*AMSE JOURNALS-2016-Series: Advances C; Vol. 71; N°1; pp 74-91*
*Submitted July 2016; Revised Oct. 15, 2016, Accepted Dec. 10, 2016*

# Design and Research of Double-Pump Fly Ash Conveying System

Yanjun Xiao*, Huan Yang, Na Zhu, Qianqian Zhang, Zonghua Zhang

School of Mechanical Engineering, Hebei University of Technology
1st Dingzigu Road, Hongqiao District, Tianjin, China
xyj_hebut@163.com

## Abstract

A constant pressure double-pump pneumatic conveying system for fly ash is proposed to address the drawbacks of pneumatic conveying engineering, such as high energy consumption, serious wear and so on, based on the application of the fly ash conveying system in China. In this control system, the A/D conversion, D/A conversion, PID auto tuning, high voltage detection and low voltage detection are studied in detail. The commissioning proves that the system can meet the demand of transportation well, increase the ratio of ash and gas, reduce the energy consumption and minimize the wear and tear furthest.

**Key words:** Pneumatic conveying, Fly ash, Double-pump, Constant pressure transportation

## 1. Introduction

Coalbed methane is a potential source of energy reserved in the coal seam [1]. Belonging to the pneumatic conveying engineering category, there are a series of problems that need to be solved and perfected in the fly ash conveying system; for instance, high speed conveyor, wear serious, great energy consumption, equipment maintenance, pipe blockage, transporting efficiency, the stability of the system etc. At present, in the domestic and foreign, the research is focus on reducing the gas solid separation, increasing the solid gas ratio, reducing the transmitted speed and improving the control performance [2-4]. Aimed at the drawbacks of the constant flow delivery system and single pump system for fly ash, the research and application of double-pump constant pressure conveying system for fly ash has a significant impact, and ultimately realizes the optimization coordination, stable and reliable production and operation of the fly ash conveying system.

## 2. Scheme Selection Of Fly Ash Transportation System

### 2.1 The Bringing Foreword Of The Transport Scheme

The types of pneumatic conveying device are mainly suction, pressure and hybrid. The pneumatic conveying state of fly ash is the fluidization conveying in dense phase pneumatic conveying. In the high concentration fluidization delivery method, the load ratio or the mixing ratio ranges in 50~250, and the pressure loss per 100 m in 300~600Kpa.

By analyzing the types and state of the pneumatic conveying system, the fly ash pneumatic conveying device is classified as high-pressure fluidized pneumatic conveying device with pressure. In the scheme, blow tank is used as the feeding device. The diameter of pipeline ranges from 80 mm to 350 mm, and the maximum conveying amount reaches 600 t/h. Using piston or screw air compressors for the air supply, its air pressure ranges from 400 KPa to 700 KPa. In order to determine the scheme of fly ash pneumatic conveying system, detailed studies of the problems existing in the pneumatic conveying system and the present situation of the fly ash pneumatic conveying in China are carried out.

### 2.2 Constant Current And Constant Pressure Pneumatic Conveying

At present, as for the conveying of fly ash, the constant current pneumatic conveying system is mostly used by domestic. The air flow, however, can't be adjusted during the conveying process. In order to prevent the blockage, the mixing ratio in the system design is relatively low, but the conveying speed will be higher, and it will lead to conveying efficiency decline and even can't be transported if the transport of fly ash characteristics changes.

Air flow control technology is adopted in the constant pressure pneumatic conveying system for fly ash; the compressed air flow can be adjusted continuously in the whole process of fly ash conveying. According to the change of the conveying pressure, the compressed air quantity and the ratio are adjusted so that the conveying pressure is constant in the whole conveying process, and the system can automatically adapt to the change of the quality characteristics of the fly ash. So that the powder can be stable and reliable transferred in the dynamic pressure boiling condition. And it can realize the ultra-low speed of conveying, obtaining minimum wear and tear. Besides, due to the reduction of the pressure of fly ash, a series of maintenance work will be greatly reduced, for instance, the seal ring damage, piping and valve wear [5-7].

## 2.3 Single Pump And Double Pump Pneumatic Conveying

When the demand of fly ash increases, there will be higher requirements to the conveying capacity of fly ash pneumatic conveying system. Single-pump transporting system is widely used in dense phase pneumatic conveying system with positive pressure, but the transmission efficiency is low and there are many disadvantages in single pump system. So the double-pump pneumatic conveying system for fly ash is used in this paper, which has a higher conveying efficiency, lower energy consumption and higher reliability.

## 2.4 Determination Of Transport Scheme

In view of the drawbacks of the fly ash constant flow pneumatic conveying system and single pump conveying system, the scheme, double-pump pneumatic conveying system with constant pressure for fly ash, is adopted in this paper. The structure is shown in Fig. 1. One of the two pumps of the machine is shown in Fig. 2.

