IOP Conference Series: Materials Science and Engineering

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To cite this article: M S M Sani *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **506** 012060

IOP Conf. Series: Materials Science and Engineering **506** (2019) 012060 doi:10.1088/1757-899X/506/1/012060

Sound Intensity Mapping of Two Stroke Engine by Using Hemispherical Surface Coordinate Arrangement

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Abstract. This paper presents to investigate the noise source identification of two stroke engine for different engine speed and different general case in two stroke engine without rear cover, with rear cover, with rear cover (composite fibre), and with rear cover (acoustic foam). The experiment carried out utilizing by sound intensity in hemispherical surface arrangement and sound intensity mapping method for engine speed at range 800 to 4800 revolution per minute (rpm). A single module of microphone is used to identify sound power level in hemispherical surface coordinate arrangement while a pair microphone in sound intensity mapping. This method can be applied on-site rather than in an anechoic chamber as long as the background noises are stationary. The sound power level is within 73.7 dB to 81.3 dB in the range of engine speed. The noise level is increasing with engine speed. Rear cover should be applied in order to reduce the sound power level. The project delivers the reliable input for the engineering practice to reduce engine noise level.

1. Introduction

Sound is such a common part of everyday life that are rarely appreciate all of its functions. It is also defined as the pressure variation in air, water and other medium that are detected by human ear. When sound produced, energy have transferred from sound source to the surrounding air molecules takes place. The energy transfer is called Sound Power that have unit of Sound Power is W (Watt). The audible range of sound power is from 10-9 W to 1000 x 10-9 W is the lowest level which can heard by people that are closed to the source and 1000 W can immediately create hearing damage. Lower level of sound power also can create hearing damage but in long period of time. Sound have affected human in positive and negative way. In positive way, sound can be defined as pleasant and relaxing. In other way, the unpleasant and unwanted sound is called noise which are occurred in high decibel (dB) frequency. Noise affected people in everyday life in different way depending on the type of noise, noise level, frequency characteristics, time of day and variance over time [1-2].

When a source produces sound power (P) it have created a certain Sound intensity (I) at distance away from the source. The intensity is a measure for the amount of power through a certain area of the distance. Sound intensity is the rate of acoustic energy flow per unit area. It is also a current of acoustic energy through medium that have magnitude and direction. Sound Intensity Mapping is by integrated over enclosing surface of an object and its sound power. Sound intensity measurement is able to determine the sound directional and localise noise hot spot. Mapping software have provided a contour map of noise level that are provided intuitive documentation of noise problems.

Noise measuring devices are typically used a sensor to receive noise signals from source. However, sensor not only detect noise from the source but it is also detected any ambient background noise. Sound measurement for machine is running, it is important to make the background noise in lower level to ensure any influence on the result. Therefore, the anechoic chamber is needed to measure the source of noise. Noise source identification (NSI) is a technique to study noise control program. Noise source have two categories which are vibration-induced noise and flow-induced noise. First category has included noise from rotating machinery, noise due to structural resonance, impact noise, etc., then second category included fan noise, pump noise, jet noise, etc. Other than that, NSI is sound field visualization techniques and find applications in non-destructive evaluation, underwater imaging and machine diagnosis [3-4]. NSI techniques is useful in estimating the sources position and sound strength. NSI is also to identify the major sources of noise radiation. The best reduction in noise can be achieved by reducing the noise that are radiated from the noisiest sources. The reduction noise is required not only the treatment of many different sources but also called for different approaches in each particular case depending upon the degree of the contribution of the various individual sources to the total noise. Noise of vehicles and machines is mainly defined by noise generated by the power part which are an engine. The main part that are highly produced engine noise is the noise that are emitted by engine surfaces [5-8].

Overall, this paper aims to investigate noise source from two stroke engine by using sound intensity mapping. A single module of microphone has been applied to identify sound power level in hemispherical surface coordinate arrangement. This study also suggests to design rear cover in order to reduce sound power level.

