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Wetting agent investigation for controlling dust of lead-zinc ores

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Abstract: The purpose of this project is to control the pollution of dust, which occurred in a typical lead-zinc mine. Two kinds of surfactants and water glass were chosen as the wetting agents to study the behaviours of suppressing the dust. The performances of the wetting agents of various sizes and water content of dust and their compositions among different weting agents were investigated. Firstly, the chemical compounds, dispersity, water content, bulk density and other relevant physico-chemical properties of the choiced dust of lead-zinc ore were mensurated. A great number of down-ward penetrating tests were conducted to different partical sizes of dust and to analyze the dust wetting behaviour respectively. The optimal compositions of wetting agents were obtained in accordance with different water contents and partical sizes of the dust after analyzing and statisting the achieved experimental data. The data show that the efficiency of chemical dust suppression of weting agents is much better than that of water. The results of the research work prove that the partical size and the water content of the dust are very important factors to the dust suppression. The results are also proved validly by the dropping experiment, which takes the penetrating diameter and penetrating time as the major factors. The superfine dust is much more difficult to be wetted. Since increasing the water content of dust is the best approach to control it, the choice of wetting agents for improving dispensation is significant.

Key words: dust of lead-zinc ore; wetting agent; down-ward penetration test, droping liquid test; dust control

1 Introduction

Lead-zinc dust pollution is one of the significiant contamination cases in nonferrous mines. To solve the problem as a first step, a systematic literature searching in the research area of dust wetting agents was made and special wetting agent for suppressing lead-zinc dust has not been discovered. Research on wetting performance of various sizes of dust has not been found either[1−16]. Therefore, the investigation on depressing lead-zinc dust with chemical wetting agents belongs to a creative activity and is important in applications.

2 Preliminary selection of wetting agents of lead-zinc dust

To reduce the testing work, fundmental knowledge on wetting agent performance of dust and its acting mechanism must be understood. Accordingly, suitable wetting agents will be selected preliminarily. Dust wetting agent is a chemical one of improving water wetting behaviour to dust. It has particular effect for fine particles. By referring many relevant achievements [1−16] in the field of chemical suppression of dust and the research experiences by ourselves[1,8−9,15−16], three agents (sodium dodecyl sulfonic salt, simplified as SDS; dodecyl benzene sulfonic acid sodium salt, simplified as SDBS; water glass or silicon dioxide) were preliminarily selected. These agents have many advantages, e.g. wide distribution, easy preparation, low cost, little pollution, good wetting performance and stable property. Specifications of three wetting agents are listed in Table 1.

3 Preparation of lead-zinc dust and its property test

Typical lead-zinc dust was collected from a lead-zinc mine in Hunan Province, China. The lead-zinc dust was simply named as dust below in this paper.

3.1 Dust sampling and preparation

During preparation and anlysis of dust, the dust

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Table 1 Fundamental properties of preliminarily selected wetting agents

Item	SDS	Water glass	SDBS
Purity	Chemical purity	Analysis purity	Chemical purity
Formula	$CH_3(CH_2)_{11}OSO_3Na$	$Na_2SiO_3\cdot 9H_2O$	$C_{18}H_{29}NaO_3S$
Relative molecular mass	288.38	284.20	348.48
Property	Powder of white or grey white, a little taste of fat, sensing smooth	Liguid and solid status products, solid powder used in experiment	White solid like wax, poisonless, no taste
Content	Greater than 85%	Ratio of Na_2O to SiO_2: 1.03±0.03	80%−85%
HLB	40	−	40
Performance	Poisonless, neutral, anionic surfactant, water soluble, little sensing to alkali and calcium oxide, combutional, decomposition at high temperature, water absorbing, with good emulsifing and foaming, etc.	Consisting of different ratio (mode number) of SiO_2 and Na_2O, neutral water glass (mode number greater than 3), alkali water glass (mode number less than 3)	With good emulsifing, dispersion, penetration behaviour, anionic surfactant, pH value 6−8
Company	Chemical Agent Plant of Yanfeng, Changsha	Southern Chemical Agent Plant, Changsha	Chemical Agent Selling Co., Shanghai

HLB is hydrophilic and hydrophobic balance value.

sample must be representative and it can be equivalent to the compositions of the original sample. Treatment of the dust includes screening, disturbution, division and drying. Since the size of dust particles influences greatly the wetting ability of wetting agents, screening sequence should be carefully chosen according to the rule of “small to large in particle size”, that is, small particle dust is screened firstly and then the middle size and large size at last. This sequence can avoid the influence of surface energy of small particle and make dust size screening more complete.