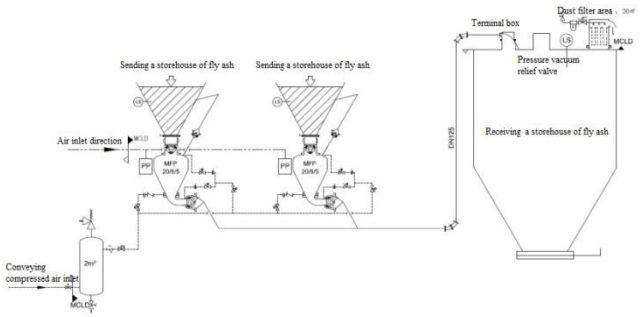


Fig1. Structure of double-pump pneumatic conveying system with constant pressure for fly ash

The two fly ash sending barns are respectively provided with a dense phase pump MFP20/8/5 (20 - pump volume, 20ft3, about 0.56m3; 8 - the feed inlet dome valve nominal diameter, 8in, a total of 200mm; 5 - conveying pipe nominal diameter. 5in, a total of 125 mm), the transmission distance is 100 (h) + 26 (M = V). The feed inlet of the dense phase pump designed as inflatable sealed dome valve, which is on-off after pressure relieved, and the dynamic and static components without friction. It is portable, fast and difficult blockage. Besides, the low material level meter is place in the below of the sending as the feed conditions for dense phase pump. The fluidization structure of the conveying pump makes the material fluidization effect well, which is help to mix with fly ash and compressed air well. The suitable ash-air concentration ratio makes the system more reliable.

Fig2. Double-pump conveying system with constant pressure for fly ash

## 3. Research On The Overall Scheme Of The Control System

### 3.1 Principle Of Double Pump Constant Pressure Delivery

According to the characteristics of double pump type fly ash constant pressure pneumatic transfer scheme, the installation in two chamber pump in the middle of the pipeline, system uses a set of discharging valve, flow control valve, in the transport process, the flow control valve according to the conveying pressure value of dynamic continuous adjustment intake air quantity so as to achieve constant pressure conveying differential pressure sensor and pressure transmitter. In order to facilitate the identification, the two fly ash pneumatic conveying dense phase pump named No. 1 and No. 2 dense phase pump, corresponding to the two positions pump, the pump on the relevant body is also named as the valve 2 and valve 1. The basic structure of the silo pump constant pressure conveying system is shown in Figure 3.

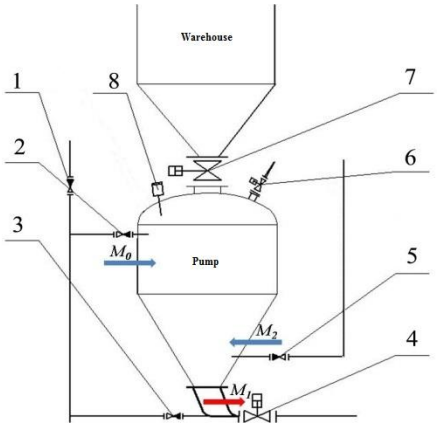


Fig3. The basic structure of the silo pump constant pressure conveying system

The principle of double pump fly ash pneumatic conveying system includes four stages:

Feed stage: system is ready, start the air compressor and roots blower, open the exhaust valve and exhaust valve 2; unloading material valve 1 and unloading valve 2 open, the fly ash from the storage material library of free fall into two strong pump, when the material level meter 1 or material level meter 2 full feed signal, close the exhaust valve and exhaust valve 2; unloading valve 1 and relief valve 2 is closed.

Flow of the compression stage: total inlet valve 1 and the total intake valve open 2; delivery valve and delivery valve 2 open, then open the flow control valve, compressed air from the dense phase pump at the bottom and the top respectively, into the gasification chamber, the two streams by fluidized bed of fly ash were fully fluidization, the pressure in the dense phase pump increases.

Constant pressure conveying stage: when the pressure transmitter on the transmission pipeline to reach the set value, the discharge valve of the system is opened, and began to enter the constant pressure delivery stage. Set the constant pressure conveying pressure value and the conveying pressure compared to the value. If the value of the pressure is high and rising, indicating that the transport resistance increases, ash and gas concentration is high, indicates that a blocking tube inclinations, at this time should be increased flow regulating valve opening, increase the conveying air compensating, reduce ash and gas concentration ratio; if the detected pressure is too low, suggesting that the reduced the resistance of pipeline delivery, ash and gas concentration ratio is low, at this time should be reduced flow regulating valve opening, so that we can reduce quantity of supplying air, improve the ash and gas concentration ratio, the constant pressure conveying process through the PID calculation flow regulating valve specific opening.

Purge stage: when the pressure transmitter detects the pressure to be reduced to a certain set value, the purge valve 1 and purge valve 2 open. Certain time, flow control valve is closed, when dense phase pump in fly ash conveying is completed, resistance of the conveying pipe is very small, according to the principle of constant pressure conveying flow regulating valve will automatically be smaller until closed. Delay a certain time, blow valve 1 and purge valve 2 off; total intake valve 1 and the total intake valve 2 closed; delivery valve 1 and delivery valve 2 closed; discharge valve closed, so as to complete a work cycle [8-9].

