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Application and research of dry-type filtration dust collection technology in large tunnel construction

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ABSTRACT

Large amounts of rock dust are produced in the process of constructing large tunnels. It then accumulates in the tunnel where, because it is difficult to disperse, it is a serious threat to workers' health; more than 90% of dust is respirable. Traditional methods to reduce rock dust concentrations, such as a water spray, ventilation, and foam are not effective. Therefore, a new dry-type filtration dust collection method is put forward to use in the construction of large tunnels, and a dry-type filtration dust collection device is designed. Experiments and field application of the dry-type filtration dust collection device were carried out. Experimental results showed that the total dust suppression efficiency reached 98.41% and the leakage rate was 7.86% with the dry-type filtration dust collector. The field application in the Chaoyang tunnel indicated that the efficiency of the dry-type dust collector in suppressing total and respirable dust was 98.13% and 97.86%, respectively. During lining trolley shotcreting operations, the total dust concentration decreased from 253.41 mg/m^3 to 29.97 mg/m^3 and the respirable dust concentration dropped from 226.73 mg/m^3 to 28.85 mg/m^3. The dust collection system also reached the optimal dust removal efficiency in two other tunnel construction operations and made an obvious improvement in the environment behind the dust collection system in the large tunnel. The dry-type filtration dust collector effectively improves the rock dust collection efficiency and makes up for the problem of inadequate treatment of respirable dust by the traditional methods.

1. Introduction

In order to solve inconveniences caused by traffic pressure, the construction of tunnels and underground projects (such as railway tunnels, highway tunnels, and municipal pipelines) has become an inevitable trend. The total mileage of railway and highway tunnels reached 25,721.9 km by the end of 2015 in China, and maintained rapid growth, where large tunnel construction was the emphasis but also the main difficulty [1–3]. Rock dust is one of the primary air contaminants in large tunnel construction. Controlling it has become a new challenge due to the high dust concentration, rapid speed of diffusion, number of dust sources, and remote discharge distance. There are several operations, such as tunnel face blasting, lining trolley shotcreting, and tunnel face mucking, that produce large amounts of rock dust, more than 90% of which is respirable dust (that is, have particle sizes less than 7.07 μm) [4]. Anyone working in the tunnel is exposed to high levels of respirable rock dust, which can lead to pneumoconiosis or silicosis, incurable diseases that seriously endanger workers' health [3,5].

Various collecting technologies have been developed and applied, all over the world, to control rock dust in large tunnel construction [6–8]. They have played important roles in reducing rock dust but still have obvious drawbacks. For instance, water sprays not only have low efficiencies against rock dust, but also consume large amounts of water. Worse still, spraying nozzles are easily blocked and damaged subject to the bad water quality in tunnels [9–12] and demand for high water pressure is hard to meet practically [13,14]. In addition, water has a high surface tension, and rock dust is mostly hydrophobic, so water cannot easily capture respirable rock dust, especially that less than 2 μm in diameter [10,15]. It is also very difficult to dilute and eliminate rock dust purely by ventilation due to the large amount of dust generated, high degree of dust distribution, and high SiO_2 content [16,17]. Foam technology is effective at suppressing respirable dust, but

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related research shows that its drawbacks include large pressure losses and a demand for high-pressure water. In some cases, it is hardly forms an effective cover for dust sources in a large tunnel [11,18]. Besides, the foam that covers dust sources obstructs workers' view, and the high cost of the foam agent severely limits its application at large tunnel construction sites [19,20]. Therefore, controlling dust in large tunnel construction has become the focus of scholarly research.

Due to advantages including efficiency, not needing water, and the ability to be used without causing secondary pollution, dry-type filtration dust collectors have been extensively applied in modern industrial production, but it less used underground [21]. In order to effectively solve the problem of dust pollution in the process of large tunnel construction, a new dry-type dust collection technology is proposed. In addition, the dry-type filtration dust collector and collection system were developed and designed independently. This is the first systematic research on the dry-type filtration dust collection technology in the large tunnel construction, which could be of great significance in guiding its field application. Therefore, this study will provide an important foundation for the application of dry-type filtration dust collection technology to large tunnel construction, making it an efficient method increase worker health and safety.

2. The dry-type filtration dust collection method and device in large tunnel construction

A new dry-type filtration dust collection method for use in large tunnel construction has been put forward as shown in Fig. 1. It takes the existing high voltage and compressed air in the tunnel as its source of operating and cleaning power. Firstly, the dry-type filtration dust collector is moved to the desired position, the extraction fan is turned on, and the dust-laden gas is sucked into the exhaust hood under the negative pressure of the extraction fan, entering the filter chamber through an air duct. Secondly, gravity causes some large particles in the dusty gas to settle, and the fine dust is captured on the outer wall of the filter cartridge in the filter chamber. Then the gas passing through the wall of the filter cartridge enters the cleaning chamber and is discharged through the extraction fan. Thirdly, as the thickness of the dust cake deposited on the surface of the filter cartridge increases with dust suppression, resistance also increases. The process of cleaning begins when the surface resistance of the filter cartridge reaches a certain value, after which compressed air is sprayed into the filter cartridge, at high velocity, through a nozzle on the injection pipe, and the rock dust on the outer wall of the filter cartridge is blown down to the deposition chamber. Finally, the rock dust in the deposition chamber is transported to the flat dust discharge valve when the scraper conveyor is turned on, and the collected dust is discharged when the flat discharge valve is pulled.

