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SELF-SUSTAINED FLOW NOISE REDUCTION USING A COANDA EFFECT

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ABSTRACT
Self-sustained flow noise reduction is obtained through a new technique: well-known unstable effects such as a Coanda effect may be used to lead a flow to a stable noise reducing path of a turbulent flow bifurcation. A main flow which is responsible for the self-sustained noise is drastically modified by a very small auxiliary flow where a Coanda effect takes place. Experimental results are reported in the situation of two baffles in tandem in a duct. Such a new technique is costless compared with usual active or passive methods.

1 - INTRODUCTION
Self-sustained flow noise has been widely studied. The noise generation mechanism has been described by Powell [1], Howe [2] and Hourigan and *al.* [3]. As an example, an air flow through two diaphragms in tandem in a cylindrical duct has been studied by Soreefan [4]. The upstream diaphragm creates a cylindrical confined jet. The vortices of the shear layer are deviated by the downstream diaphragm.
Noise reduction is usually obtained through two main techniques: a passive one which uses absorbing material or an active one which implies real time measurements and analysis.
The present paper reports a different way of reducing self-sustained flow noise.
Soreefan experiments have been slightly modified: very thin divergent slots are added to the upstream diaphragm. The noise level is reduced up to 20 to 40 dB, via a stable path of a turbulent bifurcation (Henry et *al.* [5]).
A possible Coanda effect of the thin "plane" jets inside the slots is studied with the help of visualisations and velocity measurements. As a consequence, the main cylindrical jet is drastically modified. It is proposed that the flow bifurcation and the hysteresis-like effect are the consequences of this Coanda effect in the divergent part of the slot.

2 - EXPERIMENTAL SET-UP
Figure 1 is a schematic diagram of a low velocity air flow through two diaphragms in a cylindrical duct of diameter D_o. The upstream diaphragm has been modified with four thin divergent slots from which "plane jets" are created. As reported later, these auxiliary jets play a crucial role in the noise reduction mechanism. The downstream diaphragm is a standard circular one.
Sound pressure levels are measured upstream by an ACO 7013 microphone flush mounted in the wall of the pipe. The velocity field in the "plane jet" is measured with the help of a single hot film DANTEC 55R04.

3 - NOISE REDUCTION RESULTS
Figure 3 represents the noise level in the duct versus the Reynolds number $Re{=}U_1 D_1/v$ where U_1 is the mean velocity in the axisymetric jet and D_1 is the diameter of the upstream diaphragm. Starting from a zero velocity, self-sustained tones are present up to a critical Reynolds number Re_{c1} where they suddenly disappear. A "silent path" is then reached. Noise reduction is obtained via a hysteresis-like effect as long as the Reynolds number remains greater than a second critical value Re_{c2}.

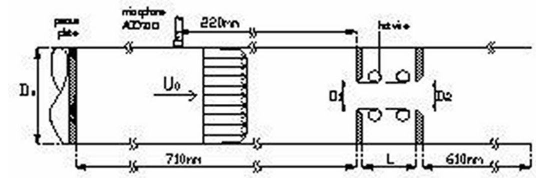

Figure 1: Flow configuration.

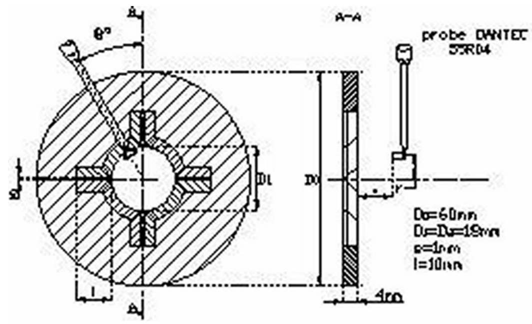

Figure 2: Probe position downstream of the upstream modified baffle.

