한국소음진동공학회 2014년 춘계학술대회논문집, pp. 191~196

Noise Evaluation Considering the Uncertainty Variation According to Frequency

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Key Words : Uncertainty, Standard Deviation, Tolerance, Confidence Probability

ABSTRACT

In the evaluation of measured noise data, tolerance shall be decided based on the uncertainty. The uncertainty has frequency variations due to the different standard deviations at each frequency. Therefore, tolerance shall be differently decided for each frequency with the same confidence probability. In the report, the evaluation method considering the frequency variation of uncertainty will be introduced. From the approach, considering the actual noise distribution characteristics of the ships, the tolerance shall be decided for each frequency with the same probability, but the overall averaged value shall be kept to the value designated in each notation.

1. Introduction

Tolerance of measured noise data is determined based on the uncertainty which may exist in the measurement. The uncertainty has variations at each frequency, and the variations can be generally defined by normal distributions having different standard deviations at each frequency. Therefore, tolerance shall be differently decided for each frequency with the same confidence probability, but overall averaged values shall be kept to the value designated in each notation. In the report, the evaluation method considering the frequency variation of uncertainty will be introduced. Using the method, the noise measurement results will be newly evaluated to compare with the results applying the BV COMF[(1)] notation for example.

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2. Background guidelines for the evaluation considering the frequency variation

2.1 Guidelines, Regulations and Standards

BV COMF Notation

Ch. 1.2 – 1.2.2

These Rules take into account various International Standards, and are deemed to preserve their general principles.

Ch.2.2 – 2.2.3

Tolerance of 3 dB(A) for 18% of all cabins and tolerance of 5 dB(A) for 2% of all cabins (with a minimum of 1 cabin)

Ch. 1.3 – 1.3.1

The following standards refer to the edition in force for the noise: ISO 2923[(2)] " Acoustics – Measurements of noise on board vessels"

ISO 2923

Ch. 6

The equivalent continuous sound pressure levels in octave bands from 31.5 Hz to 8 kHz, if required.

2.2 Discussion

From the related sentences mentioned above, the following discussion can be made.

1) The BV COMF Notation does not obviously define how to estimate the tolerance by overall or each band level.

2) ISO 2923 is a normative reference in BV COMF.

3) Based on the ISO 2923, the octave band level may be used for the evaluation of measured level, if required.

3. Measurement uncertainty of room noise

Related to the measurement of room noise, all standardised room acoustic measurement methods, e.g. ISO 10052, ISO 140 series, ISO 354 and ISO 374X series, presume that the acoustic field of a room is diffuse. Ideally, the diffuse sound field presupposes that the sound enters to any point of the room evenly from all directions.

However, in a real measurement circumstance, there is a possible existence of uneven distribution of sound in acoustic field of room. The uneven distribution of sound can lead to uncertainties in noise level measurements in rooms, modes of which are mostly responsible of sound pressure level (SPL) variations within rooms. When the modes belong to the same frequency band, they have a tendency to interfere with each other and produce a more diffuse field. Moreover, the density of room modes increases as frequency becomes higher. Therefore, the higher frequency is, the smaller the variation of SPL is and the more diffuse the sound filed in a room becomes.

For example, from the report " Measurement of low frequency noise in rooms" published by the Finnish Institute of Occupational Health, the following results can be obtained.

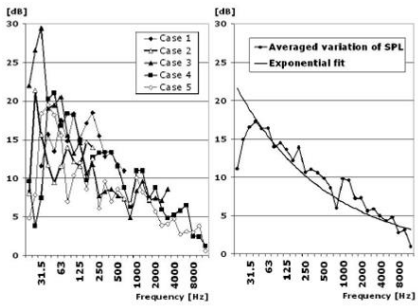

Figure 24 Left) Spatial variation of SPL measured in the five Case rooms. Right) Averaged spatial variation of SPL from the five studied Cases. An exponential curve is fitted to the averaged variation of SPL.

