Available online at www.sciencedirect.com

Journal of Applied Research and Technology

Journal of Applied Research and Technology xxx (2016) xxx–xxx

www.jart.ccadet.unam.mx

Original

Investigation and correction of error in impedance tube using intelligent techniques

J. Niresh [a,*], S. Neelakrishnan [a], S. Subha Rani [b]

[a] *Department of Automobile Engineering, PSG College of Technology, Coimbatore 641004, India*
[b] *Department of Electronics & Communication Engineering, PSG College of Technology, Coimbatore 641004, India*

Received 8 March 2016; accepted 28 September 2016

Abstract

Errors arise in the measurement of sound absorption coefficient using impedance tube due to various factors. Minimizing the errors require additional hardware or proper calibration of certain components. This paper proposes a new intelligent error correction mechanism using mathematical modelling and soft computing paradigms. A low cost impedance tube is designed, developed and its performance is compared with a commercially available standard tube. A particle swarm optimization and neural network based system is developed to reduce the random and systematic errors in the developed impedance tube. The proposed system is tested using various porous and non-porous functional textile materials and the results are validated. A significant reduction in error is obtained at all frequency ranges with PSO based prediction method.

Keywords: Neural network; PSO; Impedance tube; Sound absorption coefficient; Error correction

1. Introduction

Measurement of sound absorption coefficient is considered to be important in determining the acoustic properties of materials considered for use in noise control. Sound absorption coefficient is a quantity that represents the percentage of sound absorbed by a material. This is measured using the phenomenon of reflection of sound waves. Sound waves are generated within a medium and transmitted towards the test sample. By measuring the incident and reflected waves, reflection coefficient and hence the acoustic impedance can be calculated. The two standard methods for determining the absorption coefficient are Standing Wave Ratio (SWR) (Iso, 1996) method and transfer function method (International Organization for Standardization, 2001). The standing wave pattern and its pressure measurement are used in the former, whereas in the latter, transfer function is used. A method to measure sound absorption coefficient of acoustical materials used as wall or ceiling treatments is proposed in (Iso, 2003), providing results at random incidence. An optimization method based on flow resistivity to improve reproducibility is proposed in (Jeong & Chang, 2015). A new technique to measure sound absorption coefficient using sound intensity probes is discussed in (Bonfiglio, Prodi, Pompoli, & Farina, 2006). Another method that uses echo impulse technique to measure acoustic impedance is elaborated in (Garai & Pompoli, 2001), which requires further post processing of results to obtain accurate measurements. The acoustic impedance is generally calculated over a wide range of frequencies and these standard methods introduce errors in the measurement setup. Various procedures to mitigate these errors have been dealt in the literature.

Bias and random errors occur while finding the transfer function between the microphone positions. In (Pilon, Panneton, & Sgard, 2004), the effect of air gap in standing wave tube was discussed with experimental results. The impact of barometric pressure, sample mounting and error in apparatus was studied and an analysis was presented in (Tinianov & Babineau, 2006). The measurement is also affected by dispersion, which

* Corresponding author.
E-mail address: nireshcbe@gmail.com (J. Niresh).
Peer Review under the responsibility of Universidad Nacional Autónoma de México.

http://dx.doi.org/10.1016/j.jart.2016.09.003
1665-6423/

can be studied using reproducibility concept (Horoshenkov et al., 2007). These errors were mitigated in (Åbom, 1988) by decreasing the duct length, having a non-reflective source end and having the microphone as close as possible to the source. Also, they investigated that there should be a minimum spacing between the two microphone locations to reduce large errors due to pressure nodes at the microphone location. In (Katz, 2000), to reduce errors, proper location of microphone was determined. In this paper, an additional microphone is used to estimate the precise distance than using a ruler using ISO-method. A verified systematic framework to estimate frequency dependent uncertainties in the complex reflection and normalized acoustic impedance calculations was proposed in (Schultz, Sheplak, & Cattafesta, 2007).

A two microphone three calibration method was proposed in (Gibiat & Laloë, 2005). In this method, impedance of three known devices is connected subsequently and the impedance of the unknown device is calculated by using the three known impedance and the transfer function obtained from the unknown device.

A multiple microphone method was proposed to measure pressure at more than three positions. The acoustic impedance is calculated from the transfer function of a few combinations of microphones. An improved method was proposed in (Cho & Nelson, 2002) using least square curve fitting and optimizing the response of all microphone positions. Here again, multiple microphones were employed to determine various transfer function values and choosing the best.