4 - FLOW VISUALISATION

Thin pieces of wool have been placed in the wake of the slots, i.e. in the so-called "plane jets". On the "noisy path" of the flow, when self-sustained tones take place, the strings have the orientation of the axis of the duct. At the bifurcation Reynolds number Re_{c1} they abruptly take the orientation of one of the wall of the divergent slot. This orientation is maintained as long as the flow is on the "silent path". A complementary observation has been obtained: if the slot has no divergent part, noise reduction cannot be obtained and strings stay on the duct axis direction.

These results may be compared to Newman [6] observations on the reattachment of a bidimensionnal jet upon an inclined plane with a Coanda effect.

5 - VELOCITY MEASUREMENTS: BEHAVIOUR OF THE AUXILIARY JETS

The velocity field downstream of the slot, in the "plane jet" created by the slot, has been investigated through anemometry measurements, as indicated on figure 4. The position parameters of the sensor are the following: L/D_1=1.8, x/L_1=0.3, $r/D_1/2$=0.46, θ=0°.

On the "noisy" path, before the bifurcation is reached, the x-axis velocity component U_x has very low frequency oscillations as it is shown on figure 5a (Re ∼35000). The velocity spectral density has two components: a very low frequency f_{pj} which means that the small plane jet is oscillating around its mean position which is parallel to the duct axis, and a high frequency f_{ac} which is the one of the acoustical feedback producing the self-sustained noise.

Let us define a Strouhal number $St_{pj}=f_{pj}\,e/U_s$ with the width e of the slot and the mean velocity U_s in the slot, and let us plot this Strouhal number versus the Reynolds number $Re_{pj}=U_s e/v$ which governs the dynamics of the plane jet. The figure 6 indicates that the Strouhal number successively takes three constant values before the bifurcation, which happens at approximately Re_{pj} ∼2300. This means that, in our configuration, the plane jet oscillates with three different modes before the Coanda effect happens.

When the "silent path" is reached, figures 7a and 7b show that f_{pj} no more exists. This means that the plane jet does not oscillate any more (it is attached to the wall) and the self- sustained tones have disappeared (the axisymetric main jet is drastically affected, and Howe's conditions are no more fulfilled). Moreover the mean velocity which is measured is smaller since the plane jet has been deflected towards the wall.

6 - CONCLUSION

It appears that self-sustained noise reduction can be obtained through a new technique, which is costless since it does not require either passive or active usual procedures.

The main idea is to introduce a very slight geometrical modification with well-known unstable effects, such as a Coanda effect, and to use this unstable effects (which may have drastic consequences upon the

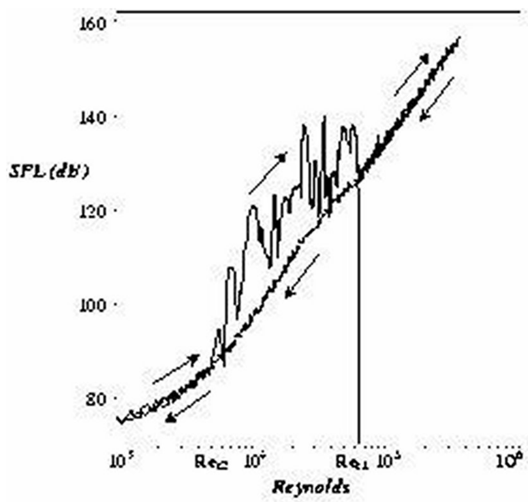

Figure 3: Sound pressure level (L/D_1=1.4): solid line: self-sustained tones path, dashed line: noise reduction path.

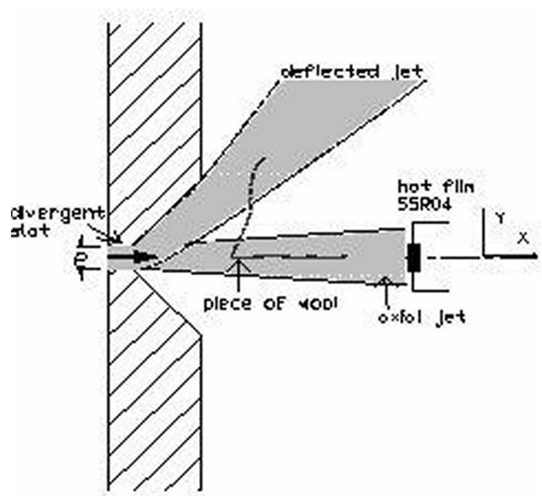

Figure 4: Behaviour of the plane jet on the "noisy" (solid line) and "silent" (dashed line) paths.

main flow) to prevent the conversion of the kinetic energy into acoustical energy. The present experiments demonstrate such a possibility, and open a door towards a new way of noise reduction.

