Noise source identification on a horizontal vibrating screen

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Introduction

Since the beginning of the industrial era, coal has been the primary energy source for electricity generation in the United States (Energy Administration Information, 2008). Therefore, many efforts have been geared to improve the safety and health conditions in coal mines. Over the past 30 years, most illnesses and injuries related to coal mining have been significantly reduced, with the exception of noise-induced hearing loss (NIHL). Overexposure to high noise levels is evident along the entire production chain, from its extraction at the face to the preparation plants.

According to a cross-sectional survey conducted by the National Institute for Occupational Safety and Health (NIOSH), 43.5% of coal preparation plant employees are exposed to noise levels that exceed the permissible exposure level (PEL) (Bauer, 2008). Furthermore, this study identified the vibrating screen (VS) machines used to separate coal from refuse and water as the main noise contributors in these plants. In this context, NIOSH is conducting research to identify dominant noise sources in VS machines. This study will allow for the design of noise-control devices and improvements to be implemented on these machines in the interest of hearing loss prevention.

Previous measurements conducted at the PRL reverberation chamber show that 84% of the total A-weighted sound power is radiated by the VS in the 160 through 1,000 Hz 1/3-octave bands (Yantek et al., 2008).

Abstract

In an effort to decrease noise-induced hearing loss (NIHL) in coal preparation plant employees, the National Institute for Occupational Safety and Health (NIOSH) is conducting research to identify and control dominant noise sources in vibrating screen (VS) machines. To this end, acoustic measurements of the noise radiated by a dewatering VS were conducted at the Pittsburgh Research Laboratory (PRL) using microphone phased-array technology. These measurements allowed for the identification of the screen as the dominant source in the 250 Hz 1/3-octave band. The sidewalls are the major contributors in the 315 and 400 Hz bands, whereas the eccentric mechanisms and the electric motor are the dominant sources in the 800 and 1,000 Hz bands, respectively.

This paper presents the results of a study conducted by NIOSH in collaboration with the Acoustical and Vibrations Engineering Consultants Inc. (AVEC) to determine the most dominant noise sources on a VS machine at low frequencies, i.e., 250 to 1,000 Hz. To this end, phased-array measurements of the noise radiated by a dewatering VS were conducted in the hemi-anechoic chamber at PRL. A 121-channel, 3.5-m- (11.5-ft-) diameter microphone phased-array built by AVEC was used for the test. To provide the most complete data set for noise source identification, the array was mounted to a movable truss, so the noise radiated by the VS machine could be measured from multiple directions. Though a very large data set was generated, this paper presents only the most important results from the seven array positions tested.

Experimental setup

Acoustic measurements were performed in the hemi-anechoic chamber at PRL. This chamber is 16.8 m long by 10.1 m wide by 6.4 m high (55 x 33 x 21 ft). The walls and ceiling are treated with Eckel Supersoft Panels (Eckel Industries Inc., 2008), resulting in a chamber cut-off frequency of 100 Hz in accordance with ISO 3744.

The device under test was a dewatering horizontal VS machine. The machine consists of a structure that is suspended on coil springs. This structure is excited by two eccentric mechanisms driven by an electric motor through a belt/pulley system. Figure 1 (a) and (b) show the VS in the hemi-anechoic chamber. The excitation for the noise radiated by the screen body is mainly provided by the eccentric mechanisms and the gears used to drive them. Each eccentric mechanism uses two rotating unbalanced shafts that are supported on two bearings each. One shaft of the first eccentric mechanism is driven by an electric motor by a belt. This shaft is directly coupled to one of the shafts in the second eccentric mechanism. The second shaft in each eccentric mechanism is driven by the main shaft through a gear set.

The microphone phased-array used in these measurements was an AVEC 3.5-m- (11.5-ft-) diameter array. The array consisted of 121 microphones arranged in a star configuration. This array was used to collect data simultaneously and continuously for all 121 channels at a sampling frequency of 51.2 kHz. The data were processed

FIGURE 1

Vibration screen with the array in the (a) top/feed end position and (b) electric motor side position.

