

Finite Element Analysis of Constant Pressure Delivery System of Flying Ashes

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Received: 20 May 2014 /Accepted: 31 July 2014 /Published: 31 August 2014

Abstract: This article introduces the working principle of flying ashes conveying system with constant pressure. Constant pressure set at constant pressure regulating process values need to be matched with a suitable speed. The simulation analysis of flying ashes constant pressure conveying system by using finite element analysis software ANSYS, obtained the situation of flow distribution in the conveying pipeline flow and pressure in different wind speeds, through the analysis of the results, selecting a convey speed which is scientific and consistent with the actual situation. This article provides a strong theoretical and practical basis for optimizing the flying ashes pneumatic conveying parameters. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Constant pressure conveying, ANSYS, Flying ashes, Finite element analysis.

1. Introduction

Because the pneumatic conveying system has a higher transmission speed, it will bring high energy consumption and serious abrasion. How to realize low speed transmission, reduce the energy consumption, and can meet the actual transportation efficiency, ensure stable operation, improve control system performance; for scientific and rational design methods and design basis, with more rigorous scientific data to guide the production, is the main trend of the development of pneumatic conveying [1]. When a single pipe transporting materials, because the air loss energy continually in the transport process, and the pressure gradually decreased with increasing length of conveying, so the density of the air decreases, expansion, airflow velocity increased. Thus led to the pressure loss of the system increases and the pipeline wears seriously. Unlike conventional

constant flow conveying system, fly ash constant pressure delivery system through the conveying pressure setting and real-time adjustment to control ash gas ratio in the process of conveying, low speed to the maximum, reduce the pressure loss, reduce the pipeline and valve wear [2]. According to the actual production situation of manufactures, the flow state in the conveying pipeline of fly ash in different pneumatic conveying parameters are analyzed based on ANSYS, we selected the application parameters of the fly ash constant pressure delivery system.

2. Principle

2.1. The Basic Structure

The basic mechanism of fly ash pneumatic conveying system was shown in Fig. 1.

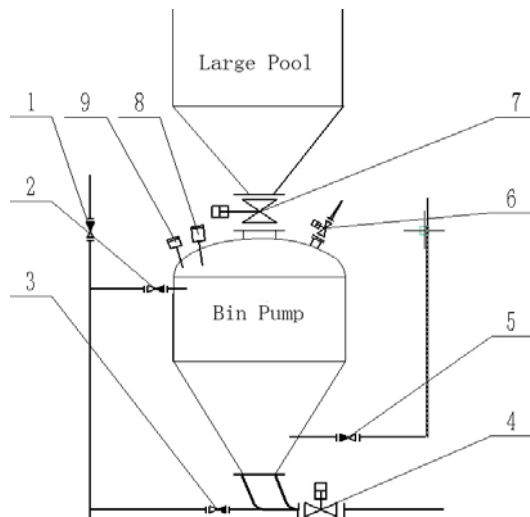


Fig. 1. The basic mechanism of fly ash pneumatic conveying system. 1 - The total intake valve; 2 - Delivery valve; 3 - Purge valve; 4 - Discharge valve; 5 - Flow control valve; 6 - Exhaust valve; 7 - Inlet valve; 8 - Level switch; 9 - Pressure transmitter.

2.2. The Principle

Constant pressure of fly ash conveying process is divided into four stages:

Feed phase: After the bin pump putting into operation the inlet valve and exhaust valve will open, fly ash free falls into the pump body, when the signal is full or reaches setting time of the indicator, the inlet valve will be closed.

Fluidization pressure stage: When the pump body delivery valve and flow control valve opening, the compressed air enters into the gasification chamber from the bottom of pump body from, and then goes through the fluidized bed after diffusion, at the same time of the material being fully fluidization, the pressure in the pump also gradually rise.

Constant pressure transmission phase: When the pressure in the pump reaches a certain value, pressure

sensor sends a signal, the discharge valve open and the system enters the stage of constant pressure conveying. Compared with the constant pressure of pressure value which have been set with the delivery pressure value, if the pressure values is high side or rising, it shows that the clear conveying resistance increases, gas concentration ratio on the high side means blocking pipe, at this point, opening of the flow control valve should be increased, expand the air compensating of pipe and reduce the ash gas concentration; if the pressure is too low, which shows that the pipeline resistance decreases, ash low than concentration gas, at this time, opening of the flow control valve should be reduced, so as to realize reducing air compensating, improve the ash gas concentration ratio, and calculate flow control valve of the specific opening by the PID.

