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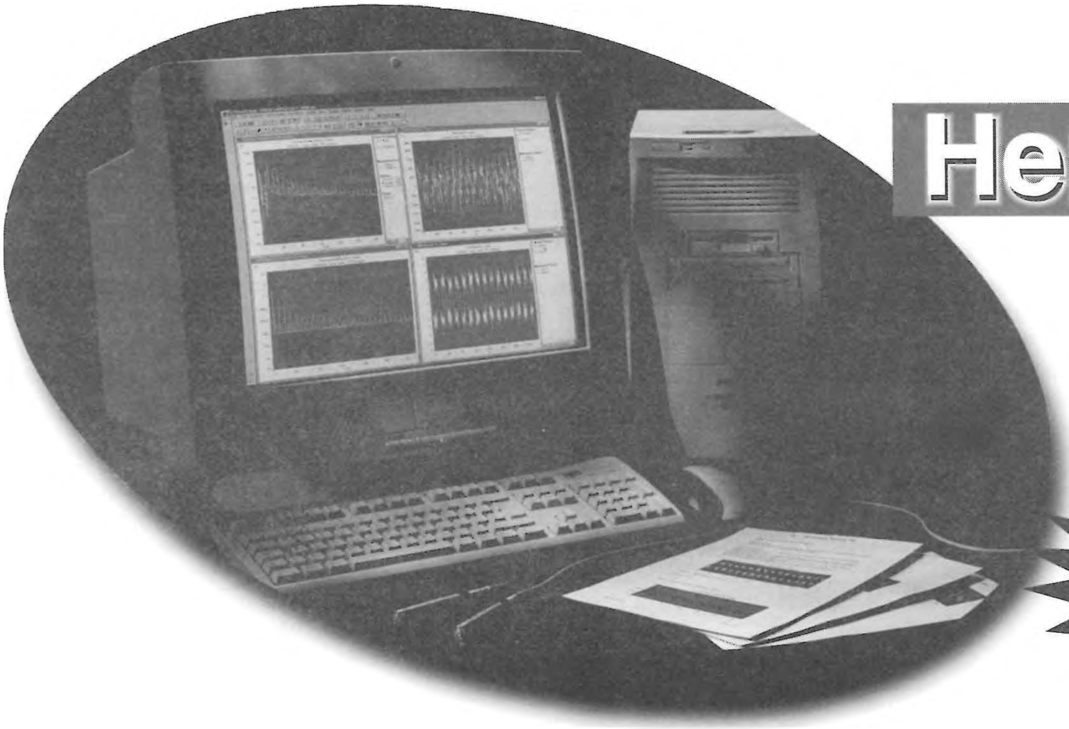

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APPLICATION OF MULTICHANNEL ACTIVE NOISE CONTROL IN A LARGE CIRCULAR INDUSTRIAL STACK

André L'Espérance (1), Martin Bouchard (2), Bruno Paillard (1), Alex Boudreau (1)

(1) Faculty of Applied Sciences, Université de Sherbrooke, Sherbrooke (Que.) Canada, J1K 2R1
andre.lesperance@gme.usherb.ca

(2) School of Information, Technology and Engineering, University of Ottawa, Ottawa (Ont.) Canada, K1N 6N5

1. INTRODUCTION

This paper exposes the solutions found to realize one of the first multichannel of active noise control (ANC) system on a large industrial chimney stack. This application has been realized at the Lauralco Aluminum plant (Deschambault, Québec) on a 40 m high and 1.8 m wide chimney stack (fig.1) that generated a 320 Hz pure tone.

