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Effects of atomization parameters of dust removal nozzles on the de-dusting results for different dust sources

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ABSTRACT

In order to obtain appropriate spray pressure and enhance the spraying and dust removal efficiency, various factors including the dust characteristics, nozzle spraying angle, effective spraying range, water consumption and droplet size are taken into account. The dust characteristics from different mines and atomization parameters of different pressure nozzles were measured. It was found that the internal pressure of coal cutters and roadheaders should be kept at 2 MPa, which could ensure large droplet size, large spraying angle and low water consumption and hence realizing a large-area covering and capture for large particle dusts. However, the external spray pressure should be kept at 4 MPa for smaller droplet size and longer effective spraying range, leading to effective dust removal in the operator zone. The spray pressure of support moving, drawing opening, and stage loader on a fully mechanized caving face and stage loader on a fully mechanized driving face should be kept at 8 MPa, under which the nozzles have long effective spraying range, high water flow and small droplet size for the rapid capture of instantaneous, high-concentration and small size dust groups. From the applications on the caving and driving faces in the coal mines, it is indicated that the optimization of spray pressure in different spraying positions could effectively enhance dust removal efficiency. Selecting appropriate nozzles according to the dust characteristics at different positions is also favorable for dust removal efficiency. With the selected nozzles under optimal pressures, the removal rates of both total dust and respirable dust could reach over 70%, showing a significant de-dusting effect.

1. Introduction

As the most widely used method for mine dust control, spraying de-dusting is a very effective technique. The appropriate spray pressure is quite crucial to the dust removal effect. In many related studies, high-pressure spraying was once thought to have a higher dust removal efficiency than low-pressure spraying. But in fact, industrial applications show that the dust removal effect of high-pressure spraying only made a little improvement and was far from theoretical results. Meanwhile, high-pressure spraying can lead to high water consumption as well as serious environmental pollution in the workplace [1–3]. Therefore, currently, the spray pressure is still determined by practical experience. This paper argues that the appropriate spray pressure needs to be determined according to the practical conditions in the mine production field, taking into account the relationships of atomization parameters with many factors such as nozzle spraying angle, effective spraying range, water consumption and droplet size. In the present work, the dust characteristics from different mine production sites and the atomization parameters of 6 types of pressure nozzles at different pressures were measured by experiments. On this basis, the atomization parameters such as nozzle spraying angle, effective spraying range, water consumption and droplet size were comprehensively considered. Spray pressure optimization was made according to the dust characteristics in various positions for internal and external spraying by coal cutters and roadheaders, coal caving, support moving, crushing, stage loader, return airway of the caving face and stage loader of the driving face. Combined with the dust-droplet coupling mechanism, the paper also provides the basis for the selection of nozzle types and further improves the spraying dust removal theory.

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2. Measurement of dust characteristics of mine production areas

2.1. Experimental system

The particle sizes of dusts from ten representative caving and driving faces of mine production areas in China were measured using a microscopic particle image analyzer (Winner99, produced by Jinan Winner Instrument Co., Ltd.) and then the dust characteristics were obtained. The microscopic particle image analyzer mainly consists of three parts: a trinocular microscope, a CCD image acquisition system and a computer software processing system. The membrane smear test was employed in the experiment in order to acquire the particle information. The acquired data were processed by computer image analysis technology so as to get the dust particle size.

2.2. Selection of dust sampling positions

Filter membrane sampling was employed for dust sampling with an AKFC-92A mine dust sampling machine and a 40 mm-diameter organic filter membrane. The sampling air flow was controlled at 20 L/min and the sampling period was 5 min. Dust sampling on the caving face was carried out at the following seven positions: shearer drum, shearer operator zone, support moving zone, drawing opening, crusher, stage loader and return airway, and dust sampling on the fully mechanized driving face was conducted at the following 5 positions: cutting head of the roadheader, roadheader operator zone, stage loader and two positions 100 m and 200 m away from the driving head, respectively.

