Fuel Processing Technology 120 (2014) 61–70

Contents lists available at ScienceDirect

Fuel Processing Technology

journal homepage: www.elsevier.com/locate/fuproc

Flotation process design based on energy input and distribution

Xiahui Gui [a,*], Jiongtian Liu [b], Yijun Cao [b,**], Gan Cheng [c], Shulei Li [a], Lun Wu [a]

[a] School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou 221116, Jiangsu, China
[b] Chinese National Engineering Research Center of Coal Preparation and Purification, Xuzhou 221116, Jiangsu, China
[c] School of Chemical and Environmental Engineering, China University of Mining and Technology (Beijing), Beijing 100083, China

ARTICLE INFO

Article history:
Received 6 August 2013
Received in revised form 2 December 2013
Accepted 13 December 2013
Available online 31 December 2013

Keywords:
Coal flotation
Flotation design
Energy consumption
Energy input
Flotation process

ABSTRACT

Energy-saving ability and high flotation efficiency are two important factors in the flotation process. In this investigation, a new concept for the flotation process design based on energy input and distribution was proposed, low energy was inputted early to recover easy-to-float materials, whereas high energy was inputted late to recover difficult-to-float materials. The flotation tests were conducted in an XFD 0.75 L laboratory-scale flotation machine. A comparison of flotation performance using constant power input and gradually increased power input was investigated. The flotation results indicated that low ash content, high flotation efficiency index, and energy-saving ability could be obtained by increasing power input step by step in the flotation process. The flotation process design based on different shaft speeds (1500, 1500, 1800, 1800, and 2400 r/min in different flotation periods) and an energy consumption of 1720.8 J is suitable for flotation performance of the coal samples in this study.

1. Introduction

Coal flotation is one of the most efficient methods for improving fine coal quality and reducing impurity contents, such as ash and sulfur [1–3]. Flotation columns and flotation cells are widely used as primary flotation equipment. With advances in technology, the developments of high efficiency, energy-saving, large-scale flotation equipments have become a hot topic [4–6]. High energy input and distribution requirements in the flotation process, which are primarily reflected in the energy consumption per unit handling capacity and the efficient selective recovery of coarse and micro-fine coal particles, should be paid enough attention. Therefore, the study of the relationship between energy consumption patterns and fine coal floatability in the flotation process is essential.

Numerous studies have been carried out in the field of flotation behavior and energy consumption in the flotation process, and a number of important conclusions have been obtained. The floatability of floating materials becomes poor along with the flotation process, and the flotation rate constant of floating materials found to be reduced gradually [7–10]. Materials with a good flotation index can be obtained with a low energy input. However, difficult-to-float materials, such as micro-fine, intergrowth, and coarse particles with low ash content, are usually recovered with a high energy input [11–13]. The main factors affecting coal flotation include coal floatability, size, density, flotation reagents, process parameters, machine performance and operational factors [14]. Energy input has been considered to be an important role in promoting collision and adhesion of micro-fine particles and bubbles [15]. Mohanty and Honaker [16] studied the role of stirring intensity in the flotation process and found that a suitable mixing intensity can promote the suspension of mineral particles as well as the uniform dispersion of air and particles. The fine coal particles cannot attach to air bubbles and be floated from the pulp effectively in a low mixing intensity environment. By contrast, the probability of fine coal particles falling from the bubble increases, combustible recovery decreases, and stability of the froth layer is negatively affected when stirring intensity is extremely high. Zeng et al. [17] measured pulp velocity in a flotation cell using the Particle Dynamic Analyzer (PDA). It indicated that a low ripple frequency in the mixing zone could deliver a powerful energy. Moreover, it demonstrated that the ripple frequency of the separation zone was suitable for separating mineral particles. The linear relationship between energy input and flotation rate constant was obtained through an energy input experiment conducted in an oscillating grid flotation cell [6,18].

These previous studies were conducted in a conventional flotation process. A strong recovery capacity was obtained using the multi-cell stirring process in a flotation machine. However, the flotation power input remained at the same level throughout the entire flotation process. The floatability of the materials remaining in the flotation cells gradually worsened, and these materials were separated under the same power input during the flotation process. The advantage of flotation column is better separation selectivity. For example, a cyclonic static micro-bubble flotation column consists of three kinds of mineralization, namely, countercurrent, pipe flow, and cyclone, which overcome the weakness of low recovery caused by low efficiency mineralization in conventional flotation columns [19–21]. The flotation process of materials with different floatabilities is strengthened by multiple mineralized

* Corresponding author.
** Corresponding author.
E-mail addresses: guixiahui1985@163.com (X. Gui), yijuncao@126.com (Y. Cao).

