

ERRORS AND UNCERTAINTIES OF CLASSICAL STANDING WAVE TUBE METHODS: SWR, TMTC AND TMTM

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1. Introduction

For the past decades, several methods based on the standing wave tube have been developed to characterize the acoustical properties (surface impedance, reflection coefficient, sound absorption coefficient) of sound absorbing materials. Due to their respective sensitivity to measurement errors, results obtained by the methods may diverge from one to another. Moreover, during measurements, two basic types of error occur: (i) random error and (ii) systematic error. Usually, the precision of a method is characterized by the repeatability of the method, but doing so, only random errors are taken into account. Methods having low random errors will then be considered more precise than they really are. In view of comparing the precision and identifying the most sensitive parameters regarding the experimental procedure and set-up, a detailed analysis on three classical standing wave tube methods is presented. The studied methods are “Standard Wave Ratio” (SWR) [1], “Two Microphone Three Calibration Method” (TMTC) [2], and “Two-Microphone Transfer Method” (TMTM) [3].

2. Methodology

A differential formulation is used to evaluate the errors and uncertainties on each of the standing wave tube methods [4,5]. As input to the formulation, sound pressure measurements and uncertainties on the experimental setup are required. To operate, each method needs a dedicated experimental setup [1,2,3] and sound pressure measurements at specific locations.

For the sake of simplicity and to avoid going into heavy experimental setups and procedures, a numerical model for each of the 3 methods is used to simulate the required sound pressures. In the simulations, the porous test sample is modeled as an equivalent fluid using the Johnson-Champoux-Allard model [6]. Also, attenuation in the tube and variations of the atmospheric pressure and temperature are taken into account in the modeling.

The different parameters, for which measurement errors may affect the accuracy of the standing wave tube methods, are: the temperature, the atmospheric pressure, the tube diameter, the test sample thickness, the length(s) of the air cavity(ies), and the position and response of the microphones

3. Results

In order to see the influence of the measurement errors on the acoustical indicators computed by each method, a detailed investigation of parameters uncertainties is performed. Preliminary results are shown in figures 1 to 3. These results are obtained for the 25-mm thick polyamide foam described in Table 1, and for the uncertainties given in Table 2. For a better comparison between the three methods, their respective optimal tube lengths and microphone positions are used.

Table 1 - Properties of the porous used in the preliminary results

ϕ	σ Ns/m ⁴	α_{∞}	Λ (μ m)	Λ' (μ m)
0.99	19163	1.6	65	130

Table 2 - Uncertainties used in the preliminary results

Parameters	Uncertainties (\pm)
Temperature	0,3° C
Pressure	0,1 kPa
Tube diameter	0,1 mm
Test sample thickness	0,5 mm
Cavities lengths	0,1 mm
Microphones position	0,1 mm
Microphones position	SWR Max (1,5° wavelength, 0,1 mm)
Microphones amplitude responses	0,2%
Microphones phase responses	0,2°

In figures 1 to 3, three types of comparison are done. Figure 1 shows a comparison of the methods' error which is defined as the difference between the theoretical value [6] and the values obtained by the methods. Figure 2 shows a comparison of the methods' uncertainty which is due to measurement uncertainties (table 2). Figure 3 shows a comparison of methods' maximal error which take into account the both uncertainty and error on the methods.

4. References

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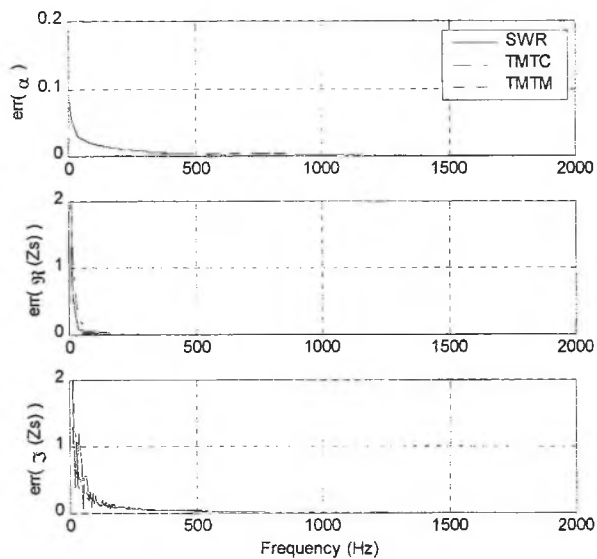


Figure 1 - Comparison of the methods' error.
Preliminary results

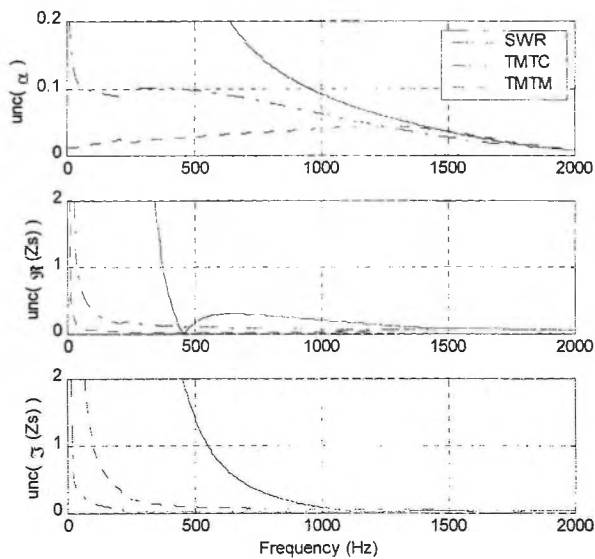


Figure 2 - Comparison of the methods' uncertainty.
Preliminary results

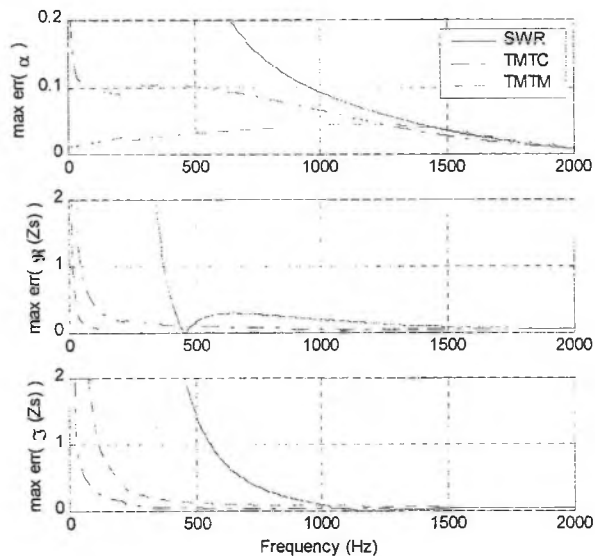


Figure 3 - Comparison of the methods' maximal error.
Preliminary results.