3.2 Chemical compositons of dust

To know the chemical compositions and content of the dust, plasma excitation-optical emission spectrometry was used for measuring the dust sample. The key elements measured are Zn, S, Pb, Fe, Ca, Cd, Mn, Al and Cu. Measuring result is listed in Table 2. It can be seen that compositions of the dust are very complex and the content of Zn is the greatest and the contents of S, Pb and Fe are rather large, which are greater than 10%.

Table 2 Chemical compositions of dust (mass fraction, %)

Zn	S	Pb	Fe	Ca	Cd	Mn	Al	Cu	Others
29.9	25.2	19.2	10.1	0.72	0.15	0.44	0.43	0.27	13.59

3.3 Dust size distribution

Dust size distribution was tested by screening and represented in mass fraction. The testing result is listed in Table 3. It can be seen that the size of main particles is concentrated in the range of <0.09 mm and 0.16−0.18 mm. The particle size in Table 3 is also represented in standard mesh and it is often used over the world. Therefore, the mesh is used to describe the size of dust mentioned below.

Table 3 Dust partical size distribution

Particle diameter/mm	Particle size/mesh	Size distribution/%
<0.09	>180	38.14
0.09−0.14	180−120	8.11
0.14−0.16	120−100	6.32
0.16−0.18	100−80	38.29
0.18−0.28	80−60	7.16
>0.28	<60	1.71

3.4 Bulk density of dust

The bulk density of dust is the mass per unit volume of dust that includes the space among particles and the gap in each particle. The measuring result by various standard screens is listed in Table 4 and it can be seen that the smaller the dust particles, the less the bulk density.

Table 4 Bulk density of dust

Range of particle size/mesh	60−80	80−100	100−120	120−180
Bulk density/ $(g\cdot cm^{-3})$	1.73	1.58	1.49	1.40

3.5 pH value test of dust

Test of pH value of dust is conducted by the following procedures. Firstly, 10 g of dust is put in a beaker and 20 mL of water is then added. After the solution is disturbed completely, it is kept for a moment untill all dust is deposited. Then universal test paper is used to measure the pH value. The testing result for different size ranges of dust is listd in Table 5 and it can be seen that the dust is almost in neutral except some has a little alkali behaviour.

Table 5 pH value of dust

Size range/mesh	>180	180−120	120−100	100−80	80−60	<60
pH value	8−9	8	7	7	8	7

4 Apparatus and testing methods

4.1 Apparatus

Main equipment and devices used in the test are electronic balance, thermostate oven, thermometer, hygrometer, standard screen, glass culture dish, volumer, glass cup, spoon, dropper, timer, glass bottle, frame of capillary, glass tube, etc.

4.2 Preparation of wetting agent solution

Test of the wetting agent performance for 4 ranges of dust size in Table 4 is carried out. Three levels of wetting agent contents are designed. For SDS solution, contents are 0.4%, 0.6% and 0.8%, respectively. For water glass, they are 3%, 6% and 9%. For SDBS solution, they are 0.2%, 0.4% and 0.8%. The preparatory procedures are as follows.

1) Depended upon the quantity of required wetting agent solution, the mass of all compositions of wetting agents is weighted. To increase the accuracy, amount of the preparatory solution is larger than that used.

2) When the mass of agents is larger than 2 g, balance with 0.1 g accuracy is used usually, and otherwise, electronic balance with 0.1 mg accuracy is applied. In this way, relative error can be controlled less than 5%.

3) When pareparing the solution in a designed content, the required quantity of water is added in a clean glass cup first and some weighted agents are put and then the solution is disturbed completely.

4.3 Experimental method selection

There are several methods that are used for testing the performance of wetting agent. These methods include tests of wetting angle, sediment, dropping liquid, down-ward or up-ward capillary and dynamic experiment etc[1,16]. After the properties of dust, cost, time, accuracy and in-situ conditions are taken into consideration, the down-ward capillary and dropping liquid methods were applied in the test.

4.4 Testing items

The main testing items in the investigation are complicated and include coupling of various sizes of dust to a wetting agent with a content, the size of dust effecting on the selected wetting agent, the water content of virginal dust at a certain range of size, the solution content of wetting agent to various dust sizes, etc. Depended on experiments, the wetting agent performances for various conditions of dust are achieved and an optimum prescription can be made. Also, the coincidence of down-ward capillary and dropping liquid is obtained in the investigation.

