A passive/active hybrid system for control of the noise radiated by a small enclosure

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Summary: Any practical noise control device requires a combination of passive and active methods. Passive control uses absorption properties of materials to reduce high frequency noise but it becomes expensive in terms of weight and bulk at low frequencies, where attenuation must be achieved with active control. Active control is based on the principle of destructive interference between the primary and the secondary sources. The aim of this work was to design and implement a hybrid passive/active system to control the exhaust noise radiated by a small generator. The fundamental frequency of the radiated periodic noise depends on the electrical load plugged in to the generator. Passive control is afforded by a rectangular enclosure with dimensions (1000 x 710 x 530 mm^3). The wall panels of the enclosure are made of steel, 1.5 mm thick, lined with a 30 mm layer of absorbing material. The measured Insertion Loss is higher than 20 dB above 500 Hz. Special attention is paid to technical aspects such as air refreshing and temperature inside the enclosure. Low frequency noise escapes the enclosure via air intake and exhaust openings. Active control, implemented in a feedforward commercial system, is used to reduce low frequency exhaust noise below 500 Hz. The reference signal is supplied by an accelerometer located on the air filter case of the generator. A high temperature loudspeaker is used as control source. Active attenuation is achieved in the band (50, 500) Hz, with the fundamental frequency reduced as much as 35 dB.

EXPERIMENTAL SETUP

The noise source is a small combustion engine, a Honda EG1900, that radiates periodic noise related with its rotational velocity. It is enclosed in a steel box designed to have the most satisfactory Insertion Loss (1). The interior walls of the enclosure are lined with absorbing material and a three-layers damping material has been intercalated between the generator mounts and the floor. A centrifugal fan located near the primary source extracts the hot gas inside the enclosure which temperature is limited by a regulator (2). Figure 1 shows the IL measured by the MLS method (3).

A MOTRAN HTL6 loudspeaker, which supports temperatures as high as 174 ºC, is used as secondary source. It is in a cubic box filled up with rock wool and placed in the exhaust pipe of the passive enclosure in a side-branch configuration, Figure 2. A cheap electrect FONESTAR 2214 microphone in the exhaust picks up the error signal. To reduce the high noise levels along the exhaust pipe, the microphone is inserted into a brass tube, closed in the end in contact with the gas flow. To avoid heating problems, the microphone is isolated from the brass tube by a Teflon ring. The designed active control system is feedforward, so that a good quality reference signal, coherent with the primary noise, is required (4-6). Instead of using a tachometer, as usual, a vibration signal was looked for. The optimal reference, shown in Figure 3, is afforded by an accelerometer over the air filter case of the generator. The reference and the secondary signals are amplified by a B&K 2651 and an Optimus ART15, respectively. A configurable ANC system, implemented on a TMS320C40 DSP by Texas Instruments, which incorporates both FX-LMS and FU-LMS algorithms, is used to optimise the SISO control system.

