Research on Measuring System for Damping Material's Elastic Parameter with the Amplitude Fitting Method

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Abstract: The damping material because of the particular micro-structure in the vibration and noise control aspects and underwater acoustic engineering have been very widely used. Elastic damping material parameters are the basis of engineering data. Presently there has been many methods of measuring elastic parameters, but the low Young's modulus measurement of the dynamic elastic parameters still no accepted standard method. Fitting the amplitude of longitudinal vibration of rods with a uniform theory, constructed experimental system, with polyurethane flexible rod as the research object, by measuring different frequency on every point of the longitudinal vibration amplitude distribution, and drew the amplitude curves, application of the minimum squares curve fitting the dynamic elastic parameter inversion. With the resonance method of measurement results were compared, demonstrated the feasibility of the method and stability, and the experimental results are analyzed.

Keywords: Longitudinal vibration; elastic parameters; amplitude distribution; least squares; curve fitting

1 Introduction

Polymer viscoelastic material is usually referred to as damping materials, it is because of the special micro-structure of both the viscous properties of liquids and elastic solids, the vibration and noise control areas and underwater acoustic engineering been very widely used. Damping materials, real modulus and damping loss factor of the two parameters can be used to measure the vibration damping material loss capacity of energy[1], evaluation of damping materials become the target energy consumption characteristics. The correct damping material elastic parameters measured, it is important for engineering applications.

In order to be more reasonable and effective application of these materials, accurate access to the dynamic mechanical properties of materials is very important. Determination of damping material on the dynamic parameters can be reduced to two types of methods. One is by measuring the vibration response of the sample materials, the dynamic mechanical properties of projection parameters; and those materials by measuring the sound field parameters sample the dynamic mechanical parameters of inversion[2]. There are loads of quality vibration measurement methods, vibrating beam method, such as dynamic mechanical analysis of several. Mass loading method is to add a quality tested material sample loading and to stimulate its vibration, force and acceleration by measuring the complex calculation of Young's modulus material. Vibration beam through the measurement in beam under certain boundary conditions of the resonant properties of materials derived measured the elastic modulus and loss factor, measured discontinuous frequency of the material parameters, applicable to measuring low-lying frequency (10Hz-2000Hz) of the complex modulus. Dynamic mechanical analysis can be directly measured low-frequency range (generally 0.001Hz-100Hz) material Young's modulus or shear modulus changes with temperature and frequency. Primarily by acoustic measurements in the free market or the impedance tube to measure the sound pressure reflection of samples (or transmission) coefficient, calculated from dynamic mechanical parameters. Acoustic inversion using dynamic mechanical parameters are also widely used in domestic and foreign scholars. Li shui used materials, sound propagation speed and dynamic modulus of the relationship, by measuring the material sound velocity to determine its dynamic elastic modulus, using broadband parameter battle as a acoustic source signal, combined with signal processing technology for fast, accurate measurement of frequency range of 20KHz-100KHz acoustic component materials, the dynamic shear modulus. Piquette would be material into spherical samples tested by measuring their scattering properties to calculate the dynamic modulus of the material. Pool in the anechoic material from the measured sample plate oblique incidence wave reflection and transmission coefficients can be inversion of the material parameters, but the low frequency measurement error is larger when the experiment[3].

As the sound wave propagation test influenced by many factors and can not be forced resonance frequency of the continuous variation of the data, is difficult to accurately describe the material in a wide temperature and frequency range of dynamic mechanical properties, viscoelastic material to expand the test frequency has been some scholars endeavors. the current method of measuring elastic parameters there are many, each method has advantages and disadvantages. How to make simple measurements, workload, high precision and wide application of elastic parameters is the main purpose of measurement.

