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Property experiments on the foam generator and its influencing factors during down-the-hole drilling

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ABSTRACT

The present study developed a suitable foam dust-remove device for down-the-hole (DTH) drilling in open-pit mines and researched its foaming properties to solve the resulting serious dust pollution. We researched the foam dust removal mechanism and two-phase foaming principle to improve the disadvantages of traditional dust removal technology such as poor effects, big air consumption and water intake difficulties. We obtained the main factors that influence the foaming performance and optimum working point of the foam generator based on performance tests on the foam flow, foaming multiple, and half-life period of the foam generator. Based on the experimental results, the gas flow rate, liquid flow rate (gas–liquid ratio), foaming net, and foaming agent concentration were deemed the four main factors that affected the foaming performance of the foam generator. The following working conditions were operated: (1) foam net 1; (2) A 1.5% concentration of the formulation 2; (3) gas pressure of 0.7 MPa; (4) liquid flow rate of 18 L/min; (5) gas flow rate of 30 m^3/h. Based on these conditions, the foam generator achieved its best performance with a foam flow rate of 515 L/min, foaming multiple of 22, and half-life of 65 min. The average dust removal rate throughout the field test was as high as 90% using foam dedusting in stope.

1. Introduction

Open-pit coal production and its many sectors such as surface peeling, drilling, blasting, loading shovel transport, and rowing of soil create a large amount of dust. The open-pit mining process and its drilling operations are directly related to the quality and accuracy of the succeeding blasting process and are the main dust source in open-pit mines. Medium and deep hole blasting technology has recently exhibited rapid development and wider use so that down-the-hole (DTH) drills generate more prominent hazards in the drilling process. These technologies pose a serious threat to both the health of workers and the adjacent mining environment, thereby causing strong public dissatisfaction for open-pit mines.

Dry dust collecting and wet rock drilling are suitable dust removal facilities for DTH drilling. The dry dust collector employs a high-pressure air motor fan that requires costs a large amount of wind pressure and affects the DTH drill efficiency (Cunningham and Dopkin, 1974; Kumar et al. 2005; Kumar et al., 2007). The collector has a very small dust removal capacity, which hinders effective dust removal. Conversely, wet rock drilling in open-pit mines also presents many disadvantages such as high water consumption, high level work points, water intake difficulties, and water or ballast removal difficulties after construction (Cui and Wang, 2004). Thus, it is essential to apply a new technology or equipment to effectively control the dust diffusion from the DTH drill, and simultaneously avoid the problems existing in the application of dry dust collectors and wet drilling equipment. Foam dust removal is a new technology that fully mixes a proportion of air, water, and a foaming agent in a foam generator to produce a large amount of foam aimed at a dust source or dust in the air to then moisten and control dust. Apart from its excellent ability of wetting, adhering and encompassing dust particles, it also has advantages involving small water consumption and high removal efficiency of both respirable dust and total dust.

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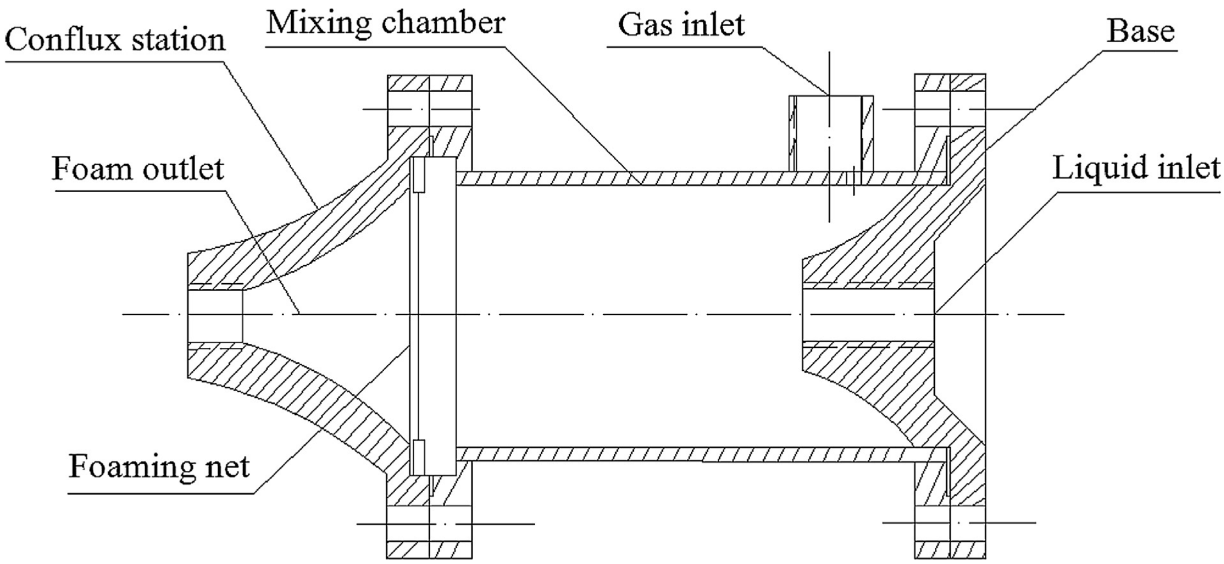

Fig. 1 – Assembly diagram of the foam generator.