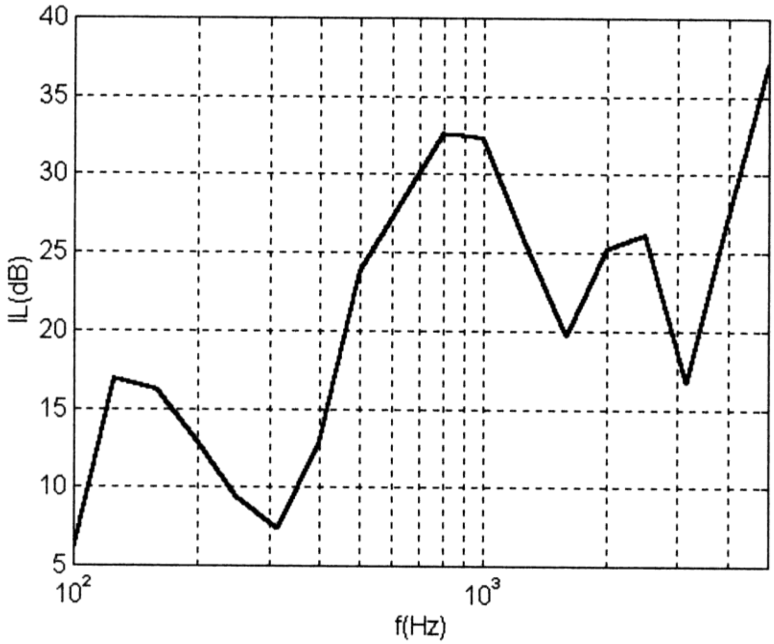

FIGURE 1. Insertion Loss of the passive enclosure

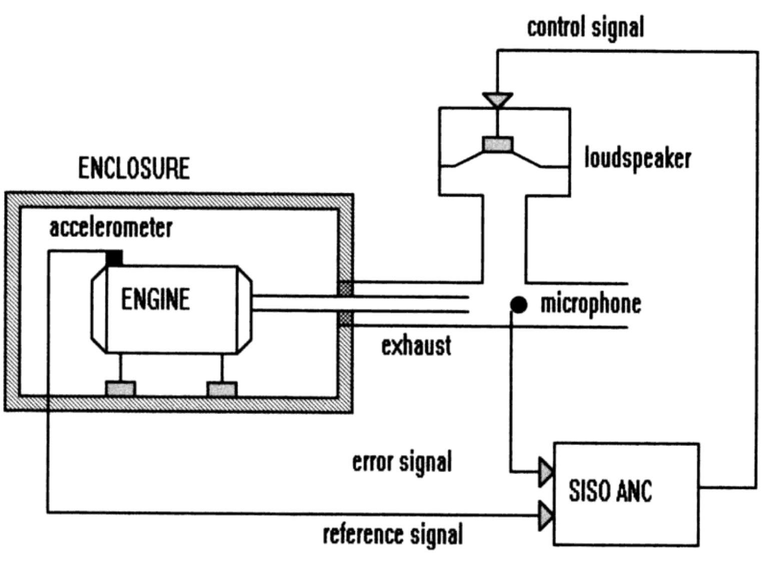

FIGURE 2. Setup of the passive/active control system

EXPERIMENTAL RESULTS

The ANC system was configured for maximum active noise attenuation. The best results were yielded by an IIR filter, with 80 direct and 50 recursive taps. Reference and error signals have been band-pass filtered between 40 and 400 Hz. Sampling rate and antialiasing frequencies were 2000 and 500 Hz, respectively. Figure 4 shows the averaged log-magnitude spectrum of the exhaust noise with the ANC system on and off. Most of the harmonics, in the frequency band (50, 500) Hz are attenuated. The fundamental frequency, N = 32.5 Hz, is out of the response frequency band of the loudspeaker. The maximum attenuation, 35 dB, occurs at the frequency 2N = 65 Hz. The 8N harmonic, at 260 Hz, drops 30 dB, while harmonics 3N and 4N, at frequencies 97.5 and 130 Hz, respectively, decrease both 25 dB.