2. Experimental set up

In conducting this experiment, it has studied in four general cases which are the condition of two stroke engine without rear cover, with rear cover, cover by composite fibre and acoustic foam. Acoustic foam and composite fibre have used in this study as noise reduction for two stroke engine.

The two stroke engine needs a proper setup before the experiment performed. Figure 1 shows the apparatus setup used in experiment which are Prepolarized Free – Field ½ Microphone type 4189, Output Generator Module 50kHz, Hand – held analyzer, and Sound Intensity Microphone Pair. The coordinates in hemispherical surface arrangement is according to ISO 3745 [9], Sound power levels (sound pressure – free field) as shown in Figure 2. Furthermore, Figure 3 shows the microphone positions on equal areas on the surface of a hemisphere. Sound power of the source is then calculated from sound pressure measurements and knowledge of acoustic environment.

Figure 1. Apparatus of Sound Intensity

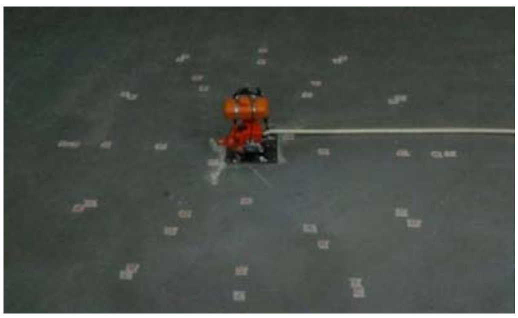

Figure 2. Hemispherical arrangement

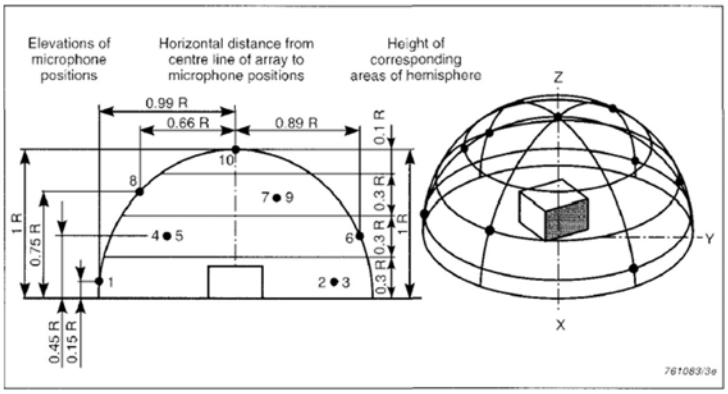

Figure 3. Microphone positions on equal areas on the surface of a hemisphere [6].

The noise on two stroke engine needs proper set up in the semi anechoic chamber before the experiment can be performed. In investigate the noise source identification at free field, four parameters, (800,1800,3600 and 4800 rpm) are setup in this experiment. The calibration for microphone is followed calibration chart from Bruel & Kjaer type 4297. The microphone has calibrated until it reaches sound level is around 94.0 dB. In Noise Source Identification experiment, Prepolarized Free-field ½ Microphone type 4189 is used. It has connected by wire to the Bruel & Kjaer Type 3160 A 4/2 Output Generator Module and the data will be transfer directly to the laptop by cable wire. The single microphone is setup by following the coordinates point on hemispherical arragement. When the test was running, data is generated and analyse by Bruel & Kjaer – PULSE LabShop Version 16.1.0 in the laptop to detect the higher noise level in the hemispherical arrangement. Graph of decible (dB) versus frequency are used to find which point of location that detected high level of decibel reading.

After the experiment of noise source identification by single microphone conducted, it is followed by using the Bruel & Kjaer Hand-held analyser Type 2270 and Sound Intensity microphone pair type 4197 to get the sound intensity mapping. Figure 4 shows the investigations that were carried out using Sound Intensity technique for each side or view of two stroke engine. The noise analysis can be interpreted by looking at the colour of the contour graph mapping to determine which part that produces major source of noise by using post processing software, PULSE LabShop Version 16.1.0. The noise measurement was carried out in Noise Source identification at 40 point of coordinates in hemispherical arrangement for single microphone than Sound Intensity Mapping were carried out at the front, rear, and at both side of the engine according to the SAE recommendation for microphone positions. The noise measurement was repeated in five level of parameter in rpm.