## 3.2 System Control Requirements

Double pump type fly ash pneumatic conveying system with a wide range of control objects, the process is complex, the need for a coordinated action to complete each step of the fly ash stable and reliable delivery. Constant pressure conveying of flow regulating valve requires high

processing speed, select the PLC of Mitsubishi FX3U-48MR/ES-A. Because of the need to apply pressure transmitter corresponding pressure to simulate signal conversion to digital signals, choose matching of the analog input module FX3U-4AD-ADP; the PLC is dealt with according to the volume converted to analog to dynamically adjust the flow regulating valve, matching the analog output module FX3U-4DA-ADP, choice of modules corresponding to the analog output range: current DC output 4mA to 20mA; output DC voltage 0V to 10V, D / a conversion time of 200 microseconds (each operation cycle more new data).

The actual requirements must realize fully automatic pneumatic conveying, double pump type fly ash constant pressure pneumatic conveying system transmission efficiency not less than 20t / h; in order to meet the transport at low speed, access to related data [10] delivery rate should not be too large, should be controlled at around 8m / S. Fly ash in pneumatic conveying process need to realize continuous automatic operation, to achieve constant pressure delivery, to ensure the safe and reliable operation, and can complete the required throughput, able to adapt to the characteristics of quality of fly ash, double pump, work coordination.

## 3.3 Electrical Control Technology Difficulties

(1) Cooperative coordination between multiple control objects.

(2) Processing conversion of analog / digital quantity.

(3) PID[11-12] controller to control the constant pressure delivery.

Double pump type fly ash constant pressure pneumatic conveying the key lies in the constant pressure conveying stability control and constant pressure conveying the key lies in the continuous dynamic adjusting PID controller for gas flow is stable and reliable, which requires of PID controller is put forward higher requirements, need of constant pressure of fly ash conveying PID controller is used for further research.

(4) Processing conversion of digital quantity and analog quantity.

The digital PID control through PLC output range transformation and module FX3U-4AD-ADP D / a conversion of 0 ~ 10V DC output signal is obtained, with the signal completed on the flow regulating valve open degree of regulation, and ultimately achieve the fly ash pneumatic conveying pressure closed-loop control.

(5) Stability

Equipment in the working process of the need for a long time continuous operation of pneumatic ash transportation, adverse effects of the working environment of the equipment control the stability and reliability of the safe and stable operation of the system for a long time,

such as position sensor and pressure sensor signal is reliable, can programming controller of anti-interference ability, a plurality of valve body of safe use, gas source of stability.

## 4. Software Design and Site Commissioning

### 4.1 Software Design

The software design is an important link to realize the stable, reliable and safe operation of the double pump fly ash pneumatic conveying system. An excellent software programming can help maintain the whole pneumatic conveying system. The general layout of the control system for the pneumatic conveying of pulverized coal ash is shown in figure 4.

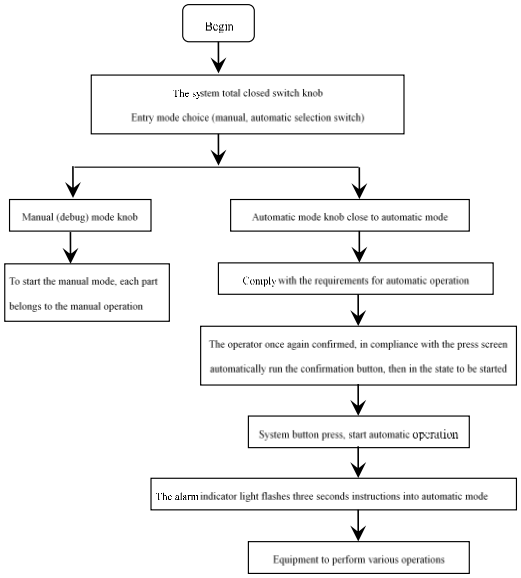


Fig4. The overall program structure

The key and difficult points in software design include A/D conversion, D/A conversion, automatic tuning of PID parameter, high voltage detection and low voltage detection.

(1) A/D conversion

The core of this control research is to convert the voltage analog signal into digital quantity. The pressure transmitter detection of 0 - 10V converted to 0 - 1Mpa, here to set the average number of FX3U-4AD-ADP channel 1 for the 3 time, the integer value to floating point. The analog conversion program is shown in figure 5.