2 Measuring principle and the fitting method

2.1 Measurement principle

Because boundary reflection, acoustic wave equation in which the transmission[4]can be written as

$$\varepsilon(x,t) = Ae^{j(\omega t - kx)} + Be^{j(\omega t + kx)} \quad (1)$$

Consider the absorption of the medium are

$$k = k_0 - \alpha j \quad (2)$$

(2)-type substitution (1) type as following

$$\varepsilon(x,t) = Ae^{-\alpha x} \cdot e^{j(\omega t - k_0 x)} + Be^{\alpha x} \cdot e^{j(\omega t + k_0 x)} \quad (3)$$

The equation can be sorted into

$$\varepsilon(x,t) = I\cos(\omega t - \varphi) \quad (4)$$

$$I = \sqrt{A^2 e^{-2\alpha x} + B^2 e^{2\alpha x} + 2AB\cos 2k_0 x} \quad (5)$$

$$\varphi = \arccos[\frac{(Ae^{-\alpha x} + Be^{\alpha x})\cos k_0 x}{I}] \quad (6)$$

We can obtained the elastic damping parameters by the measuring system of elastic rods with different frequencies the amplitude of longitudinal distribution, because by experimental measurement data protract amplitude distribution curve and least squares curve fitting available can get the coefficient of (5).

2.2 Fitting

This paper use nonlinear least squares fitting method, the method is based on the square and the smallest error as the criterion to estimate the parameters of a nonlinear static model parameter estimation.
The model based nonlinear system as following

$$y = f(x,\theta) \quad (7)$$

Type of y is the output of system, x is the input, θ is the parameters (they can be vectors). Estimated parameters of the criteria (or objective function) chosen as the model error sum of squares

$$Q = \sum_{k=1}^{N} [y_k - f(x_k,\theta)]^2 \quad (8)$$

Nonlinear least square method is to seek to achieve the minimum Q parameter estimates. This paper use nonlinear data fitting function in MATLAB lsqcurvefit fitting the experimental curves.

3 Measurement system and experimental conditions

3.1 Constitutes of measurement system

Measurement system consists of excitation, detection and vibration test bed. The sample fixed in the actuator, the signal generated by the excitation signal generator exciter to exert driving forces on the sample, the sample by the sensor and amplifying the vibration signal sent to the oscilloscope display output.

3.2 Measurement system diagram

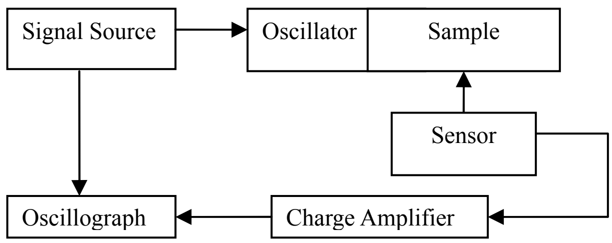

Figure 1. Measurement system diagram

3.3 Experimental Overview

Measurement system works in the normal temperature and pressure environment.

First, fix sample. The samples which is 44cm long, and 1.5cm radius is connected at one end and the vibrator, it corresponds to the middle of exciter, and to ensure pick-up probe axis aligned sample. Determine a good location and fixed with screws.

The second step, the signal source and charge amplifier parameter. FM signal used in the test as the excitation signal, the frequency range 200-635 Hz. 1/3 octave sampling, sample length along the direction of a point measured 0.5cm intervals. Charge amplifier is fixed100 times.

The third step is to measure. Start when the system stable signal source, recorded by oscilloscope observation of velocity sensor transmission amplitude. It is better not to contacts test bed, so that the vibration impact on the measurement results.