Purging stage: When the pump pressure is less than a certain value, the purge valve is opened. When the pump in the fly ash conveying have been finished, pipeline resistance is small, according to the principle of constant pressure delivery, flow control valve is turned down automatically until closed, pressure drops to the set value, delivery valve and purge valve is closed, the discharge valve will be turned off after delaying time, then a work cycle is finished.

3. Analysis Model

3.1. Analysis Model of Pneumatic Conveying System

According to the layout of the local structure, select horizontal and vertical pipelines, two elbows and termination box as the object model. Pipes adopt DN125 composite pipe, and the elbows are casted by ductile iron casting. The fly ash pneumatic conveying system diagram was shown in Fig. 2.

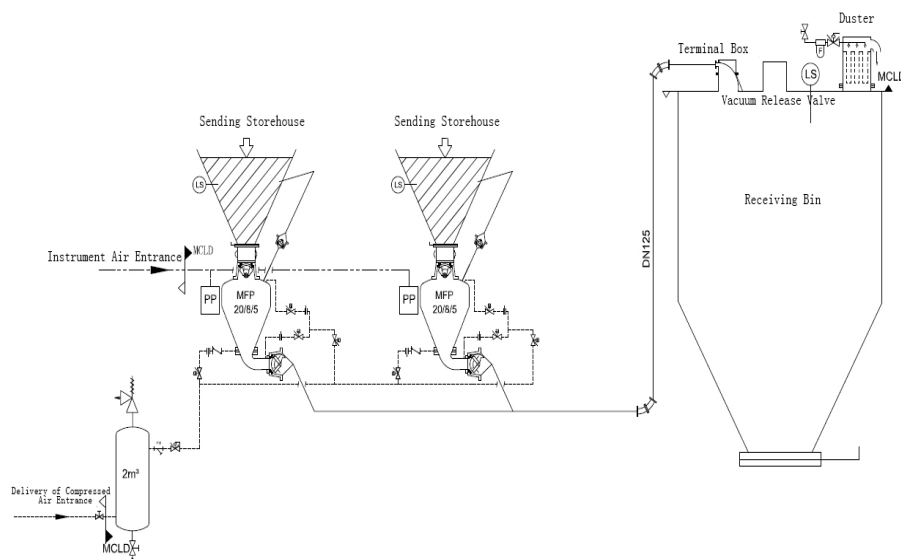


Fig. 2. The fly ash pneumatic conveying system diagram caption.

For ordinary gas-solid two phase flow, though solid particles don't have a deformation and surface tension, and no longer being divided into smaller particles, due to the factors of the particle size, particle and particle aggregation, forces between particles and flow state of uneven, there still exists a lot of very complicated phenomenon in the gas-solid two-phase flow. For such a model, to be analyzed is more complex, so it is necessary for constant pressure conveying of fly ash is to simplify the model.

In the process of constant pressure conveying, the fly ash distributes in the air and in the fluid state, there are only exchange of energy and no momentum exchange between the fly ash and air. So the performance of the gas-solid two phase mixture corresponds to with prospective gas performance in accordance with the following thermodynamic properties. Model conforms to the simplified conditions, so the two phase flow is simplified to prospective gases, whose total flow rate is $W_G + W_S$ [3].

Einstein Formula: $\mu = \mu_1 (1 + 2.5 a)$, the "a" is a not continuous phase volume fraction.

Gas Density: $\rho = (1 + m_s K) \rho_g$, the "m_s" represents mixing ratio; the "K" is the additional friction coefficient; the "ρ_g" represents air density.

Gas Constant: $R = \frac{R_g}{1 + m_s K}$, $K = \frac{v_s}{v_a}$, the v_s is

the material velocity; the v_a is the conveying air velocity.

The environment of flying ashes conveying system with constant pressure is 20 °C, air density $\rho = 1.205 \text{ kg/m}^3$, dynamic viscosity $\mu = 1.8135 \times 10^{-5} \text{ kg/(m.s)}$, flying ashes conveying simplified as quasi airflow whose thermodynamic property $\rho = 1.21 \text{ kg/m}^3$, dynamic viscosity $\mu = 1.973 \times 10^{-5} \text{ kg/(m.s)}$, which is to simulate and analyze the state of ash conveying air flow in the process of constant pressure delivery and distribution of the pressure of pipeline.

