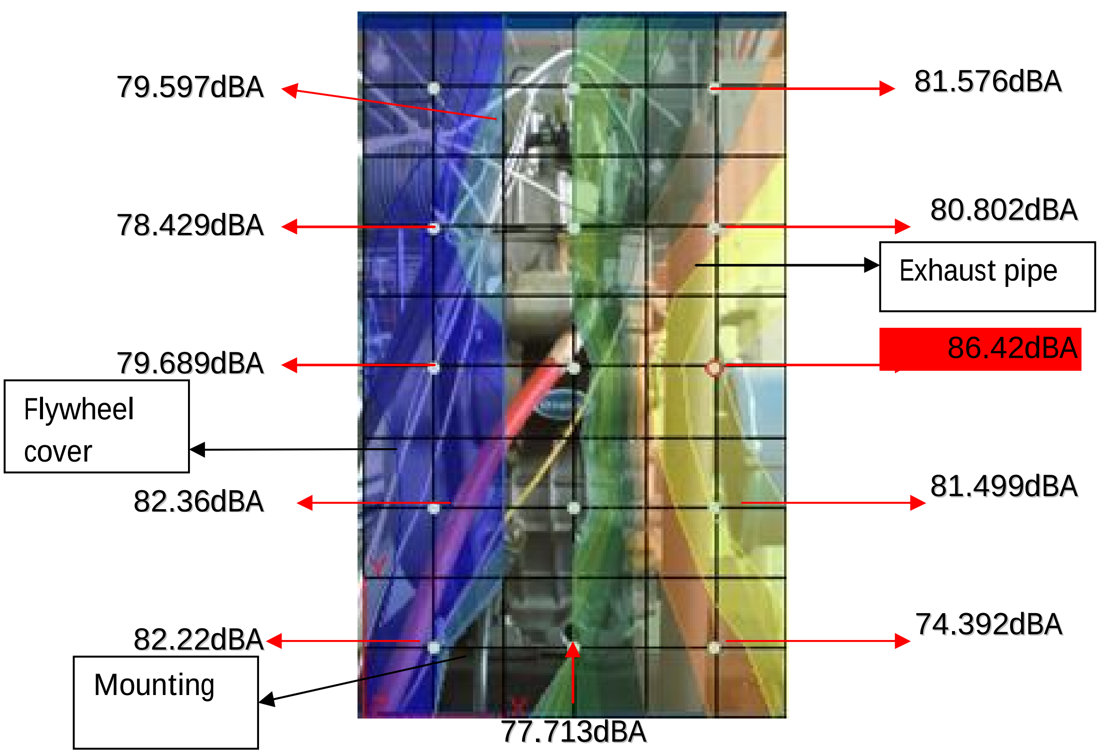


Figure 4.10: The right side color contour of the engine at the 1250Hz

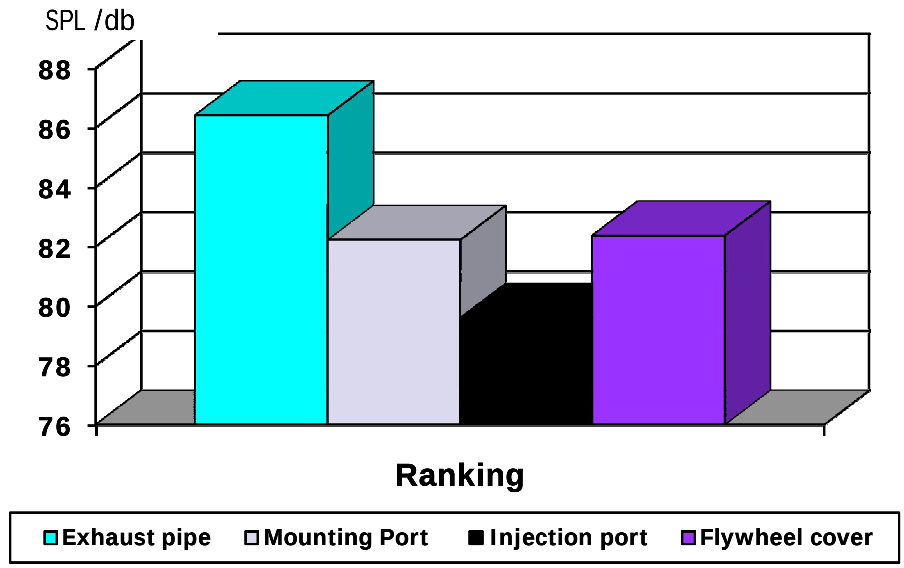


Figure 4.11: Ranking of the noise source for 1500rpm

Based on the Figure 4.11, it clearly showed the ranking of the noise is dominated by the exhaust pipe (86.42dB) compare to the flywheel cover (82.36dB) and mounting port (82.22)for the second and third place respectively.

For the 2000 rpm, the Figure 4.12 shows the frequencies at 1250 kHz is the highest sound power produced with the value 93.44dBA.

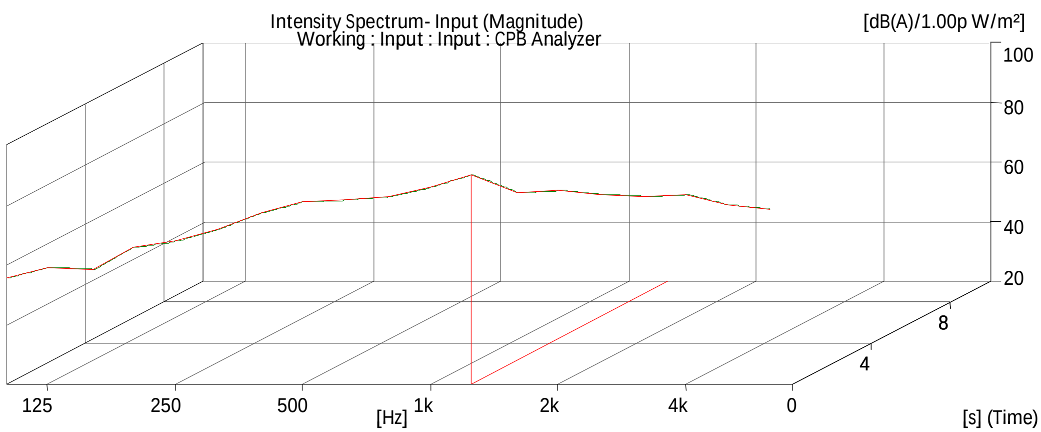


Figure 4.12: The right side magnitude of the engine at the 1250Hz with the value 93.44dB (A)/ 1.00p W/m2

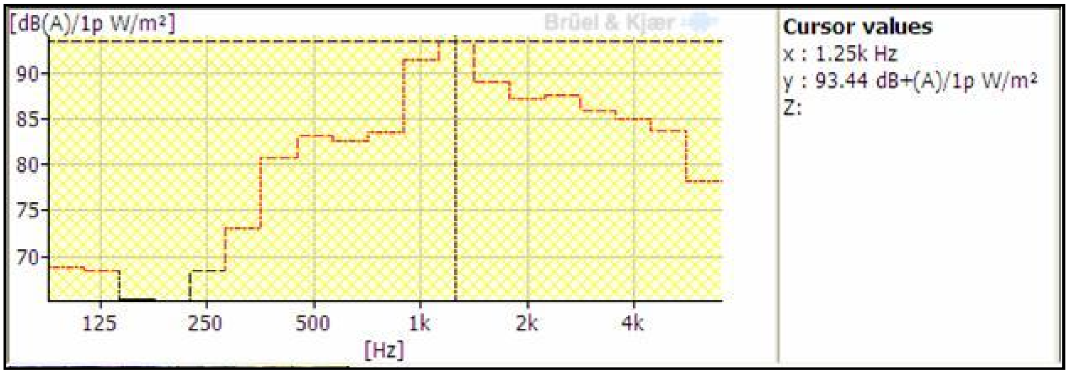


Figure 4.13: 1/3 octave CPB analysis 2000rpm

The highest value of the sound power produced is determined also by using same method that is by placing the cursor at the frequency(Figure 4.13) that had been firm earlier which is 1.25 kHz and the sound power value is 92.44dBA. Only then, the spectrum color showed is the highest value of sound power produces same as Figure 4.14 with the red highlight.

