ACTIVE NOISE CONTROL SYSTEM TO REDUCE THE NOISE EMITTED BY A LARGE INDUSTRIAL STACK

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Introduction

A precise analysis of the noise emitted by an aluminum plant has shown that one of the main noise source was a 320 Hz emitted by an exhaust stack of 40 m high and 1,8 m of diameter. This pure tone noise was generated by the two blowers of the chimney. Because the classical cost effective solutions were not practical for this chimney (silencers, stack stuffers), the active noise control (ANC) solution was investigated. Commonly used single channel ANC systems [1] were however not applicable to the chimney, since high order acoustical modes propagate in the chimney. In fact, at the operation temperature (120 °C), 5 modes propagate in the chimney: modes (0,0), (1,0), (2,0), (0,1) & (3,0).

A higher modes ANC system was thus developed to control higher modes in a circular duct. To represent the propagation case of the real chimney, a scale model has been tested in a laboratory. The efficiency of the system was analyzed for different numbers and locations of control sources and error sensors. Conclusions obtained with this scale model were used for the installation of an ANC system in the real chimney stack.

1.0 Experimental set-up with the scale model

The scale model was a PVC duct of 3.30 m long having a diameter of 0.30 m. Figure 1 shows the basic arrangement upon which the tests have been conducted. The primary source was located at 0,40 m of the extremity closed by a reflecting cap. The secondary sources were placed at about 1 m away from this extremity, and the microphones are all disposed on the same section at 0.10 m of the open extremity of the duct. In this scale model, similar propagation conditions is obtained at 1700 Hz (same λ/diameter than in the real chimney)..

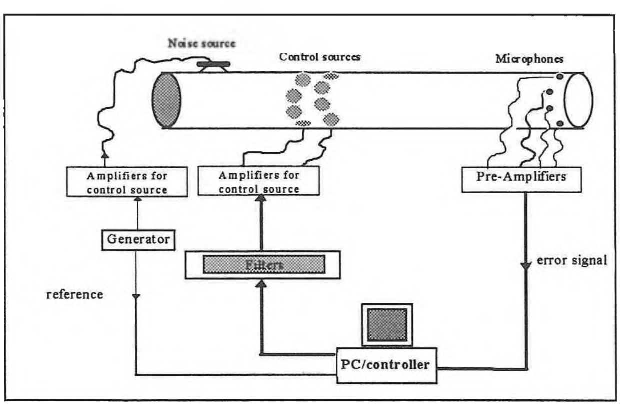
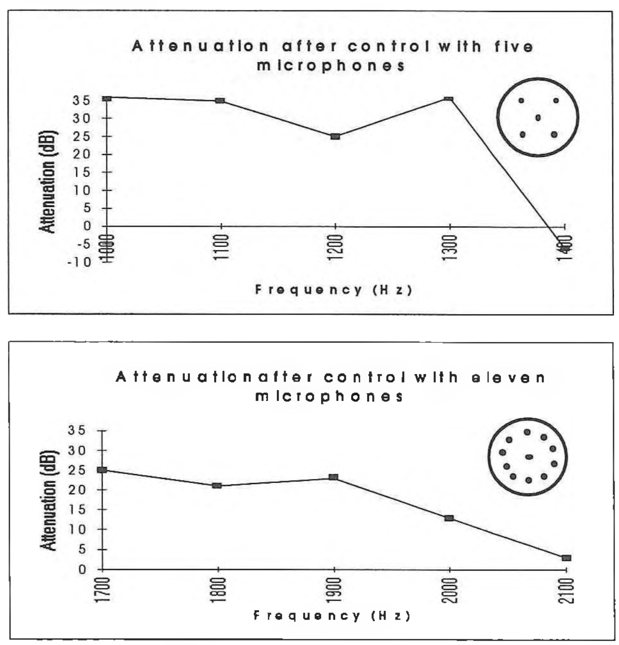


Figure 1 : Schematic of the general set-up

Amplifiers for the control sources and pre-amplifiers for the microphones are linked to a personal computer having a digital signal processing board which acts as the controller. Our controller used a common Multi-Input Multi-Output (MIMO) Filtered-X LMS algorithm[2].

Various preliminary measurements with different numbers and positions for the error microphones were conducted with the basic test arrangement described in figure 1. These measurements have shown that the location of the error microphones should be in an error sensors plane perpendicular to the cross section of the duct (patent pending). In this plane, the number and the location of the error sensors are determined such that the maximum distance between each error sensor and the boundary of the area under the influence of this error sensor is less or equal to approximately one-third of the wavelength of the maximum frequency to be attenuated. The number and location of the error sensors in the error sensors plane can be determined using the k mean algorithm[3].

2.0 Global attenuation as a function of the number of microphones



Figures 2a and 2b: Attenuation measurement results for the first source arrangement: a) 5 microphones, b)11 microphones.

Figures 2a and 2b give the global attenuation obtained as a function of the frequency for 5 and 11 error sensors in the error sensors plane respectively. With five error sensors, the ANC system is efficient up to 1300 Hz, but with 11 sensors, it is efficient up to about 2000 Hz (note that the cut off frequency for a single channal is about 900 Hz).

