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STUDY OF ENVIRONMENTAL CONDITIONS EFFECTS ON THE MECHANICAL-ACOUSTIC PROPERTIES OF MICROPHONES

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ABSTRACT

More and more applications, such as noise control in hostile environments, acoustic thermometry, gas metrology or optimization of thermoacoustic engines, require performing acoustic measurements with microphones in "extreme" atmospheric conditions or even non atmospheric ones.

Being able to predict and characterize the sensitivity and frequency response of microphones in these conditions of use is then of fundamental purpose. However, regarding the variety of potential applications, it is not realistic to perform microphones calibrations for all environmental conditions of possible interest. The main global properties of microphones should then be predicted by a reliable modelling procedure that enables to take into account the effects of environmental conditions on its mechanical-acoustic properties. Basically, the sensitivity and frequency response of a microphone are determined almost by its geometrical structure and dimensions, and by the mechanical properties of its membrane, which are both related to the temperature of the cartridge. On the other hand, the acoustic behaviour of a microphone strongly depends on the physical properties of the gas in the cartridge, which are function of the nature, static pressure and temperature of the gas and can easily be calculated.

For the sake of the present work, an analytical model available in the literature is used to describe the behaviour of a 1/4" microphone. This global modelling is associated to a mechanical study for predicting the temperature effects on the properties of the constituting materials. A comparison is presented with experimental results obtained for the resonance properties of the membrane in vacuum and for the frequency response under helium atmosphere of a 1/4" microphone in order to check the validity of the theoretical approach suggested here.

1. INTRODUCTION

The increasing need of acoustic measurements for the control of industrial processes, transportation of gas, etc, generates new requirements of calibration for airborne acoustic sensors. Indeed, some applications require to perform acoustic measurements in a large range of environmental conditions (temperature, pressure and nature of gas) that can differ significantly from atmospheric ones. However,

procedures for determining their sensitivity and frequency response in all the environmental conditions of interest are still missing. On the other hand, regarding the diversity of potential environmental conditions in which acoustic measurements could be required, microphones' calibrations in each of them can reasonably not be considered by final users in practice.

For final users, a better approach would be predicting the properties of a microphone in any environmental condition from its sensitivity and frequency response measured in one ambient condition only. To achieve that, it is necessary to model with a sufficient accuracy the mechanical-acoustic behaviour of the microphone, depending on the temperature, pressure and nature of gas, and check the validity of the modelling procedure in a large range of environmental conditions. To our knowledge few studies on the effects of environmental conditions on microphone's properties have been done until now [1–4], most of them being limited to small ranges of temperatures and static pressures.

The aim of the present work is then to provide new experimental data on the metrological properties of a 1/4" condenser microphone, commonly used for airborne acoustic measurements, in a large range of environmental conditions. This data-set allows us to make new empirical observations about the effects of temperature, pressure and nature of gas on the mechanical-acoustic properties of a microphone (membrane and cartridge). These new experimental results are also used to check the validity of modelling procedures available [5, 6] for predicting the global behaviour of condenser microphones in various environmental conditions.

2. FREQUENCY RESPONSE OF A 1/4" MICROPHONE DEPENDING ON THE ENVIRONMENTAL CONDITIONS

The characterization technique and experimental set-up are those described in Ref. [4, 7]. The frequency response of a 1/4" measurement microphone (GRAS type 40BF) is measured with the electrostatic actuator technique in controlled environmental conditions. The pressure vessel in which the measurements are performed can be filled with helium or argon gas, or set in vacuum. The experimental set-up has temperature and pressure regulations allowing us to

work at temperatures from 80K to 300K and at static pressures up to 100kPa.

2.1 First mechanical resonance frequency of the membrane in vacuum depending on the temperature

In the electrostatic actuator relative calibration technique, the oscillating force field applied to the membrane of the microphone is generated by an electrostatic field. It is then possible to measure its frequency response in vacuum. In the frequency range of the membrane's first resonance, the experimental results can be described as a simple resonant function, almost characterized by the resonance frequency f_0 that is determined by the radius, area density and mechanical tension of the membrane. The experimental values of f_0 obtained here are plotted as a function of the temperature on Figure 1.

