THE UNIVERSITY OF NEWSOUTH WALES

School of Mechanical and Manufacturing Engineering

Laboratory 2 – Measurement of sound power levels by the direct and the comparison methods

MECH9325 Fundamentals of Acoustics and Noise

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1. Introduction

In this experiment, the aim is to measure the sound power levels of a noise source, which is an electric drill, that located on a hard surface in a semi-reverberant field. The procedure outlined in AS 1217.5 is to be followed in this experiment in order to conduct the sound pressure level measurements. Two methods were performed in the laboratory, which are the direct method and the comparison method respectively. Correction for reverberation effects is to be made using both the direct method and the comparison method.

2. Instrumentation

The equipment for this experiment is shown below:

1) B&K Reference Sound Source Type 4204
   This instrument is used in the comparison method. It has been located next to the drill from the beginning while the drill was operated, is switched on and octave band sound pressure level measurements are made at the same ten locations (the drill is switched off).

Figure 1. Reference Sound Source Type 4204

2) Calibrator: B&K Type 4231 Sound level calibrator

   This instrument is used for external calibration of sound level meter. After the calibration process, the calibration level should be shown as 94.0 dB re 20 μPa.

Figure 2. B&K Type 4231 Sound level calibrator

3) SLM: B&K Type 2260 Sound level meter

   The function of sound level meter is to measure the sound level around. It was calibrated through the external calibration via the calibrator.

Figure 3. Type 2260 Sound level meter

3. Methodology

As introduced before, two methods are applied in the experiment, namely the direct method and the comparison report. The experiment should follow an Australian standard named AS 1217.5-1985.

a) AS 1217.5-1985

This standard is based on ISO 3744-1981, Acoustics—Determination of Sound Power Levels of Noise Sources—Engineering Methods for Free-field Conditions Over a Reflecting Plane. This standard sets out engineering methods for measuring the sound pressure levels on a given surface which envelops the noise source under investigation. The sound power level of the source is calculated from the results of these measurements. The method may be applied in laboratory rooms which provide a free field over a reflecting plane or in field installations whose acoustical characteristics comply with the requirements of this standard. The test environment of AS 1217.5 is normally outdoors or in large rooms.

During the experiment, the locations are specified in Table B2 and Figure B1 of AS 1217.5. The radius r was set as 1m. The table and the figure of locations are presented.

Table 1. Coordinates of microphone array for pure sounds

No	$\frac{x}{r}$	$\frac{y}{r}$	$\frac{z}{r}$
1	0.16	-0.96	0.22
2	0.78	-0.60	0.20
3	0.78	0.55	0.31
4	0.16	0.90	0.41
5	-0.83	0.32	0.45
6	-0.83	-0.40	0.38
7	-0.26	-0.65	0.71
8	0.74	-0.07	0.67
9	-0.26	0.50	0.83
10	0.10	-0.10	0.99

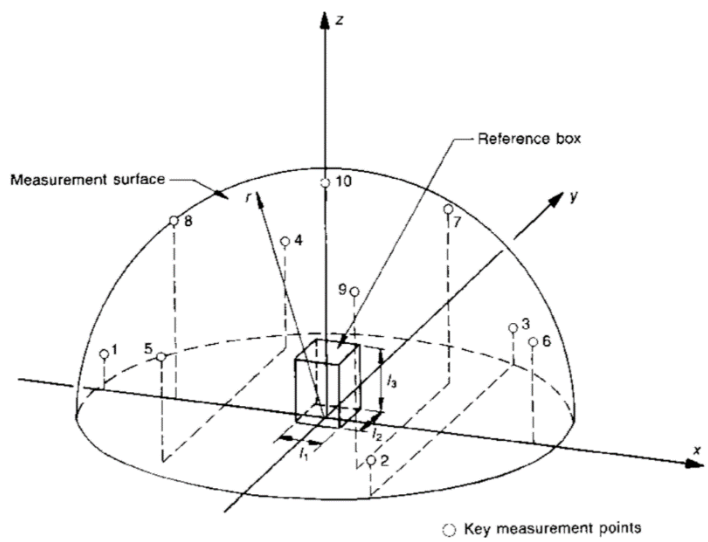

Figure 4. Hemispherical measurement surface—key measurement points

As the locations for this experiment are set up, the next step for the laboratory is calibration.

b) Calibration

The first step is using sound level calibrator to adjust the sound level meter (SLM) to make sure the calibration level at 94.0 dB. There are two approaches for calibration, one is named internal calibration and the other one is external calibration. In this experiment, the calibration method applied is the external calibration.

