PRECIPITATION OF MINING INDUSTRY DUST WITH HIGH POWER ULTRASOUND

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Abstract

The effect of high-power ultrasound in the precipitation of aerosol from underground mining facilities is being investigated. A previous study was conducted about the environment inside an underground mine. Powder samples gathered inside the facility were taken to reproduce the mine aerosol in laboratory. Acoustic precipitation experiments of those aerosols were carried out. The influence of the wave amplitude and the humidity in the agglomeration in an acoustic precipitation chamber is being studied. The results show that there is maximum amplitude that optimises the process; beyond this maximum level the results are reversed and the agglomeration drops. In general, the experiments show that acoustic filters could be a good alternative to improve the air conditions inside the mine.

Introduction

The removal from air of particles generated in an underground mine is a very important issue. The suspended particles in the mining air make necessary the use of expensive and uncomfortable devices for the workers and produce a considerable damage in the equipment. Because underground facilities have several limitations in critical aspects such as space, available electric power and harsh environment, the removal process is more difficult. For these reasons, sustained research in this field is necessary. After the illuminating research work conducted by professor Gallego-Juárez and its collaborators on acoustic precipitation [1], it seems clear that these devices are one of the leading alternatives to treat the challenging problem described above. In this paper we present a study about the effect of high-power ultrasound in the precipitation of aerosol from underground mining facilities. Batch experiments of ultrasonic precipitation of aerosol particles under different conditions were conducted. To carry out the experimental work, powder samples collected inside the mine were taken to reproduce in the laboratory an aerosol similar in particle size distribution to the mining air. The findings in this experimental work can be useful to design optimised devices to be used as acoustic filters with very interesting properties: low loading effect on the ducts, high efficiency to catch tiny particles and low spend of energy.

Materials and Methods

The experiments were done in an acoustic cylindrical chamber 220 mm diameter and 400 mm in effective length. The chamber was equipped with special inlets to introduce the aerosol and a water spray to control the ambient humidity.
The emitter it is a stepped plate transducer [2] made with titanium 200 mm diameter producing high intensity acoustic field at 20 kHz. The electronic system to drive the stepped plate has a special feed back circuit to keep the emission at constant and high efficiency level [3]. Because inside the chamber a standing wave field it is established, the relevant magnitude is the acoustic pressure in the different points in the chamber. To measuring the acoustic field special probes supporting high intensity radiation were used [4].
In the middle of the chamber a special device that consisting of a luminous source and a photodiode detector allows the measurement of powder concentration using the Beer-Lambert law. Electronic systems were designed to keep the emission power and the detector sensitivity stabilised. The system reads the attenuation of light every three seconds and the data were collected and recorded in a computer hard disk. To control the humidity a special compressor nebulizer system producing a spray with a particle size range from 0.5 to 5 µm. With this device the humidity inside the chamber it is controlled to have high moist content (60 % relative humidity) or low moist content (40% relative humidity). The experiments were done introducing the same amount of particles inside the chamber and making precipitation experiments with different intensity acoustic fields in the chamber.
The experimental set up it is shown in a block diagram shown in the figure 1. The precipitation of aerosols are measured with the classic transmission light method, after each experimental run an amount of air it is extracted from the chamber through a nucleopore filter, afterwards with a precision balance the concentration inside the chamber is established.
To have a more complete picture of the radiation level inside the chamber three measuring points were disposed (Fig. 1). The origin 0 is the top of stepped plate, the positions 1, 2, 3 are at 76, 181.2, and 282 mm from the position 0 respectively. Sweeps with the

probe were done measuring of the radial acoustic pressure distribution; this could be used to evaluate the whole energy content for each experimental situation.

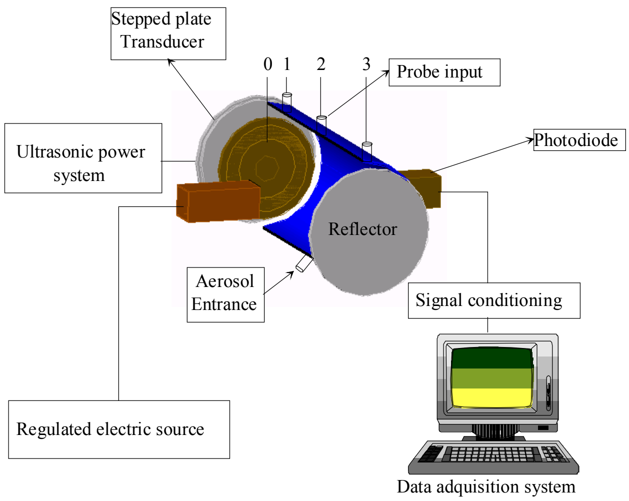

Fig. 1. Block diagram of experimental set up.

