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# Enrichment and migration regularity of fine coal particles in enhanced gravity concentrator

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ABSTRACT

Enrichment and migration regularity of coal particles in compound force field provided by Falcon concentrator were studied. Influence of centrifugal force and fluidization water pressure on the distribution rates and ash contents of materials that enriched in overflow, top separation area and bottom separation area were tested respectively. Radial velocity of fluidization water, having an important influence on the sedimentation of particles, was calculated and results show that radial velocity of fluidization water in top groove is greater than that in bottom groove, which contributed to the selectivity and recovery of combustible. Besides, density composition of products in different enrichment areas was studied. Results show that in the upward migration process, particles with high density are gradually captured. Therefore, the material density is gradually reduced from bottom to top separation area. Meanwhile, mismatch phenomena occurred as the existence of heavy particles in overflow, and light particles in the grooves. Based on the morphology analysis, it is can be deduced that particles mismatch is the results of the increase of drag coefficient since the irregular shape.



## 1. Introduction

For fine particles, conventional gravity separation technology is inefficient due to low settling velocity of particles. Therefore, enhanced gravity field was introduced into concentrator to strengthen the separation process. Enhanced gravity separator (EGS) has been proved efficient for the beneficiation of fine and ultrafine particles (Honaker et al., 1996). The initial application of enhanced gravity concentrator was for the separation of gold particles. (Lins et al., 1992; Patchejieff et al., 1994; McGrath et al., 2013). During the subsequent development, the application scope was extended to the separation of other mineral particles (Chen et al., 2008; El-Midany and Ibrahim, 2011). In addition, innovative sorting methods were also studied. The experiments that replaced fluidization water with airflow to achieve dry separation have also been reported (Kökkılıç et al., 2015; Greenwood et al., 2013).

Clean process of fine coal represents an application whereby the density differences between coal and minerals are lower than 1 g/cm$^3$. The separation performance of fine coal by different kinds of enhanced gravity separators, usually Knelson concentrator and Falcon concentrator, were discussed in the past decades. In previous studies, the effects of different variables, including operating parameters, particle size in feed, coal type and equipment types, on the separation performance were investigated. It was reported that excellent ash and sulfur rejection had been obtained in enhanced gravity fields. For the removal of inorganic sulfur, the enhanced gravity separator showed a significant advantage and 62.5% of the total sulfur could be removed (Mohanty and Honaker, 1999).

Knelson concentrator can achieve effective separation of coal particles in size of +106 μm (Honaker et al., 2005; Majumder et al., 2007; Uslu et al., 2012). Falcon concentrator of SB series and C series can provide centrifugal force of up to 300g. Research results found that the minimum sorting size can be reduced to 75 μm, excellent separation indexes were obtained (Oruç et al., 2010; Boylu, 2013; Ibrahim et al., 2014; Boylu, 2014). As for the difficult-to-float coal that is difficult to clean by flotation method due to the hydrophilicity of the particle surface, such as oxidized coal and lignite, enhanced gravity concentrator have achieved efficient separation (Sabah and Koltka, 2014; Zhu et al., 2016). Falcon concentrator (UF series), of which maximum centrifugal force can reach 600*g*, was employed to discuss the separation of ultrafine particles within size and density ranges lower than usual, that is −60 +5 μm and 1.2–3.0 g/cm$^3$ (Kroll-Rabotin et al., 2010; Kroll-Rabotin et al., 2012; Kroll-Rabotin et al., 2013).

However, researchers were mostly concerned about the quality of the final product in the above mentioned papers. Although the natures of the overflow product have been analyzed in detail, it is difficult to reveal the law of particle separation. Thus, enrichment and migration regularity of particles in the separation process cannot be revealed. Therefore, separation tests of fine coal samples were carried out to study the mass distribution and ash distribution in overflow, top

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separation zone and bottom separation zone. The enrichment regularity of particles in different enrichment areas under different operating parameters were analyzed. Therefore, the motion of particles in the separation process could be obtained.

## 2. Materials and methods

### 2.1. Test equipment

A laboratory Falcon concentrator (SB40) was used in this investigation. Mechanical structure of the concentrator is shown in Fig. 1. The slurry was fed through feed pipe to the revolving impeller. Under the action of centrifugal force, particles were settled and stratified in the flowing film at delamination area. Materials were separated by fitting the compatible centrifugal force that controlled by cylinder speed and fluidization water that flow into the inner bowel through holes in the bottom of groove. The light product was expelled into overflow, and the heavy product was accumulated in the groove.

It is clear that there are two zones in the separation area, the top and bottom separation zones. Usually, the materials enriched in the two regions are mixed as the high density product after the completion of separation process. However, the two materials were collected and analyzed respectively in this paper to investigate the enrichment regularity of particles in separation process.