3.2. Calculate Reynolds Number

Our first determine is laminar or turbulent in the analysis of fluid flow. If the Reynolds number is greater than 3000, it indicates the presence of turbulence. According to fly ash conveying speed range and field conditions of constraint and efficiency of comprehensive consideration, we choose the speed range of 8 m/s ~ 12 m/s. Use the formula: $Re = \rho v D_h / \mu$. Value: $D_h = 125 \text{ mm}$, $v_{\max} = 12 \text{ m/s}$, $v_{\min} = 8 \text{ m/s}$, $\rho = 1.21 \text{ kg/m}^3$. The calculation results: $Re_{\max} = 91991.891$, $Re_{\min} = 61327.927 > 3000$, so our simulation analysis select the turbulence model [4].

3.3. Finite Element Mesh and Set Options [5-8]

Choose Main Menu → Preprocessor → Element Type → Add → FLOTRAN CFD (fluid analysis

module) → 2D FLOTRAN 141 to analysis. We use ANSYS software to establish finite element model and use the "Mesh Tool" to carry the grid division. Finite element graph, as in Fig. 3.

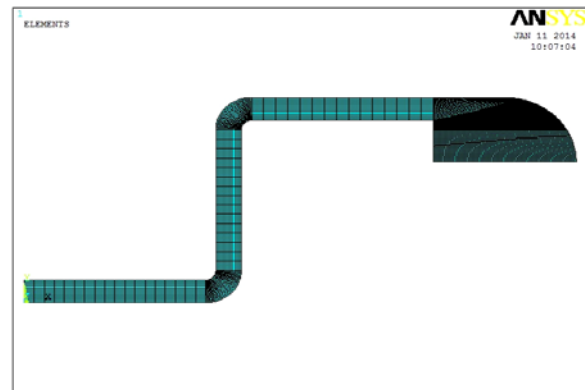


Fig. 3. Finite element graph.

Entrance boundary: Execute Main Menu → Preprocessor → Loads → Apply → Velocity → On Lines. Entrance velocity is 8 m/s, 9 m/s, 10 m/s, 11 m/s, 12 m/s.

Outlet boundary: Pressure P is in the form of the derivative in the N_s equation. We need for a given reference point pressure value. According to the data distribution diagram, the difference between pressure distributions is just a constant at most. So we set boundary conditions at the exit: P=0. Execute commands: Main Menu → Preprocessor → Loads → Apply → Pressure DOF → On Lines. Set up: P=0.

Define the solution options: Execute Main Menu → Preprocessor → FLOTRAN Set Up → Fluid Properties (set the control fluid properties); Main Menu → Solution → FLOTRAN Set Up → Execution Control → "Global iterations" (the overall number of iterations), input 50, Single click "OK"; Main Menu → Preprocessor → FLOTRAN Set Up → Solution Options (set solution controls) → "Laminar or Turbulent" (laminar or turbulent flow), choose "Turbulent", Single click "OK".

4. Analysis of Results

By using ANSYS finite element software for modeling and simulation of fly ash pneumatic conveying, the flow stress analysis result, flow velocity vector diagram, pipeline pressure distribution chart and path graph are analyzed.

Results of the flow force analysis: as shown in Fig. 4, which means the calculation results of residual, the analysis and calculation results of velocity and pressure is convergent, of which the curve of pressure change of 8 m/s relative to other more gentle [9].

Velocity vector diagram analysis: as shown in Fig. 5, a large speed change at the elbow, high-speed

airflow generated and staggered, on the velocity distribution, the smaller the curvature radius is, the higher speed. A marked increase in the outlet velocity, then decreased rapidly, there is a gas flow velocity of the region of 0, resulting in vortex [10]. The area produced by speed of 8 m/s is significantly less than the rate of 12 m/s; in the area, the velocity gradients of the rate of 8 m/s is significantly less than 12 m/s. Horizontal pipe and vertical pipe is longer, airflow in pipe is close to laminar flow.

Pressure distribution analysis: as shown in Fig. 6, the pressure increases at the elbow, there is also a low pressure area; the pressure at the outlet is low and there is a local region of reduced pressure, the distribution of these regions is irregular [11, 12]. From several graph comparison, the slower pressure changes from several view chart speed of 8 m/s case.

