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# Numerical and Experimental Research on Convergence Angle of Wet Sprayer Nozzle

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**Abstract**

Shotcrete is a popular support method in construction of both ground projects and underground projects, such as tunnels, subways, slopes and roadway, etc. However, at present researches on the influence of nozzle structure parameters on the performance of concrete injection are insufficient. This research focuses on the influence of various parameters of nozzle structure on the evenness and dust generating, and conducts a systematic study on the flow characteristics of the concrete in the nozzle of wet spraying machinery and the quality control law, through a comprehensive research method combining theoretical analysis, numerical simulation and field tests. On the basis of dynamic analysis of the internal flow field of the nozzle, the mathematical model and numerical model of the internal flow field of the nozzle are establishes. Then the simulation calculation of the flow field of the wet spray nozzle is conducted with the FLUENT® software. The fluid's contour about velocity and phase volume fraction in the nozzle were obtained. On this basis this paper analyzed each phase's volume fraction of the mixed fluid in the outlet section. The convergent section of the nozzle is tested in the spray concrete impact force distribution system. The results are in good correspondence with the results of theoretical analysis and numerical simulation, which verifies the validity and reliability of the conclusion of numerical simulation. This paper provides the basis for the optimization of nozzle structure, and the improvement of the sprayed concrete construction quality.

*Keywords:* Shotcrete; Wet Spraying Machinery; Nozzle; Convergence Angle; Numerical Simulation.

## 1. Introduction

Shotcrete or sprayed concrete, a cement-based mixture projected pneumatically in high velocities [1], is often used in various constructions, such as mine tunnels, railway and highway tunnels, and water conservancy culverts [2-4]. The flexibility of shotcrete makes it an effective alternative to conventional concrete in rock support, tunnel lining, and concrete repair. For example, the pneumatic projection allows shotcrete to be applied quickly on the uneven substrate surfaces, acting as excavation stabilization and arch lining in mines [5]. There is a problem of uneven injection and large amount of dust on the shotcrete construction site. Ulvestad et al. [6] ever indicated that mean exposures to total dust and respirable dust in shotcreters were significantly higher than in drillers (13.6, 3.4 and 3.6, 1.2 mg/m$^3$). Georg et al. [7, 8] compared the exposure situation of shotcrete dust in heading face between Swiss road tunnel and Munich subway tunnel with similar shotcrete and ventilation, results showed that the average fine dust concentration of road tunnel (13.2 mg/m$^3$) and subway tunnel (11.6 mg/m$^3$) was still higher in fact, what's more, the peak of dust concentration during shotcrete can reach up to more than 100 mg/m$^3$ for the road tunnel and up to 70 mg/m$^3$ for the subway tunnel. Praml et al. [9, 10] measured dust concentration during the shotcrete in amine tunnel construction site. Results showed that the fine dust concentration were 4.2 mg/m$^3$ for mixer operator and 11.6 mg/m$^3$ for nozzleman. The peak loads of dust concentration can reach up to five times the mean value. These problems not only waste valuable wet spray materials,

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