The 6th International Conference on Mining Science & Technology

Development and application of the active pulsing air classification

Duan Chen-long*, He Ya-qun, Zhao Yue-min, He Jing-feng, Wen Bao-feng

School of Chemical Engineering and Technology, China University of Mining & Technology, Xuzhou 221116, China

Abstract

In order to improve the separation efficiency in the air-solid phase, we proposed an innovative separation method called the active pulsing air classifier, which produce pulsing air by a pulsing air generator. In this way, the particles received a new acceleration action in each pulsing period, and then, it obtains a better performance than non-pulsing air separators in the laboratory scale. The dynamic equation of the motion particle in the active pulsing airflow was built up, showing that a higher density particle may get a small acceleration. The simulation results of airflow field show that the airflow turbulence acceleration will disperse the particles and a density dominant separation can be achieved. All high density particles, low density particles, and dust of waste catalyst can be acquired by the active pulsing air classifier. When the airflow velocity is 3.33 m/s, the frequency of air pulsing is 7/3 Hz, the separation efficiency of the active pulsing air classifier reaches its maximum: 97.63%. Based on our study, an industry-scale pulsing air classifier is developed, which provides a new and efficient method for resource reutilization.

Keywords: active pulsing air classification; dynamic models; waste catalyst; resource reutilization

1. Introduction

The pneumatic separator has been widely applied in agriculture, steel industry, mineral processing, solid waste reutilization and separation of chemical products due to its lower investment and operating cost compared to other methods [1]. But the separation efficiency is relatively low because the difference in terminal velocities of the particles in the air-solid phase is the decisive factor for effective separation, which in turn is dependent on the size, shape, and density of the particles, etc. So, in order to improve the separation efficiency with a traditional pneumatic separator, the materials must be narrow sized before separating, then the density dominant separation is possibly achieved.

To solve the problem of separation efficiency in the air-solid phase, an innovative separation method called the passive pulsing air classifier is constructed in laboratory. This is done by fixing some dampers in the column of a conventional air classifier, or the direction of separation area was designed the Zig-Zag or Zag-Zag separator [2-5].

* Corresponding author. Tel.: +86-516-83995505; fax: +86-516-83885384.
E-mail address: llaoduan@126.com

1878-5220 © 2009 Published by Elsevier B.V. Open access under CC BY-NC-ND license.
doi:10.1016/j.proeps.2009.09.105
These form an accelerating and decelerating air current in the column which alternately accelerates and decelerates the particles [6, 7]. Correspondingly, the passive pulsed air classification was systematically researched at home and abroad. However, the passive pulsing air classifier is difficult to achieve the objective of separating particles by density for it is unable to produce continuous pulsing air. Consequently, the more widespread use and application of the passive pulsing air classifier is limited.

In order to produce continuous pulsing air, the methodology of active pulsing air classification is put forward to achieve pulse air by a pulsing air generator [3, 8]. In this way, the particles can receive a new acceleration action in every pulsing period, so it obtain a better performance than the passive pulse air separators in laboratory scale [9, 10]. All the heavy particles, the light particles, and the dust are recycled by the active pulsing air classifier (APAC). During the process of air accelerating, the turbulence will be produced in the active pulsing airflow field. Because the flow pattern is complex, the mechanism of the separation of particles by density should be further researched. The dynamic equations of motion particles in the active pulsing airflow field were deduced and optimized. The velocities of motion particles with dynamic equations were numerical simulated in the active pulsing airflow field. The active pulsing airflow field is simulated by finite element analysis software. The cavernous particles contained precious metals and sintered magnetic beads are availably separated by the laboratory experimental system of APAC from the reformed industrial waste catalysts. Based on our study, an industry-scale pulsing air classifier was developed, and it provided a new and efficient method for resource dry separation.

