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IDENTIFICATION OF ADMITTANCE COEFFICIENTS FROM IN-SITU MEASUREMENTS IN ACOUSTIC CAVITIES

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Abstract. This paper proposes a method of identification of the admittance coefficient, from in-situ measurements, by applying the CRE-based updating technique to the acoustical problem. Local estimators are developed to localize defective sensors. The process is illustrated on a 1D case.

1 INTRODUCTION

In recent decades, sound intensity and quality are taking an increasingly important place in the design process of products like cars or aircrafts, and different types of absorbing materials have therefore been developed and used in such products to achieve this purpose. To predict the influence of absorbing materials on the sound propagation inside cavities, industries generally use numerical tools, in which the acoustical properties of absorbing materials are described by the admittance coefficient. However, the conditions in which these parameters are measured can differ significantly from the ones in which the materials are really used. In this paper, the parameters required to describe admittance coefficients are identified, from in-situ measurements, by using the updating technique based on the CRE [1]. The main advantages of this method are that the updated parameters keep a physical meaning, that it allows taking into account the measurement error and that it allows locally evaluating the modeling and measurement errors [2]. The CRE-based updating method is therefore applied to the acoustical problem and the process is applied on simple 1D test case.

2 ACOUSTICAL FORMULATION

2.1 Acoustical problem

Let us consider an acoustical domain Ω with boundary $\partial\Omega$. The pressure field is the solution of the Helmholtz equation (1) with associated Dirichlet (2) and generalized (3) boundary conditions.

$$\Delta p + k^2 p = 0 \text{ in } \Omega \tag{1}$$

$$p = p \text{ on } \partial_D \Omega \tag{2}$$

$$v_n = \frac{j}{\omega\rho}\frac{\partial p}{\partial n} = \lambda A_n p + (1-\lambda)\bar{v}_n \text{ on } \partial_G \Omega \tag{3}$$

where $k = \frac{\omega}{c}$ is the wave number, ω is the angular frequency, ρ is the density of the fluid, A_n is the admittance coefficient, describing the absorbing properties of the materials, $\bar{v}_n$ is the normal component of the prescribed velocity and λ is a parameter allowing to define the nature of the boundary ($\lambda = 0$ for a vibrating border, $\lambda = 1$ for an absorbing border and $0 < \lambda < 1$ for a border at the same time vibrating and absorbing)

2.2 Construction of the error

The principle of CRE-based updating technique is to split the set of mathematical equation into a set of reliable equations and a set of less-reliable equations on which the CRE is constructed. In the acoustical problem, the less-reliable equation is the generalized boundary condition and the CRE is expressed by

$$\xi_\omega^2 = \frac{\omega^2\rho^2}{D_\omega^2}\int_{\partial_G\Omega}(v_n - \lambda A_n p - (1-\lambda)\bar{v}_n)^*(v_n - \lambda A_n p - (1-\lambda)\bar{v}_n)d\Gamma \tag{4}$$

where D_ω^2 is a normalization factor. To take the errors of the measurements into account, the modified CRE is defined by

$$e_\omega^2 = \xi_\omega^2 + \frac{r}{1-r}\eta_\omega^2 \tag{5}$$

where

$$\eta_\omega^2 = \frac{|\pi p - \tilde{p}|^2}{|\tilde{p}|^2} \tag{6}$$

where $\tilde{p}$ are the measured pressures $|.|^2$ denotes an energy norm. In Eq. (5), $\frac{r}{1-r}$ is a weighting factor translating the confidence on the measurements. If the measurements are assumed to be accurate, this factor will tend to the infinity ($r \to 1$).

2.3 Local indicators

Error (5) can be rewritten as follows

$$e_\omega^2 = \sum_{i=1}^{N_{\text{Bound}}} \xi_{\omega,i}^2 + \sum_{j=1}^{N_{\text{Sens}}} \frac{r}{1-r}\eta_{\omega,j}^2 \tag{7}$$

where N_{Bound} and N_{Sens} are respectively the number of boundaries and of sensors and $\xi_{\omega,i}^2$ and $\eta_{\omega,j}^2$ are respectively the local estimators of the CRE and of the error in measurements.

2.4 Updating on a frequency range

In order to further regularize the problem, the updating process is generally performed on a frequency range $[\omega_{\min}, \omega_{\max}]$. The expression of the modified CRE (7) becomes

$$e_T^2 = \frac{1}{N_{\text{Freq}}} \sum_{f=1}^{N_{\text{Freq}}} e_{\omega_f}^2 = \frac{1}{N_{\text{Freq}}} \sum_{f=1}^{N_{\text{Freq}}} \left(\sum_{i}^{N_{\text{bound}}} \xi_{\omega_f,i}^2 + \sum_{j}^{N_{\text{Sens}}} \eta_{\omega_f,j}^2 \right) = \xi_T^2 + \frac{r}{1-r}\eta_T^2 \tag{8}$$

where N_{Freq} is the number of frequencies in the frequency range.

3 Implementation of the two-stages updating technique

The first step consists in the localization of the defective sensor, by looking at the distribution of η_{iT}^2 of each sensor i on the global error in measurements η_T^2. If the sources of error are identified, it is possible to correct the measurement. Otherwise, measurements are removed from the set of measurements. The second step is the two-stages updating process, consisting in

- the localization of the most erroneous parameters, by looking at the distribution of ξ_{ET}^2 of each boundaries E on the global CRE ξ_T^2. All the boundaries such as

  $$\xi_{ET}^2 \geq \delta \ \max_E \xi_{ET}^2 \tag{9}$$

  with $\delta = 0.8$, for example, are considered as the worst modeled and the parameters used to describe the admittance coefficients and/or the normal component of the prescribed velocity are considered as the most erroneous.

