GB

GUIDANCE TECHNICAL DOCUMENT FOR

STANDARDIZATION OF THE PEOPLE'S REPUBLIC OF CHINA

ICS 17.140.01

A 59

GB/Z 27764-2011

Acoustics - Determination of sound transmission loss in impedance tubes - Transfer matrix method

声学 阻抗管中传声损失的测量 传递矩阵法

Issued on: December 30, 2011 **Implemented on: May 01, 2012**

Issued by: State Administration for Market Regulation;

Standardization Administration of PRC.

Table of Contents

Acoustics - Determination of sound transmission loss in impedance tubes - Transfer matrix method

1 Scope

This guiding technical document stipulates the measurement of normal incidence sound insulation (or normal incidence sound transmission loss) of acoustic materials or acoustic structures, in impedance tubes, by using the transfer matrix method.

This guiding technical document is applicable to the measurement of the normal incidence sound insulation of locally reactive acoustic materials, such as sponges, cotton felts, soft thin plates, whose test frequency is in the quality control area (that is, there is no sound propagation parallel to the material inside the material). It is applicable to the comparison of sound insulation performance of acoustic materials, in the development stage. Since the sound transmission loss of a material is closely related to its physical properties (such as elastic modulus, density, structure factor, etc.), the measurement methods specified in this guiding technical document can be applied to relevant basic research and product development.

This guiding technical document is not applicable to the identification test of the sound insulation performance of the product.

This guiding technical document uses an impedance tube, one or more microphones, and a digital acquisition & analysis system.

2 Normative references

The following documents are essential to the application of this document. For the dated documents, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) is applicable to this standard.

GB/T 3947-1996 Acoustical terminology

GB/T 18696.2-2002 Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes - Part 2: Transfer function method

3 Terms and definitions

The following terms and definitions apply to this document.

3.1

Normal incidence [sound] pressure transmission coefficient

τ_p

The ratio -- of the sound pressure transmitted through a material or structure TO the incident sound pressure, when the sound wave is incident on the normal direction.

Note: Rewrite GB/T 3947-1996, Terms and Definitions 12.37.

3.2

Normal incidence [sound] transmission loss

TL

The difference -- between the incident sound power level on one side of the material and the transmitted sound power level on the other side -- when the sound wave is incident on the normal direction. The sound transmission loss is equal to the reciprocal of the square of the sound pressure transmission coefficient, taking the logarithm to the base 10, in the unit of Bell [B]. However, it is usually measured in decibels (dB).

Note: Rewrite GB/T 3947-1996, Terms and Definitions 12.26.

3.3

The first reference plane

The cross-section of the impedance tube, which is used to measure the sound pressure transmission coefficient. If the surface of the test piece is flat, usually take the front surface of the sample as the first reference plane.

Note: Rewrite GB/T 18696.2-2002, Terms and Definitions 3.3.

3.4

The second reference plane

The cross-section of the impedance tube, which is used to measure the sound pressure transmission coefficient. If the surface of the test piece is flat and the thickness of the sample is t, the second reference plane is usually taken at x = t.

Note: Rewrite GB/T 18696.2-2002, Terms and Definitions 3.3.

3.5

Wave number in the air

sequence noise or chirp. Measure the sound pressure, at two positions close to the sample in the front tube, to obtain the sound pressure transfer function of the two microphone signals. Similarly, measure the sound pressure, at two positions close to the sample in the back tube, to obtain the sound pressure transfer function of the two microphone signals. Calculate the normal incident transmission coefficient of the test piece (see Appendix B), sound transmission loss, other related acoustic quantities, by the transfer matrix method.

These quantities are all functions of frequency. Frequency resolution depends on the sampling frequency and the measurement record length of the digital acquisition and analysis system. The effective frequency range is related to the lateral dimension or diameter of the impedance tube, as well as the spacing between the two microphones. With different sizes or combinations of diameter and spacing, a wide range of measuring frequencies can be obtained.

Measurements can be made in one of two ways:

a) Four-microphone method (measured by four microphones at a fixed position);

b) Single-microphone method (measured by one microphone at four positions in sequence).

5 Test equipment

5.1 Structure of impedance tube

The impedance tube is divided into front tube, back tube, test piece holding tube. One end of the front tube is connected to the sound source, the other end is connected to the test piece holding tube. One end of the rear tube is connected to the test piece holding tube, the other end is a closed end with certain sound absorption performance. There are four microphone mounting holes, two for the front tube and two for the rear tube, arranged along the tube wall.