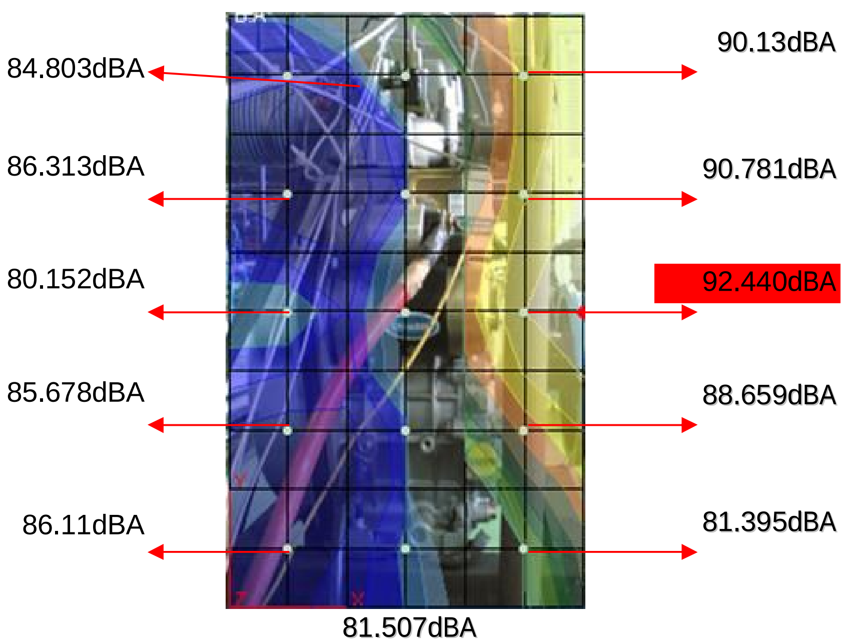


Figure 4.14: The right side color contour of the engine at the 1250Hz

SPL /db

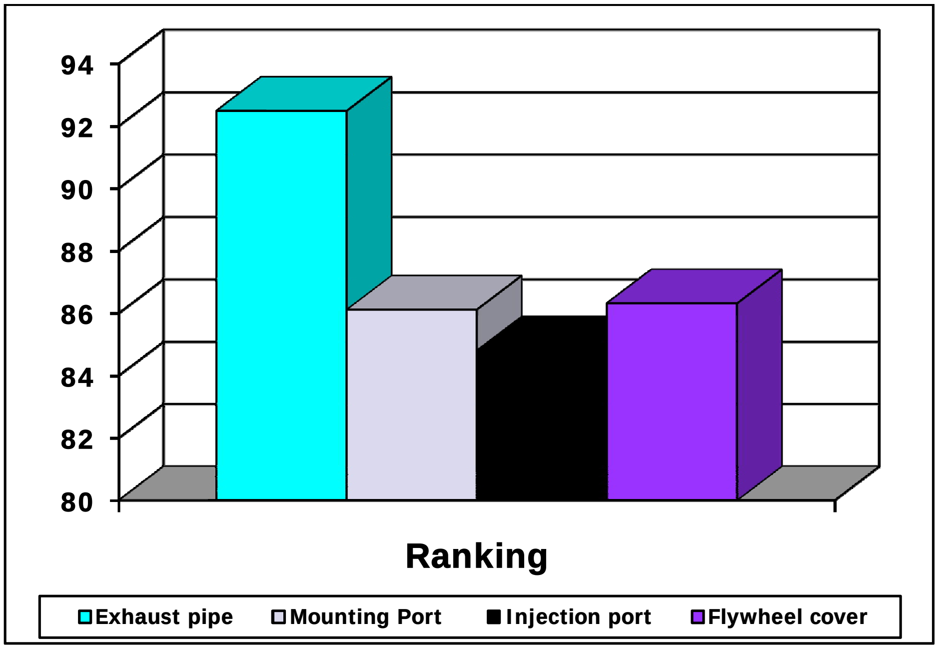


Figure 4.15: Ranking of the noise source for 2000rpm

Based on the Figure 4.15, it clearly showed the ranking of the noise is still dominated by the exhaust pipe (92.44dB) compare to the flywheel cover (85.678dB) and mounting port (86.11dB).For the 2500 rpm, the figure below shows the frequencies at 1250 kHz is the highest sound power produced with the value 90.32dBA.

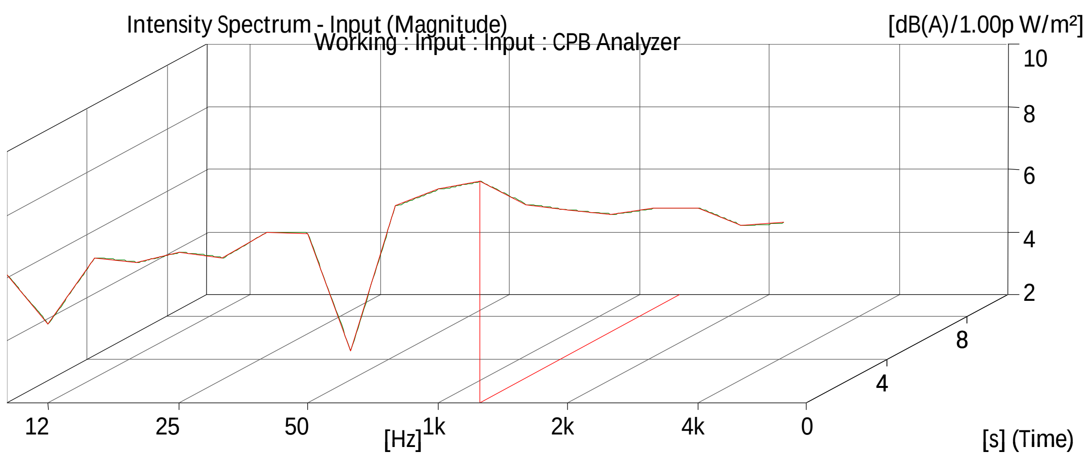


Figure 4.16: The right side magnitude of the engine at the 1250Hz with the value 90.32dB(A)/ 1.00p W/m2 .

