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Study on Speed Characteristic of Material in Pipe Pneumatic Conveyor

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Abstract

Focusing on material kinetic characteristic in horizontal pipe and vertical pipe of pneumatic conveyor, motion differential equation of the particle groups in pipe is established and solved by introduced into Matlab. By analyzing the resistance coefficient of the particle groups in different pipes and speed characteristic curves in different initial conditions, the speed characteristic of the particle groups in accelerating section of the pipe in pneumatic conveyor is obtained. The result shows that (1) resistance coefficient affects ultimate constant velocity of the particle groups in pipe, (2) different initial conditions affect acceleration (deceleration) motion time of the particle groups in pipe and (3) the power consumed in vertical pipe is larger than that in horizontal pipe when the particle groups are in accelerating section.

Keywords: pipe-line transportation, speed characteristic, numerical simulation, resistance coefficient, pneumatic convey

1. Introduction

Pneumatic convey is a technique to convey powder and granular material constantly by using air energy, which is widely used in electricity, chemical industry, steel industry and metallurgical industry. The study on pneumatic convey involves many subject branches, and is of great practical significance to manufacturing production. The dual-phrase distribution of gas solid in pneumatic convey is affected by two-phase property (e.g. fluid density, fluid viscosity, particle density, particle size distribution), operant

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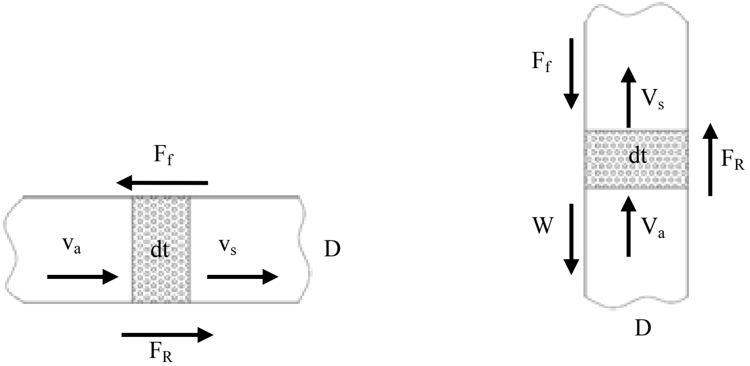
condition (e.g. conveying capacity, fluid velocity, mulling ratio and psid) and process condition, and its motion state can be divided into 3 phases: materials are suctioned from the ground, then moving at rate of acceleration (deceleration), and finally moving constantly in the pipe. Materials' motion state in accelerating section directly affects process parameter design and transferring efficiency of the pneumatic convey system. The kinetic characteristic is greatly important especially in short distance transferring. In 1997, based on numerical calculation DNS model, Pan and Banerjee analyzed materials' kinetic characteristic in accelerating section in pipe and obtained motion equation of particle groups in syphon. In 2000, Glowinski established distributed Lagrange polynomial of the particle groups in pipe and analyzed their motion stage in 3D pipe eddy flow.

2. Buildup of Mathematic Model

In horizontal and vertical pipe, the forces exerting on materials includes thrust from airflow to solid particles, gravity and friction force between solid particles and wall. For the convenience of calculation, the paper selects a collection of particles in pipe as object of study. (here in after referred to as "particle group")



(a)Horizontal line of mechanics model of particles (b)Vertical pipe mechanics model particle group

Fig.1 The mechanical model of particle group

2.1. Establishment of Objective Function[1] [2] [3]

The motion equation of the particle group can be obtained from the mechanical model of particle group in Figure 1:

Horizontal pipe
$$M_s \frac{dV_s}{dt} = F_R - F_f \quad (1)$$

Vertical pipe
$$M_s \frac{dV_s}{dt} = F_R - F_f - W \quad (2)$$

In the equation, Ms represents quality of particle group, measured in a unit of weight; Vs represents running velocity of the material, m/s; F_R represents thrust from airflow to solid particles,

$$F_R = gM_s (\frac{V_a - V_s}{V_{mg}})^{2-K} \quad (3)$$

F_f represents friction force in pipe wall,

$$F_f = \frac{\lambda_m V_s^2 M_s}{4D} \tag{4}$$

W represents weight of solid particle,W=g • Ms; K represents relative coefficient of pneumatic convey. The value of k is determined by Reynolds number Re, which is relative to grain diameter of the material and running velocity. When the grain diameter of the material is larger than 1mm, k is zero.

