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Research Article

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The pipelines pumping characteristic of coal ash slurry in high concentration cemented material backfilling mining in coal mine

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ABSTRACT

The backfilling materials of high concentration cemented material backfilling mining technique consist of coal waste rocks, coal ash, cement, additives and water. After mixing to become a high-density mixture it is pumped through pipelines to underground and then move to fill the gob. The backfilling method can both depose the coal waste rocks and extract the coal resources under the villages. Before and after pumping the high concentration cemented material, the coal ash slurry must be pumped first. So the coal ash slurry characteristics directly affect the filling effect. With the help of the particle-size analyzer to analyze the characteristics of the coal ash, the range of particle size distribution has been obtained for four kinds of coal ash. On the basis of analyzing the data obtained by laboratory rheological experiment, the rheological model for the coal ash slurry is determined. Based on theoretical analysis, the frictional and local resistance losses of the coal ash slurry through pipeline transportation are analyzed.

Key words: high concentration cemented material backfilling mining; coal ash slurry; particle size distribution; Pumping Characteristic

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INTRODUCTION

Backfill mining has the advantages of high recovery rate of resources, small damage to the environment and treatment of the ground waste, etc. It can effectively solve the "three under" pressure coal, gangue discharge, surface subsidence and other issues. It is becoming one of the key technologies for green mining in China, and has been successfully applicated in xingtai, xinwen, shanxi and other mining area.

The high concentration cemented filling materials of coal mine is composed of the aggregate, cement materials, water and additive proportionally. Normally, the aggregate is gangue, cementing material is made of cement and fly ash, admixtures include water reducer, water retaining agent, early strength agent. High concentration refers to the quality of the filling slurry is 75% ~ 80%, in this range, the binding backfill slurry is quasi-homogeneous non Newtonian fluid. The fine grained material content in the slurry obviously increased, the specific surface area increased, and evenly distributed in the slurry. Compared with low concentration cementation filling, high concentration of filling materials in the process of transportation will not occur segregation and precipitation, when delivered to the filling site, filling materials to take off the less water and has the characteristic of early strength, it can maintain the stability of the gob roof and surrounding rock better[1].

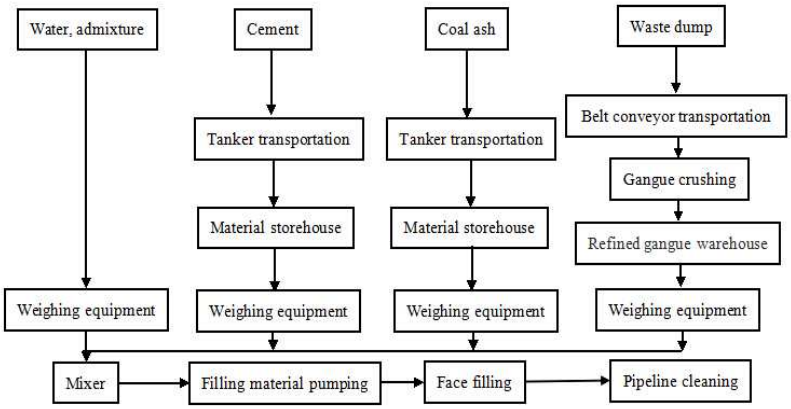

Fig.1 The main technological process of high concentration cementation filling

The process of high concentration cementation filling is a process that crush coal gangue firstly, then put the gangue, fly ash ,cement and water are mixed proportionally, use the filling pump transport to the underground goaf at last (as shown in Fig 1). In the whole process of pumping, basically have the following process: 1. Make the filling pipe full of water; 2. The coal ash slurry push the water; 3. The filling slurry push the coal ash slurry; 4. Clean the pipeline. Among them, the second process and the fourth process must convey the coal ash slurry. Through conveying cement and fly ash mortar, the second process will push out the water in the filling pipeline, at the same time mortar can isolate the filling slurry and water in the filling pipeline of the next process, to achieve the effect of lubricating pipeline and preventing the filling slurry from plugging and segregating. Through the cement, fly ash mixed mortar and water ,the fourth process flush the pipeline.

Because must carry the coal ash slurry before and after coal mine high concentration cementation filling, the characteristics of coal ash slurry directly influence the quality of the filling effect[2], therefore, it is necessary to carry on the research of the ratio and transportation characteristics of fly ash slurry.