Results

Radial sweeping measuring of the acoustic pressure was done; this could be used to evaluate the energy content for each situation. In the figure 2 the result of the sweeping of acoustic field for position 2 is presented, to avoid the excessive space consumption the selected power was 35 W. Because acoustic saturation the acoustic field for other powers are very similar. The effects of ultrasound in the agglomeration confirm this fact.
It is easily seen that because its special design the acoustic field is very high even with applied electric power as low as 35 W, it is to be noted that with 10 W of applied power the acoustic level descend only about 5 dB for all positions and frequencies. These characteristics are confirmed for the axial sweep of acoustic field realised with a 250 mm in length probe that allows to reach the chamber centre from a little hole in the centre of the back reflector. The acoustic pressure level it is presented in the figure 3 for an applied power of 35 W.
Two examples of particle size distribution can be seen in figure 4. To measure the particle size distribution inside the mine a LASER particle counter was used. The size distribution of collected powder was done using a laboratory LASER diffraction analyser. This instrument measuring size distribution in a solution and it was necessary to solve samples of collected powder in alcohol. Because it is very difficult to handle ultra fine particles, with the collected powder was almost impossible to make the same size distribution that we find in the mine experiments that we have been conducted. This fact is not too difficult to handle because the interesting thing is to have a size distribution similar to real one.

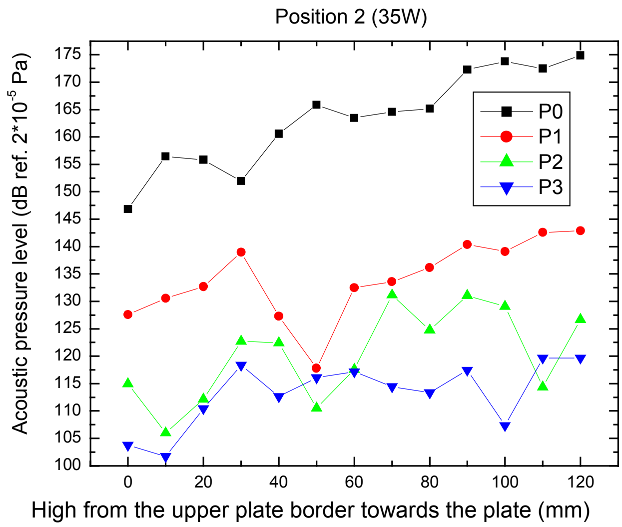

Fig. 2. Acoustic field inside the treatment chamber.

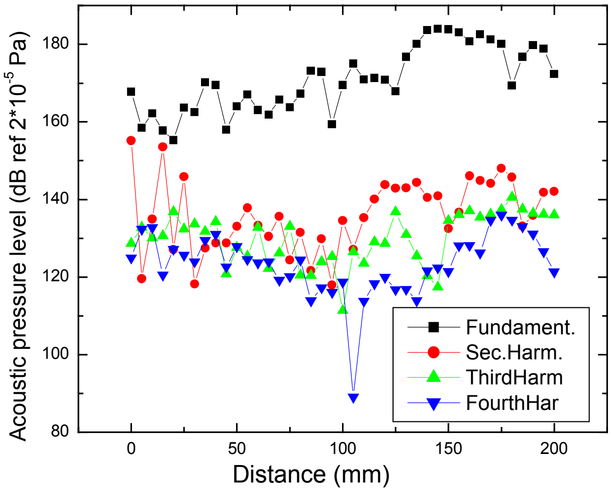

Fig.3. Axial sweep measurement, applied power 35W.