4.5 Experimental procedures

A device of down-ward capillary test was designed [1,16]. During the experiment, a dust sample was put into a glass tube with 5 mm in interior diameter, of which one end was sealed with adhesive tape. The glass tube was filled with dust to a minimum of 5 cm, and the glass tube was fixed vertically on a plate with a scale. Then, 0.2 mL of solution was injected slowly into the glass tube, and a stop watch was used to measure the required time for the front face of the solution to penetrate through the dust to a depth of 2, 3, 4 and 5 cm, respectively. In this way, the time for the solution to penetrate is a measurement of the solution penetration ability. This experimental method was used to observe the penetration process of the solutions.

5 Testing results of down-ward capillary

During experiment, size ranges of dust are based on Table 4. Since a great number of test data were obtained and it is impossible to show all in a short paper, the data were represented by clean figures of curves. In this paper, only several typical figures are shown. Usually, a datum in the listed figures was the average value of 5 testing data.

5.1 Influence of dust size on wetting agent performance

Two typical experimental results of various wetting agents to dust are shown in Figs.1 and 2.

From Figs.1 and 2 and other results that are not listed in the paper, the wetting ability of solution to coarse dust is more effective than that to fine dust. Wetting agent has great effect to wet coarse dust completely. For fine dust, a part of dust cannot be wetted completely.

With the depth increase of penetration of wetting agent solution in dust, the speed of penetration becomes slow and it means the effect of wetting agent decreases. Furthermore, the speed decrease amplitude is different for various sizes of dust. Usually, the smaller the size of dust, the quicker the penetration speed reduces. The

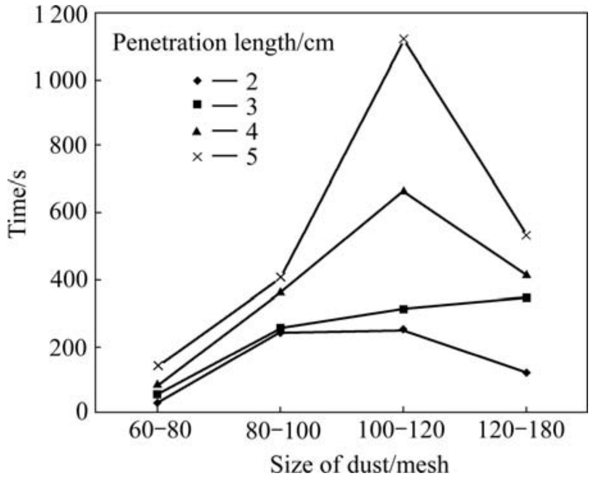

Fig.1 Penetrating time of wetting agents in different particle sizes of dust at various penetration depths (wetting agent solution 0.4%SDS; average water content of dust 0.39%; environmental temperature 31 ℃)

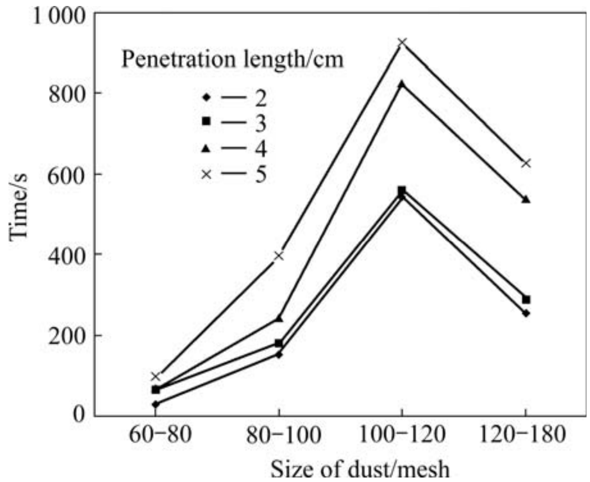

Fig.2 Penetrating time of wetting agents in different particle sizes of dust at various penetration depths (wetting agent solution 0.8%SDS; average water content of dust 0.39%; environmental temperature 31 ℃)

possible reason is that during the penetration procedure, a part of wetting agent is absorbed by dust and the concentration of wetting agent in the solution decreases. Since the fine dust particles have larger specific area, they absorb more amount of wetting agent. Therefore, the concentration of wetting agent decreases more quickly.

