The difference between several methods of sound power level for determining the sound energy emitted by a sound source

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Abstract. It is needed noise control by limiting the sound energy emitted by the source. The total sound energy emitted by a sound source in all directions per unit time is called sound power. There are several methods for measuring the sound power level emitted by a sound source. This study is comparing the sound power levels of a reference source Brüel&Kjær Type 4204 using sound pressure done in anechoic rooms and hemi-anechoic rooms method (ISO 3745), using reverberation test rooms method (ISO 3741), and using the sound intensity method (ISO 9614-3). This study result that there is a small difference between those methods.

1. Introduction

Along with the rapid development of technology today, it also increases air pollution, one of them is noise. This is certainly very disturbing of daily human activities. Therefore it noise control is needed by limiting the sound energy emitted by the source. The total sound energy emitted by a sound source in all directions per unit time is called the sound power level.

The power radiated by a sound source can generate sound pressure. Too high sound pressure emitted by a sound source may result in hearing damage. Sound pressure is the most common quantity to identify human response to sound, for instance, noise annoyance or the risk of hearing loss. The sound pressure is dependent on the distance between the sound source and sound receivers such as ears and microphones. For that reason, to quantify the noise radiated by the machines, measuring the sound pressure is not an effective way.

So by measuring sound pressure, we cannot necessarily quantify how much noise a machine makes. We have to find the sound power because this quantity is more or less independent of the environment and is the unique quantitative descriptor of the acoustic output of a sound source in its operational environment [1].

There are several methods for determining the sound power level of a sound source. That is using a sound pressure level with the precision grade, engineering-grade, and survey-grade [2]. Another method
is using sound intensity level with a discrete technic and scanning technic. The basic idea is that sound power is independent of the surrounding [3]. There are three primary considerations when choosing the right sound power measurement technique for the environment application (free field, reverberant and in-situ), accuracy (precision, engineering, and survey) and also cost (equipment, facilities, and human resources)[4]. This study wants to find the difference between three measurement methods, consisting of two sound pressure level methods with precision grade and a sound intensity scanning method to help the decision.

Measurement using different instruments with different methods have the possibility to produce different results. Determination of the method used in determining the sound power level of the object under test depends on several things, including the dimensions of the object and the availability of facilities and measurement instrumentation. For this reason, it is necessary to study the characteristics of the measurement results using several different methods, in this case, using the methods mentioned above for the same test object, namely sound source reference. The results are expected to be a benchmarking in determining the method of measuring the sound power level of an object being tested.

2. Research Method

This study was conducted with three different methods, firstly is sound power level measurement with sound intensity method, secondly is sound power level determination with the precision method in Hemi anechoic room according to standard ISO 3745, and the thirdly is sound power level measurement using the precision method in reverberation test room based on standard ISO 3741. The object being measured is the reference sound source made by Bruel&Kjaer Type 4204. It is the standardized sound source with a value of 92 dB re 1 pW that were used by the acoustical society concerning its stability and wide range of frequency bands (starting from 100 Hz to 10 kHz); also it can be operated on a wide range of voltage and electrical frequencies [5]. This sound source was measured and analyzed to obtain the value of sound power stated in dB re 1 pW and the result from each method then being compared.

Figure 1. Sound power level measurement in hemi-anechoic room
Sound power level measurement with sound intensity method performed by P3KLL according to standard ISO 9614-2:1996 [6] using the Bruel&Kjaer 2270 portable sound intensity analyzer. While the precision method for determination sound power level using sound pressure was conducted in hemi-anechoic room. This hemi-anechoic camber is located in BBTA3-BPPT, which dimension of the test section is 5.2 m (l) x 5.0 m (w) x 3.0 m (h) with the background noise 18 dB and a cut-off frequency of 100 Hz (Figure 1). The sound pressure level at 20 positions in the hemisphere surface has been collected using B&K 4189 1/2” free-field microphone. The signal from the microphone then introduced into a computer by the B&K Pulse analyzer.

The third method used in this study is sound power level measurement using a precision method in the reverberation test room based on standard ISO 3741. This method was conducted in the reverberation room belong to BSN, which has the dimension of the test room is 7.78 m (l) x 5.98 m (w) x 4.76 m (h). with the reverberation time 15.7 second on 5000 Hz and a cut-off frequency of 63 Hz (Figure 5). The sound pressure level is the parameter that was collected for this method.

