A Module-Based Active Noise Control System for Ventilation Systems, Part II: Performance Evaluation

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To utilize the full noise-attenuation potential of an active noise control (ANC) system applied to duct noise, it is important to be able to minimize the turbulence-induced noise in the microphone signals. This is the second paper in a series of two, that treats the problem of turbulence-induced noise originating from the airflow inside the ducts, when applying ANC to ducts. Part I contains theoretical and experimental investigations of the influence of the turbulence-induced noise on the filtered-x LMS algorithm used in the ANC system. Part II (the present paper) is concerned with the design and investigations of microphone installations, which produce a sufficient amount of turbulence suppression while also meeting industry requirements. These requirements are, for example, that the microphone installations should be based on standard ventilation parts, and that they should be easily installed and maintained. Furthermore, results concerning the performance of an ANC system with different microphone installations are presented. Some of the results were obtained at an acoustic laboratory according to an ISO standard. The attenuation achieved with ANC was approximately 15-25 dB between 50-315 Hz, even for airflow speeds up to 20 m/s.

1. INTRODUCTION

The theoretical and experimental investigations presented in Part I show that the performance of an ANC system based on the filtered-x algorithm and applied to duct noise can be significantly decreased by turbulence-induced noise generated in the microphone signals due to the airflow present in ducts.[1] Therefore, it is essential to reduce the amount of turbulence fluctuations that are not part of the propagating sound, to enable a high noise-attenuation potential of the active control system. Many different approaches to do so have been described over the years. The work of Åbom and Schiegg describes the use of a hot-wire that measures the fluctuating velocities, which are then used as a reference signal for the turbulence at the microphone.[2] This reference is then used to filter out the turbulence contribution to the microphone signal. Another method is to use a microphone array consisting of a number of microphones arranged in a line directed toward the noise source.[3,4] A much more practical and less expensive method is to use probe tube microphones. Design and investigations of the probe tube microphones have been performed by, for example, Neise,[5,6] Wang and Crocker,[7] Munjal and Eriksson,[8] Shepherd and Fontaine,[9] Nakamura,[10] and Larsson et.al.[11] A method similar to using probe tube microphones, is to place the microphones in outer microphone boxes mounted on the duct and connected to the duct interior via a small slit.[12,13] As shown in Refs.[11] and[13] the performance of an ANC system applied to duct noise can be improved by placing the reference and error microphones in outer microphone boxes. In this paper, a microphone installation based on a standard T-duct for reducing the airflow around the microphones is presented. Since the microphone installation is based on a duct piece already manufactured, eliminating the need for the development of new duct pieces, this makes it an attractive solution to manufacturers of ventilation systems. Because the microphones are placed in separate duct pieces, i.e., module-based, it makes the ANC system much more flexible when it is installed. For example, it can be installed with different types of passive silencers, circular or rectangular ducts, etc. Furthermore, comparative results concerning the performance of an ANC system with different microphone installations, T-duct configurations, and microphone boxes with varying slit widths are presented. The results show that the active noise-control performance is almost equal or better when using the suggested T-duct-based microphone installation as compared to using a microphone box with a slit. Some of the presented results were obtained in Lindab's acoustic laboratory in Denmark. Here, the measurements were performed according to the standard ISO 7235:2003 developed for ducted silencers and air-terminal units.[14]

2. MICROPHONE INSTALLATIONS FOR TURBULENCE REJECTION

To successfully apply ANC to duct noise, many factors other than the optimization of the controller need to be taken into consideration. One factor that will significantly restrict the effectiveness of the controller is the airflow turbulence at the microphones. As reported in Part I, high levels of measurement noise will have a negative impact on the performance of the ANC system and, therefore, it is important to substantially reduce the uncorrelated turbulence fluctuations that the microphones are subjected to.[1] As can be observed in Fig. 19, turbulent noise has broadband energy in the frequency range below 400 Hz , which is of interest in this application. Thus, the acoustic noise and turbulent noise cannot easily be separated by temporal filtering, and other methods might be suggested. In this section, different methods and microphone installations