Table 4 Numerical form of the exponential curve fitted to the averaged spatial variation of SPL in Figure 24-right.

Frequency [Hz]	20	25	31.5	40	50	63	80	100	125	160	200	250	315	400
Theoretical variation of SPL [dB]	22	20	19	18	16	15	14	13	12	12	11	10	10	9
Frequency [Hz]	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
Theoretical variation of SPL [dB]	8	8	7	7	6	6	5	5	4	4	3	3	2	1

Fig. 1 Noise test data showing the frequency variation of measured level in small room

The results are showing the variation of noise measurement results according to frequency. As known from the results, the lower frequency is, the larger the variation of SPL is.

In summary, three discussion topics about tolerance of measured noise data can be derived in total.

Firstly, the fact that every ship has different

noise sources can lead the conclusion that dominant frequencies of measured noise in ships are different. As mentioned in the introduction, tolerance of measured noise data is determined based on the uncertainty which can exist in the measurement and the uncertainty has variations at each frequency. Thus, considering fairness, tolerance shall be differently decided for each frequency with the same confidence probability, but overall averaged values shall be kept to the value designated in each notation.

Secondly, the fact that the lower frequency is, the larger the variation of SPL is can lead the conclusion that the lower frequency is, the larger the uncertainty of SPL. Therefore, tolerance shall increase with the decrease of frequency.

Finally, uncertainty in noise measurement at each frequency is defined by normal distribution in general. Moreover, the confidence probability in normal distribution is decided by standard deviation of each frequency. Therefore, the standard deviation of each frequency shall be decided to decide the tolerance of each frequency.

4. Standard deviation in the noise measurement

In terms of standard deviation, authorised institutes define the standard deviations at each frequency as given in the following table in the noise measurement.

Table 1. In noise measurement, standard deviations in each octave band

Standards/ Freq(Hz)	ANSI 220-2012[3]	ISO 374X Series[4]	DSME
31.5	-	-	5.0
63	4.0	5.0	5.0
125	3.0	3.0	3.0
250	2.0	2.0	2.0
500	1.5	1.5	1.5
1k	-	1.5	1.5
2k	-	1.5	1.5
4k	-	1.5	1.5
8k	-	2.5	2.5

As noticed in the table, the standard deviation in 31.5 Hz band is not defined in the ANSI and ISO standards. In the case, extrapolation is generally used for 31.5 Hz band value. However, the same value as that of 63 Hz band is used to evaluate conservatively.

Using the above standard deviations, DSME calculated the tolerances in each frequency band which has the same averaged values as the BV requirements and the tolerances keep the same confidence probability in each band as given in the following table.

Table 2. Tolerance in each octave band considering the confidence probability

Confidence Probability/ Freq(Hz)	75.0%	94.4%
31.5	5.8	9.6
63	5.8	9.6
125	3.5	5.7
250	2.3	3.8
500	1.7	2.9
1k	1.7	2.9
2k	1.7	2.9
4k	1.7	2.9
8k	2.9	4.8

Averaged Tolerance	3.0 dB	5.0 dB

5. Evaluation method of room noise level considering the frequency variation of uncertainty

The uncertainty in noise measurement has the variation according to frequency. Tolerance in measured noise level is based on the uncertainty in the measurement. Therefore, the tolerance shall be evaluated considering the uncertainty variation according to frequency.

Evaluation procedure of room noise level considering the uncertainty variation given in Table 2 according to frequency was conducted as shown in the following table, where Ai denotes the noise level in i Hz band.

