Energy Consumption of Dense-phase Pneumatic Conveying in Long-distance Pipe

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Abstract: In order to research the energy consumption of gas solid two phase flow, a 1:1 test bench for the pneumatic conveying system was set up. Gas-solid two-phase flow experiments of fly ash were carried out with compressed air being adopted as dynamic force. Groups of GP/DP transmitters were installed along the pipeline. Pressure drop along the pipeline was expressed by the GP values. So the energy consumption can be achieved by the given experimental data. The effect of the solids loading ratio, pneumatic conveying pressure, gas velocity and pipeline arrangement etc on the energy consumption were performed according to the experiments. Finally, the key methods of saving energy in pneumatic conveying were given, which could optimize the system design.

Keywords: Dense-phase pneumatic conveying; long distance pipeline, energy consumption

1 Introduction

Pneumatic conveying was a prevalent form of transportation of solids in industry [1].This type of transport was widely used in heat energy engineering, food industry, production of building materials, chemical industry, metallurgy and other fields But in recent years, the research focused on the dilute phase pneumatic conveying, which was high energy consumption and wear. People paid more attention on the more effective transportation style, dense phase pneumatic conveying. As an important parameter, transportation efficiency can not be ignored, which affected system design and application[2].

There were lots of methods to evaluate pneumatic transportation efficiency[3]. Such as the solids loading ratio, pressure drop along the pipe and conveying pressure etc[4-5]. But in this paper, the transportation efficiency was expressed by the energy consumption. By measuring the electric energy which transported a ton solids powder along one meter pipe length, the energy consumption of the pipeline can be given clearly.

The present paper firstly gave the effect factors of energy loss in the dense-phase pneumatic conveying process. Gas-solid two-phase flow experiments of fly ash were carried out with compressed air being adopted as dynamic force. Base on experimental data, trend of energy loss was given. Finally, energy loss reduction method was formed, which can provide some effective ways to reduce the energy consumption in process of long-distance dense phase pneumatic conveying.

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2 Experiment Set-up and Method

For the purpose of researching the energy loss of pneumatic conveying process, a 1:1 improvement of test bench for the dense-phase pneumatic conveying system in actual industry was conducted. The system in this paper was a circulating experiment bench with long-distance pipeline, which consists of an air compressor, a feeder, conveying pipeline, measurement and control system, as shown in Figure.1.

The pipeline was made of seamless steel pipe with the distance being 240 m long and pipe diameter being 80 mm. And the fluidized –bed feeder was adopted as transportation device. And 500kg fly ash was put into the feeder to be conveyed in one experiment circle. 4 group of GP/DP transmitter were installed on the feeder, setting points along pipeline and pressure drop of test segment was collected to perform the trend of pressure drop along the pipe. It must be noted that, in this paper, the average pressure drop of four test data was regarded as the pres-

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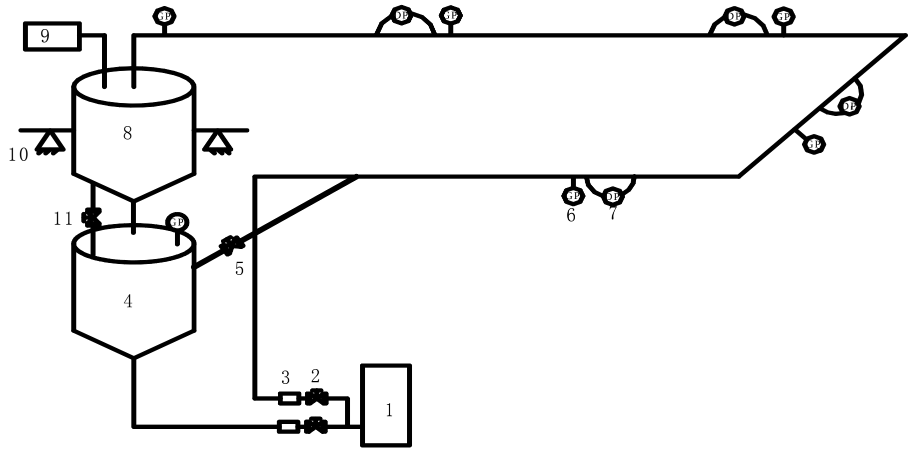
sure drop on the whole pipeline to evaluate the energy consumption of pneumatic conveying process. Electronic-weighting system was introduced to measure the discharge rate of fly ash into the feeding bin. Gas mass flow-meter was adopted to measure the mass flow ratio of the compressed air. And all the tested data was collected automatically.