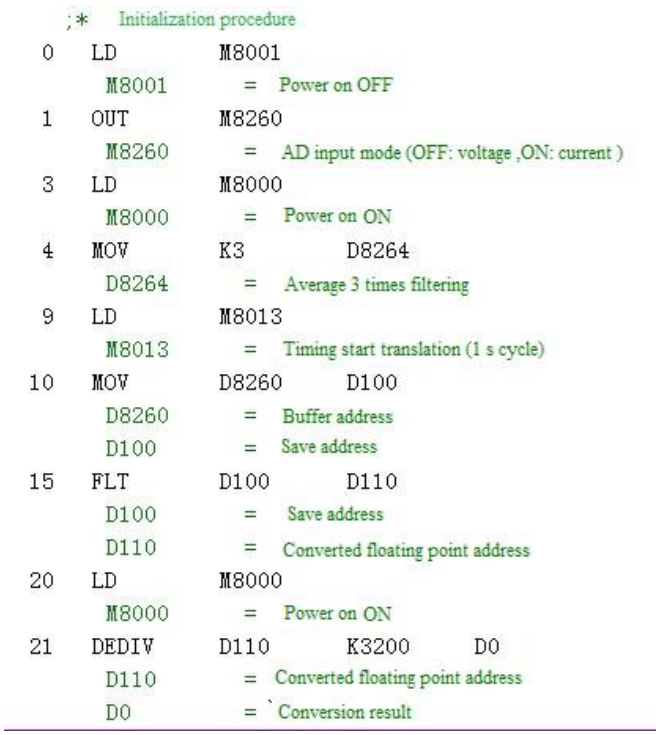


Fig5. A/D conversion

(2) D/A conversion

After the PLC self-tuning PID computing output digital quantity, it is need to carry on the D/A conversion which is the digital quantity changing to analog quantity signal to adjust the flow control valve in real time the opening degree, in order to achieve the goal of constant pressure pneumatic conveying. The selected of the module of FX3U-4DA-ADP module for the output is the voltage / current data of 4 channels of analog special adapter, D/A conversion to the actual 0~10V voltage signal to control the flow of the specific flow control valve. According to the selected flow regulating valve characteristics, selecting the channel analog output module 1, setting 0 output mode voltage output in channel 1 the corresponding bit, simulating output range -10V~10V, digital input range of 12 bit binary, -32000~+32000.

For Mitsubishi FX3U - 48 MR/ES - A programmable controller connection extended second analog special adapters, special soft components in the special auxiliary relay for M8270 ~ M8279, A special data register for D8270 ~ D8279, these special soft components responsible for output mode switches, the output data set. Channel 1 switch for M8270 output mode, use voltage output, set to OFF; Using the current output, set to ON; Remove channels 1 output setting M8274, OFF: programmable controller RUN to STOP, keep the previous analog output, ON: STOP, programmable controller output bias values; Channel 1 output data set D8270, OFF: voltage output; ON: output current. 4 da - ADP channel 1 D/A conversion of the digital value in

D1, channel 100 of the 1 data recorded in the history of D200~D299. Analog output range 0 ~ 10 v, 200 us each update operation cycle. D/A conversion program as shown in figure 6.

```
80   LD      M8002
     M8002     =  Power on OFF
81   OUT     M8270
     M8270     =  DA input mode (OFF: voltage ,ON: current )
83   LD      M8003
     M8003     =  Power on ON
84   MOV     K3          D8274
     D8274     =  Average 3 times filtering
89   LD      M8013
     M8013     =  Timing start translation (1 s cycle)
90   MOV     D8270       D200
     D8270     =  Buffer address
     D200      =  Save address
95   FLT     D200        D210
     D200      =  Save address
     D210      =  Converted floating point address
100  LD      M8003
     M8003     =  Power on ON
101  DEMUL   D210        K3200       D1
     D210      =  Converted floating point address
     D1        =  Conversion result
```

Fig6. D /A conversion

(3) Automatic tuning of PID parameter

Double constant pressure pump fly ash pneumatic conveying control system block diagram which is based on PLC is shown in figure 7.

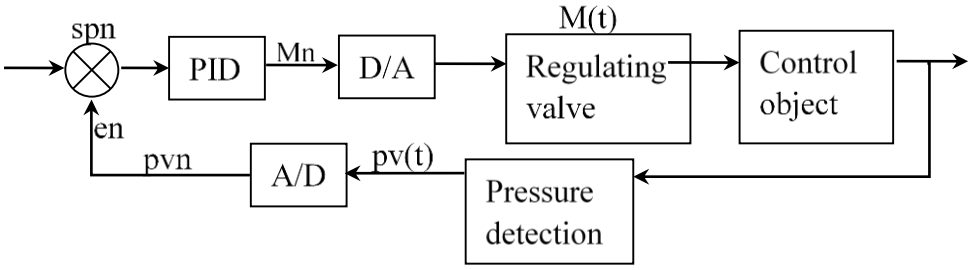


Fig7. PLC constant pressure conveying control system

FX3U - 48 MR/ES - A programmable controller PID control instruction of the 16 bit computing, to set the target S1, S2 determination value, parameter S3 ~ S3 + 6, after the execution procedures, every parameter initial S3 (1 ~ 32767 MS), the sampling time Ts to save operation result (MV) to the output value of D, as follows Fig8.