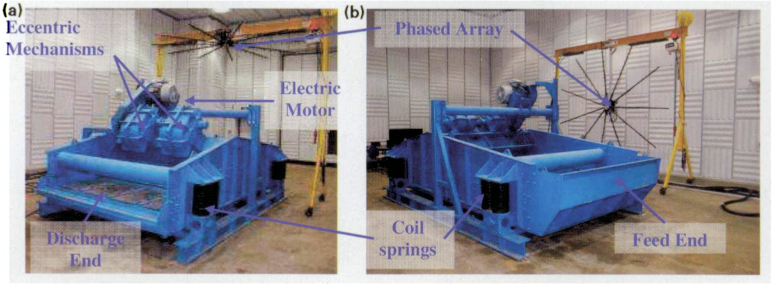
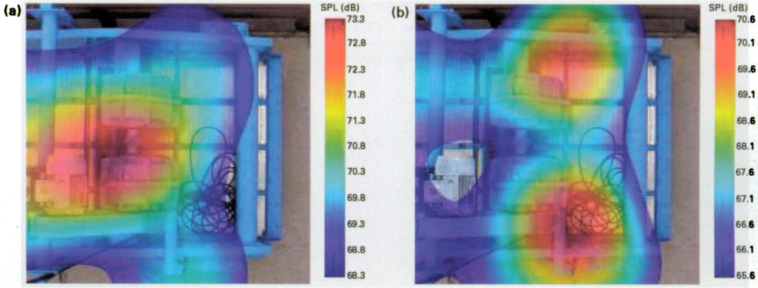


FIGURE 2

Acoustic maps at (a) 250 Hz and (b) 315 Hz. Plane at bottom of eccentric mechanisms.



using a frequency domain beamforming code (Avec Inc., 2008). Acoustic maps and integrated spectra in 1/3-octave bands were computed for each array position using conventional beamforming with diagonal removal of the covariance matrix (Mueller, 2002).

The sound radiated by the VS was measured from seven positions. These positions were chosen to give a complete picture of the noise characteristics of the machine. Three of the array positions were above the machine, as illustrated in Fig. 1 (a). These top positions are referred to as top/feed, top center and top/discharge. In these positions, the array was in a horizontal configuration. In addition, measurements were conducted from each side of the machine as shown in Fig. 1 (b). These four side positions are denoted as the electric motor, feed, discharge and eccentric side, respectively. In these positions, the array was in a vertical configuration.

Experimental results

Results were obtained in the form of acoustic maps in 1/3-octave bands. For all array positions, the scanning planes were parallel to the plane of the array. Multiple scanning planes were processed and they are indicated in the pictures to provide a good visualization of their locations. For brevity, only the results from three array positions are presented. To quantify the contribution from various components to the total radiated sound, the integrated sound pressure level (SPL) was computed from the acoustic maps. The integration was performed adding the levels of all the grid points inside the integration region and applying a normalization factor given by integration of the point spread function of the array in such region. The cutoff for the integration was set to 5 dB from the peak level in the integrated region (Mueller, 2002).

Array on top/discharge end position. Figures 2 and 3 are illustrative maps obtained with the array in this position. The acoustic maps show noise sources on the eccentric mechanisms, the side walls of the VS and the electric motor. At 250 Hz (Fig. 2 (a)), a source is present at the screen itself, whereas at 315 Hz (Fig. 2 (b)), two dominant sources are seen close to the side walls. These spots show larger levels, as the scanning plane is closer to the screen. At 800 Hz, the eccentrics are clearly the loudest sources (Fig. 3 (a)), while at 1,000 Hz a noise source can be readily identified on the electric motor (Fig. 3 (b)).

Array on electric motor side. Figure 4 (a) and (b) show sample beamforming maps for the 250 and 315 Hz 1/3-octave bands. From these maps, dominant noise sources can

FIGURE 3

(a) Acoustic map at 800 Hz with scanning plane below the eccentric mechanisms shaft; (b) acoustic map at 1,000 Hz with scanning plane at electric motor shaft.

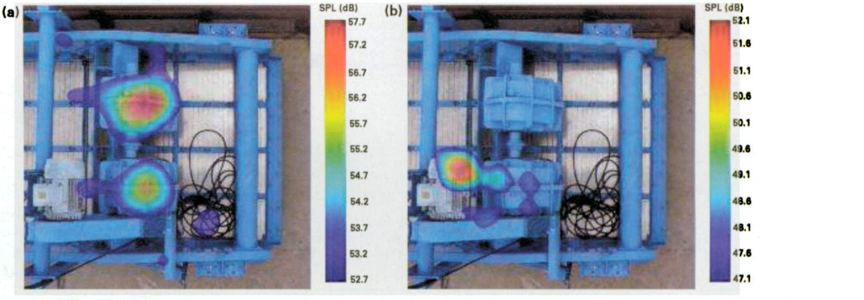
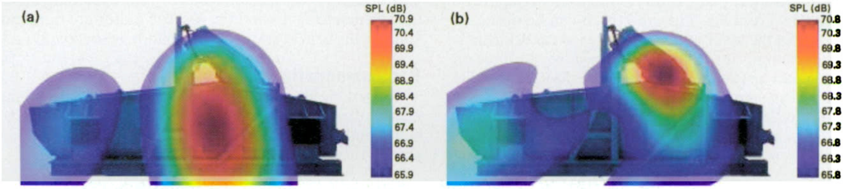


