

The Variance of Measurement of Sound Absorption of Material in the Underwater Reverberation Chamber

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Abstract. Random-incidence sound absorption coefficient of underwater acoustics materials can be measured by the method of reverberation chamber. Method of reverberation chamber used in underwater acoustics area is analog to national standard (GBJ 47~83) about “Measurement of sound absorption in a reverberation room” in air acoustics area. The ensemble variance has a great impact to the accuracy of sound absorption coefficient of underwater acoustics material. The accuracy of sound absorption coefficient can be guaranteed by reducing the ensemble variance in the measurement of reverberation time. Ensemble variance is influenced by the uniformity of the sound field, the excitation mode of source and the variation of volume、 temperature and air bubble of water. The maximum value of ensemble variance approaches 10%. The value of ensemble variance can reduce to 3% by some effective methods. Results of this research are helpful to reduce the errors in the measurement of sound absorption coefficient of under water acoustic material.

Keywords: sound absorption coefficient ; reverberation chamber ; reverberation time ; ensemble variance

Nomenclature

A_T	the equivalent sound absorption area of the test material
V	the volume of underwater reverberation chamber
c	the sound speed in water, which is 1450m/s
T_1	the reverberation time in underwater reverberation chamber without test material
T_2	the reverberation time in underwater reverberation chamber with test material
\mathcal{E}_{nk}	the standard deviation value of m times measured reverberation time of k 1/3 OCT in n decay curve.
\bar{T}_{nk}	the average value of m times measured reverberation time of k 1/3 OCT in n decay curve.
T_{mnk}	the reverberation time of m times measured reverberation time of k 1/3 OCT in n decay curve.

1. Introduction

There are many experimental methods for measuring the sound absorption coefficient of underwater acoustic material, such as wave pipe method and reflection method [1][2]. Only vertical-incidence or orientating-incidence sound absorption coefficient can be measured by those above methods. But the under water materials are not used individually, which are used in some forms of structure in practice. Then the limitation of vertical-incidence or orientating-incidence sound absorption coefficient is great. The random-incidence sound absorption coefficient of underwater acoustics materials can be measured by underwater

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reverberation chamber, which is analog to national standard (GBJ 47-83) about “Measurement of sound absorption in a reverberation room” in air acoustics area [3][4][5][6]. The equation is shown in the following:

$$A_T = 55.3 \frac{V}{c} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \quad (1)$$

Where: A_T is the equivalent sound absorption area of the test material. V is the volume of underwater reverberation chamber. c is the sound speed in water, which is 1450m/s. T_1 is the reverberation time in underwater reverberation chamber without test material. T_2 is the reverberation time in underwater reverberation chamber with test material.

According to the different property between water medium and air medium, there are lots of limitations to the application of reverberant method. The most important limitation is the ensemble variance of reverberation time in the measurement of sound absorption of material. The accuracy of sound absorption coefficient is decided by the precision of reverberation time measurement, which is shown in equation (1). Reduction of ensemble variance in measurement of reverberation time is important to guarantee the accuracy of sound absorption coefficient of material.

There are lots of documents and codes about the ensemble variance in the air acoustics fields [3][7][8]. The results of such documents are only adopted for air medium in the rectangle reverberation rooms. There are great differences between the underwater acoustics and air acoustics in sound speed、boundary condition and sound source exciting mode. In this paper, we studied the problem of ensemble variance in measurement of reverberation time in underwater reverberation chamber. Fundamentals、resolving method and measurement of such variance are also discussed and made in this paper.