Lucite pipe was selected to observe the flow style and linked with seamless steel pipe by reinforced flange.

Fly ash was transported from the feeder vessel to the receiver in dense phase. The material properties were shown in table1.

Table.1. Material physical properties

Material	Equivalent spherical diameter, mm	Particle density, kg/m^3	Bulk density, kg/m^3
Fly ash	0.03	2063	778



1. air supply 2. gas valve 3. gas flux apparatus 4.feeder vessel 5. solid injector valve 6,7. static/differential pressure cell 8 receiver vessel 9dust collector 10. weight balance 11. balanced valve

Figure.1 Schematic diagram of experimental system

3 Results and Discussion

As mentioned above, the target of this paper was electric energy when conveying 1 ton solid per meter. The calculated equation was given as below.

$$E = 2\Delta pQT \quad (1)$$

Where E stood for electric energy when conveying 1 ton solid per meter, kWh/Tkm.

Δp meant pressure drop per unit length on the pipe, kPa/m.

Q was gas volume flow, m^3/h.

T was the time when one conveying circle finished, s.

3.1 Effect of the Solids Loading Ratio

The solids loading ratio was defined as the mass ratio of .solid and phase across a fixed cross-section at a time quantum, which can be calculated as below.

$$m_s = G_s / G_g \quad (2)$$

Where, m_s meant the solids loading ratio, kg/kg.

G_s stood for the solid mass flow, kg/s.

G_g was the gas mass flow, kg/s.

This parameter reflected on the gas carried capacity. And it was one of the most important influencing factors to the energy loss.

As we all know, the solids loading ratio had some noticeable effect on the energy loss according to the experiment.

Figure.2 gave the trend of energy consumption in the same solid mass flow. From this figure, the energy losses decreased with the solids loading ratio getting bigger. It is because that, when the solid mass was constant, the needed gas mass flow became less with bigger solids loading ratio, which led to the decrease of energy loss.

As we all know, solid velocity was inverse proportional to the quantity of particles. It meant that, the more amount particles, the less solid velocity was. When the solid concentration decreased, the probability of collision, impact and friction between particles reduced too. The energy loss decreased synchronously. But at the same time the increasing of the solids loading ratio may appear solid deposition and pipe blockage.

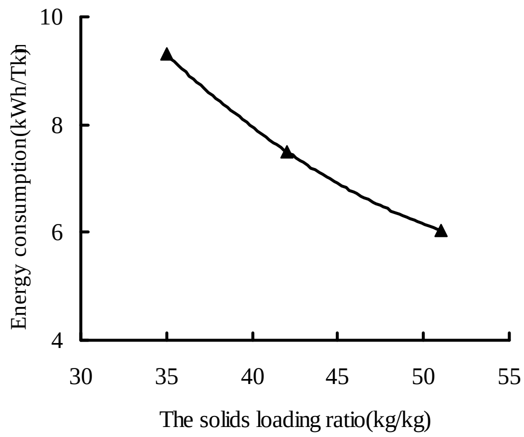


Figure 2. Trend of energy consumption in the same solid mass flux

Therefore, suitable solids loading ratio must be selected in the process of pneumatic conveying.

3.2 Effect of Conveying Pressure

In process of pneumatic conveying, the maximum static pressure in the feeder was regarded as conveying pressure, which decided the driving force in the pipe. Meanwhile, this pressure was the standard beginning of transportation process. Some present research showed that pressure drop along the pipe increased gradually with the conveying pressure getting bigger.

Figure.3 showed the trend of energy consumption in different conveying pressure. From this figure, we can achieve that energy consumption increased with the growing up of conveying pressure. But when the pressure value diminished less enough, there would be appear to block in the pipeline. Therefore, the determination of suitable conveying pressure was essential.

