REACTIVE NOISE CONTROL BY MEANS OF CAVITIES EXCITED BY AIR FLOW

B. HAYNE, M. BARTHOD, J.L. TEBEC
SINUMEF Laboratory – Acoustic team LMVA at ENSAM Paris

Abstract

Our study focuses on experimental highlighting pertaining to the physical characteristics found in the honeycomb material considered as a Helmholtz type cavity network. The reactive nature of these cavities exists when they undergo the pressure of sound waves and air flow, the latter acting upon the cavities. A test bench makes it possible to measure the acoustic reduction obtained by air flow and to show the phenomena of the reactive noise control when both features concur.

Behaviour theory of Honeycomb materials

On the acoustic level, Honeycomb material can be modelized as a network of Helmholtz cavities. Actually, this sandwich material is made up of cells (forming the cavity), stuck between two plates one of which is perforated, which allows the cavity to emerge [1].

Helmholtz cavity subjected to an acoustic source

Helmholtz resonators are largely used in room acoustic fields, when under the influence of a sound wave, they have an amplifying effect or conversely an absorbing effect at its frequency of resonance. In such a resonator, the 3 dimensions are very small compared to the wave length; hence there is no acoustic wave propagation in the cavity and its behaviour will depend only on its dimensions [1], [2], [3].

$$f_H = \frac{c}{2\Pi}\sqrt{\frac{S_{col}}{V(l+\delta)}} \qquad (1)$$

with c : speed of sound in the medium
l : collar length
S_{col} : collar section
δ : collar correction
V : cavity volume

Helmholtz cavity under the influence of an air flow

When a cavity is under the influence of an air flow, sound level is generally considered as the cavity response to hydrodynamic instabilities present in the mixture layer, and is related to the eigen modes of the geometry considered [4], [5]. In our case, Rossiter's work cannot be used because the collar diameter is much smaller than the wave length of swirls detachment. The pressure variations near cavity collar will lead the harmonic oscillator to vibrate at its resonance frequency. The air flow power is very significant relative to the sound power (ratio close to 10^5). An air flow which skims over a Helmholtz cavity can cause a significant noise level. Indeed, at the collar exit, the piston like movement of the air can be compared to a monopole.

Helmholtz cavity under the influence of both air flow and acoustic source

The approach most often used to study the resonator behavior is optimisation of impedance they present, in order to be able to maximize the power absorbed by impedance adaptation [6], [7].

In spite of a significant number of papers on the subject, the various approaches have not enabled us to completely understand the physical phenomena which occur. That is why, we handled the problem differently; the theory we suggested rests on the well-known principle of active noise control.

Reactive noise control hypothesis

If cavity is under the influence of conversely to air flow and a sound wave coming from a nearby source emitting at Helmholtz frequency and is considered, initially, as punctual, both exit of collar and source can be compared to two monopoles radiating at the same frequency but out of phase.

On the basis of the principle according to which the acoustic radiation of a dipole is less effective than two monopoles out of phase, we assume that the source relating to the radiant cavity will be self adjusted in phase opposition with the external sound wave.

Experimental study of Helmholtz cavity subjected to both air flow and acoustic source

The aim consists in checking that the two sound sources behave like a dipole. That is why, we will highlight the adjustment in phase opposition of two sound sources of the same frequency and of the same power, one of which being free to slide in phase one to the other. This configuration allows to study the minimisation of the global energy of the system leading to the reduction of the total acoustic power emitted by both sources. We intend thus to show that there is attenuation of the noise level related to a reactive control of the cavity excited by air flow, with respect to the acoustic source to which it is subjected. Hence, our approach is completely different from traditional approach.

Test bench design

First, in order to simplify both the experiments and measurements, we have chosen to consider wave longitudinal plane propagation conditions in a tube. The experiment device developed is schematized by Figure 1.