(a) (b) (c) (d)

Figure 4. Two stroke engine a) Right view, b) Front view, c) Left view, d) Rear view

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3. Mathematical Modelling

Sound intensity at any point, in a sound field in an interest direction x can be written as

$$SI_x = \frac{1}{T}\int_0^T h(t)\, w_x\,(t)dt \tag{1}$$

where T is a sufficiently long averaging time, $h(t)$ and $w_x(t)$ are instantaneous sound pressures and particle velocity in the direction of x, respectively. The sound pressure at the midpoints of two microphones can be determined by taking the average of two sound pressure signals as Eq. (2):

$$h(t) = \frac{h_1(t) + h_2(t)}{2} \tag{2}$$

The particles velocity at midpoint can be obtained by Euler's equation for a zero mean velocity medium as Eq. (3):

$$w_x(t) = -\int \nabla h(t)dt \approx -\frac{h_2(t) - h_1(t)}{j\omega\rho\Delta x} \tag{3}$$

By using Fourier transforms, sound intensity can be summarized as Eq. (4):

$$SI_x(\omega) = \frac{\mathrm{Im}\,[K_{12}(\omega)]}{\omega\rho\Delta x} \tag{4}$$

where $K_{12}(\omega)$ is the one sided cross power spectrum density function between microphone channels 1 and 2, ω is the angular frequency, ρ is the air density and Δx is the separation distance between the two microphones.

4. Result and Discussion

4.1 Engine Speed 800 rpm

Investigation NSI for two stroke engine were carried out using sound intensity technique at 40 points of coordinates in hemispherical arrangement and sound intensity mapping technique for each side of two stroke engine. The maximum noise level for two stroke engine without cover at speed 800 rpm is 80.3 dB at point 5 in hemispherical arrangement. The other sound power level for engine speed 800 rpm is at Table 1. Result shown the higher noise level is occurring at the rear part of two stroke engine. Then, noise reduction is suggested at rear part of the engine.

Table 1. Maximum Noise Level at engine speed 800 rpm

Point	Maximum Noise Level (dB)	Point	Maximum Noise Level (dB)	Point	Maximum Noise Level (dB)	Point	Maximum Noise Level (dB)
1	77.0	11	79.9	21	79.1	31	78.2
2	77.3	12	78.6	22	78.7	32	76.7
3	76.8	13	78.4	23	78.9	33	77.3
4	78.9	14	79.1	24	78.6	34	78.4
5	80.3	15	78.4	25	77.8	35	77.0
6	77.5	16	79.3	26	79.9	36	75.1
7	78.9	17	77.7	27	77.8	37	78.3
8	79.0	18	78.8	28	77.4	38	75.9
9	77.8	19	78.3	29	77.5	39	77.3
10	77.5	20	77.0	30	80.0	40	75.3

Sound Power level two stroke engine with rear cover, cover by composite fibre and acoustic foam is 79.9 dB at point 5, 81.3 dB and 81.5 at point 7. Point 5 is located at the rear part while point 7 is located at front part of two stroke engine. Based on trend data that are plotted in graph in Figure 5, several point in hemispherical arrangement shows the decreases of sound power level. Point 5 shows the decreases from 80.3 dB for two stroke engine without cover to 79.9 dB, 77.6 dB and 73.9 dB for two stroke engine with rear cover, cover by composite fibre and acoustic foam. Other point that are shows the decreases of sound power level is point 1, 2, 8, 9, 12, 15, 16, 18, 21, 23, 24, 26, 27, 30, 31, 34, 37, and 40. All presented spectra are averages of four measurements of each cooling fan speed variations.