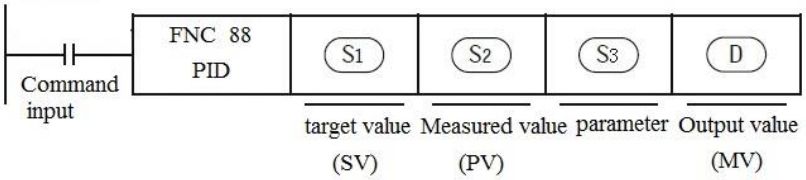


Fig8. PLC PID control parameter setting

Setting target value SV takes up 1 point, since the setting target value does not match the target when performing a PID control in the use of PID self-tuning timing, it is need to save the actual target value and add the setting and deviation in the self-tuning to sign OFF.

Measured value of S2 takes up 1 point. The action set ACT:bit1, bit2, bit5 of all "0", occupied S3 specified initial soft components for started to 25 soft components in the PID auto tuning (step response method); Occupied S3 specified initial soft components for beginning 29 soft components in the PID auto tuning (limit cycle).

The output value of MV occupies 1 point, the user side needs to set the initial output value, and then save the result of the operation before the PID control command is driven. Before the step response method is adopted, the PID auto tuning method is adopted, the user side is set with the step output value and the self-tuning process, the PID instruction side does not change the MV output. In the limit cycle method of PID self-adjusting timing, automatic output ULV or LLV value. Since the setting after the end of the set MV determined values.

In the process of PID from the whole timing, proportional gain S3+3 Kp, integral time S3+4 TI, differential time S3+6 ,which are the important parameters to make the PID control the best implementation and can be automatically set. PID control algorithm block diagram as shown in figure 9.

It is need to set the positive action or reverse action of the PID control direction in the PID timing. The calculation of the required values in accordance with the S3 after the specified parameters of the content of computing when the PID operation direction (ACT) S3+1 is positive action(OFF),its computing:

$$\Delta MV = K_p \left| EV_n - EV_{n-1}) + \frac{T_S}{T_I} EV_n + D_n \right| \quad (1)$$

$$EV_n = PV_{nf} - SV \quad (2)$$

$$D_n = \frac{T_D}{T_S + K_D \cdot T_D}(-2PV_{nf-1} + PV_{nf} + PV_{nf-2}) + \frac{K_D \cdot T_D}{T_S + K_D \cdot T_D} \cdot D_{n-1} \quad (3)$$

$$MV_n = \sum \Delta MV \quad (4)$$

$$PV_{nf} = PV_n + L(PV_{nf-1} - PV_n) \quad (5)$$

Including: $\Delta MV$ for the output variation; $K_p$ for the proportional gain; $EV_n$ for the sampling deviation; $EV_{n-1}$ for the a cycle of bias; $T_S$ for the sampling period; $T_I$ for the integral constant; $D_n$ for the differential item; $PV_{nf}$ for the sampling of measured values

(filtered); $T_D$ for the differential constant; $K_D$ for the differential gain interest; $PV_{nf-1}$ for one cycle before the measured value (filtered); $PV_{nf-2}$ for two cycles before the determination of value (filtered); $D_{n-1}$ for a period before the differential item; $MV_n$ for the amount of operation; $PV_n$ for the sampling of measured value; L for the filter coefficients.

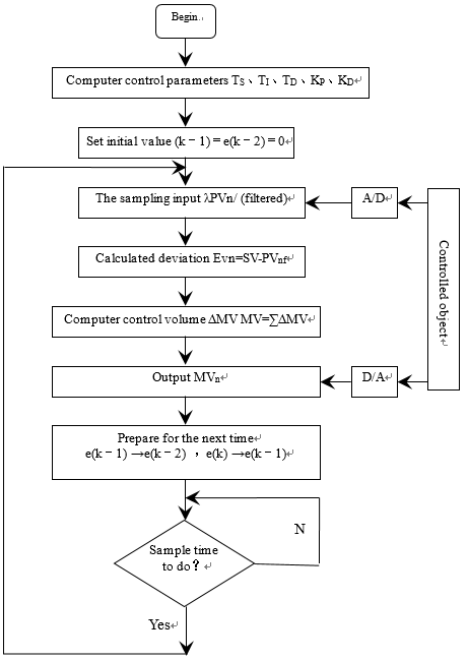


Fig9. PID algorithm program block diagram

Inputting filter α:S3+2 is to decrease the fluctuations in the soft filter caused by measuring value of PV noise, setting in accordance with the filter time constant, according to the control object and the characteristics of the noise level. This can suppress the impact of noise. Alpha over an hour, the filter effect is small; too large, the input of the corresponding variation.

Proportional gain Kp: S3 + 3 in proportional action, output (MV) and deviation (target value (SV) and determine the differential value (PV)) is proportional to the increase, the proportion is called the proportional gain Kp, performance relation: output (MV) = percentage gain (Kp) × deviation (EV), the reciprocal of proportional gain (Kp) is called the proportional band. As percentage gain (Kp), determination of value (PV) close to the target value (SV) action is stronger.