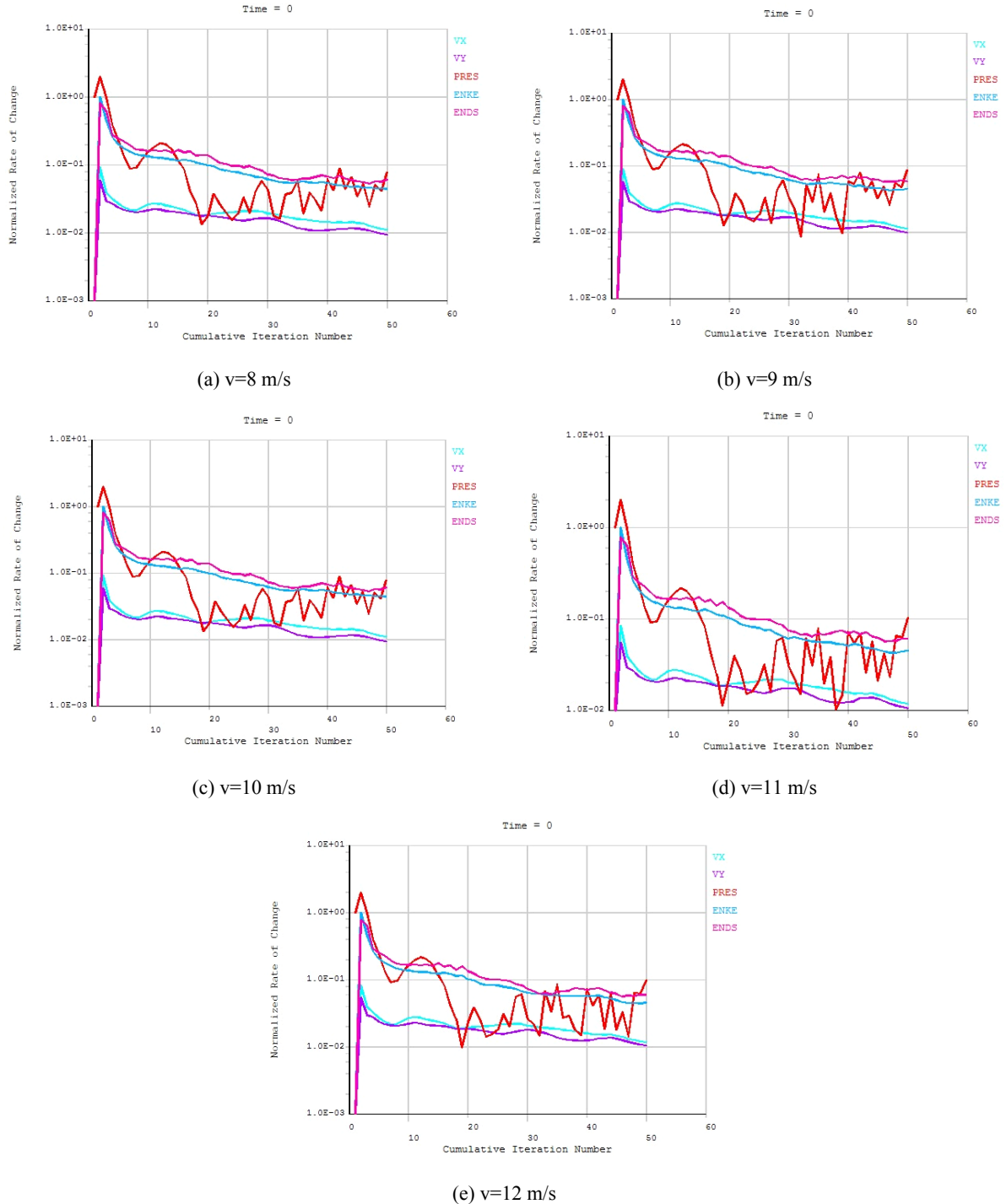
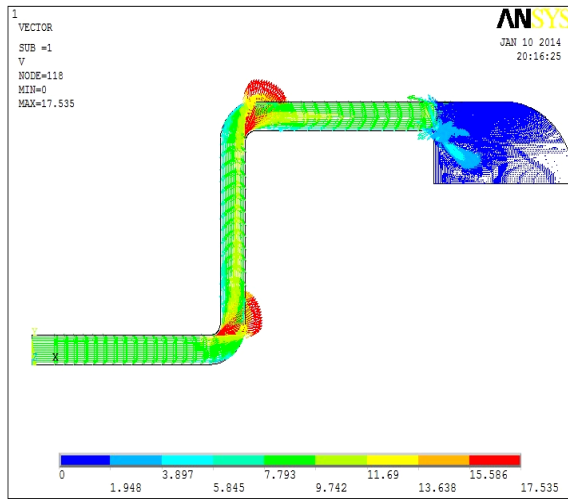
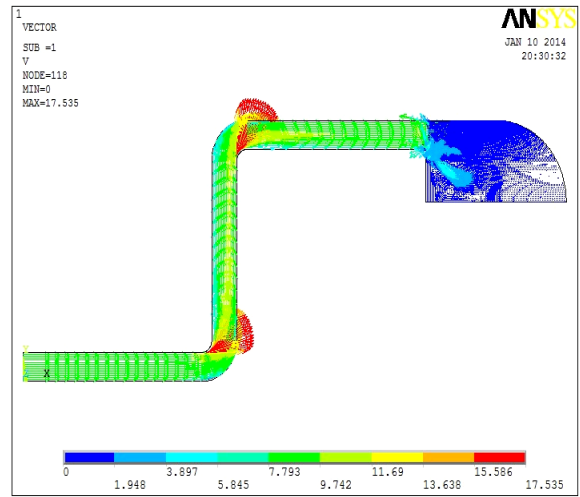