In the 1950s, research on foam dust removal began in the UK, which then adopted the method of adding a small amount of surfactant to reduce the surface tension of water, thus achieving the effect of dust removal (Takashima, 1952). In the 1960s and 1970s, researchers in the former Soviet Union explored dust control and its anionic surfactant distribution to develop a type of mechanical foam machine that was applied to actual fields and exhibited a 2- to 5-fold dust removal coefficient improvement compared to other dust removal measures (Anon, 1971). In the 1980s, the United States Bureau of Mines developed a compressed air foam dust removal machine that transported a mixture of compressed air, surfactant, and water in a metal net. A small foam was sprayed into dust producers through a catheter. This is advantageous as it decreases water consumption by four fifths compared to spraying dust removal, though the method is very expensive (Zimon, 1982; Steven and Volkwein, 1986; Parrett, 1986). At the same time, Japanese scientists improved the size parameters and installation techniques of the net foam dust separator, which greatly improved the performance of foam dust removal technology (Sandip, 1984; Kovscek et al., 1995).

Drilling foam dust removal technology studies began in China in 1986. Field tests revealed a >99% dust removal efficiency as compared to dry drilling, given that water consumption is smaller and leads to better respirable dust removal effects (Zhou, 1988). In 1995, foam stability experiments uncovered relationships between foam stability time and viscosity to obtain the stabilizer concentration. A simulation experiment concluded the structure and the optimal wind velocity of the net foam generator (Jiang et al., 1999). In 2003, foam stability influencing factor experiments concluded that (1) foam flow and half-life periods initially exhibit a lower trend following the first increase of the surfactant concentration; (2) with the increase of temperature and salinity, foam stability decreased (Wan et al., 2003). In 2011, a complete set of foam dust removal machines with a >90% dust removal coefficient were developed in an excavated roadway. The proven optimal air pressure of these devices was within 0.4 and 0.5 MPa for an optimal foaming agent concentration of 3%–3.5% (Chen, 2012).

In summary, a variety of foam generators have been developed worldwide, of which the structure type can be turbo, pore, spiral, mesh, concentric tube, baffler or jet pump and so on, but to some extent, almost every single kind of foam generator has some foaming performance defects. In this case, integrated foam generator is required to obtain better foaming performance. Of all the most widely used foam generators, spiral foam generator can produce a large amount of densely fine foam and is not easy to be blocked. These foam is uniformly distributed and has good stability, but with low foaming multiple. On the contrary, meshed foam generator produce foam with high foaming multiple but low stability, and its performance is relatively easily affected by the foaming solution, air pressure and air velocity. Therefore, a new foam generator combining advantages of spiral type and meshed type was to be developed, as an attempt to achieve larger foaming flow, higher foaming multiple and better stability.

The present study developed a new foam generator both spiral and meshed features for DTH drilling in open-pit mines, determined the main parameters that influence the foaming performance of foam generators based on performance tests on the foam flow, foaming multiple, and half-life period of the foam generator to obtain the best working point of the foam generator. These results have extremely important practical significance to improve the operating environment of open-pit mines and to protect the health of operators using DTH drills.

2. Materials and methods

2.1. *The mechanism of foam generation*

There are many forms of foam generators such as turbine-based, porous, spiral, mesh, concentric tube, baffle plate, and jet pump-type foam. The principle of foam production divides foam generators into three categories: mechanical segmentation into a bubble, the fluid mixture into a bubble, and jet dispersion into the bubble.

The foam generator employed for the foaming performance experiment belongs to the fluid mixing into bubble category, which mainly created two-phase (gas–liquid) contact during the high-speed gas and liquid mixing process. The gas was then crushed into bubbles, the size of which bubbles mainly depends on the turbulence and continuous mixing time of the liquid. Our team independently designed a foam generator that demonstrates spiral and mesh foaming characteristics. The basic structure is presented in Fig. 1. The foam generator was mainly composed of four parts: the base, mixing chamber, foaming net, and junction station. Among them, the mixing chamber followed the spiral foaming mechanism principle to achieve the initial foaming, whereas the foaming net followed the net-type foaming mechanism to create secondary foam. The innovation and superiority of this foam generator lies in the foam production characteristics of the spiral and mesh type foam generator.

Foaming observes the following mechanism: the bubbling agent entered the liquid inlet through a jet and the high-pressure gas was injected at a high speed into the mixing chamber from the gas inlet. The high speed jet then sucked the air to form the vortex, and the high-kinetic energy gas