The impedance tube shall be straight; its cross-sectional area shall be uniform (the deviation of diameter or cross-sectional size is within ±0.2%); the wall of the tube shall be smooth, rigid, dense enough, so that it will not be excited by the acoustic signal. There is no resonance in the working frequency band of the impedance tube. For round metal tubes, it is recommended that the wall thickness be taken as about 5% of the tube diameter. For rectangular tubes, the four corners must have sufficient rigidity, to prevent deformation of the side plates. It is recommended that the plate thickness be taken as 10% of the cross-sectional size of the impedance tube. The tube wall, which is made of cement, can be painted with a well-mixed adhesive, to ensure airtightness. The same measures shall be taken for tube walls, which are made of wood. Cement tube walls and wooden tube walls shall also be covered with iron or lead, to increase strength and damping.

if the requirements of formula (4) are met, the distance between the microphones shall be greater than 5% of the corresponding wavelength of the test low frequency. Increasing the distance between the microphones can improve the measurement accuracy.

If it wants to expand the test frequency band, it can use a combination of microphones with different spacing to achieve it. Note that there needs to be a frequency overlap, at the connection of each frequency band.

5.3 Impedance tube length

The impedance tube shall be long enough, to generate a plane wave between the sound source and the test piece.

In addition to plane waves, loudspeakers generally produce non-plane wave modes. For those non-plane wave modes, which have frequencies below the cutoff frequency, they will attenuate within a distance of about three tube diameters (for round tubes) or three times the length of the long side (for rectangular tubes). Therefore, it is recommended that the distance between the microphone and the sound source shall not be closer than the above-mentioned distance. In any case, it is better not to be less than one tube diameter or one long side length.

Test pieces can also cause distortion of the sound field. According to the type of sample, the recommended minimum distance between the microphone and the sample is:

Flat surface of uniform material: 1/2 of the diameter of the tube or 1/2 of the length of the long side;

Flat surface of non-uniform structure: 1 times the tube diameter or 1 times the length of the long side;

Asymmetrical or rough surfaces: 2 times the tube diameter or 2 times the length of the long side.

5.4 Test piece holding tube

The test piece holding tube can be independent and detachable, OR it can be integrated with the front tube and the rear tube, OR it can be composed of inner and outer tubes.

5.4.1 Integral test piece holding tube

For the impedance tube made as a whole, it is recommended to make the upper part of the tube, where the test piece is placed, as a movable cover. The contact surface between the movable cover and the holding tube shall be carefully ground; it is recommended to use a sealant (grease) to avoid leaks.

5.4.2 Detachable test piece holding tube

center of the microphone, see A.2.

5.9 Signal processing equipment

The signal processing equipment consists of a signal generator, a power amplifier, and a four-channel fast Fourier transform (FFT) analyzer. The device measures the sound pressure at four microphone positions; calculates the Fourier spectrum or transfer function, at each location. The signal generator shall be capable of generating a source signal suitable for the analyzer (see 5.11).

Analyzer's dynamic range shall be greater than 65 dB. The estimation error of the transfer function, due to the nonlinearity, resolution, instability, temperature sensitivity of the signal processing equipment, shall be less than 0.2 dB.

When the single-microphone method is used, the analyzer shall be able to calculate the transfer function H_{ij}, from the generator signal and two successively measured microphone signals.

5.10 Loudspeakers

The diaphragm loudspeaker (or the high-frequency pressure-cavity type loudspeaker with the horn as the transmission unit of the impedance tube) shall be placed, at the end of the front tube, as opposite to the test piece holding tube. The loudspeaker's diaphragm shall cover at least 2/3 of the cross-section of the impedance tube. The loudspeaker can be coaxial with the impedance tube, or inclined, or connected to the impedance tube through an elbow.

The loudspeaker shall be enclosed in a sound-insulating box, to avoid lateral air transmission to the microphone. Elastic vibration isolation pads are used, between the impedance tube and the speaker frame and speaker box (preferably between the impedance tube and the microphone), to avoid exciting the solid sound of the impedance tube.

5.11 Signal generator

The signal generator shall be able to generate a balanced signal, which has flat spectral density, in the test frequency range. It generates according to test requirements: one or more of random noise, pseudo-random noise, periodic pseudo-random noise, linear FM signal.