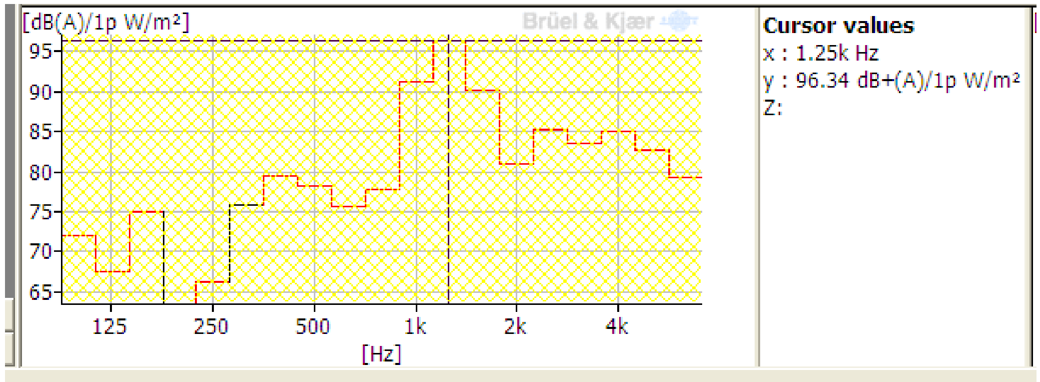


Figure 4.17: 1/3 octave CPB analysis 2500rpm

The highest value of the sound power produced is determined also by using same method that is by placing the cursor at the frequency (Figure 4.17) that had been rigid earlier which is 1.25 kHz and the sound power value is 90.32dBA. Only then, the spectrum color showed is the highest value of sound power produces same as Figure 4.18 with the red highlight.

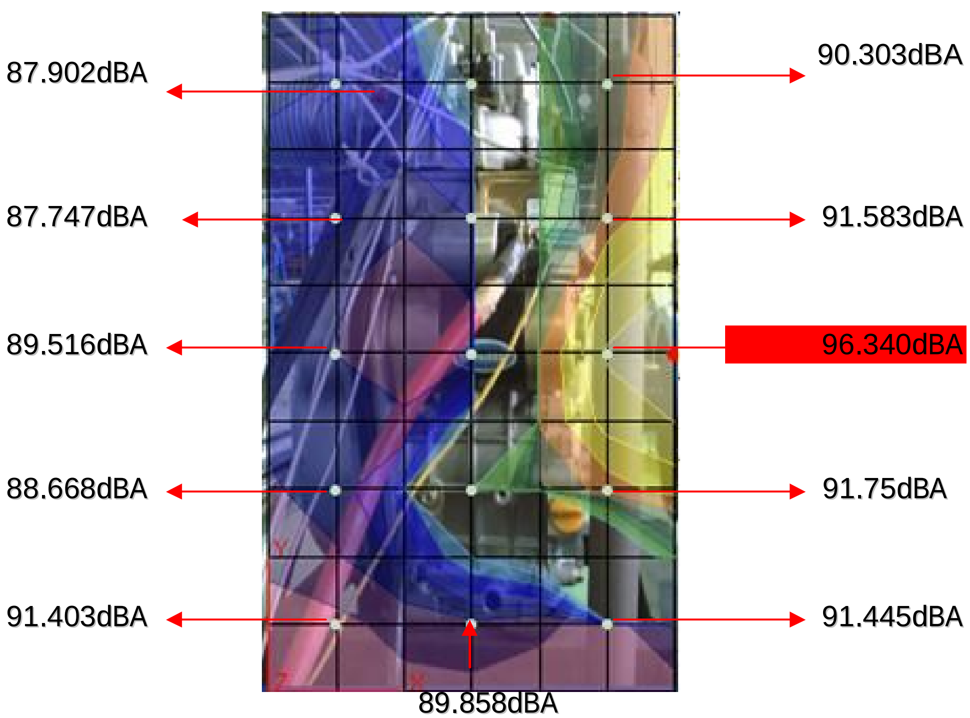


Figure 4.18: The right side color contour of the engine at the 1250Hz

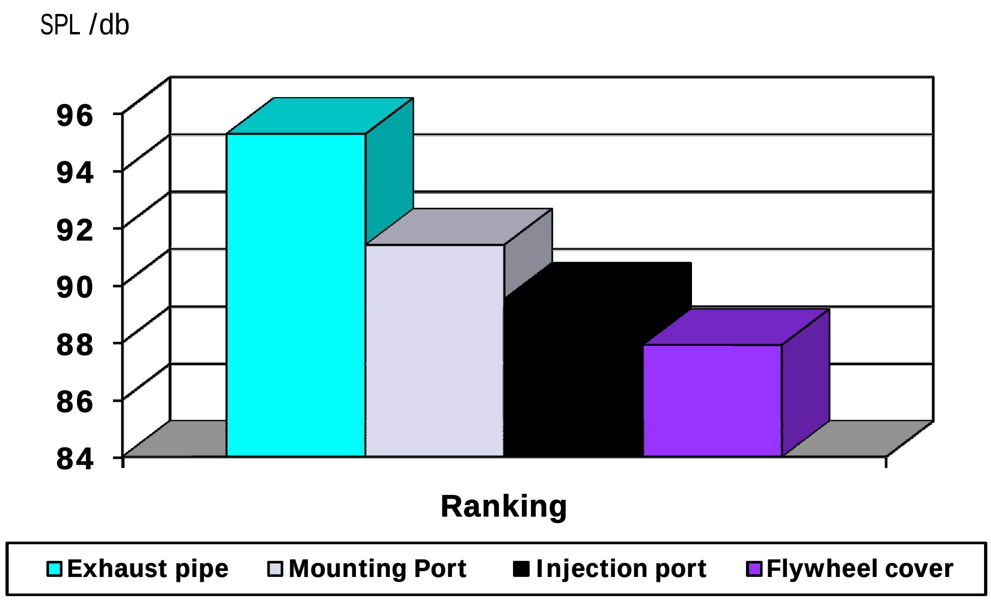
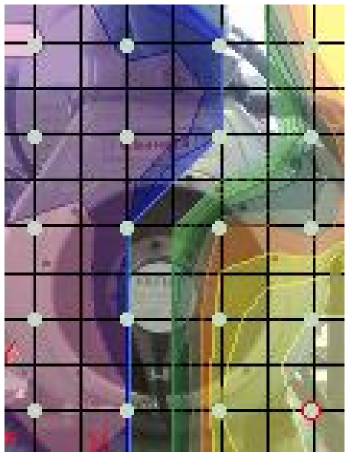


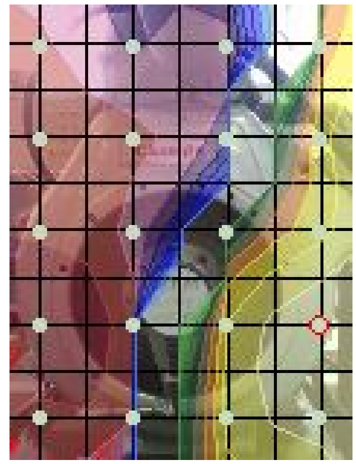
Figure 4.19: Ranking of the noise source for 2500rpm

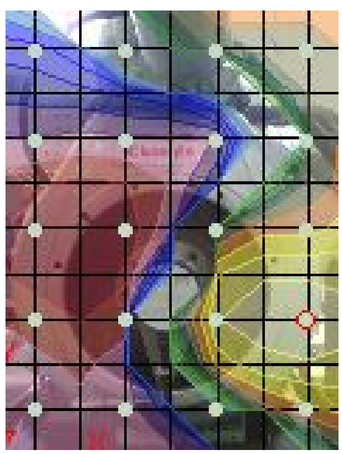
Based on the Figure 4.19, it clearly showed the ranking of the noise is still dominated by the exhaust pipe (96.340dB) compare to the flywheel cover (88.669dB) and mounting port (91.445dB). During this experiment also, higher rpm will make the noise at the mounting port is increase drastically. For 1500rpm the value is 86.42dB, for 2000rpm the value is 92.44dB, and for 2500rpm the value is 96.32dB.