4 Data processing and results analysis

4.1 The method of resonant compared with the measured amplitude fitting

Resonance methods[5] and amplitude fitting were used to measure polyurethane thin rods . the measured results as shown below:

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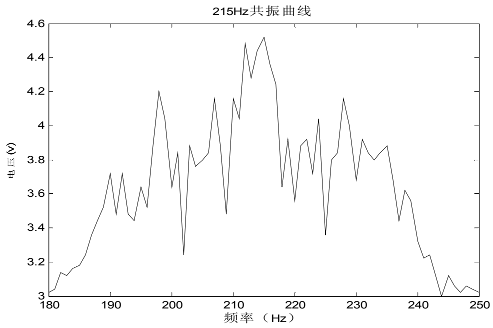

Figure 2. Resonance curves of polyurethane materials（215Hz）

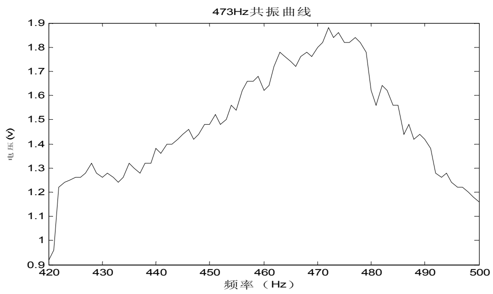

Figure 3. Resonance curves of polyurethane materials(473Hz)

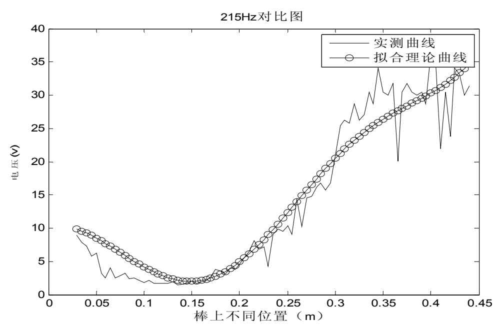

Figure 4. Comparison curve chart between theoretical and measured at 215Hz by amplitude fitting measurement

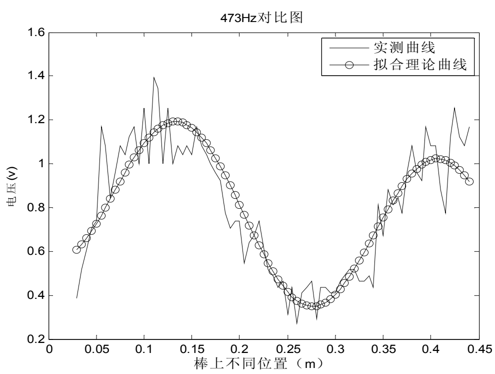

Figure 5. Comparison curve chart between theoretical and measured at 473Hz by amplitude fitting measurement

Table 1. The experimental results of resonance and amplitude measurement of elastic parameters fitting

	Frequency (Hz)	Young's modulus (MPa)	Damping loss factor
The measure of resonance	215	32.192	0.279
	473	49.878	0.15
The measure of amplitude	215	22.855	0.661
	473	55.42b2	0.082

4.2 Measure elastic parameters by the method of amplitude

Using above measurement of experiment measure the frequency of the longitudinal vibration amplitude distribution of sampling from 200 to 635 Hz in 1/3 times, following is a comparison chart on different frequency distribution curve between the measured amplitude and theory curve which obtained by curve fitting parameter：

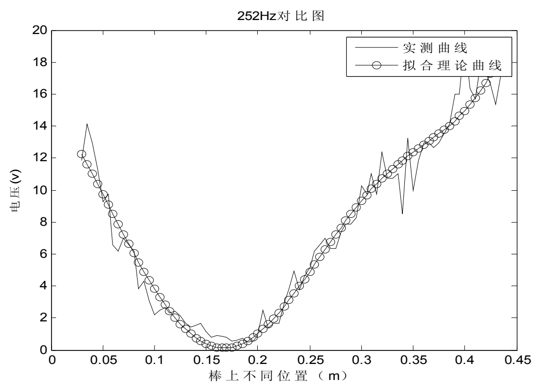

Figure 6. The comparison chart between measured amplitude and theory curve which obtained by method of amplitude fitting on 252Hz