ACKNOWLEDGEMENTS

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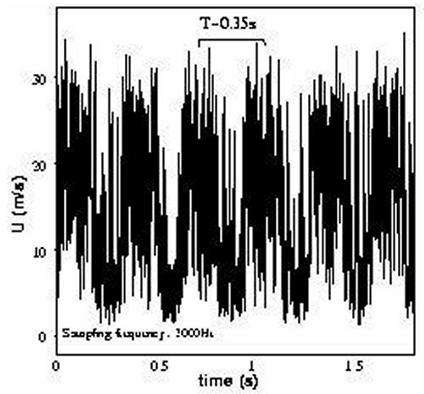

Figure 5(a): Velocity signal and the corresponding spectral density $S(f)$.

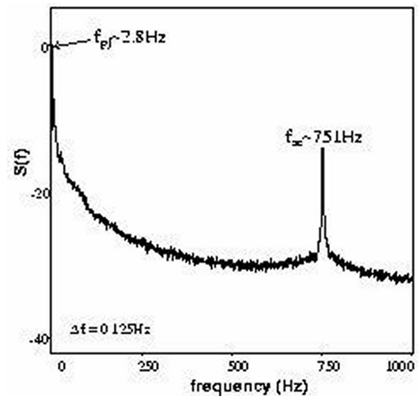

Figure 5(b): Velocity signal measured on the noisy path in the wake of one of the four slots with Reynolds number Re~35000.

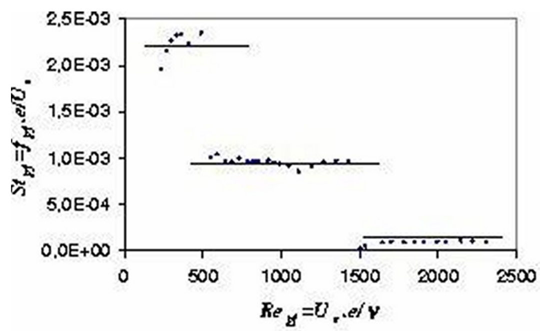

Figure 6: Strouhal number of the plane jet oscillations on the ''noisy'' path.

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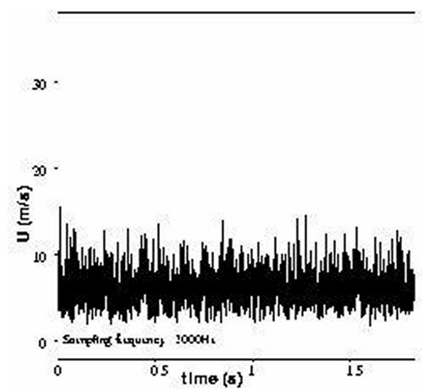

Figure 7(a): Velocity signal and the corresponding spectral density $S(f)$.

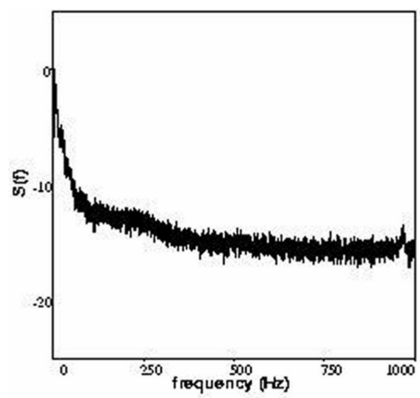

Figure 7(b): Velocity signal measured on the silent path in the wake of one of the four slots with Reynolds number $Re \sim 35000$.