This happened because vibrating object always generated sound field and reproduced by a rigid object of the same geometry covered with point source [17]. The characteristics of sound power produced can be understood when rpm increase, noise also increased that result from harsher combustion because of the increase in maximum cylinder pressure gradient. This is because combustion excitation force that is use direct injection system is transmitted from pistons to the crankshaft through connecting rods and then to the certain structure of the engine.

It can be concluded that the trend of the Sound radiation of the exhaust pipe give significant increment to the noise especially when the engine speed is increase due to the firing frequency produced during the combustion process and during exhaust gas exit the combustion chamber due to of fresh charge entering through intake port. Figure 4.20 and 4.21 showed the effect of different speed to the noise produced for each side


a)1000rpm


b) 1500


c) 2000rpm

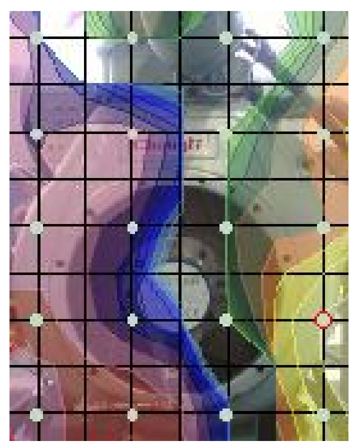
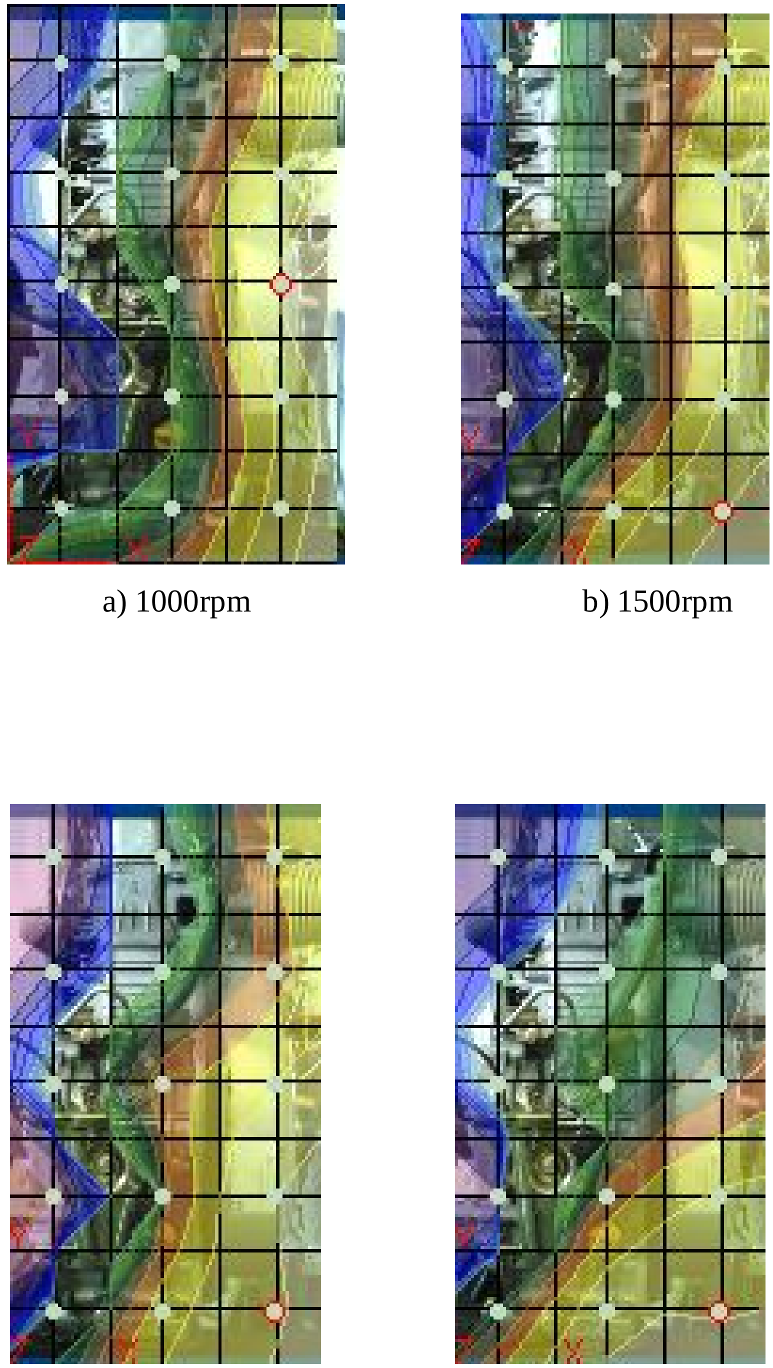

c)2500rpm

Figure 4.20(a-d) .The effect of different engine speed to the noise produced at front side:



a) 1000rpm b) 1500rpm

c) 2000rpm d) 2500rpm

Figure 4.21(a-d) .The effect of different engine speed to the noise produced at left side

Additionally, higher rpm will increase the noise at the engine mount area due to the engine’s structural vibration transfer and noise radiation behavior with respect to the excitation mechanism. The part that most influence because of this factor was found to be the fly wheel cover and the mount area between the engine and the engine rig.

The results of this project has been compared with the paper of B. B. Ghosh, P Bhattacharya, Rajsekhar Panua and Prabir Kumar Bose title Prediction of Noise Level by Mathematical Modeling in the Exhaust Muffler and Validation of these Analytical Results with the Experimental Results for 4-Stroke Diesel Engine and it show the same trend of result.

Most of the energy is at 1250Hz. The results of analysis also revealed that the 1250 Hz bands had the most significant contribution to the engine right noise. The results can also be seen that the frequencies corresponding that the frequencies corresponding to the peak noise were independent of the engine speed. This indicated that resonance were the primary causes of the engine right noise.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

In this chapter everything about the research explained in the previous chapters is summarized. Some recommendations are also included in order to enhance the results of future research related to experiment of noise source identification using sound intensity method.

5.2 SUMMARY

All the research that has been done to complete this project is very helpful in understanding experiment of noise source identification using sound intensity method. By applying all the knowledge and the tools provided the procedures in conducting the testing have been successfully executed. This project starts with the designing process. After completed with the design of the chassis structure in SolidWorks 2005, the rig frame is designed and later fabricated. It is built in such a way to provide a precise measurement of the sound intensity. The measurement technique was based on a point measurement by placing the intensity probe at the center of each mesh.

Then, the determination of the true source ranking of each situation is proceed, begin with the lower rpm to the higher rpm at the overall engine dynamometer side. After that, the data have been analyzed by using average reading. Next, the second stage of the process begins with the smaller scope where the highest source of noise from the previous stage is used as a reference and each side of the part have been measured by using same method.

