

**Performance Analysis of Gravity Concentration Methods at Narrow Particle Size Fractions**

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Abstract

*We investigated effects of the particle size distribution on the performance of gravity concentration methods used in mineral processing and measured the recovery differences between a whole size distribution and narrow size fractions. Three different gravity concentration methods (jig, spiral, and shaking table) were tested using two different artificial feed samples comprising Hematite (Fe2O3) and Quartz (SiO2) (Sample A), and Calcite (CaCO3) and Lignite (Sample B). The operational conditions followed typical industrial operational limits. The performance of the three methods was compared at narrow particle size fractions. The findings showed that the performance of all three methods increased with narrow size fractions. However, the jig method showed the strongest effect for both artificial samples, with recovery increases of 16.94% for Sample A and 21.60% for Sample B.*

Keywords: *particle size effect, performance analysis, gravity concentration*

# Introduction

Gravity concentration is the best known and oldest method of mineral processing and uses the differences in density between minerals to separate them. Yet, despite its long and widespread use, it is not yet entirely understood [1]. The gravity separation process has been used in the mineral industry to separate particles under the action of hydrodynamic and gravitational forces [2]. It uses their relative movement in response to gravity and other forces, and is broadly related to the resistance to motion offered by a viscous fluid [3]. Gravity concentration offers advantages such as small capital requirements, low operating costs, and high efficiency (depending on the feed size). As it does not require the use of chemicals or excessive heating, it is usually considered to be environmentally friendly [3],[4],[5],[6],[7],[8],[9].

The efficiency of gravity concentration falls at particle sizes below 100 µm. At these sizes separation is difficult without imparting an extra force to the particles. This led to the development of enhanced gravity separators [8],[10],[11],[12],[13].

The two principal factors affecting gravity concentration are the differences in density and particle size between the minerals being separated. When there are large particle size distributions in the feed, the separation performance is badly affected because of the loss of small heavy particles, which act like light coarse particles in the process.

All gravity concentration devices function more efficiently with prepared feeds, in which the particles are within a comparatively narrow size range [1]. The separation process takes advantage of density differences between minerals, but often there are no large density differences between the minerals to be separated. In such cases, narrow particle size distributions should be considered as a way of improving the efficiency of the separation process.

In this research, whole particle size distributions and narrow size fractions were compared, and the behavior of gravity concentration methods at narrow particle size fractions was investigated in detail. The equipment used in the research was as follows:

## Jig Concentrator

This is a device that is used in mineral processing to separate the particles in the feed based on their specific gravity. The separation of particles is effected in a bed resting on a ragging screen. The bed is fluidized by a vertical pulsating motion created by a diaphragm and an incoming flow of hutch water [7]. The particles are introduced to the jig bed (usually a screen) where they are thrust upward by a pulsing water column or body, causing the particles to become suspended in the water. To allow stratification of the material into fractions of different settling velocity in the jig, the particles must be able to move freely between each other [14]. The jigging action causes the heavier particles (of high specific gravity and size) to sink into the underflow, and the lighter and smaller particles to form a tailing overflow.

## Spiral Concentrator

This is a device used for separating particles in a slurry, based upon a combination of the solid particle density and the hydrodynamic properties of the particles, such as drag force and centrifugal force. The device has a tower and sluice. Slots or channels are placed in the base of the sluice to extract heavy particles that have settled out of suspension. As larger and heavier particles migrate to the inside of the sluice faster and experience more drag from the inside, they travel more slowly and thus move toward the center of the spiral.

## Shaking Table

This is used to separate minerals using the combined effect of mechanical motion and a thin water layer on the sloping table. The surface of the table oscillates backward and forward, causing the particles on the table to arrange themselves in different layers and zones. The minerals are then separated according to their densities.

# MATERIALS AND METHODS

Two test material samples were used. Sample A was a mix of quartz (SiO2) and hematite (Fe2O3), prepared by magnetic separating, and with particle densities of 2.65 g/cm3 and 4.9 g/cm3, respectively. The samples comprised 20% hematite and 80% quartz by weight. Sample B, a calcite and lignite feed, was prepared in a float–sink bath, with particle densities of 2.7 g/cm3 and 1.5 g/cm3, respectively. All samples were sieved at the same sieving size to obtain four different narrow fractions ranging from 1.6 mm to 0.106 mm.

Three concentration methods (shaking table, spiral, and jig) were tested using the same narrow size fractions, different solid contents, and different feed rates (except in the case of the jig). The artificial feed was introduced in four steps and the performance was analyzed and compared. Three operational parameters were tested for the spiral concentrator and shaking table methods to determine the best feed rates. For all three methods, two further parameters were investigated: the particle size and the solids contents of the feed. Eighty different conditions were tested using the spiral and shaking table methods and 20 different conditions were tested using the jig. In total, 360 different conditions were tested. The test conditions for the spiral concentrator and shaking table are given in Table 1.

*Table 1. Test Conditions for Spiral Concentrator and Shaking Table*

|  |  |  |  |
| --- | --- | --- | --- |
| **Number of Tests** | **Particle Size (mm)** | **Solids,%** | **Feed Rate (l/s)** |
| 1-16 | 1.6 + 1.18 | 15 | 1/1.5/2/2.5 |
| 20 | 1/1.5/2/2.5 |
| 25 | 1/1.5/2/2.5 |
| 30 | 1/1.5/2/2.5 |
| 17-32 | 1.18 + 0.6 | 15 | 1/1.5/2/2.5 |
| 20 | 1/1.5/2/2.5 |
| 25 | 1/1.5/2/2.5 |
| 30 | 1/1.5/2/2.5 |
| 33-48 | 0.6 + 0.3 | 15 | 1/1.5/2/2.5 |
| 20 | 1/1.5/2/2.5 |
| 25 | 1/1.5/2/2.5 |
| 30 | 1/1.5/2/2.5 |
| 49-64 | 0.3 + 0.106 | 15 | 1/1.5/2/2.5 |
| 20 | 1/1.5/2/2.5 |
| 25 | 1/1.5/2/2.5 |
| 30 | 1/1.5/2/2.5 |
| 65-80 | 1.6 + 0.106 (Whole distribution) | 15 | 1/1.5/2/2.5 |
| 20 | 1/1.5/2/2.5 |
| 25 | 1/1.5/2/2.5 |
| 30 | 1/1.5/2/2.5 |

First, the spiral and shaking table methods were tested at different feed rates. The test conditions are shown in Table 1 for the spiral concentrator and shaking table and Table 3 for the jig.