Integral time TI: S3+4 TI in the integral action, from the deviation of the output from the start to the integration of the action into the proportion of the output of the action of the time, the smaller the TI, the stronger the integral action. The integral action is the

continuous movement and the change of output, in order to eliminate the deviation, can eliminate the residual deviation in the proportion of the action.

Differential gain KD: S3+5 by differential action on the output and filtering function and derivative gain KD is small, due to disturbance as a result of the change in the measured value of produce instantaneous limit the output response; derivative gain KD is large, due to disturbance as a result of the change in the measured value of, spending a long time response. When adjusting the S3+2 input filter, the differential gain KD is set to "0". In response to the output variation of the disturbance, it should be the differential gain KD when the response is particularly good.

Differential time TD: S3+6. For measured value (PV) of the disturbance caused by changes in the sensitive reaction, and will change the inhibition to a minimum, for the use of differential time, differential time TD is to prevent because of disturbance caused by large fluctuations in the control object of action is stronger. When the disturbance is small, the differential time can't be used.

(4) High pressure test

The pressure inside the chamber is changed during the transportation. The system can judge whether the working condition of the pump is normal or not, whether the powder feeding is finished or not, and how much pressure value can be discharged. Throughout the transport process, the pressure change in the pump as shown in Figure 10, figure P indicates the pump pressure.

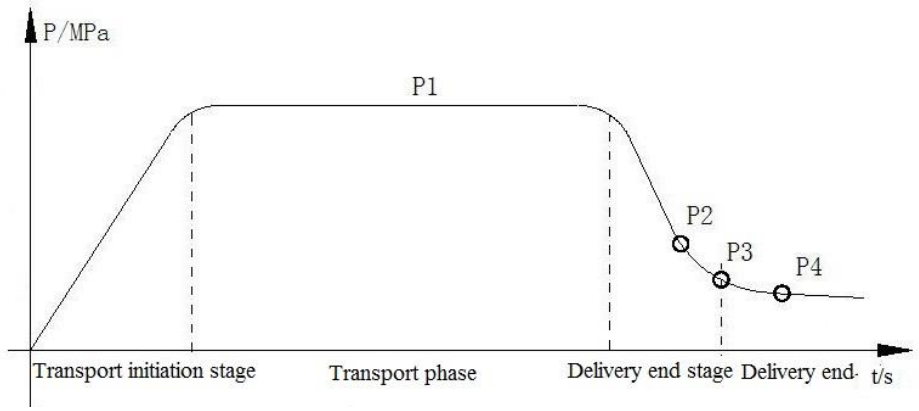


Fig10. Pressure change in pump

From the figure can be seen, when transporting, the storehouse pump pressure showed a linear growth trend, pressure is increased to P1 discharge powder; conveying process, the value of pressure in the P1 stability or on P1 under small changes; when the pump powder little or

pipeline powder concentration is significantly reduced, pump pressure will rapid fall from P1 to P2, at this point in the blowing phase; segment in the after purging, the pressure is decreased further to P3, this tube powder concentration is very low, powder has been blowing empty, the pressure is reduced to the P4 can at the end of the conveyor. The value of the pressure parameters directly affect the performance of the P1 delivery system: if the pressure value is too large, the instantaneous powder discharging conveying speed is too high, will cause great resistance prone to plugging; if P1 is too small, the powder can't fully fluidization, pipeline residual powder more, must fully purge cleaning powder the material in the pipeline, to prevent the residual powder impact on the next transportation; if P2 pressure value is too large, will end early delivery, powder pump or pipe conveying has not yet been completed, the residual powder will affect the delivery of second times; if the P4 pressure is too small, the pump and pipe material already finished but still a lot of transportation ventilation, will cause the waste of compressed air, and prolonged delivery time, reduce the transmission efficiency. According to the transmission distance and through the field commissioning to determine the discharge pressure value of 0.4MPa, high pressure test procedures as shown in figure 11.

```
401   AND      M108
        M108     =   Self - fifth process(Fluidized total gas transmission)
402   DECMP    E0.4      D0          M400
        D0       =   Conversion result
        M400     =   High pressure test
415   AND      M402
        M402     =   Self - high voltage detection mark
416   OUT      M75
        M75      =   High voltage detection assist
```

Fig11. High pressure test

(5) Low pressure test

According to the transmission distance is determined by the scene debugging purging pressure value is 0.25 MPa, the low pressure test procedure as shown in figure 12.

```
462   AND      M496
        M496     =   Self - ninth process(Discharge valve open)
463   ANI      M72
        M72      =   Screen off low voltage self test
464   DECMP    E0.25     D0          M410
        D0       =   Conversion result
        M410     =   Self - low voltage detection
477   AND      M410
        M410     =   Self - low voltage detection
478   OUT      M74
        M74      =   Low voltage detection
```