To look for the different effects that can be present in the interaction acoustic field-aerosol it is enough to use a distribution of particles with similar size. In our case the available particles for the experiment have a distribution that is like those present in the air of the mine but shifted in a range of size to the right as it is shown in the figure 4.
In a first experiment an aerosol produced injecting 1 gram of collected powder was made, this test has five steps: under the same humidity conditions it was applied different powers, each power produce a acoustic field as it shown in the figure 2. Also precipitation experiments were done without acoustic field. All the experiments were monitored with the light transmission method. After each experimental run, air was pumped from the chamber during 1

minute. The volume of air collected is 10 m^3 in normal conditions, the values of final concentration after 21 minutes of treatment is shown in the figure 5.

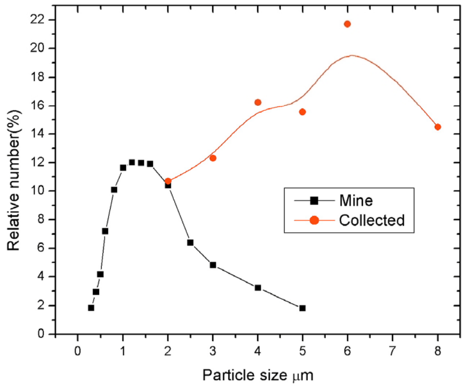

Fig. 4. Particle size distribution.

The effect of ultrasonic treatment it is very clear in figure 5.The most impressive characteristic is the reaching of a plateau in the transparency curve very soon in the case of ultrasonic treatment. However when the ultrasonic field is not applied (curve WF in the figure) the plateau in the transmission curves is not reached even after several hours.
It seems that for the case shown in Fig.5, the application of power beyond 35 W does not improve the ultrasonic effect in the precipitation; this could be because the saturation phenomena make difficult to increase the acoustic field level after a relatively well defined value [5]. This seems to be the reason why the acoustic pressure level dependence from the applied power presents a tendency to saturation, as shown in the table I. However, when the applied power is increased up to 70 W, the minimum of the acoustic field has been raised. It is not a contradiction; it is simply that for those field values the saturation level are not reached yet.
We have complete data about the applied power and the acoustic field inside the chamber, but to avoid an excessive consumption of space we present only summary of them in the table I.
In table I it is easy to appreciate that it is very difficult to increase the acoustic pressure level beyond 170 dB. The physical mechanisms that govern this saturation effect are not clear yet, but the saturation in standing waves, even for one-dimensional waves, were reported since from several decades ago [7].
It is to be noted that the diminution in the intensity of fundamental amplitude for high-applied acoustic powers was attributed, for progressive waves, to a acoustic wind effect. Such a effect was a consequence of radiation pressure [5].

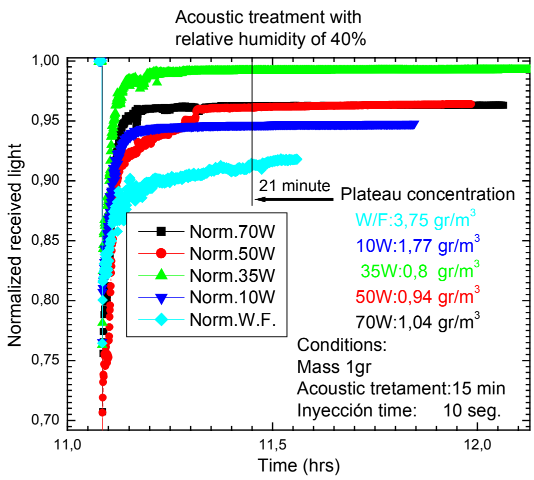

Fig. 5. Precipitation experiments.

TABLE I. Applied power vs acoustic pressure level. Position 1, Fundamental, dB ref $2*10^{-5}$ Pa.

Power (W)	10	35	50	70
APL (dB)	163.7	162	170.5	170.2

It is interesting to note that the same tendencies to saturation are produced for the higher harmonic [7]. The harmonic content inside the chamber is high and according some precedent observations at least the second harmonic level could be enough to produce aerosol coagulation [6]. To illustrate this concept the data for the second harmonic it is presented in table II.

TABLE II. Applied power vs. acoustic pressure level. Position 1, 2° Harmonic, dB ref. $2*10^{-5}$ Pa.