0378-3820/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.fuproc.2013.12.011

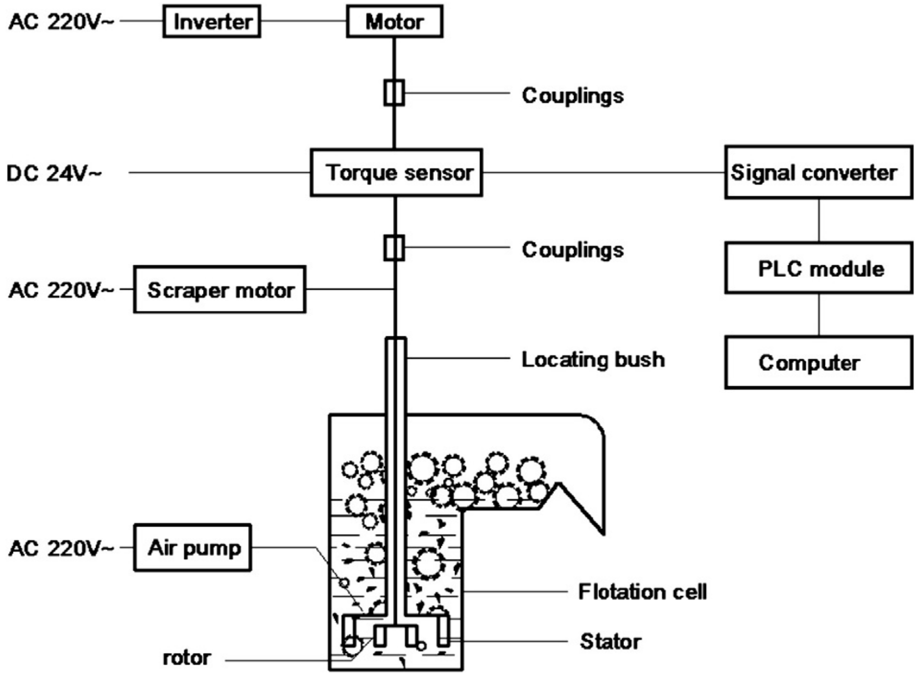

Fig. 1. Connected chart of flotation energy input measurement system.

manners, which gives a balance in the contradiction between ash content and combustible matter recovery of flotation concentrate. However, further improvements of separation efficiency are limited by the short flotation process in conventional flotation columns with single-stage column flotation.

In this study, energy input and distribution were combined with various characteristics of material floatability in the flotation process based on conventional flotation process characteristics. The flotation process was divided into five stages. The energy input in each stage was changed, whereas the energy input value in the entire flotation process was invariant. Easy-to-float materials with higher flotation rate constants were recovered during the early stage of the flotation process with a lower energy input. Difficult-to-float materials with lower flotation rate constants were recovered during the later stage of the flotation process with a higher energy input. Power input increased with the progress of flotation process. A concept of the flotation process design, which was based on energy distribution and input, was proposed by the comparison of separation efficiency of different energy input modes.

2. Experiment

2.1. Flotation energy consumption test system

A flotation energy consumption test system was established for adjusting power input in different flotation stages. The system consisted of an XFD 0.75 L flotation machine and an energy test equipment. The power test system consisted of a data acquisition, data conversion, and a data processing equipment. A TQ-662-type dynamic resistance strain torque sensor was used to measure agitation power in this experiment. The torque was converted into flotation energy by using the data conversion and processing equipment after data acquisition was finished. The torque value of the shaft would be determined by the strain bridge sensor when the strain gauges were attached to the shaft. The torque value was converted into a frequency value by voltage/frequency. The torque sensor was fixed between the power and the load using two couplings (Fig. 1).

The main energy inputted into the flotation system was used up by the agitator shaft. The power consumption of the agitator shaft in the flotation process was obtained using Eq. (1):

$$P = \frac{2\pi Mn}{60} \quad (1)$$

where P is the power consumption, M is the torque value measured by the torque sensor, and n is the speed of the shaft. Torque and power data with different flotation shaft speeds are shown in Table 1.

First, the torque value was measured without slurry in the flotation cell. The slurry suitable for the test requirement was added to the flotation cell, and a new torque value was obtained. The power values of each shaft speed in idling and loading conditions were calculated using Eq. (1). Loading power minus idling power resulted in effective power. The energy input of the flotation system was calculated using Eq. (2):

$$W = P \times t \quad (2)$$

where W is energy input, and t is flotation time.

2.2. Experiment design

2.2.1. Energy input with constant power

A flotation rate test of five minute flotation time was designed, and the flotation process was divided into five stages. Five flotation concentrate products and final flotation tailings were obtained throughout the entire flotation process. The flotation times of each stage from the

Table 1
Torque and power data with different flotation shaft speeds.

n, r/min	300	600	900	1200	1500	1800	2100	2400	2700
M, N·m	0.0054	0.0046	0.0056	0.0060	0.0082	0.0185	0.0337	0.0406	0.0674
P, W	0.17	0.29	0.53	0.75	1.29	3.49	7.41	10.20	19.06