2. Fundamental research of APAC

When a particle moves through a rising vertical air stream, it gets gravity, air buoyancy, and an aerodynamic drag. This aerodynamic characteristic depends on the particle’s size, shape and density. To a rising pulsing airflow pattern, the particle will obtain a new pulsate air action in every pulsating period. This action will accelerate the particle. The particle not only receives the effect of drag force, but also suffers from the extra mass force which is a function of the fluid density, the volume, and velocity of the particle in the energy transmitting procedure. The accelerating characterizes of different density particles are reflected in APAC, that separating process is more on the basis of density ratio but less on the basis of aerodynamic properties of particle. In conclusion, a dynamic model for particle moving through the active pulsing airflow is deduced as Equa (1).

\[
\frac{dv_p}{dt} = \left\{ -g + \frac{3 \rho (v_A - v_p)^2}{4d \rho_p} \right\} + \frac{3.6 \times 10^{-4}}{d (v_A - v_p)} + \frac{9}{2} + \frac{\rho}{2 \rho_p} \cdot \frac{\partial v_A}{\partial t} \right\}
\]

(1)

In Equa (1), the first term of the right shows that the gravity plays an important role to the particle acceleration; the second term is the drag of the particle moving through the fluid, which has an obvious relationship between the density and diameter of the particle; and the third term is regarded as the effect on the particle density and the air acceleration. The more remarkable of the pulsing air acceleration, the larger acceleration of the particle obtains. In addition, a higher density particle will get a smaller acceleration. It is now clear that in a suitable active pulsing airflow may achieve a density dominant separation.

To practical applications of APAC in laboratory, the maximum pulsing air velocity is 10m/s and the pulsing period is 0.428s. Fig. 1 shows the variation of airflow velocity field at different moment of a single pulsing cycle, which is simulated by the finite element analysis software of Fluent. Different moments correspond to different graduated scale, where \(t = 0.0214s, 0.214s, 0.2996s, 0.324s, 0.3638s, 0.3852s, 0.4066s, 0.428s\). The airflow velocity increases gradually from 0m/s to 10m/s within the first half-cycle from 0s to 0.214s. Correspondingly, the airflow velocity decreases gradually in the past half-cycle. The airflow turbulence acceleration is produced due to the airflow velocity suddenly decreasing, which will disperse the particles and is in favor of the preferable separation.
3. Experimental

3.1. The experimental system of APAC

The laboratory experimental system of APAC is shown in Fig. 2. The separation column with several segments is installed which includes a number of organics glass columns with an inner diameter of 50mm and a length of 250mm being connected by flanges. So, the height of the separation column can be adjusted in the light of actual needs. Commonly, a 1750mm high column can meet the requirement of actual material separation. The active pulsing airflow is produced by the pulsing air generator which includes pulsing valve, electromotor, and transducer. The frequency of the pulsing air can be adjusted with transducer. The screw feeder can control the feeding forcibly and equally, prevent the escape of dust as well. Different material is separated three productions which are heavy particles, light particles, and dust by the difference of density in APAC.

3.2. Separating tests of industrial waste catalyst

The reformed industrial waste catalyst contains cavernous body of precious metals and sintered magnetic beads. The density of 0.7–0.8 g/cm³ long stripe cavernous body is the valuable concentrate, and the density of 1.4 g/cm³
sintered magnetic beads is tailing. Fig. 3 is a picture of the waste catalyst. The availably separation of the confused particles is the crucial process for the following purifying of the precious metals. Wet separation of the confused particles has limited applications due to be mudding when water, wasted water treatment problems and the high cost. Consequently, the APAC is used to separate the two kinds of confused particles. Table 1 shows more than 94% separation efficiency was achieved when the frequency of air pulsing is 7/3 Hz with different airflow velocities. When the airflow velocity is 3.33 m/s, the separation efficiency of the APAC achieves its maximum: 97.63%. Fig. 4 and Fig. 5 are the pictures of waste catalyst after separation. The light component is extracted from the top of the separator, and then is recycled by a cyclone dust collector as show in Fig. 4. The heavy component is rejected to the bottom of separator through the electro motion valve as show in Fig. 5. It can be seen from the pictures that the recovery of the valuable concentrate is relatively high, and the interfusion of the broken heavy materials is small. At the same time, the tailing appears tiny interfusion of the light materials. Apparently, the active pulsing air classification is a very effective dry separation method to separate valuable material from the waste catalyst.