2. Ensemble Variance and Analysis

The definition of ensemble variance in the measurement of reverberation time is that: The ratio of standard deviation values of measured reverberation time to the average value of measured reverberation time. That is:

$$\mu_{nk} = \varepsilon_{nk} / \bar{T}_{nk} \quad (2)$$

Where, ε_{nk} is the standard deviation value of m times measured reverberation time of k 1/3 OCT in n decay curve. \bar{T}_{nk} is the average value of m times measured reverberation time of k 1/3 OCT in n decay curve. ε_{nk} and \bar{T}_{nk} can be expressed in the following formulas:

$$\varepsilon_{nk} = \left[(N-1)^{-1} \sum_1^N (T_{mnk} - \bar{T}_{nk})^2 \right]^{1/2} \quad (3)$$

$$\bar{T}_{nk} = \frac{1}{N} \sum_1^N T_{mnk} \quad (4)$$

Where T_{mnk} is the reverberation time of m times measured reverberation time of k 1/3 OCT in n decay curve. The reason of ensemble variance can be expressed in three areas: (1) Numbers of normal mode in per unit bandwidth in the under water reverberation chamber; (2) Exciting mode of the sound source ;(3) Variance of water volume and bubbles in the measurement of reverberation time.

Firstly, when the amounts of normal mode is small in per unit bandwidth, the normal mode can not be excited by the random white noise stably; When the signal was cutting off, the exciting statuses of every mode are not the same in every measurement test, then the ensemble variance will increased. If there are enough numbers of normal modes in per unit bandwidth, the ensemble variance mentioned above can be decreased greatly.

Secondly, the variance caused by exciting degree by sound source has nothing to do with the numbers of normal mode in per unit bandwidth. Random white noise excites the normal mode randomly, ensuring the same exciting degree is very difficult. The same exciting degree can be ensured by the advanced equipment

function. The RECORDER function in the PULSE analyzer can be used to record the same exciting degree signal, which can ensure the same exciting degree in every measurement.

Thirdly, the ensemble variance can be affected by other factors. There are great differences in measurement of reverberation time between air acoustics and underwater acoustics. The variances of absorption caused by volume and bubbles are great because of the high frequency of signal used in the measurement, and then the ensemble variance will be increased by this reason. This kind of ensemble variance can be decreased by accuracy control in the measurement. The volume of water must be ensured by the volume of water in reverberation chamber and by the accuracy control of the depth of water; The bubbles contained in the water can be removed by standing for several days; The temperature of water can be held in the same degree by the air conditioning system; Measuring scale should be used to ensure the precision of position of every measurement point.

3. Measurement and Result Analysis

The measurement was made in the underwater reverberation chamber, which dimension is 12m×5m×4 m, which is shown in Fig1.

Measurements of reverberation time were made in two kinds of statuses. One is the reverberation time in underwater reverberation chamber without test material. The other is the reverberation time in underwater reverberation chamber with test material. PULSE analyzer was used to record the same exciting degree signal, which can ensure the same exciting degree in every measurement; the signal was amplified by the amplifier (B&K2713) and was sent to the energy converter. There were two kinds of energy converter adopted in the measurement. One was a sphere energy converter and the other was a cylinder energy converter; the sound pressure decay was measured by a hydrophone (B&K8104); the received signal was amplified and then was sent to PULSE analyzer. The reverberation time was measured in 1/3OCT by relevant module in PULSE analyzer. The block diagram was illustrated in Fig2.

100 group data were measured when the test material in central position of reverberation chamber, namely $N = 100$ in formulas (3) ~ (4).

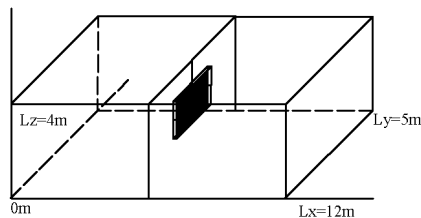


Fig.1.Perspective drawing of the under water reverberation chamber

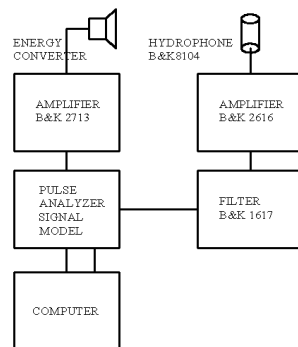


Fig.2Schematic diagram of measurement system

3.1. Influence of the distribution of sound field.

The sphere and cylinder converter are adopted in the measurement. The level of ensemble variance affected by different kinds of converter is less than 1%. The ensemble variance is great in the band width

lower than 40 kHz, approaching to 10%. The reason is that there are less normal modes in per unit band width in stable status and every normal mode can not be sufficient excited by the random white signal. When the signal is cut off, the randomness can not be erased. The average effect of normal mode can decrease the ensemble variance with the numbers of normal mode increased in per unit bandwidth.