In the case of the single-microphone method, deterministic signals are recommended; periodic pseudorandom sequences are well suited for this method. The first step in the processing is to perform m-sequence correlation calculations, followed by fast Hartman (Hadamard) transformations to generate impulse responses. The frequency response is then obtained, from the Fourier transform of the impulse response.

For the calibration of impedance tubes (see Appendix A), the generation and display of discrete frequency signals is necessary. The accuracy of frequency signal generation and display shall be better than ±2%.

5.12 Loudspeaker ends

Resonance of the air column in the impedance tube will always occur. An effective sound-absorbing material, which has a length of 100 mm to 200 mm, shall be laid near the loudspeaker in the impedance tube, to suppress these resonances. It is recommended to use a low-density porous sound-absorbing material.

5.13 Thermometers and barometers

The temperature in the impedance tube shall be measured and kept stable during the measurement process. The front tube and the rear tube shall be consistent; the allowable fluctuation shall not be greater than ±1 K.

The accuracy of the temperature sensor shall be better than ±0.5 K.

Atmospheric pressure shall also be measured; the allowable fluctuation is not more than ±0.5 kPa.

6 Preliminary test

Assemble the test equipment as shown in Figure 4. It shall be calibrated by a series of tests, before formal use. Calibration helps eliminate sources of error or meet minimum requirements. Calibration can be divided into two categories: calibration before and after each test; regular calibration, all in accordance with Appendix A. No matter what kind of calibration is carried out, the loudspeaker shall work at least 10 min before the measurement, to stabilize the working state.

If the surface of the sample is uneven or irregular, the microphone position shall be selected far enough, so that the measured transfer function is in the plane acoustic wave region.

If the test structure is uneven, at least two samples, which have the same installation conditions, shall be used for repeated tests.

If there is a regular transverse structure on the test item (such as perforated panels and resonators, etc.), then the sample shall be cut along the line of symmetry of the structure. If the size of the composite structural unit of the test object is not equal to the cross-section of the impedance tube, the samples cut from different positions of several structures shall be measured separately. For materials inhomogeneous in transverse directions (such as mineral wool products), it is also necessary to perform repeated measurements on several samples, which are cut from different parts of the test object.

8 Test steps

8.1 Determination of datum plane

After the sample is installed according to the requirements in Chapter 7, the first step in the measurement of its acoustic characteristics is to identify the first and second datum planes (x = 0, x = t). Typically, the reference plane is the surface of the test piece. However, if the surface of the sample is uneven OR has an uneven transverse structure, then the reference plane shall be located, at a certain distance in front of the surface of the test piece. The distance -- from the datum to the nearest microphone -- shall comply with the recommendations in 5.3. The position of the reference plane, as relative to the microphones 1 and 4 (see Figure 1), shall be specified; the accuracy shall be better than ±0.5 mm.

8.2 Determination of sound velocity and wavelength

Before starting the measurement, first measure the sound velocity in the tube. Then calculate the wavelength corresponding to the measurement frequency.

Knowing the air temperature in the tube, the sound velocity (unit: m/s) can be estimated according to formula (5):

$$c_0 = 343.2\sqrt{T/293} \qquad \text{(5)}$$

Where:

T - Air temperature, in Kelvin (K).

The wavelength λ_0 is obtained by formula (6):

$$\lambda_0 = c_0/f \qquad \text{(6)}$$

8.3 Selection of signal amplitude

When measuring at the selected position of the microphone, the signal amplitude of all measurement frequencies shall be at least 10 dB higher than the background noise.

Due to the existence of the anechoic end at the sample position, the frequency response of the loudspeaker shall be best equalized, so that the sound pressure response, which is measured at this position, is flat. During the test, any component 60 dB lower than the maximum frequency response shall be filtered out; however, due to the presence of samples, the equalization of the frequency response shall also be carried out.

8.4 Selection of mean

The random error caused by noise can be effectively suppressed by averaging the signal spectrum, which is measured at the position of the microphone. The required mean is related to the test material and the required accuracy of the transfer function estimate (see Appendix D.3).

8.5 Correction of microphone mismatch

Using the four-microphone method, a correction factor shall be determined in advance, to correct the measured transfer function for channel-to-channel mismatch. Each channel consists of a microphone, preamplifier, analyzer.