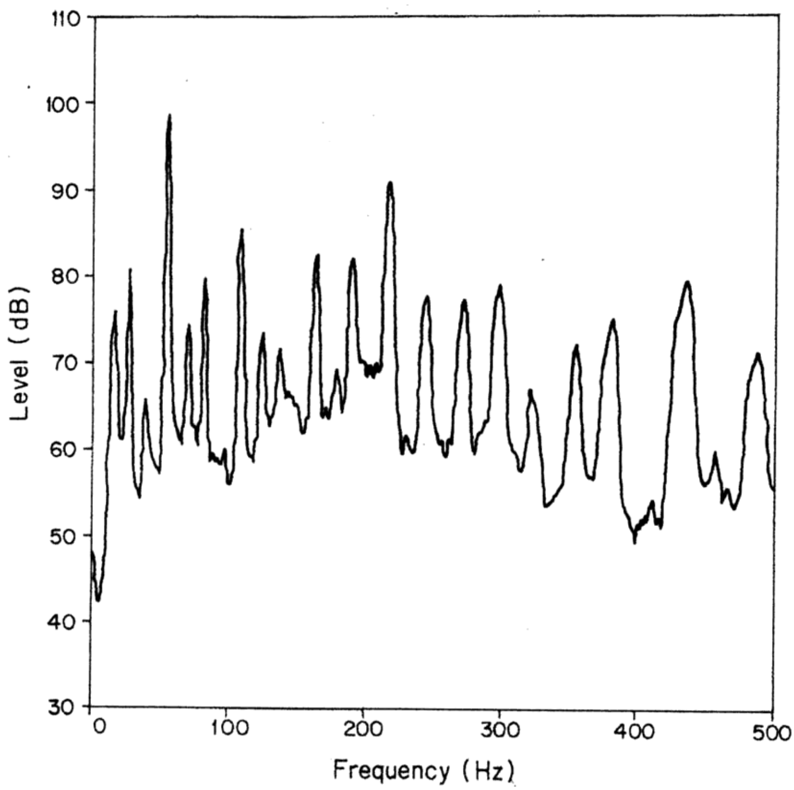

FIGURE 3. Reference signal supplied by an accelerometer over the air filter case of the generator

SUMMARY AND CONCLUSIONS

The aim of this work was to design and implement a hybrid passive/active control system to reduce the exhaust noise radiated by a small generator. Passive control is afforded by an enclosure which has been designed to provide high Insertion Loss. Special attention is paid to air refreshing and temperature control inside the enclosure. Low frequency noise escapes the enclosure through air intake and gas exhaust openings. An adaptive active control system was designed to reduce low frequency noise radiated through the exhaust. A vibration signal, picked up on the air filter case of the engine, has been used as reference. A SISO ANC system has been implemented, with a cheap electret microphone as error sensor and a high temperature loudspeaker as secondary source. Significant active noise cancellation is achieved in the frequency band (50, 500) Hz, especially at the second harmonic, where the spectral level has been reduced 35 dB.

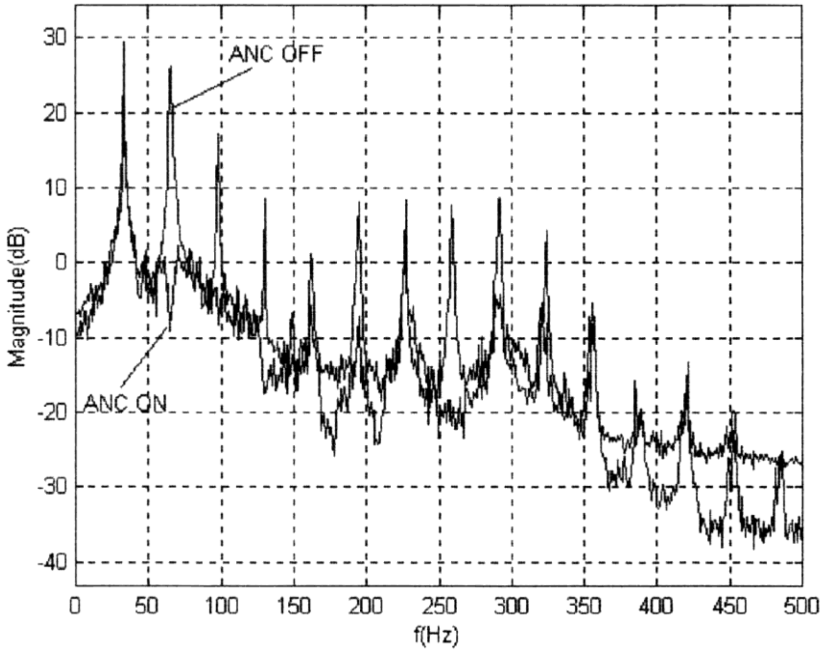

FIGURE 4. Averaged log-magnitude spectra of the exhaust noise with and without cancellation

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