Both stages mentioned above are compared in terms of frequency resonance values that is randomly select from each rpm in order to find the significant noise source and that influence by the speed of the engine. Method of comparison is done by comparing the results of magnitude and color of the contour graph produced obtained at different frequency from the CPB analyzer.

For each side of the stage tested, the data are obtained from the range of the engine speeds that have been fixed. There is a reason why the difference in the speed is chosen. This is important to observe the correct patterns of the contour color's graph produced when engine speed increased. Besides that in this experiment the limitation of the engine and safety of the student also take as a consideration.

5.3 CONCLUSION

Noise generated by engine dynamometer was measured with a view to find out the noise contribution of different sources within that lead to total noise. Sound power levels, rather than sound pressure levels were measured. Sound power is a measure of the amount of sound energy a sound source produces per unit time, independent of its surroundings. It is essentially a physical property of a sound source and an important absolute parameter that is widely used for rating and comparing sound sources.

Sound power has a number of useful of applications. It can be used to calculate the approximate sound pressure level at a given distance from a machine operating in a specified environment. It can compare the noise radiated by machines of the same or different type. For sure in engineering work, it can assist in developing quiet major noise sources in machines for noise control work. With full efforts and many trials, finally this project is completed successfully and reached its objectives. After details explanation on each chapter, there are several matters can be concluded. Surfaces integration using SI is the simplest and the most accurate way of determining the noise source of engine where the results of the noise source of flywheel cover and exhaust were presented. These were found to be the main contributing factors to the engine noise. The results of different side at different engines speed present the different contribution to the engine noise. The result is then compared with the literature review that gives the same trend of sound power produce by the diesel engine exhaust. Thus, it is valid since the difference does not change the source of the noise.

5.4 RECOMMENDATIONS FOR FUTURE RESEARCH

As seen n the previous section of the data and results obtained have little defects his is very much related to the setup of the experiment. Hence, below are some of the recommendations for future improvement of experimental noise source identification by using sound intensity method. The recommendations are:

a) In order to see the pure noise effect at the engine, the intake and exhaust orifice noise must be acoustically encapsulate and the exhaust muffler must be install back to the original position
b) A computer aided engineering tool model of the entire powertrain must be created to verify as well as provide guidelines for reducing noise levels.
c) Results obtained can be enhanced using 3D sound intensity probe and advance application by using robot control to make fast automated test and very high repeatability.
d) The usage of the waterfall graph to sea the true source of the resonance frequency while the machine is still in the running condition and also analysis at low frequency range.

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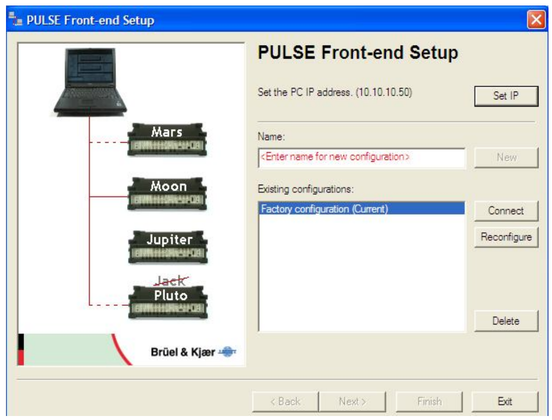
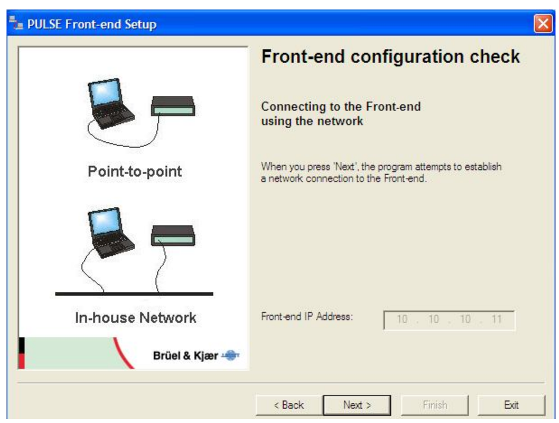
APPENDIX A

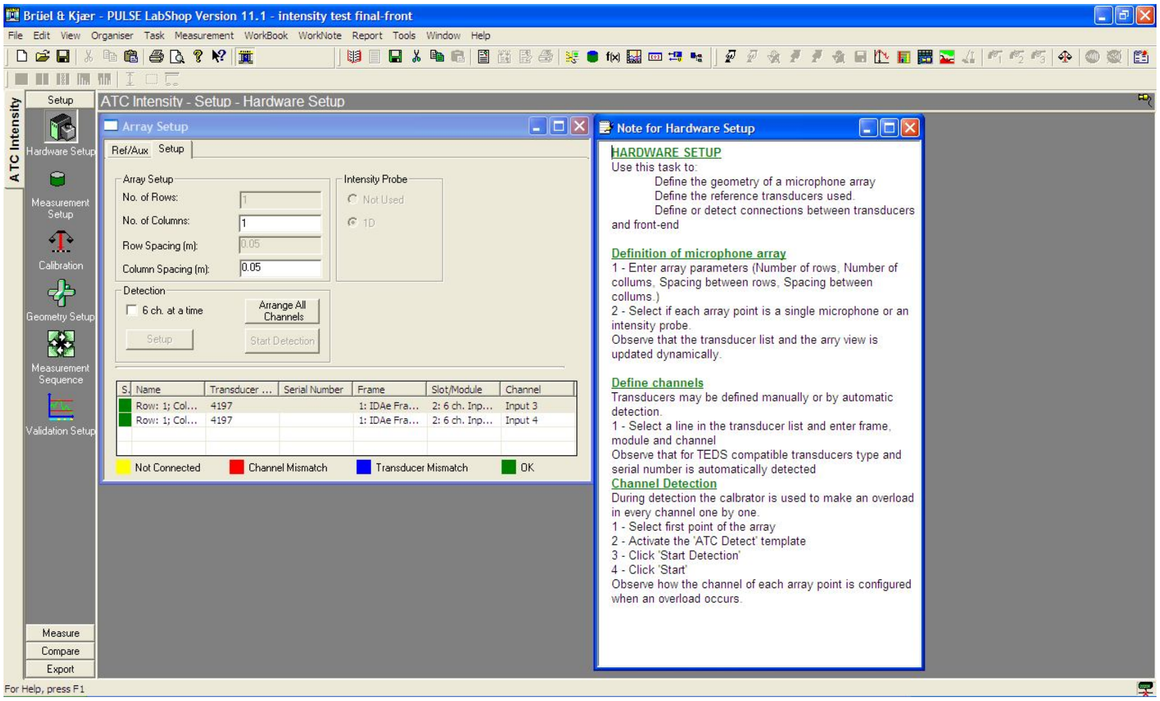
(Pulse Labshop Manuals)

- Go to –START-All Program-PULSE-PULSE front End Setup
- Click On the connect tab and make sure Front End configuration check window is connected.





- Then open Pulse Labshop Version 11.1



HARDWARE SETUP

Use this task to:

Define the geometry of a microphone array
Define the reference transducers used.
Define or detect connections between transducers and front-end

Definition of microphone array

1 - Enter array parameters (Number of rows, Number of collums, Spacing between rows, Spacing between collums.)
2 - Select if each array point is a single microphone or an intensity probe.
Observe that the transducer list and the arry view is updated dynamically.