Table 1. Separation results of waste catalyst with different airflow velocities

| NO. | Airflow velocity (m/s) | Light component (g) | Heavy component (g) | Separation efficiency (E) (%) |
|-----|------------------------|---------------------|---------------------|-----------------------------|
|     |                        | Concentrates        | Tailings            | Concentrates                 | Tailings                   |                          |
| 1   | 5.56                   | 23.50               | 1.50                | 0.01                        | 13.00                      | 94.67                     |
| 2   | 5.00                   | 23.50               | 1.10                | 0.01                        | 13.20                      | 96.06                     |
| 3   | 4.44                   | 23.50               | 1.00                | 0.02                        | 13.20                      | 96.37                     |
| 4   | 3.89                   | 23.30               | 0.90                | 0.04                        | 13.20                      | 96.67                     |
| 5   | 3.33                   | 22.50               | 0.60                | 0.10                        | 13.50                      | 97.63                     |
| 6   | 2.98                   | 22.00               | 0.50                | 0.30                        | 13.00                      | 97.47                     |
| 7   | 2.78                   | 21.95               | 0.54                | 0.40                        | 13.00                      | 97.10                     |
| 8   | 2.50                   | 21.90               | 0.52                | 0.40                        | 13.10                      | 97.19                     |

3.3. Practice of APAC

In 2008, an improved novel separator and assembly flowsheet was proposed and established by further researches and experiments, especially in air distributors, feeding system, and dust-removal system. The improved and assembly APAC with 200 kg/h of capacity for waste catalyst is shown in Fig. 6. In this system, the separation column is 2.4m high. Three stereoscopes are installed to observe the conditions of feeding and separating of particles. Stable and uniform air flow is produced due to installation of two air distributors inside of the air supply pipe. The lights, heavies, and dust are recycled in APAC, and the separation efficiency is more than 95%.
4. Conclusions

1) The dynamic equation of the motion particle in the active pulsing airflow is built up, which shows that a higher density particle will get a small acceleration, and a density dominant separation can be achieved.

2) The simulation results of airflow field show that the airflow turbulence acceleration can disperse the particles, which is in favor of the preferable separation.

3) The separation results of the reformed industrial waste catalyst show that the pulsing airflow can achieve a good separation with the wide-sized powder. When the airflow velocity was 3.33 m/s, the frequency of air pulsing was 7/3 Hz, the separation efficiency of the APAC achieved its maximum: 97.63%.

4) An improved APAC with 200 kg/h capacity and more than 95% separation efficiency for waste catalyst is set up. The lights, heavies, and dust of waste catalyst were recycled in APAC.

5) The active pulsing air separation provides a high efficiency and environmental friendly separation method for resource reutilization.
Acknowledgements

The financial support for this work, provided by National Natural Science Foundation of China (50774084), the China Education Ministry Key Lab Open Project (CPEUKF06-11, 08-08), and Youth Science Foundation of CUMT (2007A021), is gratefully acknowledged.

References

[1] Y. Q. He, Y. M. Zhao, Technology of Pulsing Air Separation. Beijing: Chemical Industry Press, 2009.
[2] J. J. Peirce, W. Nancy, Zig-zag configurations and air classifier performance. Journal of Energy Engineering, 110 (1984) 36-47.
[3] R. I. Stessel, J. J. Peirce, Comparing pulsing classifiers for waste-to-energy. Journal of Energy Engineering, 112 (1986) 1-13.
[4] H. Lin, Z. Liu, S. Ito, Development of pneumatic separator. Metallic Ore Dressing Abroad, 5 (2003) 38-42,23.
[5] C. L. Duan, Y. Q. He, H. F. Wang, Separating mechanism of passive pulsing air classifier. Journal of China University of Mining and Technology, 6 (2003) 725-729.
[6] Y. He, H. Wang, C. Duan, Airflow fields simulation on passive air classifier, The South African Institute of Mining and Metallurgy, 105 (2005) 525-531.
[7] C. L. Duan, Y. Q. He, The Fundamental Study on the Reutilization of Electronic Scrap by Passive Pulsed Air Classifiers. Proceedings of the International Symposium on Electronics & the Environment, New Orleans, LA USA, 2005.
[8] Y. Q. He, Y. M. Zhao, C. L. Duan, Mechanism of Active Pulsing Air Classification and Its Application to Waste PCBs Disposal. 2007 International Symposium on Environmental and Science and Technology, Beijing, 2007.
[9] Y. Q. He, Y. M. Zhao, C. L. Duan, Study on dynamic models of the active pulsing air classification and the application to electronic scraps recycling. Proceedings of XXIV International Mineral Processing Congress, Science Press, Beijing, 2008.
[10] Y. Zhao, Y. He, C. Duan, Simulation and application of the active pulsing air classification. Proceedings of the 11th International Mineral Processing Symposium, 2008.