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Controlling the quality of coal sifting by means of acoustical analysis and monitoring

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Abstract

In coal industry sifting is used to remove relatively small fractions (coal dust) from coals, commonly using vibrating screens. The perforated plate of the screen separates smaller coal particles (coal dust) from larger coal parts. Clogging of the screen perforations with coal dust reduces the effectiveness of the screen, resulting in an output of "dirty coals". In that case the input volume has to be reduced, which is contradictory with the desired highest possible efficiency (high input volume) for the screen without reducing the effectivity of the installation.

It appeared possible to detect whether the sifted coals are still dirty based on differences in the sound that is produced when the coals fall onto a coal pile. A system has been developed by which the quality of sifted coals can be determined by means of permanent sound monitoring. The ultimate goal is a system that automatically controls the quality of the sifted coals by means of sound measurement and analysis.

Keywords: sound monitoring, condition monitoring, process quality, coal processing.

1. Introduction

Vibrating screens are commonly used to remove relatively small fractions (coal dust) from coals in the coal industry. The screens work on the principle that coal moves over a perforated plate, allowing only the smaller coal particles (coal dust) to fall through the perforations and in that way are separated from larger coals. Larger coals are transported by a conveyor belt to the coal pile. When sifting wet coal or sifting with high volume, the perforations can get clogged with coal dust, reducing the effectiveness of the screen resulting in an output of "dirty coals". In that case the input volume has to be reduced. Logically the highest possible efficiency (high input volume) is desired for the screen without reducing the effectiveness of the installation.

A coal handling company has observed that it is possible to detect whether the sifted coals are still dirty based on differences in the sound that is produced when the coals fall from the conveyor belt onto the coal pile. Peutz was asked to develop a system by which the quality of sifted coals can be determined by means of permanent sound monitoring.

The ultimate goal is to determine the (continuously varying) optimal volume for the screen by analyzing the sound spectrum of falling coals at the end of the conveyor belt. When the detected sound spectrum indicates that coals are dirty, the system signals that the volume of the screen has to be (manually, or ultimately automatically) reduced. This sound analysis system has to deal with background noise, weather influences (wind, rain, frost), varying output speeds and varying height of the coal pile.

This paper describes the system and specific acoustical characteristics of the sound levels due to the coal sifting process.

2. System principles

The system that has been developed consists of a microphone, signal analysis unit, data processing unit and flashlight or control unit.

The sound pressure level at the chosen measurement location is continually measured. The microphone signal is amplified and fed into the analysis unit. Frequency dependent sound pressure levels are real-time determined by the analysis unit. Data processing consists of testing the sound characteristics to pre-set criteria and, when these criteria are not met (and therefore the coals are dirty), engaging the flashlight or control unit.

Two options are available for adjusting the vibrating screen volume when the systems detects dirty coals:
- A flash-light signals nearby employees, who then manually adjust the settings of the vibrating screen (reduce input volume). This set-up is especially useful during the test phase, enabling the fine-tuning of the response criteria of the data processing unit.
- Direct intervention on the screen's control unit. In this case the measurement system is integrated in the screen vibration control unit.

3. Hard- and software

3.1. Microphone selection and accesoires

The measurement system has to be located in the open in the coal handling area and therefore has to withstand weather influences and coal dust. Conventional permanent sound measurement systems for outdoor use are equipped with a microphone that itself can not withstand rain. These systems are therefore equipped with a wind screen with integrated rain cap. However in the current case coal dust would accumulate in the pores of the wind screen, possibly influencing the sound transmission through the wind screen. For use in coal handling therefore a water, wind, frost and dust resistant microphone is used, placed unprotected in the open air. Because of the downward positioning of the microphone (see figure 1), accumulation of dust on the microphone membrane is prevented.


Figure 1: Microphone positioning

3.2. Signal processing

Real-time analysis of the microphone signal and data processing is executed by a conventional netbook with sound card. The analysis software has been developed by Peutz for sound measurement purposes in general. The data processing software has been developed by Peutz especially for this product.