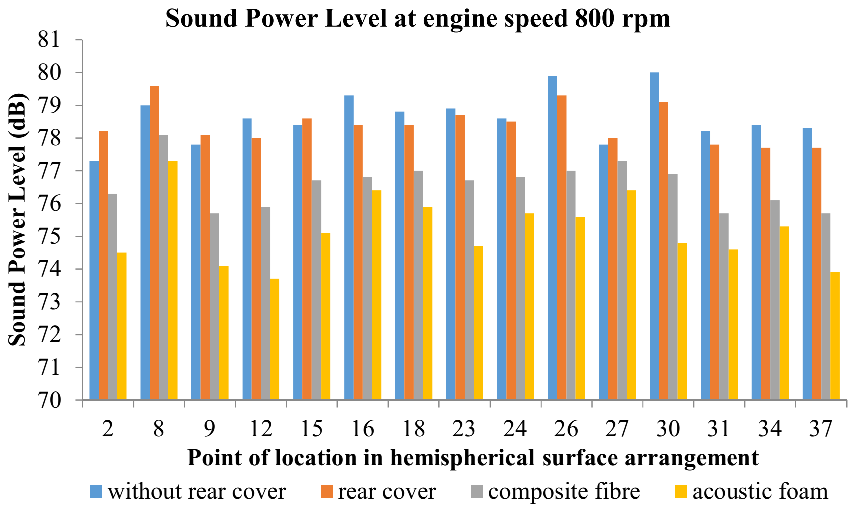

Figure 5. Graph of comparison Sound power level at engine speed 800 rpm

Then, investigations were carried out using sound intensity mapping technique for each side of two stroke engine had been made. Thus, in this section the results of the experiment are showed. In order to analyzed and interpreted the results produced by CPB analyzer that presented on the screen of a Hand-Held analyzer, sound power level also can be determined by looking at the colour of the contour graph to know the part that produces major source of noise. As shown by the colour indicator at the right side of the picture, sound power level that produced ranging from 75 dB to 116 dB. 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. The highest of sound power level produce during the test have been conducted is 93.89 dB at rear view, 99.54 dB at right view, 95.15 dB at front view and 95.75 dB at left view. Other sound power level ay engine speed 800 rpm is shown in Table 2. The yellow shape indicates the engine part that are produced the highest noise level while the green shape indicates the lower noise level of two stroke engine.

4.2 Engine Speed 1800 rpm

Sound power level (dB) at engine speed 1800 rpm was recorded is 83.3 dB as the maximum noise level at frequency 800 Hz and located at point 25 in hemispherical arrangement. Others for maximum noise level (dB) at engine speed 1800 rpm is shows in Table 2.

Table 2. Maximum Noise Level at engine speed 1800 rpm

Point	Maximum Noise Level (dB)	Point	Maximum Noise Level (dB)	point	Maximum Noise Level (dB)	point	Maximum Noise Level (dB)
1	77.3	11	79.0	21	77.6	31	77.8
2	78.2	12	78.0	22	79.1	32	77.2
3	77.5	13	78.4	23	78.7	33	78.4
4	79.2	14	79.3	24	78.5	34	77.7
5	79.9	15	78.6	25	78.1	35	77.6
6	78.6	16	78.4	26	79.3	36	78.1
7	79.5	17	78.0	27	78.0	37	77.7
8	79.6	18	78.4	28	77.6	38	76.8
9	78.1	19	78.9	29	78.1	39	77.4
10	78.1	20	77.9	30	79.1	40	76.7

The maximum noise level (dB) for two stroke engine without rear cover is 85.1 dB at point 1 in hemispherical surface while for two stroke engine with rear cover, cover by composite fibre and acoustic foam is 83.3 dB, 84.1 dB and 84.9 dB at point 25. Point 1 is located at the right part while point 25 is located at front part of two stroke engine. Based on trend data that are plotted in graph in Figure 6, several point in hemispherical arrangement shows the decreases of sound power level. Point 37 shows the decreases from 81.6 dB for two stroke engine without cover to 81.2 dB, 80.7 dB and 79.4 dB for two stroke engine with rear cover, cover by composite fibre and acoustic foam. Other points that are shows the decreases of sound power level is point 1, 2, 8, 9, 12, 15, 16, 18, 21, 23, 24, 26, 27, 30, 31, 34, 37, and 40.