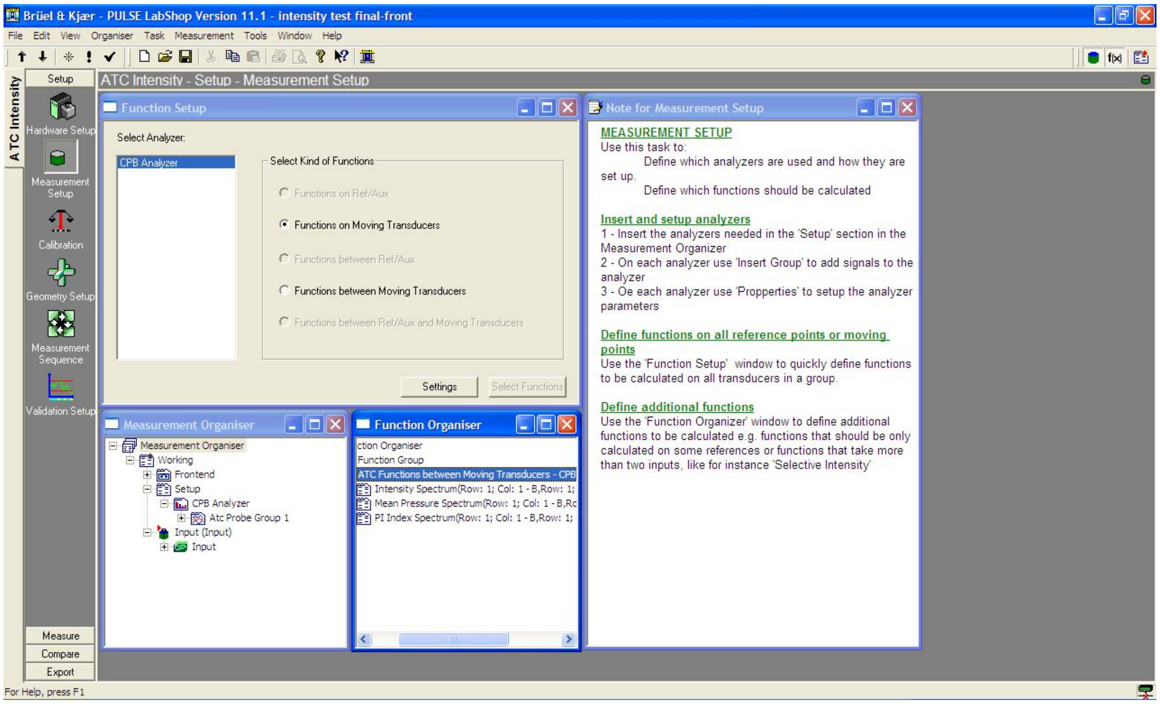
Define channels

Transducers may be defined manually or by automatic detection.
1 - Select a line in the transducer list and enter frame, module and channel
Observe that for TEDS compatible transducers type and serial number is automatically detected

Channel Detection

During detection the calbrator is used to make an overload in every channel one by one.
1 - Select first point of the array
2 - Activate the 'ATC Detect' template
3 - Click 'Start Detection'

4 - Click 'Start'
Observe how the channel of each array point is configured when an overload occurs.



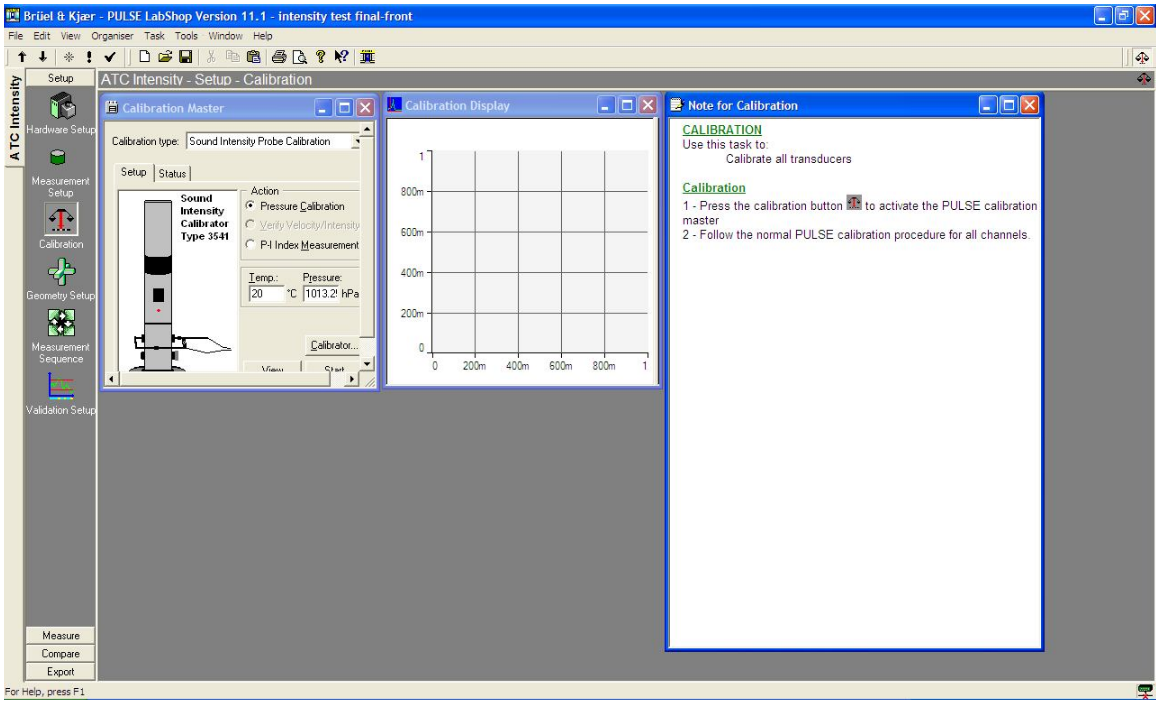
<u>**MEASUREMENT SETUP**</u>
Use this task to:

Define which analyzers are used and how they are set up.
Define which functions should be calculated

<u>**Insert and setup analyzers**</u>
1 - Insert the analyzers needed in the 'Setup' section in the Measurement Organizer
2 - On each analyzer use 'Insert Group' to add signals to the analyzer
3 - Oe each analyzer use 'Propperties' to setup the analyzer parameters

<u>**Define functions on all reference points or moving points**</u>
Use the 'Function Setup' window to quickly define functions to be calculated on all transducers in a group.