For convenience sake and to minimize cable lengths the netbook, sound card, battery and flash light are integrated in one water proof and dust proof casing, connected to the microphone and a power supply.

4. Microphone location

In this situation the equipment is placed on top of the conveyor belt in order to prevent it being hit by machinery (shovel) and to provide a power supply to the microphone (see figure 2). The distance between the microphone and the point of coal impact (top of coal pile) varies from 0,5 to 4 meters.

Figure 2: Microphone and measurement system location on top of conveyor belt

5. Signal testing criteria

5.1. Production circumstances

The discriminant(s) that are to be used as process control criteria should be useful for all possible process conditions. The following local circumstances are variables that have been taken into account:

- The coals fall onto a pile which builds up from the ground (4 m below the end of the conveyor belt) to a height of approximately 3,5 m. The distance between the falling coals and the microphone (placed at the top of the conveyor belt) therefore varies with the height of the coal pile.
- The volume of the coals falling from the conveyor belt onto the pile is related to the speed (in- and output volume) of the vibrating screen. With increasing screen input volume, the volume output and conveyor belt speed increases.
- The size of the coals is variable. The same small fraction (dust) is removed from the coals, the size of the remaining screened coals is variable. This might influence the acoustical characteristics.
- The humidity of the coals is variable. After a period of drought the coals are relatively dry, but in a rainy period the coals are moist. Moist coals tend to clog the vibration screen faster than dry coals, so the humidity also influences the effectiveness of the screen.

On behalf of this study sound measurements have been executed. During these measurements the aforementioned variables have been varied in order to get an accurate insight into the influence of these variables on the sound signal. The measurement signals have been stored and studied afterwards using sound analysis software.

5.2. Interference noise

The coal handling company for which the research has been executed is located in a major harbour. At the site, foreground interference noise is caused by the machinery that are present there, such as power shovels, cranes and the vibrating screen. Furthermore there is environmental noise caused by airplanes, surrounding industries and ships.

In choosing the discriminant and testing criteria, the occurrence of interference noise has been taken into account.

5.3. Chosen test criterion

After studying the results of aforementioned sound measurements, it is concluded that the signals of falling dirty and clean coals can best be discriminated on basis of spectra. A difference in the spectra for both situations can be seen for all process circumstances described; see for instance figure 3. The influence of interference noise as described in paragraph 5.2 on the signal occur mostly at low and middle frequencies. In the high frequency range (3 to 10 kHz) these interference noises are negligible compared to the signal due to falling coal, which makes this frequency region suitable for this monitoring system.