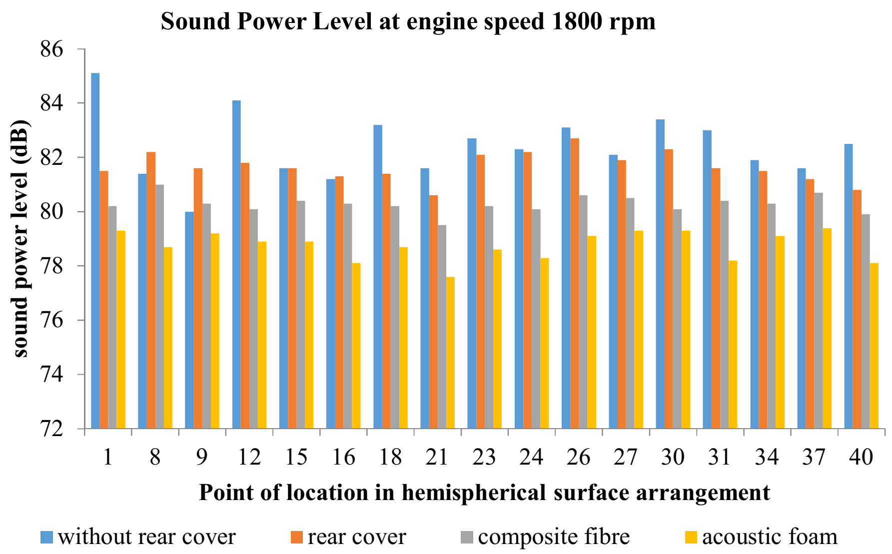

Figure 6. Graph of comparison Sound power level at engine speed 1800 rpm

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4.3 Engine Speed 3600 rpm

The maximum noise level at engine speed 3600 rpm is 87.2 dB at frequency 100 Hz and located at point 4 and 7. Table 3 shows the other maximum noise level at engine speed 3600 rpm.

Table 3. Maximum Noise Level at engine speed 3600 rpm

Point	Maximum Noise Level (dB)	Point	Maximum Noise Level (dB)	point	Maximum Noise Level (dB)	point	Maximum Noise Level (dB)
1	78.1	11	77.1	21	76.1	31	75.7
2	76.3	12	75.9	22	79.9	32	77.9
3	79.5	13	78.8	23	76.7	33	80.1
4	80.3	14	80.4	24	76.8	34	76.1
5	77.6	15	76.7	25	79.3	35	78.9
6	79.9	16	76.8	26	77.0	36	79.2
7	81.3	17	79.7	27	77.3	37	75.7
8	78.1	18	77.0	28	77.9	38	78.8
9	75.7	19	81.2	29	79.2	39	78.7
10	79.3	20	79.3	30	76.9	40	76.9

The maximum noise level (dB) for two stroke engine without rear cover is 86.9 dB at point 11 in hemispherical surface while for two stroke engine with rear cover, cover by composite fibre and acoustic foam is 86.4 dB at point 11, 87.2 dB at point 4 and 7 and 87.5 dB at point 7. Point 4, 7, and 11 is located at the right and front part of two stroke engine. Based on trend data that are plotted in graph in Figure 7, several point in hemispherical arrangement shows the decreases of sound power level. Point 12 shows the decreases from 86.9 dB for two stroke engine without cover to 84.4 dB, 82.5 dB and 81.7 dB for two stroke engine with rear cover, cover by composite fibre and acoustic foam. Other points that are show the decreases of sound power level is point 1, 2, 8, 9, 12, 15, 16, 18, 21, 23, 24, 26, 27, 30, 31, 34, 37, and 40.