In the case of the single-microphone method, since only one microphone is used, there is no need to correct for microphone mismatch, in the estimation of the transfer function.

Calibration is performed with an empty tube (i.e., no test piece installed); the calibration is valid for all subsequent measurements, since the state of the microphone remains unchanged after calibration. When doing calibration measurements, the mounting holes of the microphones, that are not used temporarily, shall be properly sealed, such as plugging the dumb head of the microphone, OR leaving the unused microphones in their original positions.

The microphone is installed according to the layout method I (see Figure 5 for the standard method); the measured transfer function H_{ij}^{I} is stored. Exchange the two microphones A and B, as shown in Figure 6.

When exchanging microphones, it shall be ensured that the position of microphone A in arrangement II is exactly the position of microphone B in arrangement I, and vice versa. Do not connect the microphone to the preamplifier or signal analyzer, when exchanging.

Appendix A

(Normative)

Preliminary test

A.1 Before and after the test

A.1.1 Calibration of microphone sensitivity

Before and after each test, the sensitivity of the microphone shall be calibrated, with a stable sound source, within the operating frequency range; the sound level accuracy of the sound source shall be better than ±0.3 dB. If the microphone is known to have a linear frequency response over the operating frequency range, then a single-frequency sound source, such as a pistonphone, is considered sufficient.

A.1.2 Temperature measurement

Before and after each test, the air temperature shall be measured, using a temperature measuring device, which has a measurement accuracy better than ±0.5 K, meanwhile written into the test report.

A.1.3 Signal-to-noise ratio

Before each test, the sound pressure spectrum, when the noise source is switched on and off, shall be determined at each microphone position. The sound pressure spectrum of the noise source shall be at least 10 dB higher than the background noise, at all test frequencies. The frequency, with which test results do not comply with this requirement, shall be recorded in the test report.

A.2 Periodic calibration

A.2.1 Impedance tube attenuation

A.2.1.1 Correction of impedance tube attenuation

Due to viscous loss and heat conduction loss, the incident sound wave $p_I(x)$ and the reflected sound wave $p_R(x)$ are generally attenuated, during the propagation process. The main effect of attenuation is that, the amplitude of the sound pressure minima increases monotonically with increasing distance from the reflecting surface. Under normal circumstances, this will not affect the results measured using the method of this technical guidance document. However, when the distance -- from the surface of the sample to the nearest microphone -- is greater than three times the diameter of the impedance tube (round tube) or the length of the long side (rectangular tube), then it is necessary to make corrections, when evaluating the acoustic characteristics measured

S_{12} - The cross-spectrum of the signal of microphone 1 and the signal of microphone 2;

S_{11} - The auto-spectrum of the signal of microphone 1;

S_{22} - The auto-spectrum of the signal of microphone 2.

Note: There are deviations, which are caused by the signal record length (or frequency resolution) and the reverberation effect in the tube in the determination of the coherence function. In the case of a highly reflective tip, the coherence will be less than 0.5, at the frequency corresponding to the sound pressure node, where either microphone is positioned. In addition, it can be expected that the coherence between the microphone signals will be greater than 0.9.

D.4 Calculation of sound transmission loss uncertainty

The measurement uncertainties of sound transmission loss are derived from measurements of transfer function, spacing, temperature. The measurement uncertainty of temperature has little effect on the uncertainty of sound transmission loss, so it can be ignored; only the influence of the uncertainty, which is introduced by transfer function measurement and spacing measurement on the uncertainty of sound transmission loss, is calculated.

D.4.1 Spacing measurement uncertainty

The uncertainty of spacing measurement mainly depends on the uncertainty u_1 of the measurement dispersion and the uncertainty u_2 of the scale error of the scale used. The uncertainty caused by other temperature effects and elastic effects can be omitted.

The uncertainty of measurement dispersion is obtained by statistical methods, which belongs to category A assessment, using the Bessel method; the scale uncertainty is obtained from the accuracy of the measuring scale used, which belongs to category B assessment.

D.4.1.1 Spacing measurement dispersion

Assuming that the spacing is measured n times, x_1, x_2, ..., x_n are obtained.

Its average value is the best value:

$$x = \bar{x} = \frac{1}{n}\sum x_i \qquad \text{(D.4)}$$

Where:

x_i - The value of the i-th measurement.

Its standard deviation is its standard uncertainty u_1:

------ The End ------