By analyzing the slope of curves in Figs.1 and 2, size of dust can greatly affect the wetting time. With the decrease of dust size, the required wetting time to the same penetration depth increases sharply. Especially for the dust in the range of 60−80 mesh and 100−120 mesh, the wetting time for the same wetting agent and the same concentration increases by more than ten to huandred times. These results reflect the influence of dust size on wetting speed during wetting procedure.

However, the wetting time also has relationship with the particle size disbtribution. For example, the wetting time of the dust ranging 120−180 mesh is shorter than that of dust ranging 100−120 mesh though the particle size is rather small than that of 120−180 mesh.

The optimum concentration of weting agent is different for various sizes of dust. This means that when designing wetting agent concentration, dust size and its size distribution should be taken into consideration. Generally speaking, the smaller the dust size is and the larger the size distribution, the more difficult it is to be wetted.

5.2 Influence of dust water content on wetting performance

0.6% SDS solution was used to wet the dust, of which the water content is different. Two group experimental results are shown in Figs.3 and 4.

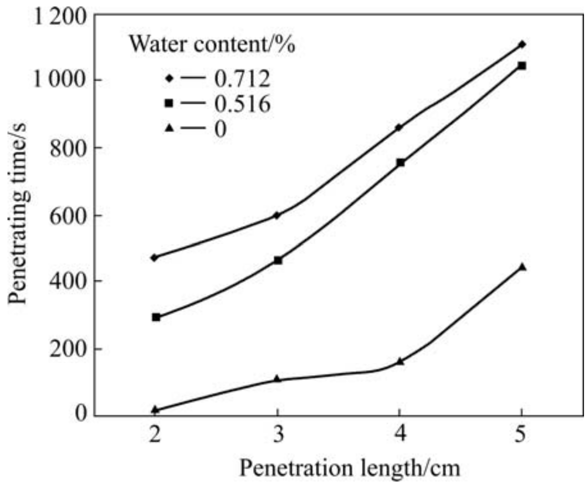

Fig.3 Penetrating time of wetting agents versus penetration depth in various initial water contents of dust (wetting agent solution 0.6% SDS; dust particle sizes 100−120 mesh; environmental temperature 30 ℃)

From Figs.3 and 4 as well as other experimental results that were not listed in this paper, it can be seen that the drier the dust, the easier it is wetted. For fine dust, above phenomenon is more obvious and the wetting time to the fine dust is reduced greatly.

5.3 Influence of wetting agent content on dust wetting performance

Usually, single wetting agent and complex wetting agents are effective in improving the wetting behaviour to dust. However, the effect is different for various contents of wetting agent.

5.3.1 Penetration ability in dust of SDS with various contents

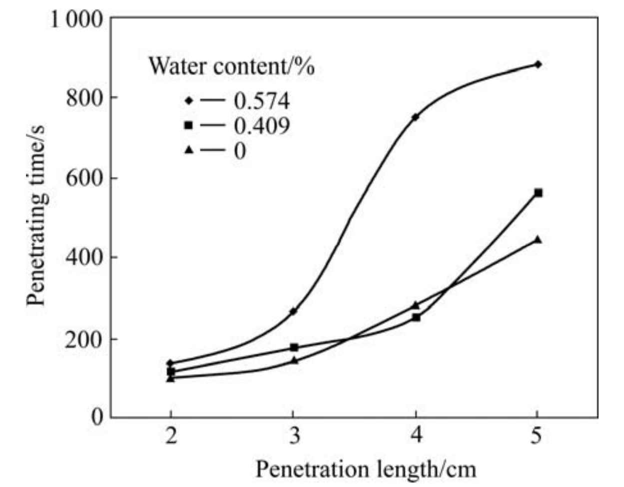

Fig.4 Penetrating time of wetting agents versus penetration depth in various initial water contents of dust (wetting agent solution 0.6% SDS; dust particle sizes 120−180 mesh; environmental temperature 30 ℃)

Fig.5 is a typical experimental result of the penetration time in dust versus various contents of SDS solution.

From Fig.5 and other experimental results that were not listed here, it shows that:

1) The dynamic penetration ability is various with different contents of wetting agent and different sizes of dust. For SDS solution with various contents, the rank of wetting ability from large to small to different sizes of dust is: for 60−80 mesh, 0.6%→0.8%→0.4%→0; for 80−100 mesh, 0.6%→0.4%→0.8%→0; for 100−120 mesh, 0.6%→0.8%→0.4%→0; for 120−180 mesh, 0.4%→0.6%→0.8%→0.