The positions of the error sensors plane and the control sources were also modified to evaluate their influence on the global attenuation obtained. Results have shown that the location of the speakers or of the microphones plane may change only slightly the general effectiveness and the cut-off frequency of the system. (mainly due to the effectiveness of the controller at the different controlling points).

3.0 Installation in the real chimney stack

According to the experimental results obtained in the scale model, a 10 channel MIMO controller was required to reduce the 320 Hz pure in the real stack. In this case, 9 of these sensors were located on a ring at 0.79 m of the wall, equally spaced at 40 ° intervals, and the last one was located in the middle. For convenience this error sensors plane and the 10 control sources have been installed in an existing turret located in the middle of the chimney. Figure 3 shows the installation of the control sources in the turret.

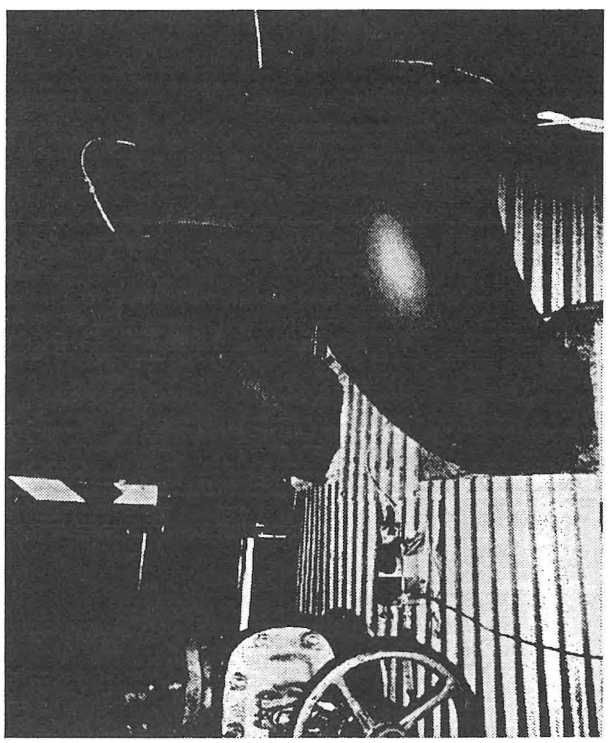


Figure 3 Installation of the speakers in the stack.

Using this 10 channels ANC system, the sound pressure level before and after the control have been measured at about 500 m of the stack. These measurements have shown that the noise reduction of the 320 Hz was about 7 dB(A) (figure 4).

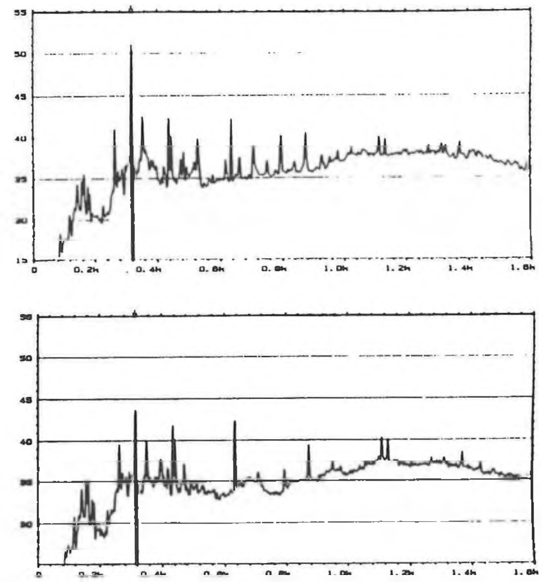


Figure 4 Noise spectral before and after the control at about 500 m from the chimney..

Some additional investigations have shown that the factor that have limited the noise reduction to 7 dB was the rapid variations of the 320 Hz level at the error sensors due to the asynchronicity of the two blowers. Simulations from records taken in the chimney have however shown that with some fine tuning of the controller, the global attenuation in the error sensor plane could be now increased to 12-13 dB.

It is now planed to install a permanent ANC system with this fine tuned controller to solve the noise problem related to this stack.

4.0 Conclusion

As long as a MIMO controller can reduce the noise level at the error points then, using the error sensors plane concept (patent pending), global attenuation can be obtained with ANC system at high frequencies for any type of duct shapes. The locations of the speakers or of the microphones plane changes only slightly the global efficiency of the system.

A 10 channel MIMO ANC system has been installed on an industrial stack and a 7-8 dB(A) noise reduction of 320 Hz has been obtained. It is however expected that 12 -13 dB(A) noise reduction can now be obtained with some fine tuning of the controller.

References

1. S. S. Wise et al., " Case Histories of active noise control on industrial fans and air handlers used for heating, ventilating and air conditioning". Proc. of Inter-Noise 92, Toronto Canada, p.307-312 (1992).
2. S. Douglas, J. Olkin, " Multiple input, multiple output, multiple error adaptive feedforward control using the filtered-X normalized LMS algorithm" , Proc. Recent Advances on Active Control, 1993
3. J. Markhoul " Vector quantization in speech coding ", Proc. IEEE, **73**, No 11, p. 1551-1588, 1985.