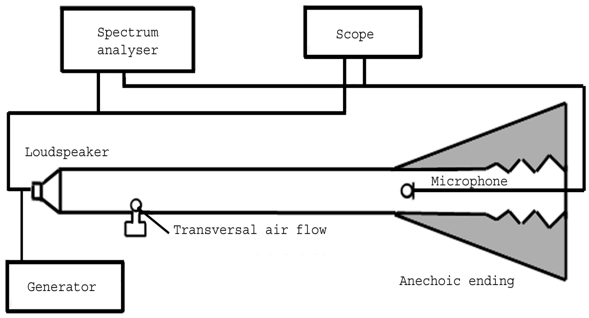

Figure 1 : Test bench

Results

Experimental conditions

The frequencies of both acoustic excitation for the loudspeaker and cavity resonance, under effect of air flow, are identical, as well as the noise levels of each sources taken separately. Noise levels used will be between 105 and 110 dBA.

Two types of measurement were carried out:

a) The loudspeaker (LS) is turned on first, then the cavity is brutally excited by air flow.

b) The cavity, subjected to an air flow, is already in resonance then the loudspeaker is activated.

Highlighting the adjustment

On the scope, we visualized both frequency generator signal and microphone signal.

The observations are identical for the two types of measurement: as soon as the second source is turned on, we note that the reaction is immediate: there is an adjustment between the two signals. The excitation by air flow doesn't have a phase well defined at the beginning therefore it adjusts easily on the signal of the loudspeaker.

Description of acoustic attenuation obtained

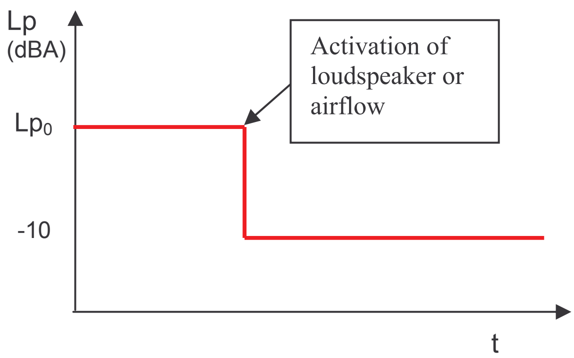

Figure 2 : Adjustment and attenuation representation

The phenomenon is identical in both type of measurement *a* or *b*, as soon as the loudspeaker or the air flow is activated, the level of pressure rapidly decreases by 10 dBA (Cf. Figure 2).

Conclusion

The phenomenon of phase adjustment between two same frequency sounds, generated by a sound source and a cavity subjected to an air flow, has been highlighted. Measurements of noise between one source only and the two sound sources thus defined show a significant attenuation.

This new concept represents an original approach of active noise control; the energy of the active source does not come from the loudspeaker supplied with an electric signal, but from the air flow which excites a resonant cavity directly.

It is envisaged to carry out the tests with several cavities in a network to verify the coupling between cavities. Tests in free field condition are also envisaged in an anechoic room.

A better control of this phenomenon shows there could be useful applications to attenuate noises of sources associated with flows, such as those generated by plane engines.

References

[1] JOUHANEAU, *Traitement et insonorisation des bâtiments.* Techniques de l'ingénieur, 1996.

[2] JUNGER and PERULLI, *Eléments d'acoustique physique*. Collection Université de Compiègne, ed. M.S.A.E. Paris. 1978.

[3] BRUNEAU, *Manuel d'acoustique fondamentale*, ed. Hermés. 1998.

[4] CHATELLIER, LAUMONIER and GERVAIS. *Contrôle actif du couplage aéroacoustique en cavité sous écoulement affleurant*, in XV Congrés Français de Mécanique. 2001.

[5] ROSSITER, *Wind-tunnel experiments on the flow over rectangular cavities at subsonic and transonic speeds,* Report and Memoranda N°3438, October 1964.

[6] GUESS, Calculation of perforated plate liner parameters from specific acoustic resistance and reactance. Journal of Sound and Vibration. 1975. 40. p. 119-137.

[7] JULLIARD, J., G. RIOU, and C. LOZACHMEUR, *Récents développements dans les techniques de réduction et de contrôle du bruit des turboréacteurs*. Revue scientifique SNECMA, 1995.