FIGURE 4

Acoustic maps at (a) 250 Hz and (b) 315 Hz. Scanning plane at machine side wall.



be observed at the wall of the VS, the eccentric mechanisms and the feed end. It should be considered that the current array position limits the capability of determining the sources positioned along the axis perpendicular to the array, i.e., poor depth resolution.

The integrated spectra for the four different regions shown in Fig. 5 were computed and are presented in Fig. 6. From Fig. 6, it can be seen that the side wall is the loudest source over most of the frequency range. Given that the sides of the machine are parallel to the array, it is expected that plate vibration would radiate directly towards the array and generate louder levels for this particular array position. Thus, with the array in the horizontal configuration (i.e., above the machine), the noise from this component should be less dominant.

The second highest source in Fig. 6 seems to be the eccentric mechanisms. Considering that the sides of the machine are "shielding" the propagation path from part of the eccentrics to most of the array microphones, the spectrum may not be very accurate, but it is still a very good estimate of what an operator located at the array position would be exposed to.

Another major source located with the array on the electric motor side is at the feed end. These sources could also be related to plate vibrations. From other array positions, it was determined that this noise source is not related to the suspension springs in the frequency range of interest, i.e., 250 to 1,000 Hz. Finally, the integrated spectrum over the electric motor indicates that the noise radiated from the side of the motor is about 8 to 10 dB less than the noise radiated by the side wall (loudest noise source) for most of the frequency range. Because these values are close to the signal-to-noise ratio (SNR) of the array, the integrated levels are due to sidelobes of louder sources at the same frequency. This is a clear indication that the electric motor does not significantly contribute to the side noise radiation below 1,000 Hz.

FIGURE 5

Integration regions. Array on electric motor side.

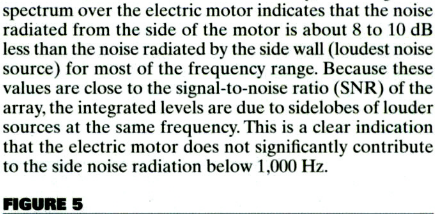
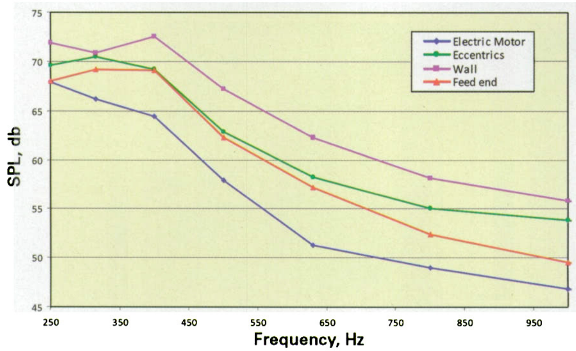


FIGURE 6

Integrated spectra. Array on electric motor side.



Array on discharge side position. This array position rendered the most useful results in terms of noise source identification. Figures 7 through 10 show the beamforming results for different planes and frequencies between 250 and 1,000 Hz. From Fig. 7 (a) and (b), it can be observed that at 250 Hz, the main source is the screen itself. Furthermore, the scanning at the discharge end shows a source on the screen and a reflection/source in the floor, suggesting that the vibration of the screen is exciting the cavity underneath the VS machine and, thus, radiating more noise in the direction of the array. Similar results were observed on the feed end. Figure 8 (a) and (b) shows that, at 400 Hz, the sidewalls of the machine are a major noise source, in particular the left wall (electric motor side). At 800 Hz, noise from the eccentrics and the electric motor are major sources (Fig. 9), whereas, at 1,000 Hz, noise from the electric motor is dominant (Fig. 10). These results are consistent with other array positions.