2) For dust of 60−80 mesh, the wetting time is almost the same when the content of SDS is from 0 to 0.4% and the improvement of wetting ability is not obvious. When the content of SDS increases to 0.6%, the wetting ability increases by 3 to 5 times. For dust of 120−180 mesh, the wetting performance is very good at 0.4%. Further increasing its content, the wetting ability decreases. These phenomena show that the content should be adjusted for various sizes of dust.

3) For drying dust, there exists an optimal content for various wetting agents. For SDS solution and the dust in sizes of 60−80, 80−100, 100−120 mesh, the optimal content is 0.6%. However, for dust of 120−180 mesh with rather large range, the optimal content is 0.4%. Accordingly, when preparing wetting agent solution in field application, combined effect of wetting agent to all sizes of dust should be taken into consideration.

4) At temperature near 30 ℃, SDS solution with 0.6% to dust of 100−120 mesh, the wetting effect is excellent and the wetting time can be reduced from several times to several decades times.

5) At temperature near 30 ℃, the improving ability cannot be further increased when the content of SDS is over 0.6%.

5.3.2 Penetration ability of water glass solution with various contents in dust

Fig.6 shows a typical experimental result of the wetting time versus content of water glass. From Fig.6 and other un-listed results, the improving effect is not obvious compared with SDS for the same drying dust. It shows that:

1) With the variation of water glass content, the dynamic wetting ability will vary for various sizes of dust. The rank of wetting ability from large to small is: for 60−80 mesh, 3%→9%→6%→0; for 80−100 mesh, 6%→9%→3%→0; for 100−120 mesh, 9%→6%→3%

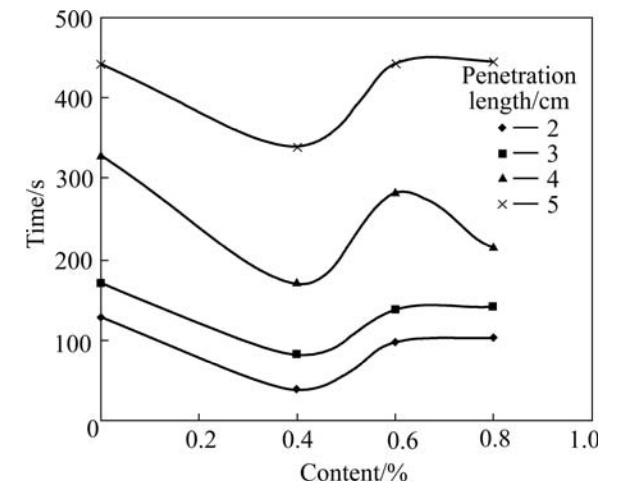

Fig.5 Penetrating time of wetting agents versus contents of wetting agent SDS at different penetration depths (down-ward penetration; drying dust; dust partical size 100−180 mesh; environmental temperature 30 ℃)

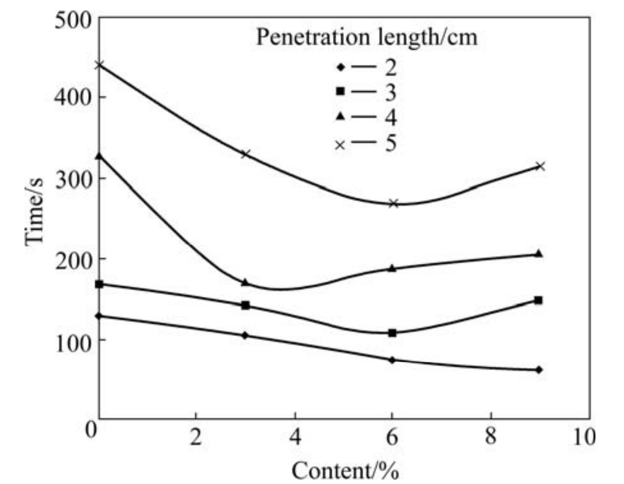

Fig.6 Penetrating time of wetting agents versus content of water glass at different penetration depths (down-ward penetration; drying dust; dust partical size 100−180 mesh; environmental temperature 30 ℃)

→0; for 120−180 mesh, 9%→6%→3%→0.

2) There exists an optimal content of water glass for different sizes of dust. For dust of 60−80 mesh, the optimal content is 3%; for dust of 100−120 mesh and 120−180 mesh, 9%. It shows that the optimal content is different for various sizes of dust. When preparing the wetting agent solution in in-situ application, dust size variation should be taken into consideration.