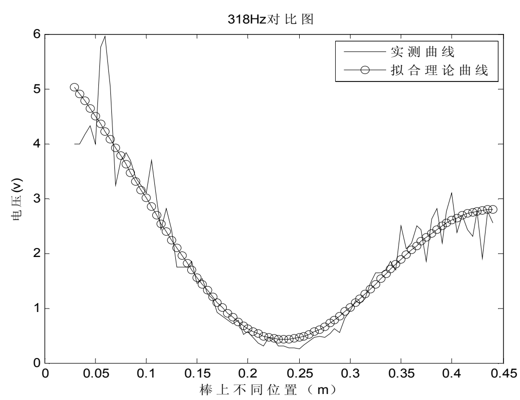

Figure 7. The comparison chart between measured amplitude and theory curve which obtained by method of amplitude fitting on 318Hz

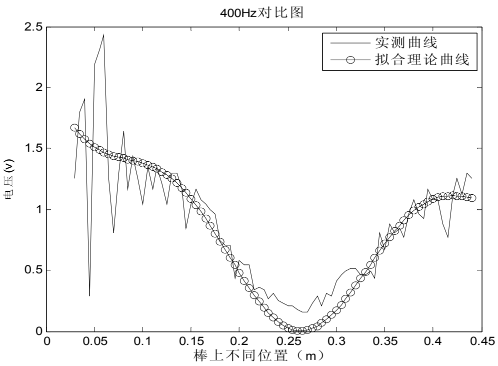

Figure 8. The comparison chart between measured amplitude and theory curve which obtained by method of amplitude fitting on 400Hz

Table 2. Results of amplitude fitting method of elastic parameters

Frequency（Hz）	Young's modulus（MPa）	Damping loss factor
200	19.270	0.617
252	30.202	1.018
318	87.872	0.629
400	92.821	0.801
504	101.521	0.738
635	161.619	0.768

4.3 Results analysis

Compared with the resonance measurement method we can see the results by amplitude fitting measurement is similar with the resonance, which further demonstrates the feasibility of amplitude fitting. This method can measure the elastic parameters of continuous frequencies and get ideal results in the low frequency measurements.

By measure elastic parameters on samples from 200Hz to 635Hz in 1/3 times frequency distance, The measurement results can be seen that the material Young's modulus increases gradually with increasing frequency, damping loss factor is big, but the change with the frequency relationship does not significantly.

5 Errors analysis

The measurement system base the small rod (diameter much smaller than the length of the wave) of the longitudinal vibration theory as the theoretical foundation, but did not reach the measured material requirements of small sticks, so the radial vibration can not be ignored and measurement method itself is imperfect, will cause measurement errors; curve fitting method itself will introduce some error. The results of the above will lead to a certain extent the real value of the error

6 Conclusions

By theoretical analysis and experimental demonstration on amplitude fitting method proved this method can be used to measure the amplitude of the elastic damping parameters. Compared with the resonance, this method can measure the elastic parameters with continuous frequency, also increases the utilization of experimental data. Measured elastic parameters by amplitude fitting method is simple and easy to operate, is a good measurement of low frequency damping material elastic parameters, rather to promote the valuable

References

[1] LIU Li-hua forward. Viscoelastic damping vibration and noise reduction applied technology [M]. Aerospace Press, 1990 (1), 96-105.

[2] Lv Li, BAI Shu-Xin , Zhang Hong etc.. Viscoelastic dynamic performance testing of materials [J]. Rubber Industry, 2006,53 (10) ,622-624.

[3] WANG Bing, Zhang Yong-bing, Lin Xin-zhi, etc.. Viscoelastic dynamic mechanical test analysis research [J]. Materials Development and Application, 2009, 24 (3) :77-79.

[4] HE Juo- yong, ZHAO Yu-fang book. Acoustics theory [M]. National Defense Industry Press, 1981 (1).

[5] YANG Wen-Ping, LU Zhong-jian. Using resonance determination of Young's modulus of engineering materials [J]. Scientific and Technological Advice, 2006, (12): 235.

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