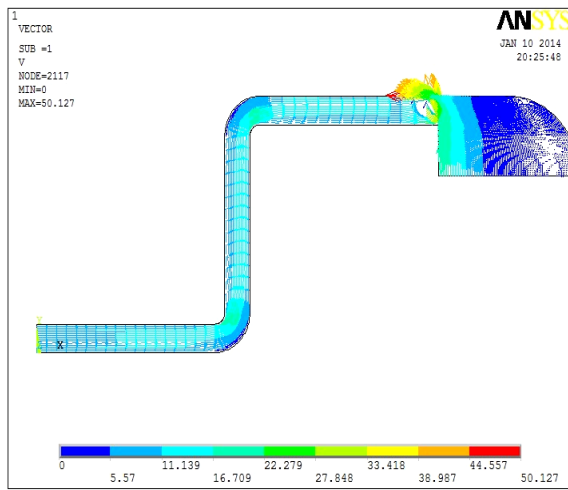
Fig. 4. The flow stress analysis result.



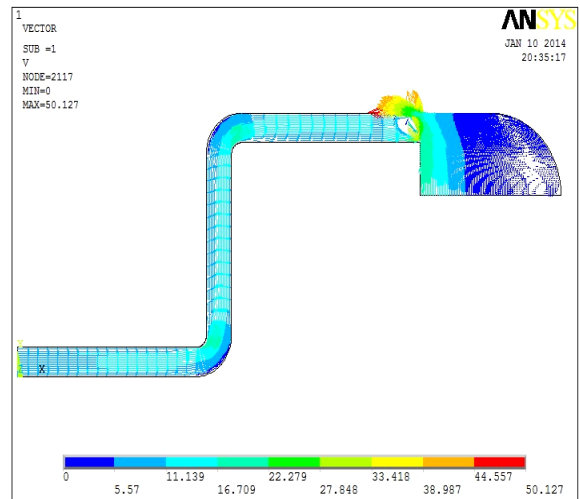
(a) $v=8$ m/s



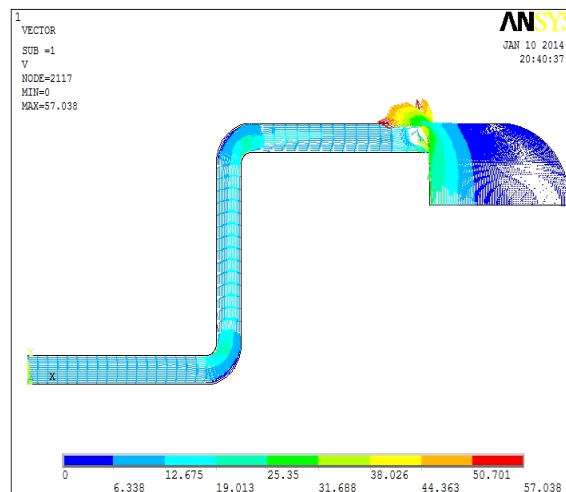
(b) $v=9$ m/s



(c) $v=10$ m/s

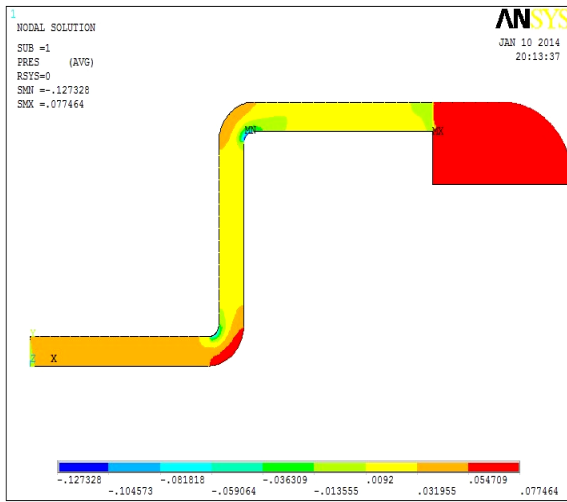


(d) $v=11$ m/s

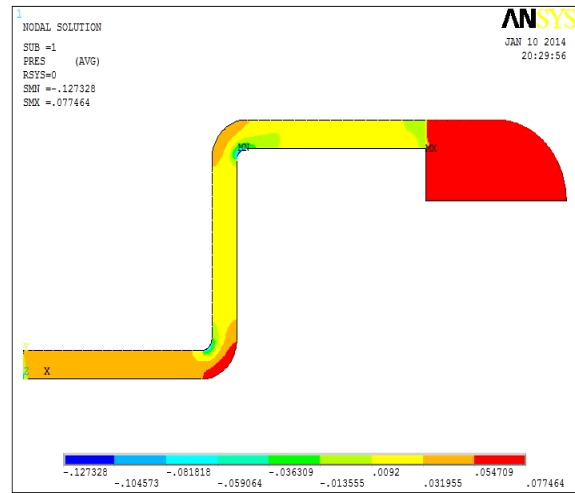