EXPERIMENTAL SECTION

1 Analysis of coal mine high concentration cementation filling fly ash characteristics

Coal ash is a similar pozzolanic hybrid materials formed by the combustion of pulverized coal, mainly from the solid waste discharge of power plants, metallurgy, chemical industry. The power plant grind the coal into the pulverized coal under 100 microns, with hot air sprayed into the furnace to make its suspension combustion, high temperature flue gas was captured by dust collecting device and get the coal ash, also known as fly ash , accounting for about 80%~90% of the total weight. Because of the collision, a handful of pulverized coal burn and bond at the same time, with massive deposition in the bottom and become the bottom ash, accounting for about 10%~20% of the total weight of the ash. Fly ash collection includes the removal of the dust in the flue gas and the removal of the slag in the bottom ash two ways, its discharge mode is divided into dry method and wet method[3]. Dry discharge is that transport the collected fly ash directly into the ash bin. Wet emission is that through the mortar pump and pipeline, use the pressure of hydraulic for conveying fly ash into the landfill or the ash storage field.

1.1 Classification of coal ash

At present, there are many standards and methods for the classification of coal ash, such as its physical properties, chemical properties, application needs,etc. According to the national standards, combined with the test needs and actual conditions, only based on the physical properties of coal ash to make simple classification of coal ash[4].

(1) According to the different water content of coal ash ,it can be divided into dry ash, wet ash and old ash.

Dry ash is the coal ash that the water content is not more than 3% of new emissions or storage time within half a year. For the low calcium coal ash, the influence that the length of storage time to its properties is not significant; Wet ash is the coal ash mixed with a certain amount of water in their emission process; Old ash is the coal ash placed in the open air, this ash even with dry emission, still has high moisture content, because the rain or moisture in the air are inhaled through often in the process of placing.

(2) According to fineness and ignition loss of coal ash, it can be divided into three levels, as shown in the table 1.

Table 1 Classification of coal ash

Grade	0.045 mm square hole sieve allowance	Burning vector
First grade flyash	12%	5%
Second grade flyash	20%	8%
Third grade flyash	45%	15%

1.2 Analysis of the coal ash particle size

This paper selects the scene of the secondary ash, crude ash, the original grey, fine ash four kinds of coal ash, according to those kinds of fly ash, uses particle size analyzer to determine their size distribution respectively in the laboratory, it is concluded that the four kinds of the difference within the range of fly ash particle size distribution, as shown in the table 2, the test data are consistent with the objective facts, provide an important reference basis for the next test and analysis of test results.

Table 2 Interval size distribution of coal ash particles

Type of coal ash	Particle size distribution range
Second grade coal ash	5~30 μm
Coarse coal ash	400 μm above
Original coal ash	200~500 μm
Fine coal ash	15~70 μm

1.3 The physical and chemical properties of fly ash

(1) Physical properties

Fly ash is grayish white or gray powder material, the higher the carbon content, the deeper the color, the larger the particle size, the worse the quality. The density of fly ash and its chemical composition are closely related. The density of low calcium ash is generally between 1800~1800 kg m^{-3}, the density of high calcium ash is in the range of 2500~2800 kg m^{-3}. The loose dry density of coal ash is in the range of 600~1000 kg·m^{-3}, after compaction the density between 1300~1600 kg m^{-3}, the compaction density of wet ash increases with the increasing of the moisture content[2]. Fly ash particle size within the range of 0.5 ~ 300μm, fineness of 4900 square hole sieve, the sieve allowance is between 10% ~ 20%, the specific surface area in 2000~4000 $cm^2 \cdot g^{-1}$ range.

The effect of the coal ash activity includes compaction effect, morphological effect and micro aggregate effect.The main structure of fly ash is micro glass beads, characteristics with fine grain, the surface is smooth, dense texture, good liquidity, small specific surface area, the water adsorption force is small, in slurry it have played an important role like ball bearing, to improve the fluidity of the slurry and also reduces the water requirement [5].

The micro-aggregate effect refers to the fly ash particles act as aggregate, filled in the capillary clearance of slurry, to improve the density of the slurry. First, the strength of fly ash particles is very high, up to 700 MPa; Second, the good interfacial effect of these particles can enhance is the most fragile interface of cement stone; Third, uniform particles of fly ash filling ability, on the one hand, the pore porosity of cement paste is reduced, on the other hand to make free water increased, so as to achieve high plasticity slurry, make the aggregate matching more reasonable, fill rates increase, cement dispersed more evenly.

Compaction effect is the external performance from the combined action between the volcanic ash effect and the micro aggregate effect, it can fill the gap of cement skeleton and water film, improve the slurry density. The physical activity of fly ash is generally regarded as the main source of early strength and activity of fly ash[6].