All the above methods of error correction involve a constructional change in the impedance tube or at least a calibration mechanism, which is not standardized. To overcome the difficulty, a novel intelligence based error correction mechanism is developed based on soft computing techniques. In this paper, error reduction in impedance tube is considered as an optimization problem. Numerous soft computing techniques such as Firefly Algorithm (Nasiri and Meybodi, 2012), Simulated Annealing (Mantawy, Abdel-Magid, & Selim, 1998), Ant colony optimization (Xiao, Zhou, & Zhang, 2004), Artificial Bee colony (Karaboga & Basturk, 2007), Bat and Artificial immune system (AIS) (Taha, Mustapha, & Chen, 2013), have already been applied to different optimization problem. Neural networks have been used in various application areas for error correction and proved to be efficient. In (Ren, Xu, Sun, & Yue, 2011), thermal error correction is carried out using back propagation neural network and rough sets in CNC machine. Error minimization in radio occultation electron density retrieval (Pham & Juang, 2015), wind speed forecast (Zjavka, 2015), colour correction (Zhuo, Zhang, Dong, Zhao, & Peng, 2014) and coordinate boring machine (Yang et al., 2014) with neural networks have been addressed in the literature. PSO is combined with a time difference of arrival algorithm to reduce error in finding emitter location for various applications (Cakir, Kaya, Yazgan, Cakir, & Tugcu, 2014). Calibration of three axis magnetometer is done using Particle Swarm Optimization (PSO) and its variant (Wu, Wu, Hu, & Wu, 2013) by reducing the sensor errors. Various other applications include tool positioning (Mahapatra & Devi, 2013), prediction of geometric errors in robotics (Alici, Jagielski, Ahmet Şekercioğlu, & Shirinzadeh, 2006). To minimize error in impedance tube, soft computing techniques have not been applied yet in the literature. Neural network has been used to model different materials to estimate the sound absorption coefficient (Gardner, O'Leary, Hansen, & Sun, 2003). PSO (Kennedy & Eberhart, 1995) and ANN (Sarle, 1994) have been chosen in this paper, as these two algorithms have already been used successfully in the literature as discussed earlier. The errors arising in the measurement of acoustic impedance due to various reasons is modelled mathematically from sample data available through experiments. Neural network and PSO are designed to reduce the errors, and their results are compared with the standard tube.

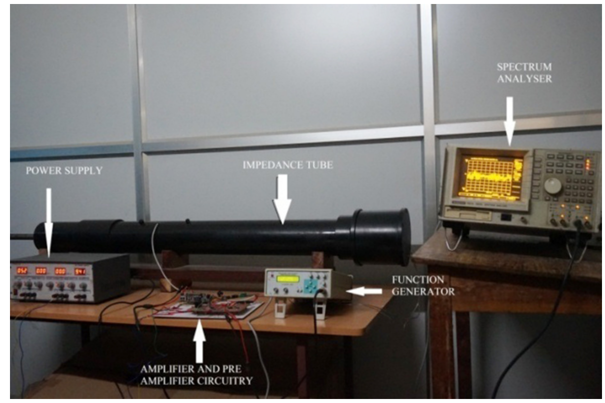

Fig. 1. Impedance tube setup.

2. Impedance tube

To test the sound absorption coefficient, a transfer function based impedance tube has been developed. One microphone method is employed by using a single microphone at two location successively, thereby avoiding phase mismatch between two different microphones (Allard, 1993). The theory of transfer function method has already been discussed extensively in the literature (Chung & Blaser, 1980a, 1980b). The developed impedance tube along with the entire setup is shown in Figure 1.

2.1. Methodology

In this method, the sound source emits sinusoidal waveforms in order to generate the plane waves in the tube. The sound pressures are measured in two locations in close proximity of the sample. The complex acoustic transfer function of the two microphones signal is determined and then used for calculating the normal – incidence complex reflection factor (r), normal – incidence absorption coefficient (α) and impedance ratio of the test material. It is found that the frequency range depends on the diameter of the tube and the distance between the microphone positions.

The normal – incidence complex reflection factor can be calculated using the formula

$$r = \lfloor r \rfloor e^{j\emptyset r} = \frac{H_{12} - \mathrm{H_I}}{H_R - H_{12}} e^{2jk_0x_1} \quad (1)$$

Please cite this article in press as: Niresh, J., et al. Investigation and correction of error in impedance tube using intelligent techniques. *Journal of Applied Research and Technology* (2016), http://dx.doi.org/10.1016/j.jart.2016.09.003