(e) $v=12$ m/s

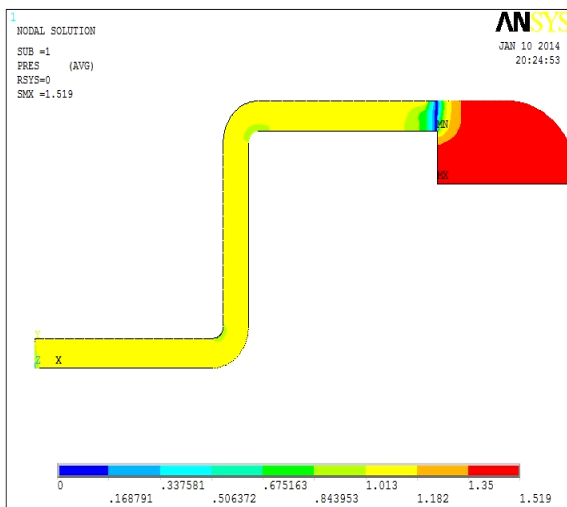
Fig. 5. Flow velocity vector diagram.



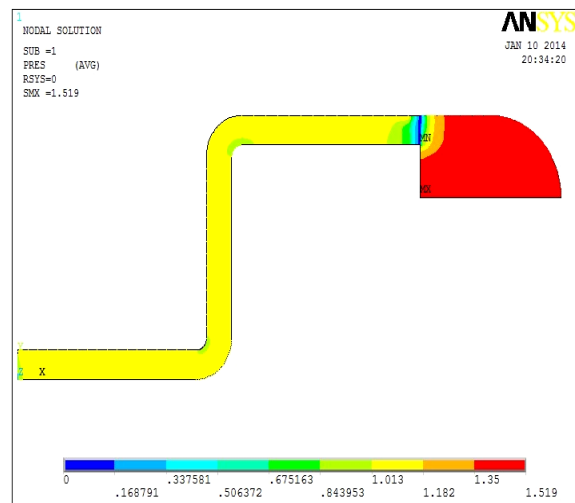
(a) $v=8$ m/s



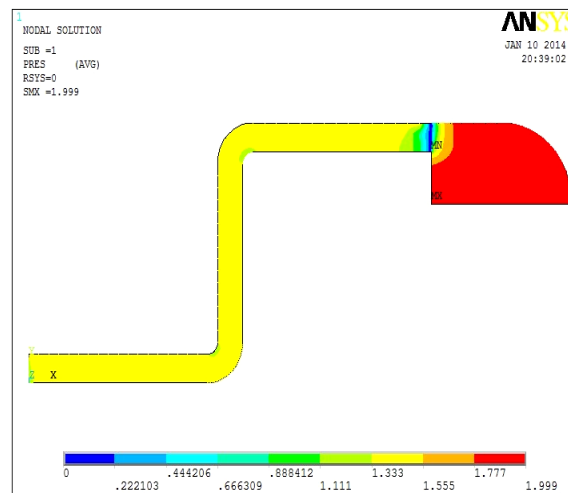
(b) $v=9$ m/s



(c) $v=10$ m/s



(d) $v=11$ m/s



(e) $v=12$ m/s

Fig. 6. Pipeline pressure distribution chart.