2.3. Analysis of experimental results

A sample is actually the group of particles collected from a dust sampler at a specific position in a 5 min period. The particle size of the group reflects the particle size at the sampling position. Therefore, to analyze the experiment results, the weighted average diameter of the dust particles in the whole group (denoted as X_{SV}) was selected as being representative of the dust particle size and the calculation formula is $X_{SV} = \sum N_i d_i^3 / \sum N_i d_i^2$, where d_i is the average diameter, and N_i is the number of particles for diameter d_i Figs. 1 and 2 display the dust particle size in different positions on the fully mechanized caving face and driving face, respectively.

It was found from the measurement results that, at different positions in the coal mine, different dust particle sizes are present. For the fully mechanized caving face, the dust particle sizes could be arranged in descending order as: shearer drum > shearer operator zone > drawing opening > support moving zone > crusher > stage loader > return airway; for the driving face, the order is: cutting head of the roadheader > roadheader operator zone > stage loader > 100 m away from the driving head > 200 m away from the driving head.

3. Classification of mine-use spraying nozzles

At present, the mine-use spraying nozzle can be divided into six types according to their working principles: pressure nozzle, rotary nozzle, pneumatic nozzle, electrostatic nozzle, vibration nozzle and ultrasonic nozzle [4,5], among which the pressure nozzle is widely applied in industry. According to the spray shape, the pressure nozzle can be further divided into fan nozzle, beam-shaped nozzle, solid cone nozzle and hollow cone nozzle. By considering the spraying pattern, the pressure nozzle can be classified into the following types: mixing nozzle containing a spiral groove and diversion core, vortex centrifugal mixing nozzle, tangential centrifugal mixing nozzle, external spiral groove nozzle, X-shaped core diversion mixing nozzle, lateral diversion-hole centrifugal nozzle, etc. All nozzles have their own advantages and disadvantages and exhibit different atomization parameters under various spray pressures [6–9]. Currently, there is no reasonable standard or theoretical basis for the selection of spraying nozzles, resulting in the misuse of nozzles and poor efficiency in dust removal. Therefore, research on the atomization parameters of nozzles under different pressures is needed in order to provide a theoretical guidance for the selection of nozzle types and spray pressures for dust removal in mines.

4. Experimental study on atomization parameters

For the six types of pressure spraying nozzle mentioned above, the relationships of their spray pressure with the nozzle spraying angle, effective spraying range, water consumption and droplet size were determined by experimental method in order to explore the spraying characteristics of pressure nozzles and provide a theoretical guidance for the selection of nozzle types and spray pressure for mine dust removal. The six types of spraying nozzle used in the experiment are listed in Table 1.

4.1. Experimental study on the atomization parameters of nozzles

4.1.1. Experimental system

The experimental device consists of a water tank (shown in Fig. 3), a high-pressure plunger pump (shown in Fig. 3), and a SGC-type bifunctional high-pressure water meter (shown in Fig. 4). The pressure of the plunger pump is continuously adjustable in the range of 0–28 MPa. The water is delivered to the nozzle through a high-pressure rubber hose via the SGC-type bifunctional

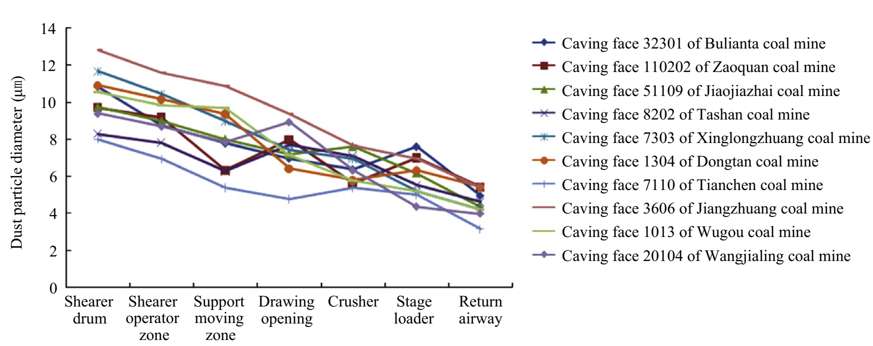

Fig. 1. Measurement results of dust particle diameter for different positions of fully mechanized caving face.