3) At temperature near 30 ℃, the wetting improving effect is almost the same for four ranges of dust size. Particularly, the improving effect for fine dust of 120−180 mesh is not obvious compared with the SDS and the wetting ablility can increase by 30%−50%.

5.3.3 Penetration ability in dust of SDBS solution with various contents

Fig.7 shows a typical experimental result.

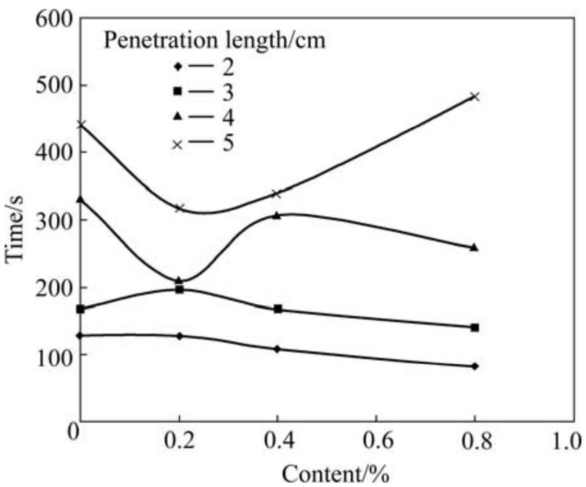

Fig.7 Penetrating time of wetting agents versus content of weting agent SDBS at different penetration depths (down-ward penetration; drying dust; dust partical size 100−180 mesh; environmental temperature 30 ℃)

From Fig.7 and other un-listed results, it shows that:

1) With the variation of SDBS content, the dynamic penetration ability in various sizes of dust is different. The rank of wetting ability from large to small is: for dust of 60−80 mesh, 0.4%→0.2%→0.8%→0; for dust of 80−100 mesh, 0.4%→0.2%→0.8%→0; for 100−120 mesh, 0.4%→0.8%→0.2%→0; for 120−180 mesh, 0.8%→0.4%→0.2%→0.

2) There exists an optimal content of SDBS. For dust of 60−80 mesh, 80−100 mesh and 100−120 mesh, the suitable concentration of SDBS is 0.4%. For dust of 120−180 mesh with rather large range in size, the wetting improvement is not obvious.

3) At temperature near 30 ℃ and the dust of 100−120 mesh, the optimal content of SDBS is 0.4%. In this case, the wetting effect is excellent and the wetting time is reduced from several times to several decades times.

4) Generally, when the content of SDBS increases from 0.4% to 0.8%, the wetting ability has no improvement.

5.4 Main specifications of wetting performance of various wetting agents

Based on a great number of experiments, the main specifications of wetting performance of three wetting agents to dust are listed in Table 6.

Table 6 Optimal wetting agent and its concentration for various dust partical sizes by down-ward penetration test

Dust size/ mesh	Water content/%	Wetting agent and content	Reducing wetting times of time
60−80	0.452	0.6% SDS	0.6
80−100	0.428	0.6% SDS	1
100−120	0.712	0.6% SDS	0.7
120−180	0.574	9% water glass	2
60−80	0.264	0.8% SDS	3
80−100	0.264	0.6% SDS	1.5
100−120	0.516	6% water glass	1
120−180	0.409	6% water glass	1.5
60−80	0	0.6% SDS	1
80−100	0	3% water glass	1.5
100−120	0	0.6% SDS	3
120−180	0	0.6% SDS	0.6

5.5 Effect of complex wetting agent solution

Some research results proved that complex wetting agents have both functions of increasing and decreasing wetting ability. Therefore, test of complex wetting agent performance is still significant. In this experiment, 0.6% SDS that is the suitable content for drying dust was combined with water glass solution. A typical test result is shown in Fig.8.

From Fig.8 and other un-listed experimental results, compared with the single wetting agent, the complex wetting agents are a little better in increasing the wetting ability for dust of 60−80 mesh and 80−100 mesh. However, for dust of 100−120 mesh and 120−180 mesh, the function of improving wetting effect is very limited. The key data are summarized in Table 7. When water glass is used as dust binding agent and a little SDS as wetting agnet is added, the penetration ablity of water glass solution can increase and dust suppression function can also be reinforced generally.