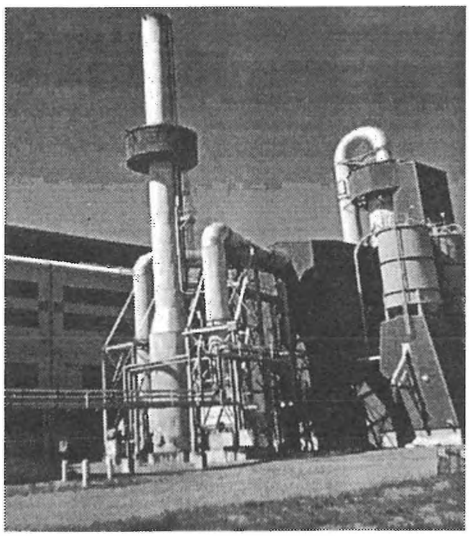

Figure 1 Chimney stack of the aluminum plant.

The first part of this paper reviews the error sensors plane concept recently proposed[1] to obtain an efficient control in the case of a complex sound propagation in a circular duct. The second part describes the software and hardware used for the industrial installation, and the special features used to ensure the effectiveness, robustness and easy maintenance of the system.

2. ANC of high mode using the error sensor plane concept

According to common knowledge in ANC, *M* error sensors have to be used to control *M* modes, and those sensors should not be located at the nodal lines[2]. However, in circular ducts, the location of the nodal lines changes along the duct axis[3], which may explain why ANC of high order modes in circular or irregular ducts appears to be difficult[4].

To overcome this problem, an alternative strategy of locations of the error microphones has recently been proposed, the *error sensor plane* concept[1]. The objective of this error sensor plane is to create a *quiet cross-section* in the duct so that, based on the Huygen's principle, the noise from the primary source cannot propagate over this cross-section.

According to this method, 10 error sensors were necessary to reduce the 320 Hz pure, one error sensor being located at the center of the duct axis, and 9 at 0.21 meters from the duct wall, at 40° intervals.

3. Operation of the system

The controller developed is based on a VME-RACK mount with a PC and a C-40 DSP board. The algorithm used is a multi-channel filtered-X LMS. The hardware of the control system (controller, amplifier, error sensors and control sources) have been installed in an existing platform located at a height of 20 m on the stack (figure 2). When the power of the system is turned on, the controller system automatically proceeds the following steps :

1. Load the control code
2. Make a calibration/compensation of the acoustic sensors
3. Identify the 100 transfer function (10 x10 systems)
4. Start the active noise control
5. Continuously verify the efficiency of the system

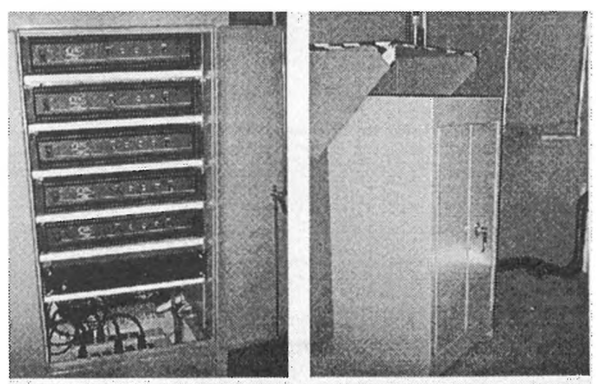

Figure 2 Active noise control system at the sampling platform of the chimney.

3.1 In situ calibration/compensation process

Because it was unthinkable to request an operator to do the calibration of the 10 error sensors regularly to ensure the efficiency of the system, an automatic calibration/ compensation process was developed to calibrate the probes at their operating location.

This procedure consists in generating a number of pure tones with the control speaker and in measuring the value of those pure tones at each error microphone. This process is repeated with each speaker, and the mean value of some of the pure tones at each error sensor are then compared to compensate the response of the error sensors.

3.2 Continuous verification of the system's efficiency

To verify the performance of the system, the mean sound pressure level of the 320 Hz at all error sensors with control is continuously compared to the level without control on the front panel of the controller (fig.3). The reference level with control is evaluated from measurement made at different occasions. For example, the control may be stopped for 30 seconds every day and the reference level estimated from the mean value of the last 10 measurements.