Fig12. Low pressure test

### 4.2 The Scene Debugging

The double constant pressure pump fly ash pneumatic conveying system has been applied on site and commissioning, it is need to satisfy the fly ash pneumatic conveying efficiency not less than 20 t/h to ensure the supply of the fly ash in the normal operation of the process. Because the system USES a constant pressure conveying technology, through to the delivery pressure setting and adjust to control a gray gas concentration ratio, so as to achieve maximum transmission at low speed, reduce the loss of pressure piping and valves and the wear and tear. Set the constant pressure of pressure value in the process of constant voltage regulation need to match the speed of 8 m/s. The commissioning according to the different discharge of set pressure for fly ash pneumatic conveying velocity average as shown in table 1.

Table 1 Discharge pressure and conveying speed

| Discharge pressure value | Conveying speed | Discharge pressure value | Conveying speed |
|---|---|---|---|
| 0.3MPa | 7.1m/s | 0.4MPa | 8m/s |
| 0.35MPa | 7.5m/s | 0.45MPa | 8.8m/s |

Finally selected set of pneumatic conveying of fly ash discharge pressure is 0.4 MPa, in the process of debugging to get double pump constant pressure conveying system of fly ash concrete operation parameters as shown in table 2.

Table 2 System operating parameters

| Test parameter | Test value (average) | Test parameter | Test value (average) |
|---|---|---|---|
| System average speed | 8m/s | Gasification time | 25s |
| Discharge pressure | 0.4MPa | Delivery time | 60s |
| Purge pressure | 0.25MPa | Single air consumption | 9.6 m3/min |

According to the parameters of the field test, the double storehouse for output capacity of pump unit is made of fly ash conveying system:

$$Q_m = \frac{3600\varphi\rho_b V_p}{T_2 + T_3} = \frac{3600 \times 0.7 \times 0.75 \times 0.56 \times 2}{25 + 60} = 24.90(t/h) \quad (6)$$

Type: $\rho_b$ for fly ash pile density, according to the actual situation value $0.75t/m^3$; Take $\varphi$ for the material filling coefficient, 0.8 for the upper limit, lower limit values according to actual situation; $T_3$ for gasification time (that is, the time needed for conveying unit pressure to set pressure value); $T_2$ for the delivery time (the time needed for transporting materials in unit a waft); The sum of $V_p$ for conveying unit warehouse pump volume. Calculate gas concentration ratio:

$$\mu_s = \frac{G_s}{G_g} = \frac{750 \times 8 \times \pi \times r^2}{1150 \times \frac{9.6}{60}} = 40.02kg/kg \tag{7}$$

Type: $G_s$、 $G_g$ respectively, through the pipe cross section of the quality of the fly ash and air flow. Air heavy $\gamma_a$ values $1150kg/m^3$.

According to the actual operating parameters of the double pump fly ash conveying system, the system unit output is $24.90t/h$, and the ash gas ratio is $40.02kg/kg$. It is proved that the application of the new double bin pump unit coal ash conveying system can work well for a long time, and can well meet the requirements of the fly ash conveying system.

In the field collecting real-time data on the touch screen shows the process of PID regulator, in order to facilitate observation PID regulating process real-time curve, input and output of various parameters such as range conversion, all the data are converted to a uniform scale. And the input value is added to a specified range of variation with the appropriate constant, and the partition is adjusted to allow it to be in the proper range, when the value is out of range, the maximum value is two. This improvement eliminates part of the deviation from the control system. Test test the discharge pressure of 0.3MPa, 0.35Mpa, 0.4MPa, 0.45MPa the double pump constant pressure conveying system speed and stability of the system, PID curve obtained by experiment show that discharge pressure is 0.4MPa when conveying the average speed of 8m / s, the system is stable, can be in an open discharge valve after a short time at constant pressure conveying state, following the discharge pressure 0.4MPa PID control effect. For the full flow of the 15s time to open the discharge valve, PID control panel on the change in the display curve is shown in figure 13. The green line represents a given value of SP, the red line represents the process of PV (gas to gas pressure, and the green line, blue line almost coincident) output value of Mn. as shown in Figure 15s, time open the discharge valve in the pipeline, because the powder is filled, the increase of the concentration of pressure rise, and in the rising process with fluctuation. In order to avoid plugging, and achieve constant pressure as soon as possible, PID

control flow regulating valve with a larger opening of the air as soon as possible so that the diffusion concentration in the tube; after delivery for a period of time, in the pipeline by the air traffic control becomes more uniform concentration, the PID flow control valve to rise quickly to the constant pressure delivery pressure from the figure, we can see that the 25s-30s between the pressure in the pipe to rise quickly to the constant value, and the output value can be stable conveying pressure constant pressure in the vicinity of PID show that adjustment curve is convergence. It shows that the PID control of constant pressure conveying system is stable.