(2)Chemical properties

From the perspective of engineering application, the chemical properties of fly ash mainly refers to the activity of fly ash. The activity of fly ash refers to the condensation sclerosis performance after it mixed with lime and water . The fly ash with the chemical activity has no hydraulicity itself, fly ash activity derived from the total content of Al_2O_3 and SiO_2 among them, under the condition of water, they can react with $Ca(OH)_2$ to generate hydrated calcium aluminate and hydrated calcium silicate, then show the hydraulicity.

$m_1Ca(OH)_2+Al_2O_3+nH_2O \rightarrow m_1CaO \cdot Al_2O_3 \cdot nH_2Om_1Ca(OH)_2+ SiO_2+nH_2O \rightarrow m_1CaO \cdot SiO_2 \cdot nH_2O$

Therefore, the activity of fly ash is potential, needs the application of activator to play out, so there are a lot of activators in the practical application, such as lime, and a small amount of gypsum, lime and a small amount of cement, etc.

2 The test results of the high concentration coal mine cemented filling with fly ash slurry

2.1 The working principle of conveying round-pipe-test system

The filling paste round-pipe-test system in the process of test is mainly completing the ratio of filling materials, slurry concentration, velocity of slurry and slurry flow rate and temperature of slurry and slurry density, slump, exudation rate and viscosity of slurry flow parameters and characteristics of the testing work (including slurry density, slump, bleeding rate, viscosity by sampling test, test data), and on the basis of test data, map the relation curve between each parameter, it is important for the mining engineering research and analysis of basic equipment[7]. Its working principle is shown in Fig 2.

According to the ingredient set, the system sequentially unload the aggregate into the measuring bin, after the measurement is completed, start the belt conveyor, and then start inclined flat belt feeding machine, to upgrade measuring fine aggregate to mixing chamber; The measured powder in the weighing hopper is sent by a screw conveyor in sent to stir storehouse, the measured water is sent by water pump into the mixing warehouse; Then open the mixer to stir,the mixed slurry (fluid) will be discharged into the pump under the hopper, the slurry will be transported to pipeline loop system by the pump pressure(piping system is composed of casing ND100mm and ND150mm road).Through the corresponding experimental data from the thermometer, pressure gauge, flow meter installed in pipe, computer will process and store the real-time measuring data, through the analysis software to data analysis.

At the end of round-pipe-test, the material will be carried into the filling times line bin to do artesian test. The pressure difference sensor in the pipeline will measure the pressure difference under artesian condition. Finally part of the test materials will be embedded within the cast iron module to make the test piece, then experimental analysis will be made on the test piece, such as compressive strength, tensile, permeability, etc.

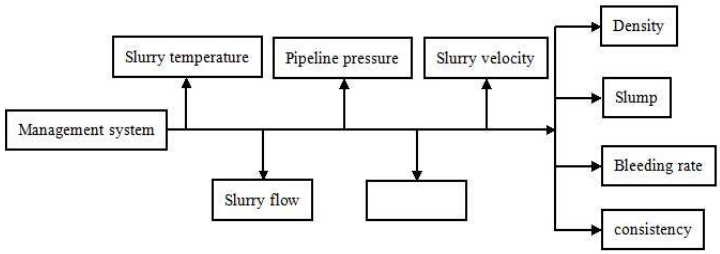

Fig.2 The diagram of filling slurry ring pipe system working principle

2.2 The characteristics of the transmission loop test system

(1) Using the differential pressure sensor of high precision, compared with the previous pressure sensor, measurement accuracy is improved, and the differential pressure sensor has strong compressive ability.

(2) Due to the use of the data acquisition card, the data acquisition is more convenient and quick, not only avoid the human error, also have multiplied the amount of data accessing. Data acquisition card can obtain a very short time interval, the same time data of multiple sensor and record them, a large amount of data can facilitate the understanding of the pumping tiny details in the whole process, and conducive to the processing of test data .

(3) Using quick connectors and pipe clamp to do pipe connection is conducive to speed up the pipe installation, more important is that it can facilitate to the processing of blocking pipe accidents may occur in the process of test, etc.

(4) To test the pipes of different diameters in series, it will have some problems in the aspect of velocity control, if test with the different pipe diameter separately, it will cause the waste of seamless steel tube material and filling slurry, so take the scheme that connect the end variable diameter pipe and eccentric pipe, make all kinds of testing schemes transform freely, the adjustment of testing scheme can also be flexible , to meet the demand of all kinds of test fully[8-9].

2.3 The proportion plan of transmission loop test materials

The material proportion for coal powder mortar round pipe test: The amount of fly ash which accounted for 47% of the total, Ordinary Portland cement dosage is 11%, the dosage of the water is 40%, admixture dosage is 1% ~ 2%, thus the made slurry concentration can be controlled in the range of about 60%. With concentration of 60%, for example, filling pulp with its corresponding filling materials per cubic meter as shown in table 3.