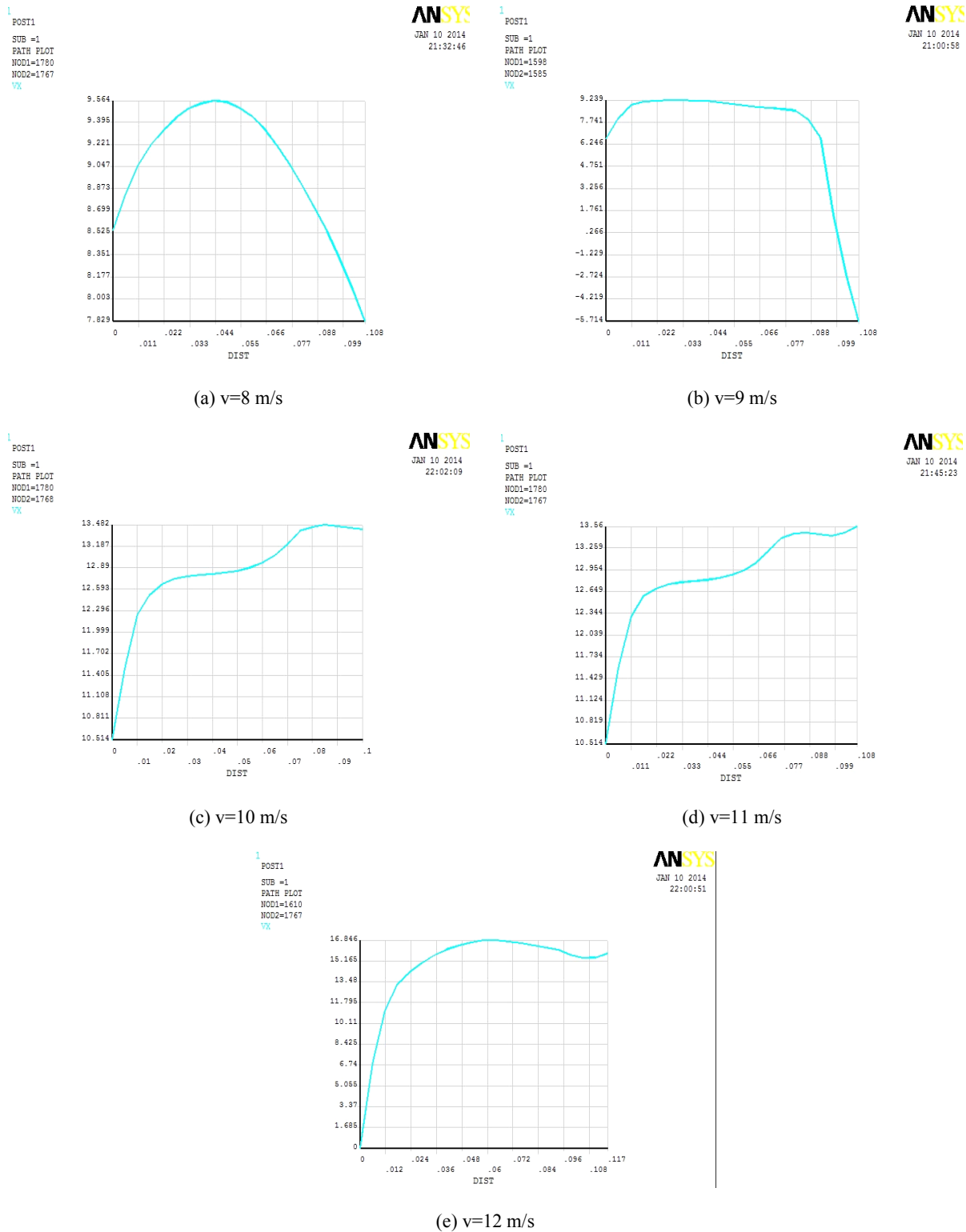


Fig. 7. Path graph.

Path analysis: as shown in Fig. 7, at the outlet of the pipe, fluid situation at the speed of 8m/s is better, close to a parabola.

From the theoretical level to prove results: there is a negative pressure zone in the outside of the elbow and inside of the straight area of elbow, which is easy to produce cavitation in these areas. The rate of velocity change in the corner and near the outlet pipe

is too large, so the inner wall and the outlet has been a lot of steady state and transient fluid impact force, thereby increasing the wear of the pipe, the pressure loss of pneumatic conveying and energy consumption. For reducing the power index, it is necessary to reduce gas flow rate and increase the load ratio, and the former is superior; wear of the solid particles and material is proportional to $2^{\text{nd}}\text{-}3^{\text{rd}}$

power of the speed [13-15]. So reducing the flow velocity is beneficial to reducing the power index and the wear of the pipe.