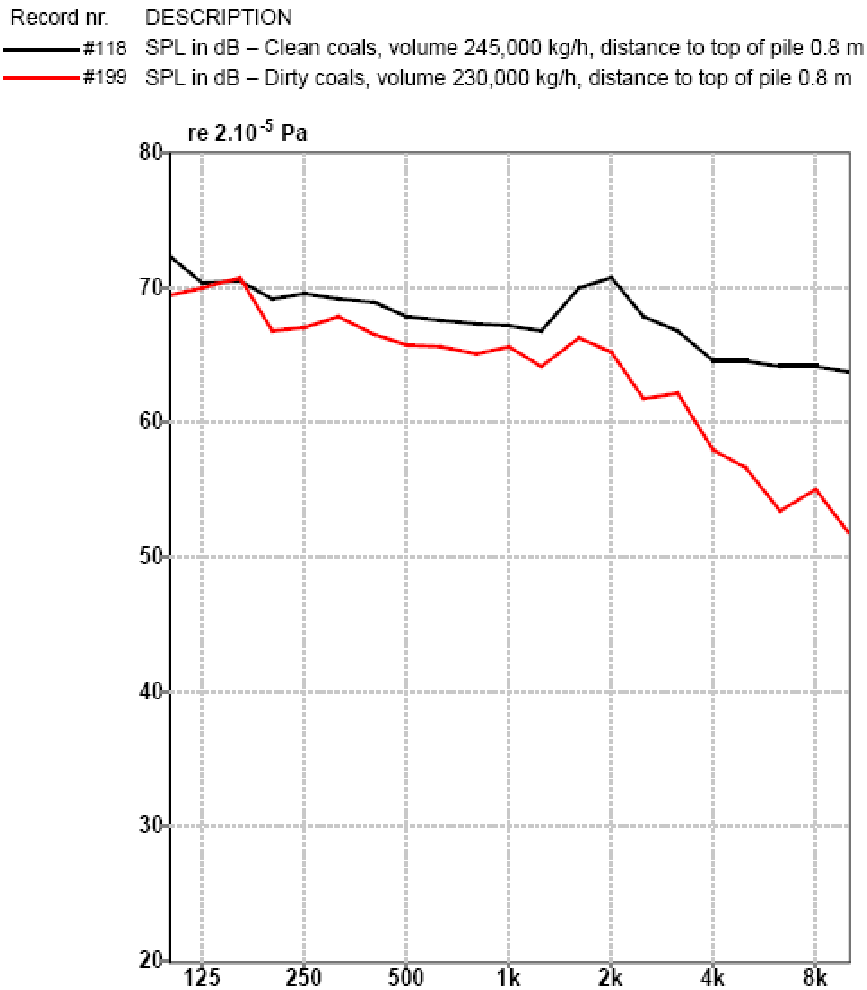

Figure 3: Clean and dirty coals sound spectra comparison

Other studied possible criteria (e.g. the absolute SPL or the difference between the SPL_{max} and SPL_{min}) have proved not to be applicable because they were too strongly dependent on pile height and/or output volume.

6. Testing

6.1. Phase 1

The measurement system has been tested for several days at the actual location during normal operating conditions. During this test, the response of the measurement system has been registered (dirty or clean), as well as the judgement by an employee of the coal handling company based on visual observations.
Comparison of the system response with human observations resulted in the following conclusions:
- At low coal pile heights (0 to 1,5 m) 43% of the dirty coal situations reported by the system where false, 0% of the dirty coal situations where missed by the system.
- At high coal pile heights (2 to 4 m) 5% of the dirty coal situations reported by the system where false, 40% of the dirty coal situations where missed by the system.
- In total, the accuracy of the measurement system was 74%.

After analysis of the signals from false dirty coal reports it appeared that this was caused by a low SPL when the falling coals were at a greater distance from the microphone (low coal pile). In this situation the background noise is dominant for the SPL measured, which leads to a false report of dirty coals. To prevent these incorrect reports a lower limit in SPL has been set preventing the system to give a dirty coal report. This alteration results in approximately one minute response time of the measurement system at low pile height, because the system responds after the coal pile has built up to approximately 1,5 metres. Furthermore the test criteria have been fine-tuned based on the measurement results (alteration of sound spectrum response criteria).

After some weeks of testing a microphone malfunction occurred. This malfunctioning is believed to have been caused by water penetrating the microphone and causing a short-circuit in the membrane condenser. The malfunction occurred during frost (-10 °C), although this temperature is within the operating range specified by the microphone manufacturer.

To prevent this malfunction occurring again, the microphone casing has been altered. A rain cap has been used to prevent (minimize) raindrops running down the microphone housing and ending up hanging (and freezing) under the microphone membrane. Furthermore the microphone is now electrically heated by a heat strip inside the microphone housing.

6.2. Phase 2

The second test phase has been started in April 2010. The results of this test should show a significant improvement of the measurement system accuracy (90 to 100%). In this situation the system should be ready for daily use in the specific studied situation. After evaluation the coal handling company will decide whether the accuracy is sufficient to directly control the input volume of the vibrating screen without human intervention.

7. Conclusions

From this study it appears that with the sound measurement and control system that has been developed it is possible to discriminate between two process situation regarding the sifting of coals. The system can be applied in any process where a difference in product characteristics (quality, weight, etcetera) causes a difference in the sound emission spectrum at some point during product handling.

With this system it is possible to realize an in-line system that can test these characteristics by means of sound measurements and (directly or indirectly) intervene in the process that is to be monitored.