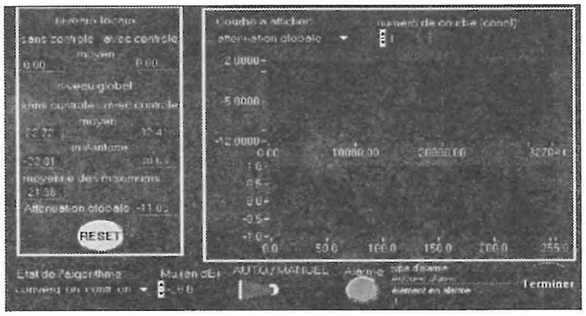

Figure 3 Main front panel of the controller

3.3 Automatic failure detection system

An automatic *failure detection system* has been included in the control process to ensure its effectiveness and trustworthiness. For example, if the noise at the error sensor plane increases compared to the reference level, then the control is immediately stopped. The adaptation filters are then re-initialized and the control process is restarted. If successive divergences are detected, the control process is restarted at step 2, i.e. a new calibration/compensation of the error sensors is done, as a new identification of the transfer function.

The divergences may be due, for example, to a malfunction of an error sensor or speaker. Then, during the calibration/compensation process, different tests are done to verify the functionality of each of those elements. If there is a malfunction of one of them, then an error sight is shown on the front panel of the controller display and the element in fault is identified.

Note finally that the daily performance of the system as well as the status of the controller (calibration, control on/off, divergence, misfunction an specific element) are recorded as function of the time. Using this information, one can verify the performance and trustworthiness of the active noise control system. In the actual application, this information is automatically transferred to the plant exploitation system, so that the personnel can easily follow-up the operation of the active noise control.

3.4 Noise reduction

Figure 4 gives the mean spectra measured at 200 m of the stack, with and without the active noise control system on. The contribution of the 320 Hz pure is reduced to the background noise level, which corresponds to a 10 dB noise reduction. The noise reduction objective has thus been achieved.

The actual active noise control system is in continuous operation since April 1997, and no failure has occurred until now.

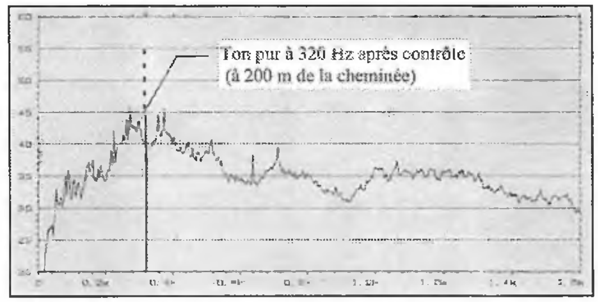

Figure 4 Typical frequency response of the speakers with the teflon membrane

4. Conclusion

An active noise control system has been developed in order to reduce the propagation of the 320 Hz emitted by an industrial stack. A 10 MIMI control algorithm using the error sensor plane concept was developed and installed in the stack. The system is fully automatic so that, when the power is turned on, the control algorithm does all the steps to achieve a control, and a verification process is continuously in operation to ensure the efficiency of the system. This system has been installed on the industrial stack, and the objective of a 10 dB noise reduction of the 320 Hz pure tone in the neighborhood of the industrial plant has been reached. The actual active noise control system is in continuous operation since April 1997 and no failure has occurred so far.

ACKNOWLEDGMENTS

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REFERENCES

[1] A. L'Espérance et al. "*Method and apparitus for active noise control of high order modes in ducts*". United States Patent no 5,748,750, May 1998.

[2] Baumann D. C. et al., "*Number of error microphones for multi-modal cancellation*", Proc. Inter-noise92, Toronto, Canada p. 345-351(1992).

[3] C.L. Morfey, "*Rotating pressure patterns in ducts: their generation and transmission*", J. Sound & Vib.***1***, p.60-87 (1964).

[4] S. Laugesen, "*Active control of multi-modal propagation of tonal noise in ducts*", J. Sound & Vib, **195**(1), 33-56 (1996).