5. Conclusions

Fly ash conveying system controls the ash conveying gas concentration ratio by setting and controlling conveying pressure, for reaching low speed, reduce the pressure loss, reduce the conveying pipeline and valve wear. Constant pressure set at constant pressure regulating process values need to be matched with a suitable speed. By ANSYS finite element simulation analysis, in the 8 m/s speed, gas flow state is best, which confirms the low speed is good for overcoming the problem of pneumatic conveying. Because the transmission speed less than 8 m/s is restricted by field conditions and operating efficiency, all things considered, it is better to select 8 m/s as the fly ash of constant pressure delivery. After debugging experiment in the field, fly ash constant pressure conveying can operate well, mitigating pipe blockage, abrasion and a series of pneumatic conveying problem effectively.

References

- [1]. Lou Jian-Yong, Lin Jiang, Study status quo and development tendency of pneumatic conveying system, *Light Industry Machinery*, Vol. 26, Issue 3, 2008, pp. 4-7.
- [2]. Zhang Zhi-Yong, Wu Jian-Qiang, Yang Yu-Qing, DCS automation design and application of dense phase constant pressure conveying system, *Power Generation & Air Condition*, Vol. 33, Issue 2, 2012, pp. 5-9.
- [3]. Zhang Yuan-Jun, Wang Hui-Yu, Zhang Zhen-Peng, Two Phase Fluid Dynamics, *Beijing Aviation Industry Press*, Beijing, 1987.
- [4]. Yang Lun, Xie Yi-Hua, Pneumatic Conveying Engineering, *Machinery Industry Press*, Beijing, 2006.
- [5]. Deng Fan-Ping, ANSYS 12 Finite Element Self-study Manual, *Ren Min Post Press*, Beijing, 2011.
- [6]. Zhou Hui, Yang Xiang-Jie, Zou Wei, Xu Lin, Analysis on pneumatic conveying in cigarette factory by the finite element method, *Machine & Hydraulics*, Vol. 35, Issue 1, 2007, pp. 217-222.
- [7]. S. B. Kuang, A. B. Yu, Micromechanic modeling and analysis of the flow regimes in horizontal pneumatic conveying, *AIChE Journal*, Vol. 57, Issue 10, 2011, pp. 2708-2725.
- [8]. Akira Rinoshika, Masahito Suzuki, An experimental study of energy-saving pneumatic conveying systems in a horizontal pipeline with dune model, *Powder Technology*, Vol. 198, Issue 1, 2010, pp. 49-55.
- [9]. G. E. Klingzing, F. Rizk, R. Marcus, L. S. Leung, Pneumatic conveying of Solids, 3rd ed., *Chapman & Hall*, London, 2010.
- [10]. S. S. Mallick, P. W. Wypych, Modeling solids friction for dense-phase pneumatic conveying of powders, *Particulate Science and Technology*, Vol. 27, Issue 5, 2009, pp. 444-455.
- [11]. Yan Zheng, Akira Rinoshika, Fei Yan, Multi-scale analysis on particle fluctuation velocity near the minimum pressure drop in a horizontal pneumatic conveying, *Chemical Engineering Science*, Vol. 72, 2012, pp. 94-107.
- [12]. Lu Na, Zhang Ming-Yi, Zhang Yan-Qing, The human-inspired algorithm: a hybrid nature-inspired approach to optimizing continuous functions with constraints, *Journal of Computational Intelligence and Electronic Systems*, Vol. 2, Issue 1, 2013, pp. 80-87.
- [13]. Sun Chuan-Yu, Xiao Lin-Jing, Wang Shu-Ping, Mathematic model control algorithm for microgravity radial magnetic suspended bearing, *Journal of Mechatronics*, Vol. 1, Issue 2, 2013, pp. 103-108.
- [14]. S. K. Jain, S. S. K. Titus, Performance of a piezoelectric force actuator in low force measurement application, *Journal of Mechatronics*, Vol. 1, Issue 2, 2013, pp. 109-111.
- [15]. Yang Cheng-Hui, A kind of supervisory design on vibratory stress relief (VSR) control engineering system, *Journal of Mechatronics*, Vol. 1, Issue 2, 2013, pp. 139-144.

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