Active Noise Control on a High Pressure Fan

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1. INTRODUCTION

High pressure fans offer very interesting aerodynamic specifications for several domestic applications (vacuum cleaners and fans). However, those fans generate a great pure tone caused by the rotation of the blades. The adding of passive silencers in the ducts to reduce the noise of the blade rotation unfortunately brings non negligible pressure drops, which affects the performance of the systems.

Active noise control is an interesting noise reduction alternative when the pressure drops are an important factor in the conception (see ref. 1 and 2). However, active noise control, which is still a rather recent technology, may seem too expensive. The objective of our work was to develop a compact and less expensive active noise control system for high pressure fans for domestic use.

2. DESCRIPTION OF THE FAN

The fan used in this study has 11 blades, and its rotation frequency is about 56 Hz. It generates a pure tone at the following frequency :

$$f = nbr.pale \bullet f_{rot}$$

where f_{rot} is the rotation frequency of the wheel

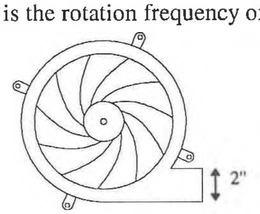

Figure 1 Scheme of the high pressure fan

Since the rotation speed varies little in function of the load, a 615 Hz pure tone comes out from 20 to 30 dB of the noise spectrum (see Figure 4). And, this type of pure tone is very disagreeable in terms of acoustical discomfort. With a 2 inches diameter duct, the cut off frequency of the first mode is about 4000 Hz. Thus, in this case, a single channel control system is sufficient.

3. THE DEVELOPED SYSTEM

Firstly, several control systems have been evaluated (sensor, actuator and algorithm), disregarding the cost constraint in order to define the problematic of the studied case. The control algorithms which were used have been implemented on a DSP C31 put on a PC. For the feed-back or the feed-forward type control algorithms, there must be a measurement of the acoustical pressure in the duct. And, since the flow speeds are high in the duct (100 km/h), it is difficult to take a noise measurement directly in the flow. Expensive and cumbersome protective barriers have to be used. Other geometrical constraints also have to be considered. The control system must be compact : it must be applied the closest possible to the noise source, thus near the fan outlet.

From those preliminary tests, and considering several geometrical and cost constraints, the following system has been developed (see Figure 2):

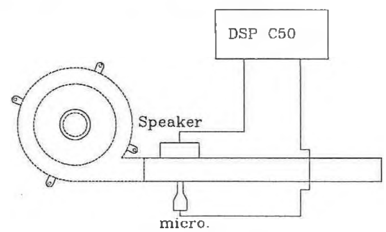

Figure 2 Scheme of the developed control system

The algorithm :

The type of algorithm was chosen following the geometrical constraints and the type of noise to be controlled. The feed-back type is more compact than the feed-forward type, since it only uses one microphone. The feed-forward type uses a second reference microphone upstream. The causality problem between the error microphone and the noise to be controlled leads to some geometrical constraints. Moreover, the feed-back type gives a great performance for the harmonic noise control. Thus, a feed-back type algorithm with perturbation reconstruction has been implemented on an independent DSP C50. The algorithm has been modified in order to meet the needs of the application (see Figure 3).

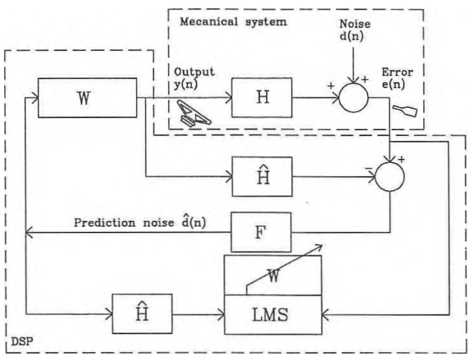

Figure 3 Scheme of the control algorithm

A pass-band filter F around the tone has been implemented in order to minimize the number of coefficients for the control filter. In this way, less computation power is needed for an equivalent performance. Moreover, the F filter ensures a great controller performance on the tone, even if the spectral content around the tone changes. Indeed, the resonance on either side of the tone (see Figure 4) due to the longitudinal interference patterns inside the duct may vary depending on the geometrical conditions. Furthermore, the system had to be completely independent; thus, an automatic procedure has been developed to detect the divergences of the system as well as possible mechanical component failures.

Actuator :

The actuator used in this study is a low cost typical full range speaker, just like the ones that come with portable radios. Several tests showed that the linearity of that type of speaker was sufficient to ensure a good control in the ranges of frequency and sound pressure levels needed for this application. Indeed, the required sound power to generate the opposite wave is little, since the interior of the duct is very enclosed, and it is easy to generate high levels of noise. For example, with 0.2 watt, the control is appropriate on the tone at 615 Hz. The speaker has been installed very close to the duct, brushing against it, so as not to disrupt the flow.

Error sensor :

The error measurement is done with a low cost condenser microphone also fixed brushing against the wall but protected with a thin film. This technique allows to avoid static pressure problems related to high flow speeds. It also showed great performances compared to the expensive and cumbersome protective barriers.

4. RESULTS

The typical performance of the developed system is showed on Figure 4. The performance is of about 25 dB to 35 dB on the tone in function of the emergence of the tone. Note that the shape of the spectrum to be attenuated may change depending on the configuration and on the length of the duct. For all the configurations evaluated in laboratory, the system gives the same very good performance : a complete elimination of the tone.

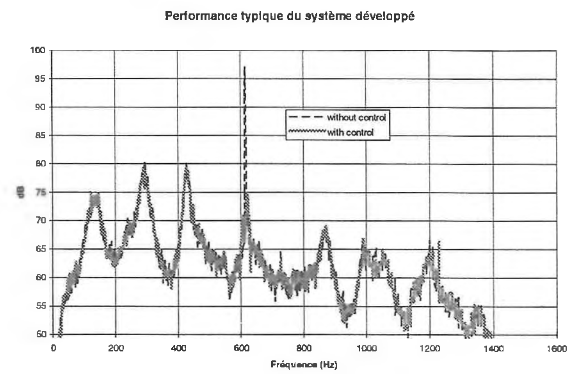

Figure 4 Typical performance of the control system

The computation power required to carry out a control is about 1/10 of the one taken by the DSP C50. This allows to consider the use of a lower cost DSP (a C20 for example). A preliminary cost analysis shows that a card containing a preamplifier for the error microphone, a 2 watt amplifier for the speaker, and the DSP would allow to have a complete system for less than 75 dollars.

5. CONCLUSION

The active noise control system developed for this type of application shows good performances. The noise component that causes most nuisance is eliminated without perturbing or restraining the flow. Moreover, the cost restraint has been considered : the complete system costs more or less 75 dollars.

6.0 REFERENCES

[1]BESOMBES M., MICHEAU P. (1995) *Active control device integrated in a centrifugal turbo-machine : a compact solution for the periodic noise control,* ACTIVE 95, Newport Beach, p. 263-274.

[2]CHRISTENSON T.N. (1996) *Active noise cancellation in a duct with highly turbulent airflow,* Noise-con 96, Seattle Washington, p. 369-374.