Introducing the parameters above into equation (1) and (2), the motion equation of the particle group in pipe can be obtained:

$$\frac{1}{g}\frac{dV_s}{dt} = (\frac{V_a - V_s}{V_{mg}})^2 - \frac{\lambda_m V_s^2}{4gD} \tag{5}$$

$$\frac{1}{g}\frac{dV_s}{dt} = (\frac{V_a - V_s}{V_{mg}})^2 - \frac{\lambda_m V_s^2}{4gD} - 1 \tag{6}$$

In the equation, Va represents airflow speed, m/s; Vmg represents floating velocity of the particle group, m/s; λm represents resistance coefficient of the particle group; D represents diameter of transfer pipe.

2.2. Establishment of Design Variable[4] [5]

In this paper, the grain diameters of the particle group are set for 1mm, 2mm, 5mm and 10mm. The particle density is 2700kg/m^3,. The airflow velocity Va is 32m/s. The diameter of transfer pipe D is 75mm. The floating velocity of single particle V_0 and floating velocity of particle group V_{mg} can be calculated as follows:

$$V_0 = 5.45\sqrt{\frac{d_s(\rho_s - \rho)}{\rho}} \tag{7}$$

$$V_{mg} = V_0(1-\varphi_0)^\beta \tag{8}$$

In the equation, V0 represents floating velocity of single particle; ds represents particle grain diameter;ρs represents particle density; ρ represents air density, 1.225 kg/m3;β represents laboratory index, 2.3; Φ 0 represents volume fraction of material, 0.25.

3. Result and analysis

3.1. Result and Analysis of Numerical Calculation

In the paper, Matlab is applied in numerical calculation. Runge-Kutta method is applied in solution algorithm, and corresponding function is ODE (Ordinary Differential Function). The program editor in the software is used to compile motion differential equation of solid particle group and File M of constraint function. Then Matlab calls directly File M and ODE resolver to strike the relationship between velocity and time and depicts the velocity-time curve.

These five speed curve variation charts in Fig.2 & 3 show that:

① After a period of acceleration (deceleration) motion, the particles move constantly at last.

② With the increase of resistance coefficient, motion time of the particle group in accelerating section in pipe and the motion velocity both decline. Take the particle group of 10mm grain diameter in horizontal pipe for example, when the resistance coefficient rises from 0.1 to 1.0, the motion time in accelerating section decreases from 0.5s to 0.15s.

③ With the increase of initial velocity, motion time of the particle group in accelerating section in pipe decline.

④ When the resistance coefficient is same, the ultimate motion velocity of the particle group in horizontal pipe is larger than that in vertical pipe. Take the particle group of 10mm grain diameter for example, when the resistance coefficient is 0.1, the ultimate motion velocity of the particle group in horizontal pipe is 7.2 m/s., while it is 6.4 m/s in vertical group.