<u>**Define additional functions**</u>
Use the 'Function Organizer' window to define additional functions to be calculated e.g. functions that should be only calculated on some references or functions that take more than two inputs, like for instance 'Selective Intensity'



CALIBRATION

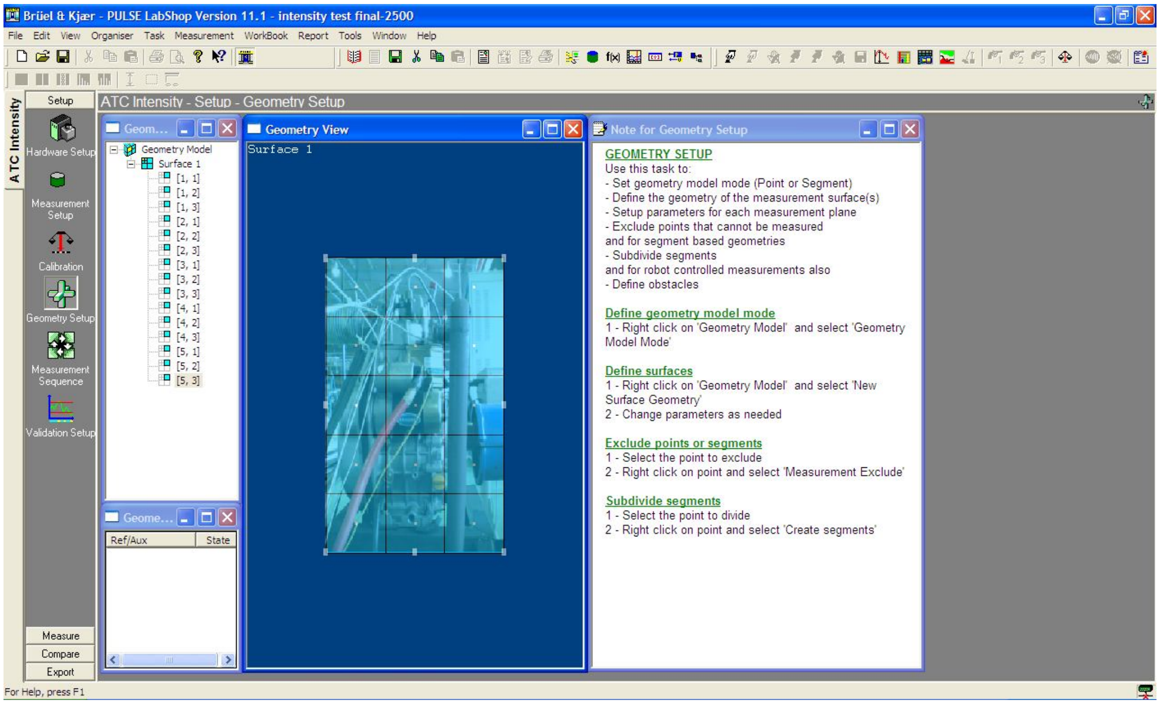
Use this task to:

Calibrate all transducers

Calibration

1 - Press the calibration button to activate the PULSE calibration master

2 - Follow the normal PULSE calibration procedure for all channels



GEOMETRY SETUP

Use this task to:
- Set geometry model mode (Point or Segment)
- Define the geometry of the measurement surface(s)
- Setup parameters for each measurement plane
- Exclude points that cannot be measured

and for segment based geometries
- Subdivide segments

and for robot controlled measurements also
- Define obstacles

Define geometry model mode

1 - Right click on 'Geometry Model' and select 'Geometry Model Mode'

Define surfaces

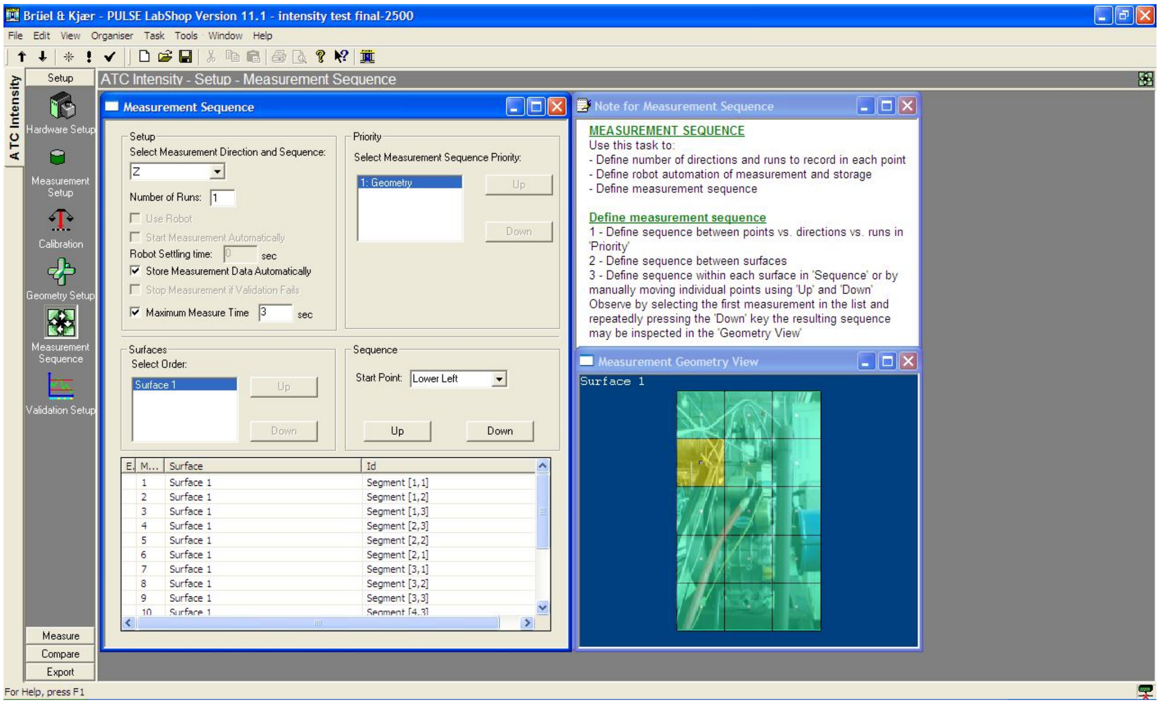
1 - Right click on 'Geometry Model' and select 'New Surface Geometry'
2 - Change parameters as needed

Exclude points or segments

1 - Select the point to exclude
2 - Right click on point and select 'Measurement Exclude'

Subdivide segments

1 - Select the point to divide
2 - Right click on point and select 'Create segments'



MEASUREMENT SEQUENCE

Use this task to:

- Define number of directions and runs to record in each point
- Define robot automation of measurement and storage
- Define measurement sequence