- the correction of the parameters identified as the most erroneous.

At each iteration of the two-stages process, the global modified CRE e_T^2 is calculated and compared to the required quality level e_{T0}^2. If this level is reached, the process ends. Otherwise, a new iteration is performed.

4 APPLICATION

4.1 Reference problem

Let us consider a 1D acoustical domain of 1m length. The domain is meshed with 40 elements, and the frequency range is from 100Hz to 1000Hz. The domain is excited by a loudspeaker covered by felt at $x = 0m$ and that at $x = L = 1m$, the border is covered by foam. The boundary conditions are therefore defined by

- at $x = 0$: $\lambda_0 = 0.5$ - $\bar{v}_{n,0}(\omega) = f_{\text{HP}}(F/m, \zeta, \phi, \omega_0, \omega)$ - $A_{n,0}(\omega) = f_{\text{DBM}}(\sigma, d, \omega)$
- at $x = L$: $\lambda_L = 1$ - $A_{n,L}(\omega) = f_{\text{DB}}(\sigma, d, \omega)$

where f_{HP} represents the velocity of a membrane of a loudspeaker (F is applied force to the loudspeaker, m is the mass of the membrane of the loudspeaker, ζ is the damping ratio, ϕ is a phase and ω_0 is the eigen-frequency of the membrane), f_{DB} and f_{DBM} respectively represent the Delany-Bazley model (for the felt) and the Delany-Bazley-Miki model (for the foam) used to describe the admittance coefficient of the absorbing materials (σ is the resistivity and d is the stiffness of the material). The exact values of the coefficients used in these models are given in Table 1. The second column of this table gives the initial value of the parameters.

Let us consider that all the nodes, excepted those at the boundaries, are considered as a sensor location. The measured pressures are given by the numerical solution of the 1D acoustical problem, using the exact value of the parameters. In order to verify the step of localization of defective sensors, 3 sensors (at $x = 0.25m$, $x = 0.5m$ and $x = 0.75m$) are considered as defective with an error of 50%.

4.2 Localization of defective sensors

The first step of the process is to ensure that the pressures are correctly measured. Figure 1 gives the distribution of the local estimators η^2_{iT}. It is clearly shown that the 3 defective sensors have a bigger contribution to the global error in measurement η^2_T than the other ones. It is therefore possible to localize defective sensors.

4.3 Updating process

Table 1 gives the results of the updating process, considering with (third column) and without (fourth column) defective sensors, allowing to conclude that the correction of the erroneous measurements allows to improve the results of the updating process.

5 Conclusions

A method to identify acoustical properties of absorbing material, from in-situ measurements, based on the CRE updating technique, is developed. In addition, local estimators are used to localize and correct the erroneous measurements. The technique is applied on

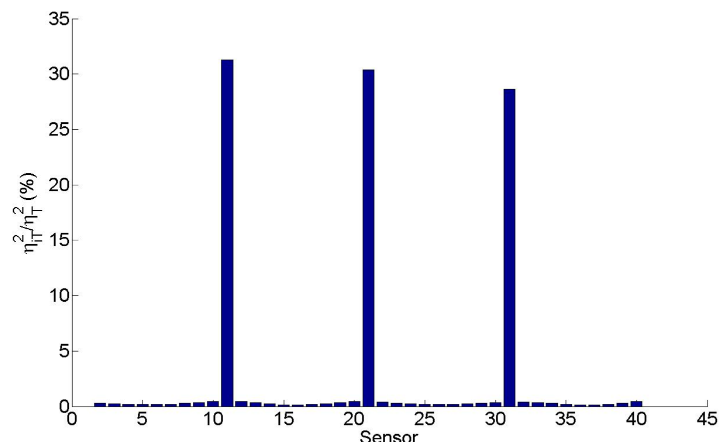

Figure 1: η_{iT}^2/η_T^2 (in percent) for $r \to 1$

Parameters		Exact value	Initial value	Final Value without	Final Value with
$\bar{v}_{n,1}$	F/m (m/s^2)	0.20	0.15	0.1922	0.20
	ϕ (rad)	$20\pi/180$	$30\pi/180$	$31.1535\pi/180$	$20.0006\pi/180$
	ζ	0.45	0.60	0.4480	0.45
	ω_0 (Hz)	$2\pi200$	$2\pi150$	$2\pi199.5813$	$2\pi200.0005$
$A_{n,1}$	σ (Ns/m^4)	$2\ 10^4$	$1.5\ 10^4$	$1.5003\ 10^4$	$2.0200\ 10^4$
	d (m)	0.02	0.015	0.0203	0.0200
$A_{n,2}$	σ (Ns/m^4)	$1.5\ 10^3$	$2\ 10^3$	$1.6003\ 10^3$	$1.4963\ 10^3$
	d (m)	0.015	0.02	0.0150	0.0150

Table 1: Values of the parameters of the problem

a 1D simple test case, in order to illustrate the localization of defective sensors and the influence of the correction of the erroneous measurements on the results of the process.

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