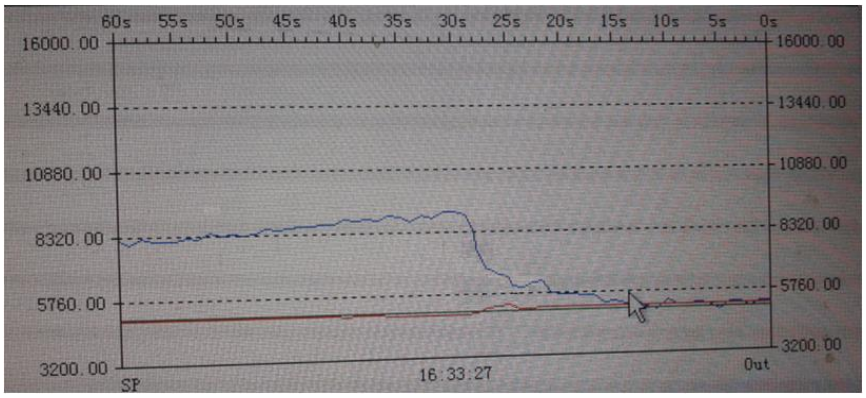


Fig13. PID adjustment curves

## 5. Conclusion

This paper introduces the types of fly ash conveying system research status and development trend, through the understanding of pneumatic conveying device type, pneumatic conveying state. In view of the drawbacks of the constant flow delivery system and single pump system for fly ash, a constant pressure double-pump pneumatic conveying system is proposed. And the schematic design of this system is studied in this paper. Based on the difficulties of electrical control, the A/D conversion, D/A conversion, PID auto tuning, high voltage detection and low voltage detection are particularly studied in the software design. It is verified that the application of double-pump constant pressure conveying system for fly ash can effectively address the disadvantages of traditional pneumatic conveying devices by testing. Further, it can well meet the transportation demands, achieve ultra-low speed conveying, reduce energy consumption, and minimize the friction and wear.

## References

H.T. Zhang, C. Liang, J.P. Wei, Y.G. Wang, Z.H. Wen, B.H. Yao, Experimental Study on the Parameters Effect on the Sampling Method Based on Negative Pneumatic Conveying,2016, International Journal of Heat and Technology, vol.34, no.1,pp.51-56.

1. L. Shen, C. Liang, X.P. Chen, P. Xu, G.L. Xu, G.Y. Yuan, Z.Z. Han, C.S. Zhao, Flow behaviors and resistance properties of inclined pipe for different materials in pneumatic conveying,2014, Journal of southeast university, vol.44,no.5,pp.975-980.
2. C.H. He, X.L. Shen, H.J. Zhou, Stability analysis of dense phase pneumatic conveying of pulverized coal at high pressure, 2014, CIESC Journal, vol.65, no.3, pp.820-828.
3. Charalampos Arapatsakos, Anastasios Karkanis, Christina Anastasiadou, THE LOAD AND The gas emissions measurement of outboard engine, 2015, International Journal of Heat and Technology, vol.33, no.4, pp.221-228.
4. D. Mills, V. K. Agarwal, The application of pneumatic conveying to the removal of fly ash from coal fired power stations, 2013, 11th International conference on bulk materials storage, handling and transportation,2013, Newcastle, NSW, Australia.
5. A.A. Cenna, K.C. William, M.G. Jones, W. Robinson, Effects of surface modifications on wear mechanisms in fly ash conveying pipelines,2015, Springer international publishing, no.3, pp. 147-154.
6. Y.D. Zhang, D. Wang, J.P. Yang, L. Tian, L.J. Wu, Research on the Hydrate Formation in the process of Gas Phase CO2 Pipeline Transportation,2016, International Journal of Heat and Technology, vol.34, no.2, pp.339-344.
7. N. Tripathi, A. Sharma, S.S. Mallick, P.W. Wypych, Energy loss at bends in the pneumatic conveying of fly ash,2015, Particuology, vol.21,no.4,pp. 65-73.
8. E.S.M. Essa, M.A. Aboelela, M.A.M. Hassan, Position control of hydraulic servo system using proportional-integral-derivative controller tuned by some evolutionary techniques,2016, Journal of Vibration & Control, vol.22, no.12, pp. 2946-2957.
9. B. Chen, K.C. Williams, M. G. Jones, Y. Wang, Experimental investigation of pressure drop in bypass pneumatic conveying of fly ash,2012, Advanced materials research, vol.508, pp.11-15.
10. Y.J. Bao, X.Y. Qian, Y.M. He,High-Reliable Constant-Current Source Based on PID Algorithm,2014, Journal of Nanjing university of Aeronautics& Astronautics, vol.45,no.4,pp. 570-574.
11. M.S. Li, J.J. Zhao, Z.X. Zhu, B. Xie, R.J. Chi . E.R. Mao, Fuzzy-PID self-adaptive control method in electro-hydraulic hitch system,2014, Chinese journal of agricultural machinery, vol.44, no.2, pp. 295-300.