Table 3 Fly ash materials proportioning per cubic meter

Material categories	Consumption（kg/m3）
Cement	205
Fly ash	825
Admixture	28.5
Water	687

Table 4 Round pipe test ratio

Slurry type	Fly ash content	Concentration
Pure mortar	47.26%	60.0%
	47.04%	59.5%
	46.81%	59.0%

2.3 The results of round pipe test

According to the method and steps of round pipe test before-mentioned to carry on filling slurry round pipe test, the pipeline length between the 2 sensors used for collecting frictional resistance loss is 6m, the pipe used for acquisition of local resistance loss between two sensors is a bend, as shown in figure 3.

Fig 3 The elbow section used for determination of local resistance loss

The test results shown in table 5.

Table 5 the results of high concentration cementation material ring pipe test

Slurry type	Fly ash content	Concentration	Frictional resistance loss（kPa）	The local resistance loss（kPa）
Pure mortar	47%	60.0%	22.59	3.99
		59.5%	18.55	3.37
		59.0%	15.45	2.73

According to the data in table 5, when fly ash content is 47% and coal ash slurry concentration is 60%, the slurry pipeline frictional resistance loss and the local resistance loss reach the maximum value, it is respectively 22.59 kPa and 3.99 kPa. The value of frictional resistance loss for the conversion of unit length loss is 3.77kPa/m.

3 Analysis of coal mine high concentration cementation filling fly ash slurry pipeline transportation characteristics

3.1 The relationship between the resistance loss of pipe transportation and slurry concentration

The pipeline resistance loss of pure mortar is shown in Fig 4.

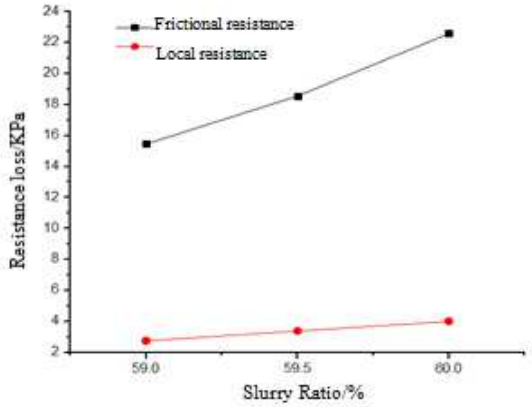

Fig 4 The relationship curve between slurry ratio and pipeline resistance loss

Figure 4 shows that the relationship between pure mortar concentration and pipeline resistance loss is similar to the relationship between high concentration cementation filling slurry concentration and pipe resistance loss, pure mortar concentration increases by 0.5% each, then the pipeline frictional resistance loss increases by about 21%, and the pipeline local resistance loss increases by about 20%, the influence of the concentration of the pure mortar to pipeline frictional resistance loss and local resistance loss is obvious, the influence of the frictional resistance loss is greater than the influence of local resistance loss. When the concentration in the range of 59.5% ~ 60%, frictional resistance loss is greater than its value in the range of 59% ~ 59.5%, this suggests that the frictional resistance loss increases with the increase of concentration.

3.2 The calculation of filling slurry pipeline transportation resistance loss

The calculation formula of high concentration slurry pipeline resistance loss is not entirely obtained by theory analysis, because of the variety and the complexity of the pipeline, so the formula is derived on the basis of experiments, called empirical formula. First, through the test data, to do analysis of slurry rheological parameter under different concentrations, and then fit the relation formula of rheological parameters and concentration, combined with the results of theoretical analysis, it is concluded that the final formula[10-11].

By rheological equation to determine the semi-empirical formula of high concentration slurry, high concentration filling can be approximately regarded as bingham plastic body, buckingham equation is available (equation (3.1)), the relationship between shear stress in the pipe and resistance loss as shown in equation(3.2)[12-14].

$$\tau_w = \frac{4}{3}\tau_0 + \eta\left(\frac{8v_{cp}}{D}\right) \tag{3.1}$$

$$\tau_w = \frac{\Delta pD}{4L} \tag{3.2}$$

In laminar flow state, the equation (3.3) can be used to define horizontal straight pipe resistance losses, through the simultaneous equation (3.1), (3.2) and (3.3), the relation formula of resistance loss and rheological parameters as shown in the following equation (4.4) :

$$j_m = \frac{\Delta p}{L} \tag{3.3}$$

$$j_m = \frac{16}{3D}\tau_0 + \eta\frac{32v_{cp}}{D} \tag{3.4}$$

In the formula: v_{cp}—The average velocity of the slurry in the pipe
D—Pipe diameter.