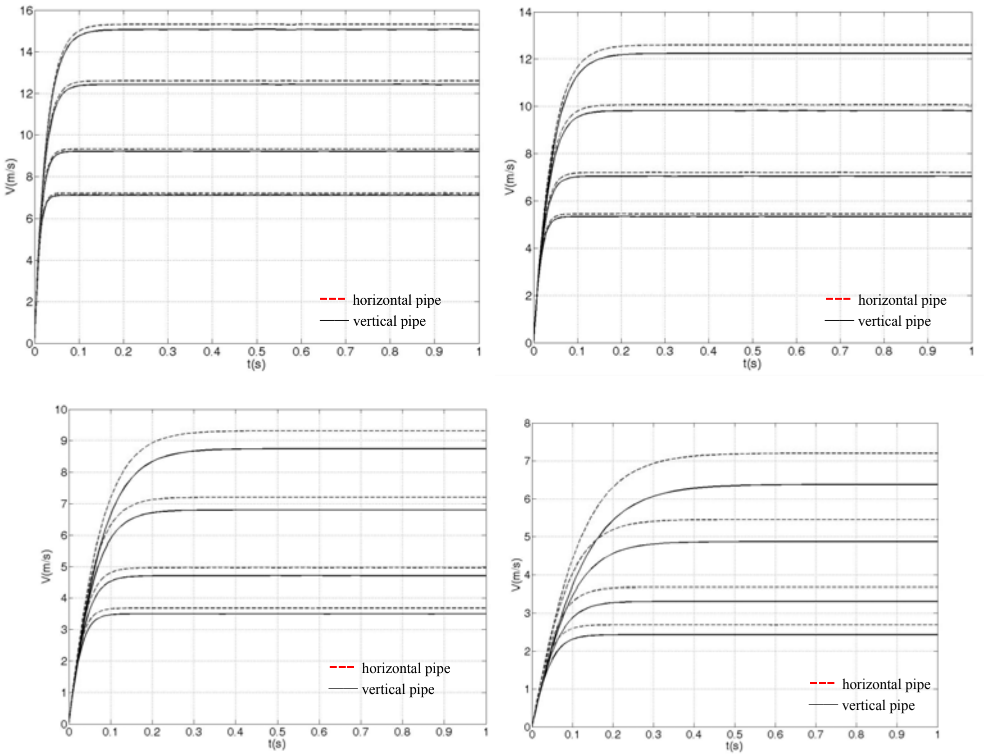


Fig.2 Resistance coefficient of particle group of the influence of the movement speed

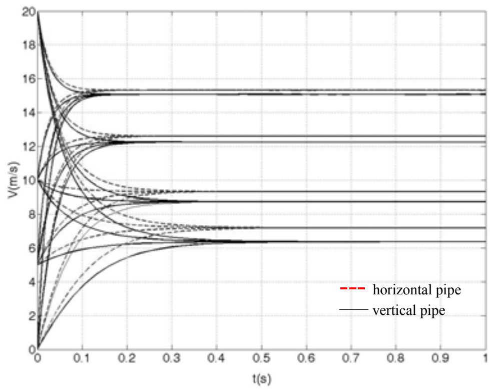


Fig.3 Different initial velocity of particle group velocity effect

4. Conclusion

In sum, the velocity characteristic of the particle group in accelerating section can be served by equation (3)&(4). Through analyzing velocity-time curves of the particle group in different initial condition, the conclusion can be drawn as follow:

(1) Different initial velocities only affect the motion time of the particle group in accelerating section. The motion of the particle group in pipe can be accelerating and decelerating, which is relative to the initial velocity.

(2) The ultimate motion velocity is relative to resistance coefficient and material diameter. When the material diameter is same, the ultimate motion velocity and accelerating (decelerating) motion time is longer with the lesser resistance coefficient.

(3) When conveying the materials of same weight, the energy consumed in vertical pipe is larger than that in horizontal pipe.

Reference

[1]John D.Baker,George Klinzing, Optimal performance of pneumatic transport systems. POWDER Technology 104(1999)240-247

[2]J.A.Ottjies, Digital simulation of pneumatic transport, Chem.Eng.SCI33,1978, P783-786

[3]C.Herbreteau,R.Bouard, Experimental study of parameters which influence the energy minimum in horizontal gas-solid conveying. Power Technology 112(2000)

[4]Andrew Cowell, Don McGlinchey, Determination of pneumatic transport capabilities of dry pulverised coal suitable for entrained flow processes. Fuel 84(2005)2256-2266

[5]Tsuji.Y,Morikawa, Numerical simulation of gas-solid two-phase flow in a vertical pipe,Gas-Solid Flows ASME FED-VOL 121,1991,PP123-128