For external calibration, firstly, ‘external calibration’ was selected in the interface of SLM. Then, the sound level calibrator was turned on. Afterwards, the calibrator was connected to the microphone of SLM and the calibration process began. Once the calibration process started, the calibrator would be removed from the microphone and turned off. When the process was finished, the result of calibration level shown up as 94.0 dB.

c) Measurement

After calibration was done, the final step was to measure the noise levels. The noise source was generated by either the electric drill itself or the reference source. The noise source should be located in the center of the hemisphere for data measurement.

For the comparison method, firstly, the reference source was turned on to generate the noise of drill. Then, the group colleagues held SLM to make sure the microphone is aimed at the reference source at certain heights to test the sound pressure levels of the ten positions mentioned in the AS 1217.5. The angle of SLM was 45 degrees above horizon and SLM was kept far from human body to avoid disturbance. For each position, it took around 30 seconds for SLM to measure noise and generate results. At each position, the sound pressure levels of each octave band were measured.

The steps for measuring the direct drill noise was basically the same. The main difference for direct method is the sound noise will be replaced by the electric drill.

4. Results and discussion

The results of this experiment is to analyze the difference between the direct method and the comparison method. The raw data of these two methods are shown below in tabular form.

Table 2. Experiment data of the direct method

Frequency(Hz)	1	2	3	4	5	6	7	8	9	10
125	55.5	57.8	54.7	54.1	54.8	54.6	53.9	54	53.5	52
250	53.6	54.6	52.6	52.5	52	52	51.7	52.3	52	52.9
500	53.6	55.4	53.6	52.8	53.8	53.3	54.3	53.4	53.1	53.1
1000	57.2	59.5	59.3	60.5	58.8	57.9	57.3	60.5	60.5	58.8
2000	63	63.7	61.5	63.8	61	62.1	61.8	62.5	63.2	64.4
4000	63.4	62.1	61.7	67.8	64.4	61.5	61.9	61.4	61.6	60.1
8000	62.6	63	62.7	61.8	62.8	62	61	61.8	60.5	56

Table 3. Experiment data of the comparison method

Frequency(Hz)	1	2	3	4	5	6	7	8	9	10
125	59.3	60.5	61.2	60.1	59.3	59.9	57.2	58.7	57.1	54.0
250	68.4	69.4	68.9	67.7	67.9	68.2	65.7	66.0	64.3	64.8
500	73.8	75.0	74.9	72.9	72.5	73.7	71.3	72.0	71.8	73.2
1000	79.1	81.0	78.6	79.1	79.5	78.2	80.5	81.0	80.2	82.2
2000	79.4	78.7	82.0	81.9	81.6	82.3	80.3	81.0	80.2	80.1
4000	78.5	79.9	79.4	78.7	78.7	79.0	77.1	77.9	76.0	74.2
8000	73.6	74.1	74.8	73.4	73.5	73.8	71.6	72.1	69.6	66.4

The data of these two methods will be processed to derive the sound power levels of each octave band and the total sound power level for comparison.

4.1 Results of the direct method

The average measured surface sound pressure level $\overline{L_{pm}}$ can be determined for each octave band. As the data is unweighted, the measured sound pressure level should be A-weighted first. The environment correction factor K must then be subtracted from $\overline{L_{pm}}$ to correct for the fact that the space is not a true free field but is reverberant. To determine K, the octave band reverberation time T_{60} should be measured in each octave band. The equivalent sound absorption area A can be calculated using the equation in AS 1045, which is $A = \frac{55.3V}{cT_{60}}$, where c=331+0.6×22=344.2 m/s. The factor K is then given by $K = 10log_{10}(1 + \frac{4}{A/S})$ where S is the area of the enclosing hemispherical surface, which is given as 6.28 m^2. Then, the corrected, free field average surface sound pressure level $\overline{L_{pf}}$ is obtained by subtracting K from the average measured surface sound pressure level $\overline{L_{pm}}$. The sound power level is then given by $L_w = \overline{L_{pf}} + 10log_{10}(\frac{S}{S_0})$ where S_0=1 m^2. The measurements are to be made in each octave band. The results are shown in table 4.