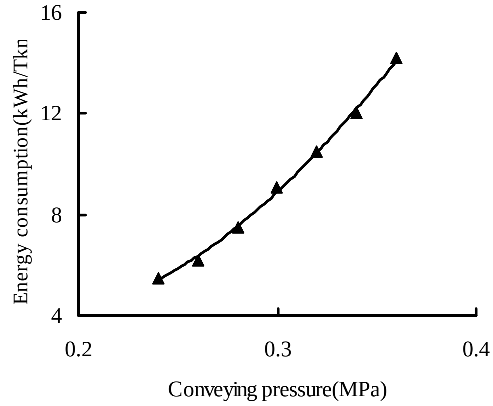


Figure.3 Trend of energy consumption in different conveying pressure

3.3 Effect of Conveying Velocity

Conveying velocity was defined as the gas velocity in the pipe, which can be given as following.

$$v_g = Q / A \quad (3)$$

Note that, A stood for sectional area of pipeline. From Equation.(1), we can know, energy loss was direct proportion to pressure drop and gas volume flow. Meanwhile, gas volume flow and pressure drop was direct proportion to the gas velocity and its square value. So energy loss was proportion to cubic gas velocity. That meant, little change of gas velocity value may lead to larger alteration of energy loss.

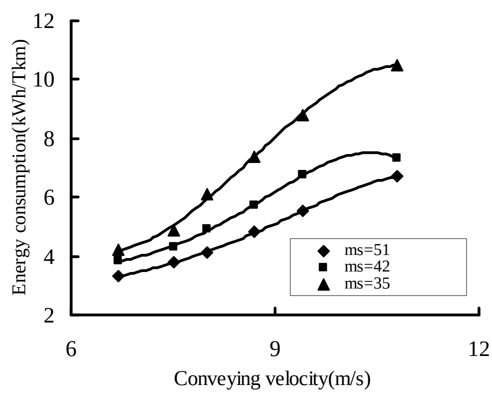


Figure.4 Trend of energy consumption in different conveying velocity

Figure.4 showed trend of energy consumption in different conveying velocity. From the figure, energy con-

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sumption increased with the enlargement of gas velocity. So the more gas velocity, the energy losses bigger was. But if we decreased gas velocity low enough, the block in pipe would happen. In other word, the critical gas velocity must be identified.

3.4 Effect of Pipe Distance and Layout

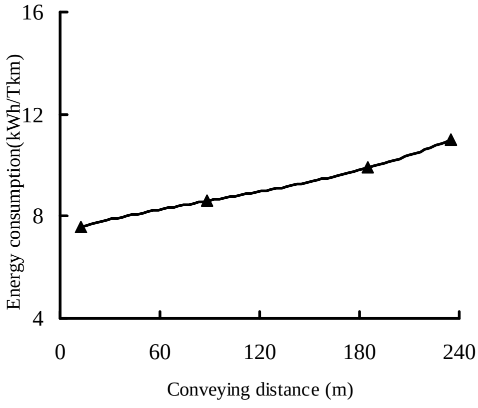

Figure.5 Trend of energy consumption in different conveying distance

In the long distance pipeline, the energy consumption along the pipeline would increase because of the reduction of static pressure in the pipe and expansion of gas phase. Figrue.5 showed trend of energy consumption in different conveying distance. This figure illustrated that energy consumption increased along the pipeline. From the conclusions above, shorter pipeline was prevailed in a specific circumstance. If the long distance pipeline can not be avoided, the stepped pipeline can be adopted to diminish the energy consumption.

Meanwhile, the pipe layout played an important role in energy consumption during the conveying process. The amount of elbow and that with less radius of curvature must be decreased, which can avoid the blockage of pipeline and high energy loss.

3.5 Effect of Pipe Power Equipment

Dynamic equipment supplied the compressed gas during the conveying. According to the practical reference, liquid piston compressor or Roots vacuum blower was adopted in the suction pressure pneumatic conveying system, while in the positive pressure system, piston or screw type air compressor were selected. If the gas supply equipments were selected properly, the power efficiency of equipment would be high, which led to energy conservation.

3.6 Effect of Pipe Solids Properties

The influence of solid physical property on the energy loss was not identified because of the single solid material, fly ash. But according the previous research, the solid properties such as percent moisture content, bulk density, porosity etc affected conveying energy obviously. So the critical factors of solids must be paid attention to in the system design.

4 Conclusions

Long-distance pneumatic conveying experimental system was set up and gas-solid two phase flow experiments were carried out by conveying fly ash. The trends of energy consumption in different influencing factors were given. By experimental research, conclusions below can be achieved.

(1) The solids loading ratio, conveying pressure, gas velocity, pipeline length and layout, power equipment and solids properties had noticeable effect on the energy consumption along the pneumatic conveying system.

(2) In the design of pneumatic conveying system, transportation stable must be paid more attention to.

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