Fig. 2 shows the dry-type filtration dust collector created by the authors. It consists of a shell, filtration system, cleaning system, discharging system, extraction fan. It is 7040 mm long × 1300 mm wide × 1050 mm high; weight 2000 kg; has inlet and outlet 600 mm in diameter; uses a FBCD No. 5.6/2∗11 extraction fan (with rated voltage, power, and air flow of 380/660 V, 22 kW, 200–280 m^3/min, respectively), 100 filter cartridges, 20 pulse valves, compressed air at pressures between 0.5 and 0.7 MPa; and has a total filtration area of 240 m^2. The electrical motor of the scraper conveyor YBK2-80M2-2 has a rated voltage and powder of 380/660 V and 0.75 kW, respectively.

The filtration system consists mainly of pleat-type metal mesh filter cartridges fixed with three bolt connections. A single filter cartridge has the following dimensions: 145 mm outer diameter × 80 mm inner diameter × 600 mm depth, initial filtration accuracy 15 μm, 60 pleats 20 mm deep, and a filtration area of 2.4 m^2. The pleat-type structure can significantly increase the filtration area, and the metal mesh filter material has a good flame-retardant and anti-static effect as addition to its role as a support, which can increase the service life of the filter cartridge. There is no dust on the new filter cartridge during the initial operation of the dry-type filtration dust collector, but after a few minutes a thin layer of dust cake is formed on the surface of the filter material. This dust cake, which is 0.3–0.5 mm thick, is called the primary dust cake; the dust which is re-deposited on it is secondary dust cake. The main role of the filter material is to form the primary dust cake and support its frame; the function of filtration relies mostly on the primary dust cake [22].

Fig. 3(a) –(c) shows the filter material, in different states, magnified 1000 times under a scanning electron microscope. Fig. 3(a) illustrates that the unused metal mesh filter material looks smooth, without any foreign materials on it; it can be clearly observed that the metal fibers are knitted together and combine tightly, with a fiber gap of at most 15 μm. Fig. 3(b) shows the used

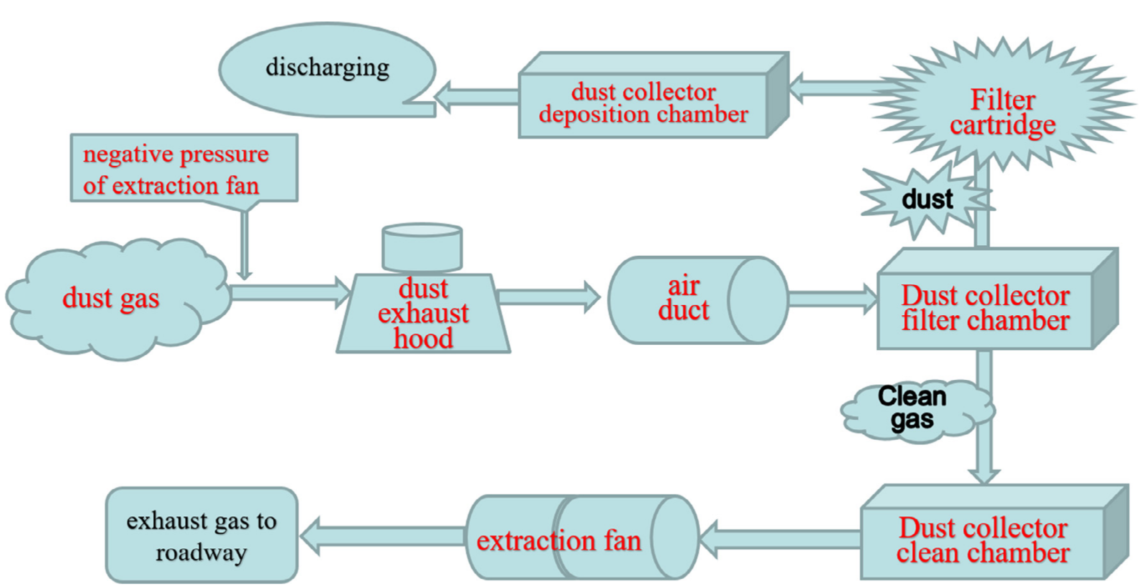

Fig. 1. The dry-type filtration dust collection method.

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