*Table 2. Feed Rate Results for Spiral Concentrator and Shaking Table (15% Solids)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Spiral** | | | **Shaking Table** | |
|  | **Recoveries (%)** | | | |
|  | **Sample A** | | **Sample B** | |
| Feed Rate (l/s) | Total of Narrow Fractions | Whole Distribution | Total of Narrow Fractions | Whole Distribution |
| **1** | **97.40** | **81.64** | **89.76** | **71.98** |
| 1.5 | 94.80 | 79.71 | 86.98 | 69.87 |
| 2 | 93.45 | 79.08 | 58.52 | 69.09 |
| 2.5 | 91.45 | 78.05 | 83.39 | 67.86 |

*Table 2. Test Conditions for Jig*

|  |  |  |
| --- | --- | --- |
| **Number of Tests** | **Particle Size (mm)** | **Solids,**  **%** |
| 1-4 | 1.6 + 1.18 | 15/20/25/30 |
| 5-8 | 1.18 + 0.6 | 15/20/25/30 |
| 9-12 | 0.6 + 0.3 | 15/20/25/30 |
| 13-16 | 0.3 + 0.106 | 15/20/25/30 |
| 17-20 | 1.6 + 0.106 (Whole distribution) | 15/20/25/30 |

All tests were operated as batch processes. Two discharge units were used, the positions of which were fixed.

Samples were fed directly into the separators and the products were collected as concentrates and tailings. The hematite was separated by a magnetic separator, and the lignite was separated using a float-sink bath. The products were dried and weighed out; they were finally analyzed, and their recovery rates calculated.

Samples of the concentrates and tailings were taken simultaneously during the tests. In each new test, the equipment was cleaned, calibrated and operated in a manner appropriate to the new test conditions. To allow comparisons to be made between the methods at whole particle size distributions from 1.6 mm to 0.106 mm and at four narrow size fractions, the concentrates from all the methods were treated in the same way.

# results and dıscussıons

The particle size distributions were set between –1.6 + 1.18 mm and –0.3 + 0.106 mm, and the solids% ranged from 30% to 15% by weight for all methods. All these ranges were within typical industrial operational limits. The relationships between particle size and recovery rates are given in Figures 1 to 3, and the differences in recovery rates between the methods are given in Figure 4, for both samples A and B.



*Figure 1. Spiral Recovery versus Particle Size for Both Samples*



*Figure 2. Shaking Table Recovery versus Particle Size for Both Samples*



*Figure 3. Jig Recovery versus Particle Size for Both Samples*



*Figure 4. Recovery Differences between Whole Distribution and Total Fractional Particle Size for Both Samples*

The results for both samples showed that the best recovery rates were obtained at a 1 l/s feed rate for all solids contents. The recoveries at 15% solids contents are given in Table 2.

In the spiral and shaking table concentrators, slight differences in recoveries were observed for different solids contents of the feed. As can be seen from Figures 1, 2, and 3, however, the recoveries were more strongly affected by increases in the particle size.

The recoveries using the shaking table were lower than those from the spiral concentrator, but the results showed the same overall trend of increasing with particle size. A direct relationship with the particle size distribution was found in both concentrations for both samples. The jig recoveries showed the most significant increase as the maximum particle size increased, as shown in Figure 4. The total recoveries were calculated using Equation 1.

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where *Ci* is the amount of feed fraction, *ci* is the grade of hematite at fraction, *F* is the total feed amount, *f,* is the grade of total feed, and *n* is the number of fractions.

The results suggested that the performance of all methods increased as the feed departed from narrow size fractions. The jig performance increased by 16.94% for sample A and 21.60 for sample B, the shaking table performance increased by 6.08% for sample A and 9.20% for sample B, and the spiral concentrator performance increased by 3.98% for sample A and 7.79% for sample B.

# conclusıon

In this study, the effect of the particle size distribution on the separation performance of gravity concentrators was investigated. The experiments tested four narrow fractions of –1.6 + 1.18 mm, −1.18 + 0.6 mm, −0.6 + 0.3 mm, and −0.3 + 0.106 mm and with whole fractions, comprising all four, of –1.6 + 0.106 mm, with four different solids contents. The performance of the concentrators was demonstrated to be directly related to the particle size distribution. The performance of all methods increased as the feed departed from narrow size fractions.

The effect of particle size was greater for Sample B than Sample A. All three concentrators showed improved total recovery performance using prepared feeds with particles falling into a comparatively narrow size range.

The effect of the prepared feed on the concentrator was different for the different methods. The most significant improvement in performance was recorded for the jig, with recovery increases of 16.94% for Sample A and 21.60% for Sample B.

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**BIOGRAPHY**

He is graduated from Hacettepe University, Department of Mining Engineering at the date of 2001. He had M.Sc. and Ph.D. degrees from the mineral processing section of same department at 2004 and 2009 respectively. He has been working at Hacettepe Vocational School since 2002. He is head of Alternative Energy Sources Program, his professions are mineral processing, coal cleaning and industrial raw materials.

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