Power (W)	10	35	50	70
APL (dB)	130.3	135.5	137.2	145.3

In the case of second harmonic for the radiation inside the chamber the saturation level is not reached at 145 dB, but it is a value higher enough to produce interesting phenomena inside the chamber.
Looking at influence of humidity in the phenomena studied a new set of experiments were done, the results are rather surprising but it seems very interesting. The precipitation curves for 60% humidity are presented in figure 6.
The precipitation experiments for a relative humidity of 60% are very interesting; the humidity was reached injecting an aerosol made with a compressor nebulizer system producing distilled water drops in a size range between 0.5 to 5 microns.

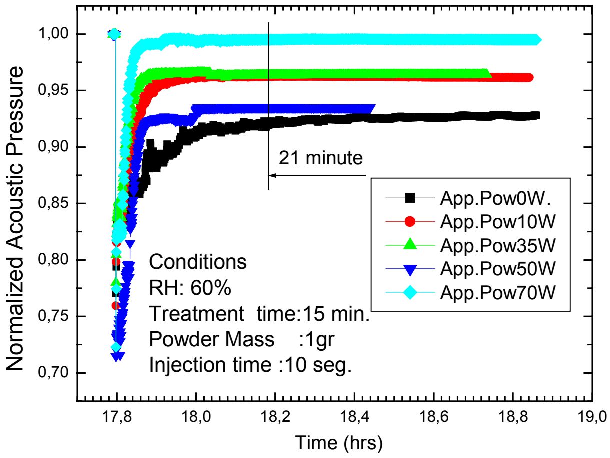

Fig. 6. Precipitation experiments.

It is interesting to note that these are the same size ranges that there are present in the aerosol. It is to be noted that the injection of the aerosol produces some effect in the light detection system. The received light is increased just at the introduction of the aerosol. This can be produced by light scattering from the little water drops almost in the proximity of the detector. But more interesting is to note that in this case, when the applied power is 70 W the results are better than for an applied power of 35 W. The reason for this behaviour are not clear yet but some hypothesis will be suggested in the discussion. Even with saturation problems the acoustic field for an applied power of 70 W is about 3 dB higher than the produced for an applied power of 35 W, see figure7.

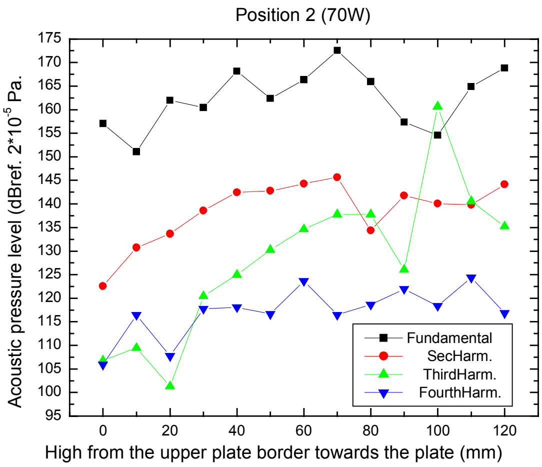

Fig. 7. Acoustic field level, applied power 70 W.

Discussion

The data analysis shows very good results because the air inside the treatment chamber is much cleaner when the acoustic treatment is realised. In fact, the concentrations measured with the nucleopore filter and those measured with the LASER analyser coincide. For instance the ambient aerosol concentration measured is 0.005 mg/m^3 and in the chamber treatment is approximately 1 mg/m^3 with acoustic treatment versus 3.7 mg/m^3 when the deposition is natural.

On other hand, the results show that when water is added as tiny drops (relative humidity of 60%) a better precipitation curve is obtained for an applied power of 70 W. In this case the final value of precipitation reaches a level that it is very similar to the clean air, about of 0.005 mg/m^3. With the described experimental set up is not possible to determine the reason of that behaviour. For this reason, this fact will be consigned as an interesting experimental fact that will be studied ahead. Especially it is very interesting to establish if the new interaction is particle-water drop or it is a superficial phenomena produced because it become humidified.

Conclusions

An experiment was done about the ultrasonic precipitation of mining particles.

A very good precipitation rate is obtained if the acoustic field exceeds 150 dB.

The process is improved substantially if tiny water drops are added to the mining air.

The acoustic filter could be a very good alternative to improve the mining air.

It seems that the main ultrasonic effect present in our case is the orthokinetics.

More research work must be done in order to know better the phenomena and to optimise the process.

References

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