According to the ring pipe test and the experimental data in table 5, to fit the relationship between the resistance loss of pure mortar(concentration 47%) and slurry concentrationon, to summarize these fitting equations and the correlation coefficient, as shown in table 6.

Table 6 The resistance loss of concentration curve fitting equation

Sample	Fly ash content	Curve		The fitting equation	R^2
Pure mortar	47%	$\Delta p - c$	Frictional resistance loss	$y=18800x^2-21658x+6249$	1
			The local resistance loss	$y=-400x^2+602x-213.2$	1

The fitting formulas on the basis of theoretical analysis and experimental data can be used to calculate the pipeline resistance loss under the condition of different operating mode, to extend the application of test, also can fill the lack of theoretical research. However, due to the limitation of space and equipment, the results of the ring pipe test can only be close to the actual situation, it can't completely consistent with industrial site. In spite of this, the datas of ring pipe test can still guide the industrial transportation practice of filling slurry.

CONCLUSION

(1) Through the experiments, it is concluded that the particle size interval distribution and relative activities of the used fly ash. High concentration cemented filling material is composed by silicon cement, fly ash, coal gangue and

water, at the same time, there will be the intervention of admixture, before and after coal mine cementation filling pulp must transport the fly ash slurry, the properties of fly ash slurry will directly affect the filling effect. In this paper, There are four kinds of fly ash from the power plant near the test field. Through the laboratory test, by using particle size analyzer, it is concluded that the particle size distribution interval of four kinds of fly ash.

(2) The ring pipe test can determine the parameters of resistance loss under various working conditions, not only can do effective analysis to the rheological characteristics of slurry and the pipeline performance, also provide data support for the scene of the filling system design work. Analyzing the influential factors of pipeline resistance loss can provide the basis for filling system stability, and guarantees for the emergency treatment of system.

(3) On the basis of the theoretical calculation and the ring pipe test, the influence factors of resistance loss are analyzed, the fly ash slurry concentration degree has the greatest influence, the friction loss will increase with the increase of the concentration, and increase the magnitude of increase in high concentration range. The increase of the fly ash dosage will lead to the increase of friction loss, the fluidity of slurry is decreased, pure mortar concentration increased by 0.5%, the pipeline frictional resistance loss increased about 21%, and the pipeline local resistance loss increases by about 20%.

(4) Through the fly ash slurry ring pipe test, obtained the maximum unit length frictional resistance loss value of the slurry pipeline transportation(3.77 kPa/m). This data can provide a reference for the filling system designation.

REFERENCES

[1]LIU Jian-gong, ZHAO Qing-biao. *Journal of china coal society,* **2010**, 35(9):1413-1418.
[2]Guo Zhen-hua. *China University Of Mining and Technology*,**2008**.
[3]SUN Wen-biao, GUO Jun-jie, ZHANG Jian-li. *Mining Safety & Environmental Protection*, **2008**,(01):70-72.
[4]MIAO Xie-xing, ZHANG Ji-xiong, *Journal of Mining & Safety Engineering,* **2007**, 24(4)379-382.
[5]KANG Li-feng, YU You-jiang. *Hebei coal,* **2009**(6):25-28.
[6]ZHANG Zhen-nan, MIAO Xie-xing, GE Xiu-run. *Chinese Journal of Rock Mechanics and Engineering,* **2005**, 24(3):451-455.
[7]GUO Zhi-jie, YAO Bao-zhi. *Mine surveying,* **2010**(3):82-84.
[8]HAO Bao-sheng, ZHANG Shu-guo. *Coal science & technology magazine,* **2009**,35(11)：63-65.
[9]Li Xing-shang. *China University of Mining & Technology*.**2008**.
[10]YAN Shao-hong, ZHANG Hua-xing. *Coal Mining Technology,* **2008**,(03):1-3,10.
[11]ZHANG Ji-xiong. Study on Strata Movement Controlling by Raw Waste Backfilling with Fully-Mechanized Coal Winning Technology and Its Engineering Applications. [D]. China University of Mining & Technology.**2008**.
[12]ZHANG Ji-xiong, LI Jian1, AN Tai-long. *Journal of Mining & Safety Engineering,* **2010**,35(3)357-362.
[13]WU Fei-long, ZHOU Hua-qiang, LI Feng. *Energy technology and management,* **2008**(1):21-26.
[14]WANG Jia-chen. The theory and technique on the thick coal seam mining [M].