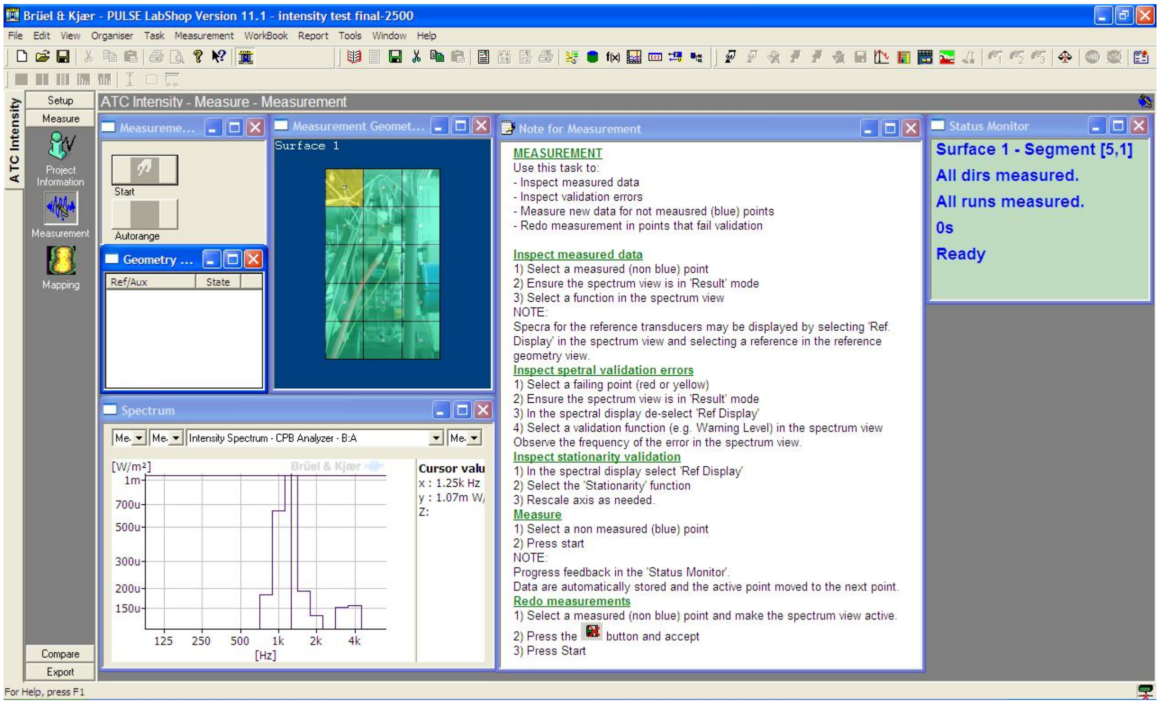
Define measurement sequence

1 - Define sequence between points vs. directions vs. runs in 'Priority'

2 - Define sequence between surfaces

3 - Define sequence within each surface in 'Sequence' or by manually moving individual points using 'Up' and 'Down'

Observe by selecting the first measurement in the list and repeatedly pressing the 'Down' key the resulting sequence may be inspected in the 'Geometry View'



MEASUREMENT

Use this task to:

- Inspect measured data
- Inspect validation errors
- Measure new data for not meausred (blue) points
- Redo measurement in points that fail validation

Inspect measured data

1) Select a measured (non blue) point
2) Ensure the spectrum view is in 'Result' mode
3) Select a function in the spectrum view

NOTE:

Specra for the reference transducers may be displayed by selecting 'Ref. Display' in the spectrum view and selecting a reference in the reference geometry view.

Inspect spetral validation errors

1) Select a failing point (red or yellow)
2) Ensure the spectrum view is in 'Result' mode
3) In the spectral display de-select 'Ref Display'
4) Select a validation function (e.g. Warning Level) in the spectrum view

Observe the frequency of the error in the spectrum view.

Inspect stationarity validation

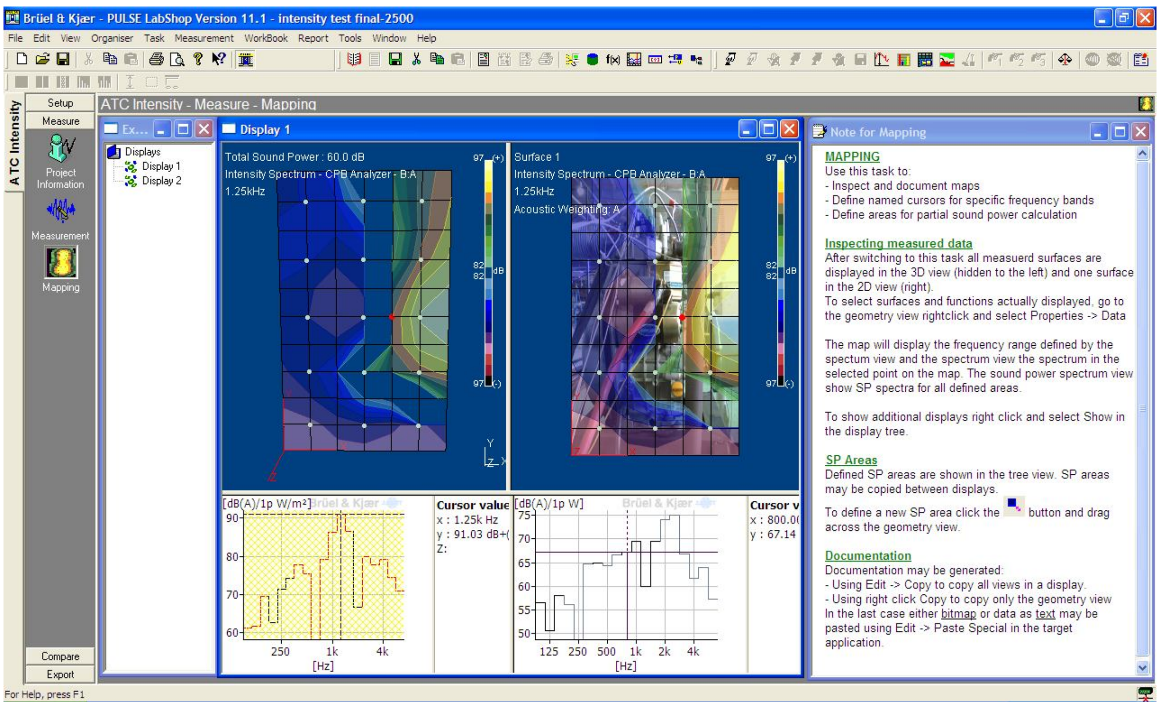
1) In the spectral display select 'Ref Display'
2) Select the 'Stationarity' function
3) Rescale axis as needed.

Measure

1) Select a non measured (blue) point
2) Press start
NOTE:
Progress feedback in the 'Status Monitor'.
Data are automatically stored and the active point moved to the next point.

<u>Redo measurements</u>

1) Select a measured (non blue) point and make the spectrum view active.
2) Press the  button and accept
3) Press Start



MAPPING
Use this task to:
- Inspect and document maps
- Define named cursors for specific frequency bands
- Define areas for partial sound power calculation

Inspecting measured data
After switching to this task all measuerd surfaces are displayed in the 3D view (hidden to the left) and one surface in the 2D view (right).
To select surfaces and functions actually displayed, go to the geometry view rightclick and select Properties -> Data

The map will display the frequency range defined by the spectum view and the spectrum view the spectrum in the selected point on the map. The sound power spectrum view show SP spectra for all defined areas.

To show additional displays right click and select Show in the display tree.

SP Areas
Defined SP areas are shown in the tree view. SP areas may be copied between displays.
To define a new SP area click the  button and drag across the geometry view.

Documentation
Documentation may be generated:
- Using Edit -> Copy to copy all views in a display.
- Using right click Copy to copy only the geometry view
In the last case either bitmap or data as text may be pasted using Edit -> Paste Special in the target application.

APPENDIX B

(Gantt Chart for FYP 1 and FYP 2)

GANTT CHART FOR FYP 1

FINAL YEAR PROJECT 1															
Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Identify the title	■														
Study on literature review	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Finalize the objective & scope			■	■	■										
Finalize the project methodology & flowchart						■	■	■							
Prepare for the mock presentation									■	■					
Presentation with supervisor											■				
Make report chapter 1												■			
Make report chapter 2													■		
Make report chapter 3													■		
Complete the FYP log book proposal														■	
Prepare for proposal presentation														■	
Final presentation															■

GANTT CHART FOR FYP 2

FINAL YEAR PROJECT 2														
Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Design and fabricate rig														
Experimental Analysis														
Data Collection														
Analyze data														
Presentation with supervisor														
Make report chapter 4														
Make report chapter 5														
Final presentation and Report Submission														