Table 3. Evaluation procedure of room noise level

Overall Averaged Tolerance/ Freq(Hz)	3 dBA	5 dBA
31.5	A31.5 – (5.8)	A31.5 – (9.6)
63	A63 – (5.8)	A63 – (9.6)
125	A125 – (3.5)	A125 – (5.7)
250	A250 – (2.3)	A250 – (3.8)
500	A500 – (1.7)	A500 – (2.9)
1k	A1k – (1.7)	A1k – (2.9)
2k	A2k – (1.7)	A2k – (2.9)
4k	A4k – (1.7)	A4k – (2.9)
8k	A8k – (2.9)	A8k – (4.8)
Overall	B	B
Confidential Interval	75.0 %	94.4 %

In order to evaluate room noise level considering the frequency variation of uncertainty defined in Table 3, the following steps could be used.

Step 1: the lower boundary of the measured value is calculated by considering the confidence interval in each frequency band.

Step 2: The overall value (B) is calculated by summing each frequency band value.

Step 3: The overall value (B) is compared with the limits described in the BV COMF.

6. Example of noise evaluation

In order to compare the newly proposed method with the BV COMF notation, an A-weighted " Pink noise" as given in the following table is used as an example of noise source.

Table 4. Example of Pink noise

Noise Level(dBA)/ Freq(Hz)	3 dBA
31.5	48.5
63	48.5
125	48.5
250	48.5
500	48.5
1k	48.5
2k	48.5
4k	48.5

8k	48.5
Overall	58.0

Evaluation 1

With the BV' s method, which applies even tolerance of 5 dB over all frequency bands, the overall noise level is calculated as the following table.

Table 5. Evaluated noise level with even toleracne over all frequency bands

Freq. (Hz)	Original Level(dBA)	Tolerance & Confidence	Modified Level(dBA)
31.5	48.5	-5/68%	43.5
63	48.5	-5/68%	43.5
125	48.5	-5/91%	43.5
250	48.5	-5/99%	43.5
500	48.5	-5/100%	43.5
1k	48.5	-5/100%	43.5
2k	48.5	-5/100%	43.5
4k	48.5	-5/100%	43.5
8k	48.5	-5/100%	43.5
Overall	58.0 dBA		53.0

Since evaluated overall noise level is equal to the noise level requirement, measured noise level can be said to satisfy the noise requirement. In this method, the uncertainty variation according to frequency is not considered. Therefore, tolerance in each frequency band has different confidence probabilities.

Evaluation 2

On the other hand, with the new method, where the tolerance with the same confidence probability over all frequency bands is used, the overall noise level is calculated as the following table.

Table 6. Evaluated noise level with toleracne with the same confidence probability over all frequency bands

Freq. (Hz)	Original Level(dBA)	Tolerance & Confidence	Modified Level(dBA)
31.5	48.5	-9.6/94%	38.9
63	48.5	-9.6/94%	38.9
125	48.5	-5.7/94%	42.8
250	48.5	-3.8/94%	44.7
500	48.5	-2.9/94%	45.6
1k	48.5	-2.9/94%	45.6
2k	48.5	-2.9/94%	45.6
4k	48.5	-2.9/94%	45.6
8k	48.5	-4.8/94%	43.7
Overall	58.0 dBA		53.7

In this case, the calculated noise level is 0.7 dBA larger than the noise requirement. Therefore, measured noise level is not satisfied with the noise requirement. That is, this method, which used tolerance with the same confidence probability over all frequency bands, is the most conservative method, but keeps the same confidence probability in each frequency band.

7. Conclusion

In this report, the newly evaluated method on the room noise considering the measurement uncertainty of the room has been proposed.

From this approach, the following conclusions can be made from the previous results.

Considering the actual noise distribution characteristics of the ships, the tolerance shall be decided for each frequency with the same probability, but the overall averaged value shall be kept to the value designated in each notation.

Reference

(1)Bureau Veritas, 2007, Rules for the Classification of Steel Ships, pp. 21 ~27.

(2)ISO 2923, Acoustics - Measurement of noise on board vessels

(3)ANSI 220-2012, Reverberation Room Qualification and Testing Procedure for Determining Sound Power of HVAC Equipment.

(4)ISO 3740, Acoustics — Determination of sound power levels of noise sources — Guidelines for the use of basic standards