5.6 Problem analysis of down-ward penetration test

After conducting a great number of down-ward

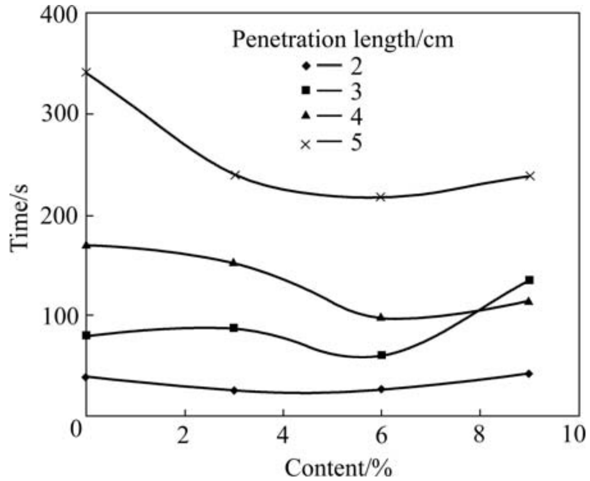

Fig.8 Penetrating time of wetting agents versus content of water glass added by 0.6% SDS at different penetration depths (down-ward penetration; drying dust; dust partical size 100−180 mesh; environmental temperature 30 ℃)

Table 7 Optimal complex wetting agent compositions for drying dust by down-ward penetration test

Dust size/ mesh	Suitable composition	Reducing wetting times of time campared with that of single wetting agent
60−80	0.6% SDS + 6% water glass	1
80−100	3% water glass + 0.6% SDS	0.6
100−120	0.6% SDS + 6% water glass	0.4
120−180	0.6% SDS + 6% water glass	0.3

penetration tests, several problems during experiment were discovered. The problems include breaking of dust capillary, leakage and bulb phenomena, etc. To investigate the regulation of down-ward penetration, statistic experiments should be made and above problems should be attended.

1) The smaller the dust particles, the easier the bulbing and breaking phenomena in the capillary of dust occur during penetrating procedure. When the phenomenon happens, larger experimental error will produce. When breaking happens in dust pillar of capillary, the penetration time of solution can be extended more than several minutes or longer. Usually, the breaking happens at 0.5−1.0 cm away from the top of dust capillary and at this case, experiment should be done again. When the leakage and bulbing occur in dust pillar, the wetting time may be extended to 20−50 s. This also results in a larger error of achieved data.

2) The reasons of breaking and bulbing phenomena are that it is difficult to put the fine dust into the capillary homogeneously. There is a large volume of gas in the leakage of dust, particularly the fine dust with large specific area. When doing wetting test, gas in the leakage of dust should be discharged, but the top part of dust becomes denser by solution action and it seals the gas discharged. In this way, breakage phenomenon will happen. The gas in the middle of dust pillar will resist the wetting agent penetration and extend the penetration time.

3) If the dust in capillary is inhomogeneous, penetration does more quickly for the denser part of dust than the looser part. The reason is that little gas for the denser part of dust and the solution is quickly dispersed. For the looser part of dust, the gas in dust resists the liquid penetration.

In fact, there are many factors that affect the penetration test, such as vertical status of capillary tube, accuracy of scale, drying and cleaning status of inside part of capillary tube, homogeneous status of dust, adding pattern and speed of wetting agent, reading error, temperature and humidity. Among them, homogeneous status of dust and speed of adding wetting liquid are main factors. Therefore, if test is made at once, the result is unreliable.

6 Dropping liquid test and its comparison with down-ward penetration test

To further analyze the accuracy of down-ward penetration test, dropping liquid test was used to make comparison. The dusts used in two experiments are the same.

6.1 Dropping liquid and device

Procedures of dropping liquid test are as follows: 1) The weighted dust (20 g) is put into a glass span and is made in plain. 2) A drop of liquid from a dropping pipe is added into the dust and at the same time, the time that the drop disappears into the dust is determined by a timer during the experiment. 3) The size of wetted area of the dust by the drop is measured. The detailed description and device are shown in the Refs.[1,9,16]. The same experiment is done repeatly ten times and average value is got to keep the error under the allowable limit.

6.2 Results of dropping liquid and analysis

Temperature of liquid was controlled near 30 ℃. Typical experimental results are shown in Figs.9−10.