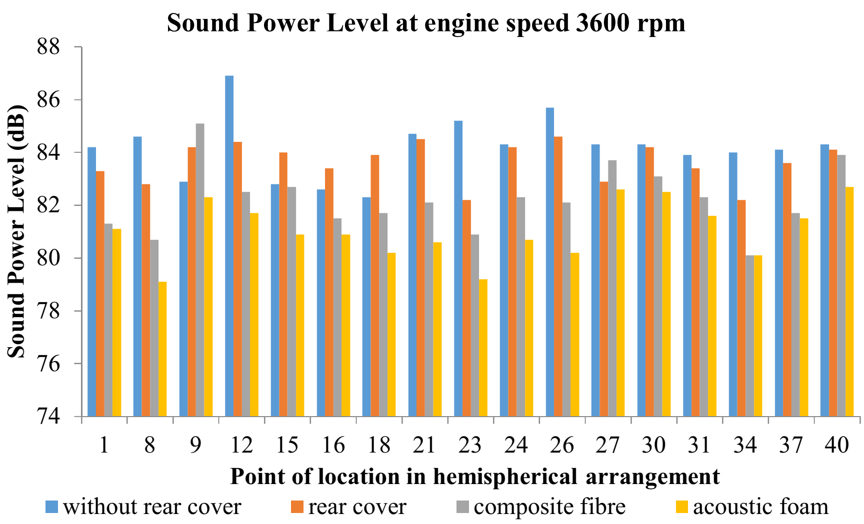

Figure 7. Graph of comparison Sound power level at engine speed 3600 rpm

4.4 Engine Speed 4800 rpm

The maximum noise level at engine speed 4800 rpm is 93.3 dB at frequency 125 Hz and located at point 14. The other maximum noise level and graph of sound power level at engine speed 4800 rpm as shown in Table 4.

Table 4. Maximum Noise Level at engine speed 4800 rpm

Point	Maximum Noise Level (dB)	Point	Maximum Noise Level (dB)	Point	Maximum Noise Level (dB)	Point	Maximum Noise Level (dB)
1	78.0	11	78.1	21	76.3	31	74.6
2	74.5	12	73.7	22	79.3	32	78.2
3	79.9	13	79.2	23	74.7	33	81.0
4	80.5	14	80.3	24	75.7	34	75.3
5	73.9	15	75.1	25	79.8	35	79.6
6	81.4	16	76.4	26	75.6	36	78.7
7	81.5	17	79.5	27	76.4	37	73.9
8	77.3	18	75.9	28	77.1	38	79.7
9	74.1	19	80.7	29	79.4	39	79.8
10	80.1	20	79.7	30	74.8	40	76.6

The maximum noise level (dB) for two stroke engine without rear cover is 92.9 dB at point 5 and 26 in hemispherical surface while for two stroke engine with rear cover, cover by composite fibre and acoustic foam is 92.5 dB at point 1, 92.7 dB at point 22, 32, and 38 and 93.3 dB at point 14. Point 5 is located at the rear part while point 1, 22, 32, and 38 is located at right and front part of two stroke engine. Based on trend data that are plotted in graph in Figure 8, several point in hemispherical arrangement shows the decreases of sound power level. Point 21 shows the decreases from 90.9 dB for two stroke engine without cover to 89.6 dB, 88.1 dB and 87.7 dB for two stroke engine with rear cover, cover by composite fibre and acoustic foam. Other points that are show the decreases of sound power level is at point 1, 2, 8, 9, 12, 15, 16, 18, 21, 23, 24, 26, 27, 30, 31, 34, 37, and 40.