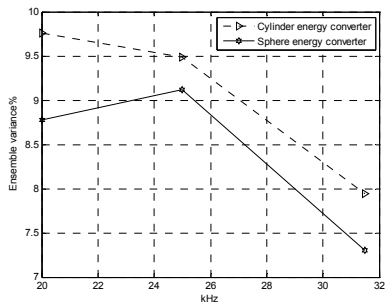


Fig.3 Ensemble variance of reverberation time influenced by two kinds of energy conversion device in 20 kHz~31.5 kHz

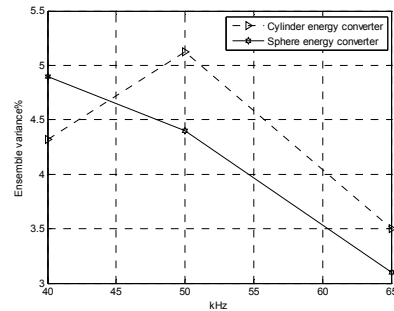


Fig.4 Ensemble variance of reverberation time influenced by two kinds of energy conversion device in 40 kHz~65

3.2. Influence of the Sound Source Excitation

Random white noise and reordered white noise by PULSE are used alternatively in the excitation in underwater reverberation chamber. The ensemble variance of reverberation time is illustrated in Fig.5. This kind of ensemble variance is not only related to the distribution of the sound field but also related to the excited degree of sound source. If the sound source can be excited at the same degree, the ensemble variance could be decreased by this way. The ensemble variance can be reduced by guaranteeing the same excitation of the sound source. The ensemble variance can be reduced to 3% by the function of “RECORDER” in PULSE analyzer.

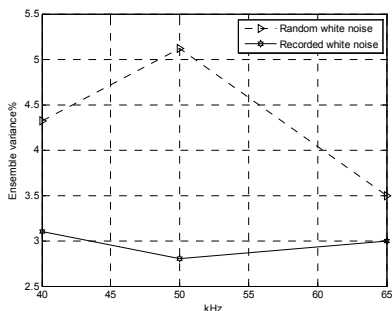


Fig.5 Ensemble variance of reverberation time influenced by different the excitation mode of source.

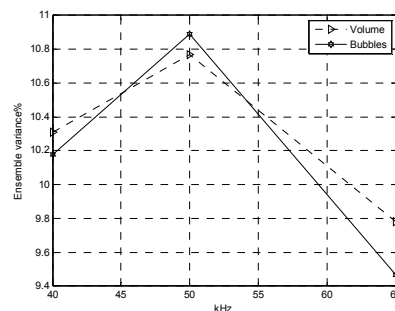


Fig.6. Ensemble variance of reverberation time influenced by the variation of volume, air bubble and temperature of sea water.

3.3. Other Influence Factors

The measurement of reverberation time should be made in two status of underwater reverberation chamber (with material and without material), then some other factors which affected the accuracy of reverberation time should be considered. The influence of other factors could be measured, when the ensemble variance created by sound source excitation and by the distribution of the sound field is excluded by those above mentioned methods. The volume of water and the quantity of bubbles in the water are individually changed some levels and the ensemble variance of reverberation time are measured, which is shown in Fig.6. The influences of quantity of bubbles are great comparison to those of volume. The influence level by those factors amounts to 10%, which should be paid more attention in the measurement and should be decreased by accurate control in the measurement.

4. Conclusion

This work has shown that:(1) Ensemble variance will be small when there are enough normal modes in per unit band width;(2) Ensemble variance caused by exciting grade of sound source can be reduced by

recording the same signal of white noise;(3) Ensemble variance caused by water volume and bubbles in the water is greater and such ensemble variance should be paid much more attentions in the measurement.

5. References

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