From Figs.9−10 and the un-listed results, it can be seen that SDS has some function of improving wetting performance for dust with various sizes at temperature

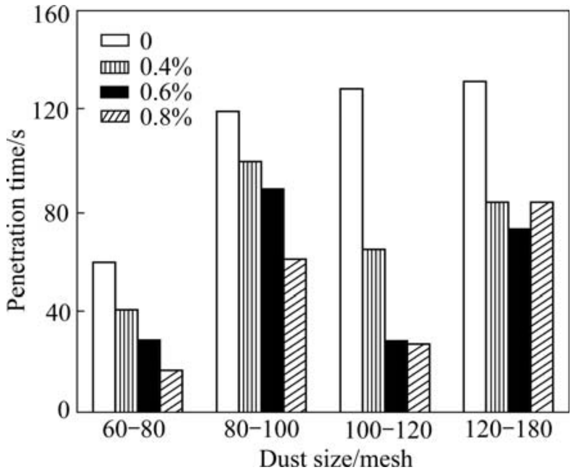

Fig.9 Penetrating time of wetting agents versus various partical sizes of dust for different contents of SDS (dropping liquid test; environmental temperature 30 ℃)

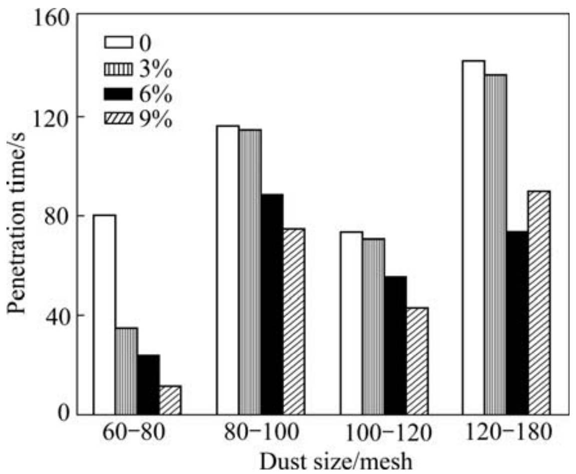

Fig.10 Penetrating time of wetting agents versus various partical sizes of dust for different contents of water glass (dropping liquid test; environmental temperature 30 ℃)

near 30 ℃. Especially for dust of 60−80 mesh, its improvement of wetting ability increases by three times. In this case, the suitable content is about 0.6%.

When content of SDS is about 0.6%, the wetting performance increases by more than four times for dust of 100−120 mesh. For dust of 60−100 mesh, its wetting ability with 0.8% is much better than that of 0.6%. The diameter of dispersion liquid in dust is un-proportional to the content of wetting agent and the dispersion time. Compared with the down-ward experiment, the suitable content is almost the same for the same size of dust with the same water content.

Wetting improvement of water glass with 3% content is not obvious for the dust of 80−180 mesh, but is effective for the dust of 60−80 mesh. For various sizes of dust, the wetting improvement is different. By measuring the diameter of dispersion, it is discovered that the larger the content is, the better the wetting performance is but is not very obviously.

The comparison of dropping test with down-ward penetration shows that they are suitable to be used for investigating the wetting behaviour of dust of smaller than 180 mesh. For smaller dust particles, dropping liquid test has no error phenomena like those described in down-ward penetration.

From the experimental results, the wetting ability is different with various sizes of dust even the same wetting agent and testing conditions are applied. For hydrophobic dust, wetting improvement is more obvious. In field application, the whole effect should be taken into consideration. Also, the conditions used to invent a wetting agent should be the same as the field ones.

7 Conclusions

1) The wetting performances of wetting agents to various sizes of dust were investigated firstly and the research results are creative and valuable. It is very important as reference in similar research project.

2) The compositions of lead and zinc dust are very complicated and is composed of many kinds of minerals with various crystal sizes. When inventing a wetting agent, effect of all compositions should be taken into account. If the experimental conditions in laboratory are different from the field, the wetting agent may be uneffective.

3) All selected wetting agents in the investigation can improve the wetting performances to dust, but the effects are different. Wetting ability of SDS is better than that of water glass. Among three wetting agnets, SDBS is rather poor. For SDS, suitbale content is 0.6% in general and good wetting performance can be achieved.

4) The size of dust and its water content are main factors of influencing the penetration speed of wetting solution. For smaller size of dust with lower water content, wetting agent has great function of improving wetting ability. The volume density of dust also affects the wetting agent performance. Therefore, physical and chemical properties of dust must be taken into consideration.

5) Complex wetting agents have some function of increasing wetting ability for dust with higher water content. 6% water glass added with 0.6% SDS is better than the single one in some extent.

6) Generally, there are many factors that influence the accuary of down-ward penetration test during experimental procedures. To make the experimental results more reliable, repeated and statistic tests should be conducted when investigating a regulation.

7) Dropping liquid and down-ward penetration test results have coincidence in some way but also exist differences. Every test method has its applying conditions. When selecting test method, the goals and applying field conditions should be taken into account.

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