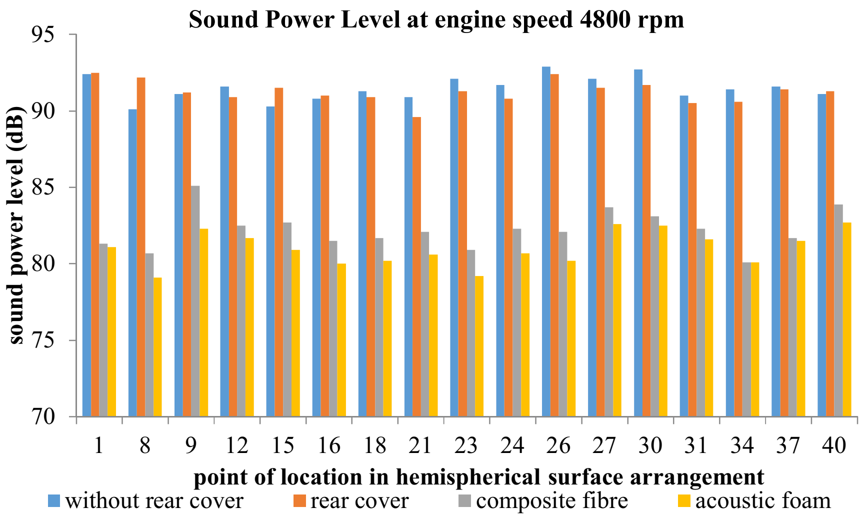

Figure 8. Graph of comparison Sound power level at engine speed 4800 rpm

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5. Conclusion
Sound intensity mapping is an effective technique to investigate the maximum noise level that are produced by the two stroke engine. Data have been analysed by using hemispherical surface arrangement that are plotted 40 points in this area and sound intensity mapping that are detected noise at rear, front, right and left view of two stroke engine. Higher engine speeds contribute more noise level. Maximum sound level has increases 6 dB in every increases of engine speed. The results of different side at different engines speed present the different contribution to the engine noise. Thus, results in the sound intensity mapping shows the decreases from two stroke engine without cover 4 dB, 6dB and 7 dB at two stroke engine with rear cover, rear cover (composite fibre) and rear cover (acoustic foam).

Acknowledgments
The author would like to greatly acknowledge the support by focus group of Advanced Structural Integrity of Vibration Research (ASIVR) and Universiti Malaysia Pahang for providing all the equipment used for this project under UMP research grant scheme – RDU 130392.

References
[1] S Gustafson, R MacCreecry, B Hoover, J G Kopun and P Stelmachowicz 2014 Listening effort and perceived clarity for normal-hearing children with the use of digital noise reduction *Ear and hearing* vol 35(2) pp 1-13
[2] R B Mingsian and L Jia-Hong 2007 Source identification system based on the time-domain nearfield equivalence source imaging: Fundamental theory and implementation *Jounal Sound and Vibration* Vol 307(1-2) pp 202-225
[3] N Razak, Sani M S M, W Azmi and B Zhang 2017 Noise and vibration analysis for automotive radiator cooling fan in *IOP Conference Series: Materials Science and Engineering* p 012083
[4] Sani M S M, Zaman I, Rahman M 2015 *Journal of Advanced Research in Fluid Mechanics* vol 9 pp 28-33
[5] Sani M S M, Rahman M M, Baharom M Z and Zaman I 2015 Sound intensity mapping of an engine dynamometer *International Journal of Automotive and Mechanical Engineering* Vol 12 pp 2820-2828
[6] W J P Casas, E P Cordeiro, T C Mello and P H T Zannin 2014 Noise mapping as a tool for controlling industrial noise pollution *Journal of Scientific & Industrial Research* vol. 73 pp. 262-266
[7] J H Zhang and B Han 2005 Analysis of engine front noise using sound intensity techniques *Mechanical Systems and Signal Processing* vol.19 pp 213-221
[8] X Jian, F Zengming, W Guoqiang and W Fei 2015 Vibration and noise source identification methods for a diesel engine *Journal of Mechanical Science and Technology* vol. 29 pp 181-189
[9] ISO 3745:2003(E) Acoustics: Determination of sound power levels of noise sources using sound pressure: Precision methods for anechoic and hemi-anechoic rooms