Conclusions

Noise source identification on a dewatering VS machine was performed by NIOSH at the Pittsburgh Research Lab. Measurements were conducted using an AVEC 3.5-m- (11.5-ft-) diameter, 121-microphone phased-array in a hemi-anechoic chamber. Data were collected from seven array positions over and around the VS machine. The main goal of these experiments was to identify the dominant noise sources at low frequencies, i.e., from 250 to 1,000 Hz. The results consisted of acoustic maps and integrated spectra over identified noise source regions in 1/3-octave bands. Sample results for the most representative array positions, frequencies and scanning planes were presented. Exhaustive analysis was performed to determine the dominant noise sources. Whenever possible, the integrated spectrum was analyzed in an effort to quantify the contribution from different sources.

The results show that, at 250 Hz, the main source is the screen itself, and the results show that the vibration of the screen is exciting the cavity underneath the VS machine, radiating noise towards the feed and discharge ends. It was also found that the sidewalls are the major contributors in the 315 and 400 Hz bands; whereas, the eccentric mechanisms and the electric motor are dominant sources in the 800 and 1,000 Hz bands, respectively.

Recommendations

Based on the results from this work, it is recommended that the following noise controls aimed at reducing the sound radiated by the various sources on the VS machine should be studied:

- to attenuate the sound radiated from the cavity below the screen, the cavity could be sealed at the edges with acoustic blankets;
- to reduce the radiation from the sidewalls, they can be treated using constrained layer damping or implementing weak radiating cells (Ross and Burdisso, 1998); and
- to attenuate the noise radiated from the eccentric mechanisms, they can be surrounded with an acoustic enclosure and the gear and/or bearing designs can be changed.

FIGURE 7

Acoustic maps at 250 Hz. Scanning planes at (a) eccentrics shaft and (b) discharge end.

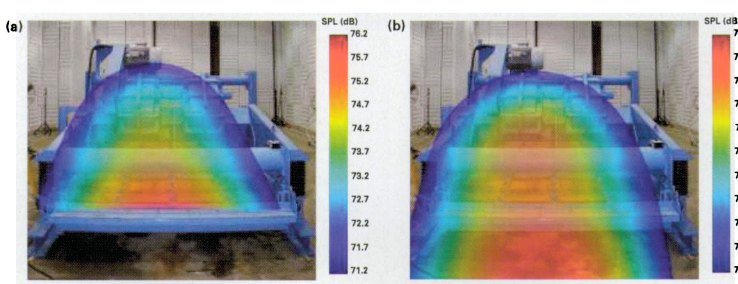


FIGURE 8

Acoustic maps at 400 Hz. Scanning planes at (a) eccentrics shaft and (b) discharge end.

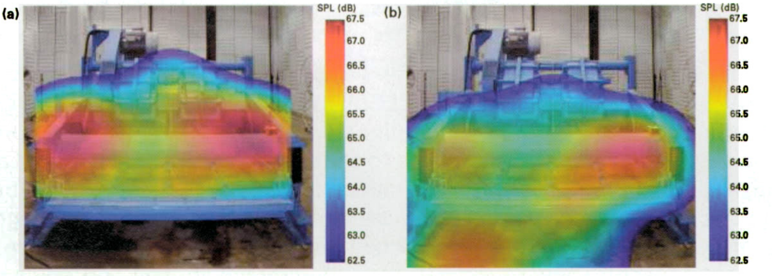


FIGURE 9

Acoustic map at 800 Hz. Scanning plane at eccentrics shaft.

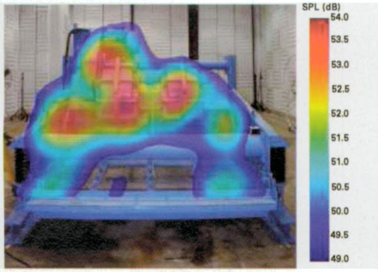
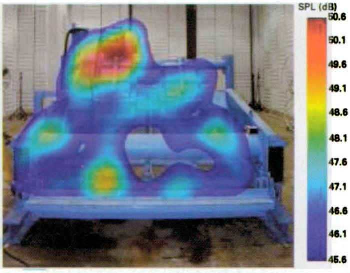


FIGURE 10

Acoustic map at 1,000 Hz. Scanning plane at electric motor shaft.



In addition, a mechanical filter could be designed to transmit the low-frequency force due to the rotation of the eccentric shafts at 15 Hz while filtering the higher frequency excitations due to bearing and gear forces. ■

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