2.1 Sound power determination using sound intensity method

Sound power level using sound intensity method is an excellent way for measuring sound source that has a significant dimension and placed outdoor. The measurement needs a sound intensity analyzer that capable of measuring the sound intensity level of one-third octave band frequency. One that we must pay attention to is that the measurement values are sensitive to the directivity pattern from the sound source [7].

The reference sound source is transformed to an imaginary surface with a box-like measurement surfaces consist of five surfaces (top, left, right, front, and behind). Each of the measurement surfaces is then scanned using a sound intensity probe equipped with a 12 mm microphone spacer done with scanning technique (Figure 2).

The measurement consists of two steps scanning direction. The first step is to scan the measurement surface from up and down and from left to right. The second step is to scan from side to side and from top to the bottom measurement surface (Figure 3).
2.2 Sound power determination using a hemi-anechoic room

Sound power level determination in the hemi-anechoic room is identified from the averaged sound pressure level on the hemisphere surface with segments having equal areas. The sound power level ($L_W$) in each frequency band of interest shall be calculated using the equation below [9]:

$$L_W = \overline{L_p} + 10 \log \left( \frac{S_1}{S_0} \right) dB$$

Where $\overline{L_p}$ is surface time-averaged sound pressure level for the noise source under-tested (dB), $S_1$ is the area of the spherical measurement surface (m$^2$) and $S_0 = 1m^2$.

Microphone positions refer to the ISO 3745:2012 standard. Based on this standard, the sound pressure level is collected at the 20-points of the microphone position in the measurement surface (hemisphere), as shown in figure 4.

2.3 Sound power determination using reverberation room

Reverberation rooms are mainly designed to produce a reverberant sound field by making the walls and the boundaries as highly reflective as possible. The idea with such a room is to have controlled acoustical measurements; that is why it is typically used for sound power determination of noise sources [10].
3. Results and discussions

All sound power level data obtained from this research covering three facilities, three different methods, one reference sound source, recorded at 21 different frequencies starts from 100 Hz up to 10000 Hz are presented in Figure 6.

Based on the mean separation test employing paired t-test as shown in the analysis of variance table (Table 1), it can be concluded that there is no significant difference statistically between the three institutions in which testing using three different methods.

|     | t stat | t tabel | p value |
|-----|--------|---------|---------|
| BSN – P3KLL | 0.8482  | 1.6838  | 0.2007  |
| BBTA3 – P3KLL | 0.1235  | 1.6838  | 0.4512  |
| BSN – BBTA3  | -0.5496 | 1.6838  | 0.2928  |

Figure 5. Sound power level measurement in the reverberation room

Figure 6. Sound power level in each frequency (Lwf)
The overall sound power level values are shown in Table 2.

|        | P3KLL | BSN | BBTA3 |
|--------|-------|-----|-------|
| (dB re 1 pW) |   89  |   91 |    90 |

It is interesting to note that there is no significant statistical difference between the three measurements result. In which the p-value for the sound power test value from the three laboratories that conducted the test and compared with the Lw value from the factory using student t was 0.96291, which is greater than the significant alpha value of 0.05 indicating there was no significant difference between the test results of the three laboratories. It can be seen from the graph in Figure 6 that for all methods from the 400 Hz frequency relatively the same, but for the 100 Hz to 315 Hz frequencies, the intensity method is different from the others while the methods in the reverberation room and the hemi-anechoic room are relatively the same for all frequencies.

4. Conclusions
The statistical data analysis stated that the sound power output in the frequency basis from the measurements results are not significantly different. It can happen because of the same grade accuracy; that is precision grade. One thing to notice is that sound power level measurement using sound intensity gives higher values at the lower frequency below 315 Hz compared to other methods, also notice that at higher frequencies, it happens on the contrary. This study also identifies that there is a small difference in overall sound power level between those methods concerning that the maximum difference between three measurement methods is only 2 dB re 1 pW from the 92 dB re 1 pW stated value. That difference is quite satisfying enough, considering large uncertainty on the acoustical measurement, and in the standard conformity, only the overall value is regulated. It must be noted that the sound power level measurement using sound intensity done in-situ is easier because large sound sources can not be measured consider of installation and operational difficulties in hemi anechoic room or reverberation room. On the other hand, the in-situ measurement can not be done in adverse environmental conditions such as heavy rain or wind. The results suggested that all of the three methods can be used in sound power level measurement with the same grade of accuracy.

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