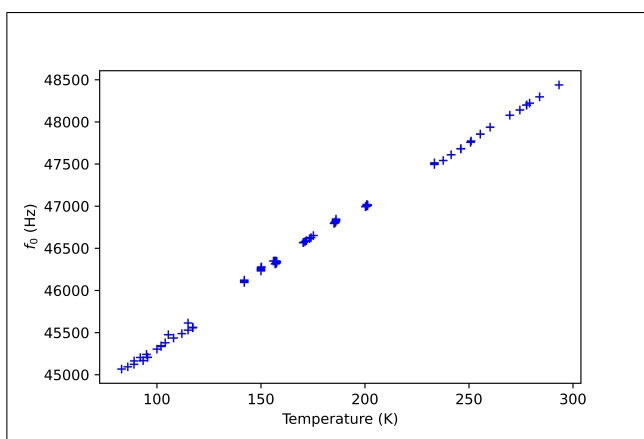


Figure 1. First resonance frequency of a 1/4" microphone's membrane in vacuum as a function of the temperature.

As expected, since the radius of the cartridge, the density of the membrane and its tension all depend on the temperature, the influence of the temperature on the mechanical properties of the microphone's membrane is significant. The trend illustrated here is a straight line, which slope has to be related to the thermal expansion and elasticity properties of the microphone's structure and materials [8].

2.2 Global mechanical-acoustic behaviour in different environmental conditions

Thus, the empirical values illustrated in Fig. 1 are used in a unified modelling procedure for describing the global mechanical-acoustic behaviour of the microphone [6] in order to calculate its metrological properties in any conditions of temperature, pressure and nature of gas. The values calculated for the frequency response of the 1/4" microphone are compared to the experimental results obtained with the electrostatic actuator in helium gas at 278K, for different static pressures (from 1 kPa to 100 kPa).

The good qualitative agreement between theoretical and experimental results illustrated by Figure 2 highlights the validity of the approach developed here to predict the

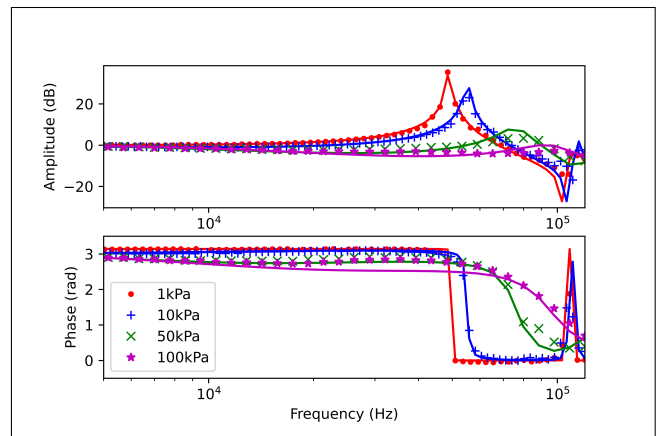


Figure 2. Frequency responses of a 1/4" microphone calculated (plain lines) and measured (bullets) in helium gas at 278 K for several static pressures.

global behaviour of a condenser microphone in various environmental conditions.

3. CONCLUSION

The new approach described here seems promising for predicting the metrological properties of a measurement microphone in various possible environmental conditions of use, and for taking part to the design and optimization process of new measurement microphones as well. The robustness of the predictions strongly depend on *i.* the knowledge of structure and material of the membrane and cartridge and *ii.* the accuracy of the global modelling procedure describing the mechanical-acoustic behaviour of the microphone.

The first point should now be improved by studying more deeply the mechanical structure and properties of a microphone varying as functions of the temperature [8]. Such a study should also be generalized to other kinds of acoustic sensors than microphones with vibrating membranes (MEMS microphones with vibrating plates, optical fiber microphones, etc).

If necessary, the global modelling of condenser microphones used here could be completed by including the effects of the acoustic load in front of the membrane related to the electrostatic actuator, which could be significant at high static pressures as shown on Figure 2. This would be a significant step for considering the possibility of designing acoustic sensors with integrated electrostatic actuators for situ calibrations.

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