### 2.2. Materials

Coal sample with ash content of 30.21% was chosen as the test materials. The particle size and density had significant effect on the particle sedimentation. Thus, the size composition and density composition were obtained by screening and float/sink test and the results are shown in Fig. 2 and Fig. 3 respectively.

As can be seen in Fig. 2, the yields of narrow size classes decrease with the decrease of the particle size. Sample is dominated by coarse particles, and the yield of +0.074 mm reaches 85.05%, the yield of micro size fraction (−0.045 mm) is only 4.4%. Meanwhile, ash contents increase with the decrease of particle size, which shows that the mineral content is gradually increasing.

Density composition analysis results show the low-density peak (1.3–1.4 g/cm$^3$) and high-density peak (+2.0 g/cm$^3$) are significantly higher than other density peaks, which illustrate that density distribution of sample is mainly composed of low-density particles and high-density particles. The significant difference in density is helpful to the process of gravity separation. Ash contents of narrow density fractions increase with the increase of density. Ash content of −1.5 g/cm$^3$ are all lower than 10%, meanwhile, ash content of +2.0 g/cm$^3$ density increased to 70%. The significant correlation between density and ash content is the basis of the gravity separation to achieve the reducing ash.

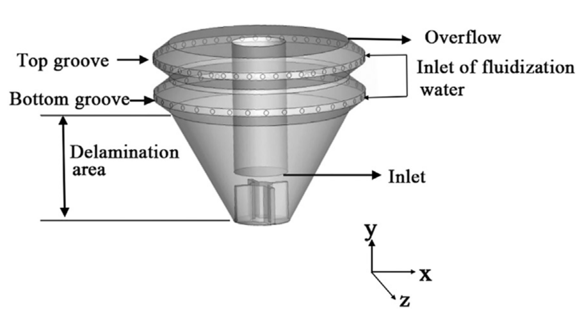


**Fig. 1.** Structure of Falcon concentrator.

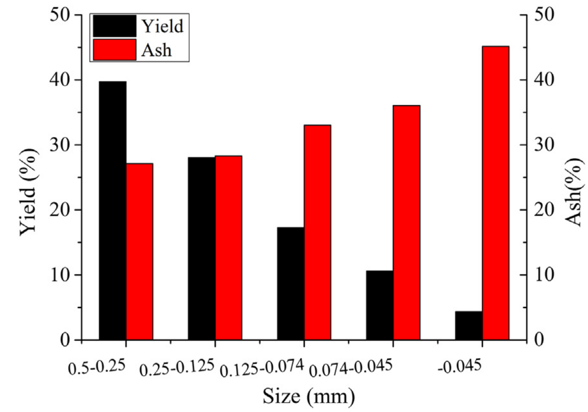


**Fig. 2.** Size composition of coal sample.

### 2.3. Experimental methodology

#### 2.3.1. Radial velocity of fluid in separation area

In separation zone, including top separation area and bottom separation area, the main factors affecting particle sedimentation are centrifugal force and radial velocity of fluidization water. In this part, outlet flow rate of fluidization water was measured under different fluidization water pressure. The geometric parameters of the separation area of the concentrator were determined, thus, the radial velocity of the fluidization water in the radial direction on top and bottom groove were calculated consequently. The above analysis was based on the assumption that the radial velocity of the fluid was uniformly distributed over the section. The result is helpful to understand the enrichment law of particles in the separation process.

#### 2.3.2. Separation tests

There were two grooves in Falcon concentrator, which were called as top groove and bottom groove in the following discussion.

Sorting process has been elaborated in Section 2.1. In the shutdown process of concentrator, the fluidization water in cavity will make the material layer re-fluidization. The key to solve this problem is to adjust the frequency converter and water valve cooperatively, which is usually empirical. Concentration tests were carried out under different centrifugal force and fluidization water pressure. Three products were finally obtained, that is, products in overflow, products in top groove and products in bottom groove. The products were screened and ash contents were tested.

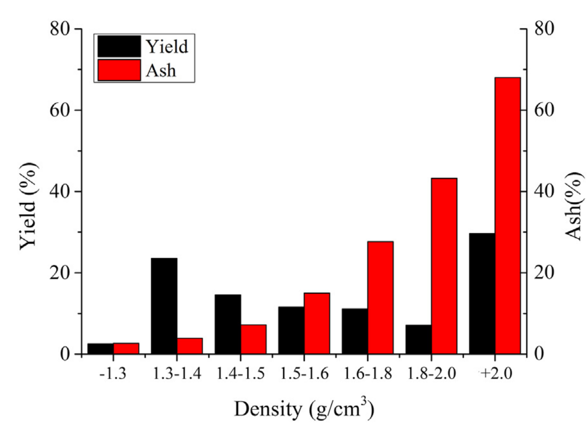


**Fig. 3.** Density composition of coal sample.