Table 4. Sound power level with the direct method

Frequency (Hz)	T_{60} (s)	A	K	$\overline{L_{pm}}$ dB(A)	$\overline{L_{pf}}$ dB(A)	L_W dB(A)
125	1.2	114.87	0.86	38.64	37.78	45.76
250	2.96	46.57	1.87	44.11	42.23	50.21
500	2.4	57.44	1.58	50.50	48.93	56.91
1000	2.81	49.06	1.80	59.19	57.40	65.38
2000	2.53	54.49	1.65	64.03	62.38	70.36
4000	1.89	72.94	1.29	64.20	62.91	70.89
8000	0.96	143.59	0.70	60.65	59.95	67.93

The total sound power level is calculated by the equation $L_{Wtotal} = \overline{L_{pftotal}} + 10log_{10}(\frac{S}{S_0})$, where $\overline{L_{pftotal}} = 10log_{10}(10^{\frac{N1}{10}} + 10^{\frac{N2}{10}} + \cdots + 10^{\frac{N7}{10}})$.

Thus, $\overline{L_{pftotal}} = 67.26\ dB(A)$, $L_{Wtotal} = 75.24\ dB(A)$.

4.2 Results of the comparison method

The data of the comparison method is used to calculate the sound pressure levels for each octave band. The collected data were already A-weighted. The calculated average measured surface sound pressure level is used to determine the uncorrected sound power level of the reference source $L_{Wr(unweighted)}$ by the equation $L_{Wr(unweighted)} = L_p + 10log_{10}\left(\frac{S}{S_0}\right) - 10log_{10}(\frac{\rho c}{400})$ where ρ= 1.29 kg/m^3. Then the correction factor K is given by K=$L_{Wr(uncorrected)}$-L_{Wr}. The results are presented below.

Table 5. Sound Power level with the comparison method

Frequency (Hz)	L_p	$L_{Wr(unweighted)}$ dB(A)	L_{Wr} dB(A)	K	$\overline{L_{pm}}$ dB(A)	$\overline{L_{pf}}$ dB(A)	L_W dB(A)
125	59.12	66.65	64.4	2.25	38.64	36.39	44.37
250	67.44	74.97	73.8	1.17	44.11	42.94	50.92
500	73.28	80.80	79.4	1.40	50.50	49.10	57.08
1000	80.11	87.63	87.1	0.53	59.19	58.66	66.64
2000	80.90	88.42	88.1	0.32	64.03	63.71	71.69
4000	78.21	85.74	85.1	0.64	64.20	63.56	71.54
8000	72.82	80.34	79.6	0.74	60.65	59.91	67.89

As mentioned in direct method part, after calculation, $\overline{L_{pftotal}} = 68.09\ dB(A)$, $L_{Wtotal} = 76.07\ dB(A)$.

4.3. Comparison between the direct and comparison method

The results for the two methods are both accurate. The results between these two methods show that the sound power levels of the comparison method are higher than those of direct method, apart from the two octave bands 125Hz and 8000Hz. The total sound power level of the comparison method is also higher. The reason for this is due to the values of K in different octave bands. The environment correction factor K of the comparison method shows an inverse relationship compared with the sound power levels. The values of K increase to a maximum value and then decrease in the direct method, while in the comparison method the values decrease to a minimum value and then increase. The possible reason is that the different sound sources in the two methods have effects to the measurement of the sound pressure levels, which results in the different results of the calculated sound power levels.

5. Conclusion

This experiment is aimed to compare the difference of two different methods, namely the direct method and the comparison method, based on sound power levels. The procedure depends on the Australian Standard AS 1217.5. In the results part, the raw data and the calculated sound power levels are presented in order to analyze the difference between the two methods. The two methods are basically accurate while some difference exists on the correction process. The environmental correction factor K contributes to the variation of the sound power levels.