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Effectiveness of Gravity Separation of Low Grade Nigerian Gold Ore Using Shaking Table

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Abstract

The response of Imogbara (Nigeria) gold ore to shaking tabling gravity separation methods was investigated in this research work. Gold concentration in run-off mines is usually as low as 0.005 ppm and must be upgraded in order to reduce the recovery process extraction costs. Gravity separation method (the focus of this work) is one of the readily affordable beneficiation methods. Shaking table is a developed separation equipment of gravity method that has been adopted to increase concentrate based on difference of specific gravity. The output result of the concentration process using shaking table is basically influenced by a number of variables, such as rotational shaking speed, particle size and deck slope. In this research, the range of rotational speed shaking was between 100 rpm and 200 rpm, the particle size was between (−300 μm > X < +75 μm) and (−75 μm) and deck slope was between 10˚ and 30˚. EDXRF was used to measure gold concentration in the concentrate as well as the tailings. The result shows that the optimum condition is obtained at a shaking speed of 100 rpm, with a slope of 10˚ and particle size less than 75 μm.

Keywords

Gravity Separation, Concentrate, Gold Ore, Shaking Table, Upgraded

1. Introduction

Precious metals such as gold usually have very rare occurrence [1]. The earth crust is known to contain gold at a very low concentration of just about 0.005 part per million. Therefore, when it is mined, it is usually required to be upgraded by a factor as high as between 3000 to 4000 to realize a concentrate that is commercially acceptable and can be economically recovered [2]. Gold ore milling has to do with the process whereby ore particles are liberated from gangue materials through progressive size reduction in the form of crushing or grinding. The cost associated with this process represents single largest cost in gold extraction process [3].

Mineral processing methods to upgrade gold include floatation and gravity methods [4]. Previous studies have revealed gold flotation to be an inherently slow rate process when compared to the flotation of other naturally floating minerals, such as chalcopyrite, chalcocite, and sphalerite [5]. Gravity separation methods include the use of Jigs, Spirals and Tables. The principle of separation in them is based on the variation that exist in the specific gravity of the target mineral and the associated gangues. Shaking table has been widely used in concentrating various minerals ores. They are designed to have a plane surface that is slightly inclined to the horizontal along its breadth and is shaken in the direction of its length with a different movement. Their throughput is considered relatively low compared to other notable gravity concentration equipment. However, it is a very relevant concentration method because of its ability to produce high grade concentrates at excellent recoveries. Shaking tables are often used on low volume, difficult to treat streams and as a means of producing final concentrates from previous stages of gravity separation [5] [6]. Maximizing the operation of the shaking table is one of the effective strategy that can be utilized in gold mineral processing to obtain excellent recoveries. The separation on the shaking table is based on the principle of the motion of particles according to specific gravity (SG) and size moving in slurry across an inclined table, which oscillates backwards and forwards essentially at right angles to the slope, in conjunction with riffles which hold back the particles which are closest to the deck. Therefore, the efficiency of separation that can be obtained from the operation of a shaking table can always be determined by the particle size of the ore, the speed at which the table oscillate and the angle of tilt. Products obtained from the tabling process are usually of three categories which are: concentrates, midlings and tailings. There are notable analytical methods available for the determination of gold concentration in each category [7]. These include fire assay method which is the oldest and relatively reliable method used for the concurrent determination of silver and gold in all gold-bearing materials. Another known method involves the extraction of gold using methyl isobutyl ketone (MIBK) followed by direct gold determination by flame atomic absorption spectrophotometry. Graphite furnace atomic absorption spectrophotometry (GFAAS) enables the detection of low concentrations of silver and gold, but previous extraction of the precious metals is required before their determination.

2. Experimental Descriptions

2.1. Materials

Gold ore sample was collected from active mine in Imogbara village, within Atakumosa Local Government Area of Osun State, Nigeria. Panned sample was adequately mixed after washing to achieve homogeneity [7]. Dried sample was crushed using Pascal Engineering crushing mill with machine number 18,862 operated at 415 V, 2200 W, 4.9 A and 50 Hz [8]. A working sample size of 500 g obtained using random sampling method followed by cone and quartering sampling method was pulverised using a pulverizer and sieved through 300 μm and 75 μm sieve sizes [9]. Chemical composition of the ore sample was determined using energy dispersive X-ray fluorescence (model NEX QC + EDXRF) manufactured by Rigaku corporation and the result is presented in **Table 1**.

2.2. Experimental Procedure

Shaking tabling was carried out on the gold ore samples adopting methods established by [10]. The shaking table used was manufactured by Brook Crompton Parkinson Motors with model number 148566Q. Representative sample was carefully taken from the size ranges (−300 μm > X < +75 μm) and (−75 μm). These size ranges were selected so as to work with optimum liberation size as established by [9] [11]. About 30 g of each size distribution was measured into a

Table 1. Chemical composition of gold-bearing rock ore using EDXRF.

Composition	Ppm
K	14452.59
Se	168.23
Rb	2781.25
Ti	5863.56
Pb	1113.48
Fe	274874.88
Ca	3529.31
S	1629.78
Sr	73.48
Th	462.38
As	266.13
Ag	0.86
Mo	239.77
Au	113.78
Zn	4407.29
Ni	1264.57
Co	1374.97
Mn	14076.40
Cr	1707.55
V	449.37

500 ml measuring cylinder. At the first instance, 30 ml of water was added and carefully agitated to achieve complete mixture [12]. Thereafter, 60 ml of water was added to the mixture and further agitated to achieve homogenous mixture. The mixture after the solid—liquid combination gave a slurry of 25% solid by weight [13]. This procedure was adopted to prepare all samples used on the shaking table.

The shaking tabling separation was done by first setting the deck slope at 10˚, stroke speed to 100 RPM and water flow rate of 120 L/hr. Sample was fed at the rate of 250 ml/min. The products were collected into tailings and concentrates using ores of particle sizes (−75 µm) and (−300 µm > X < +75 µm) at different instances. Also deck slopes of 10˚ and 30˚ were used at stroke speeds of 100 and 200 RPM. The collected tailings and concentrate products were allowed to settle, decanted and dried. Thereafter, individually collected products were weighed and recorded. The products collected were analysed using EDXRF to determine the gold percentage present [14]. About 10 g of the product was leached using aqua regia prepared by mixing HCl and HNO_3 (ratio 3:1) [15]. Leached solutions were analysed using NEX QC + EDXRF analyser. About 6 g of each leached sample was fed into a standard 32 mm XRF measurement cells and was explored directly on the analyser. A linear empirical calibration was built using four calibration standards that has been assayed by Atomic Adsorption. The results obtained from the shaking tabling separation are presented in **Table 2**.

3. Results and Discussion

The experimental results are presented and discussed in the following sections.

Abbreviations and Acronyms

The results obtained using shaking table manufactured by Brook Crompton Parkinson Motors with model number 148566Q reveals the effectiveness of gold

Table 2. Shaking table at various parameter combination.

S/N	Deck Slope (˚)	Speed (RPM)	Particle size (µm)	W_f (g)	W_c (g)	W_t (g)	C_f (%)	C_c (%)	C_t (%)	Newton's Efficiency (%)
1	10	100	−75	30	9.2	20.1	0.0242	0.1362	0.0173	98.5761
2	10	100	−300	30	9.7	19.6	0.0234	0.1413	0.0154	94.5867
3	10	200	−75	30	10.4	18.8	0.0241	0.1421	0.0166	96.8650
4	10	200	−300	30	8.7	20.8	0.0237	0.1401	0.0151	97.2653
5	30	100	−75	30	8.5	21.2	0.0242	0.1344	0.0163	94.2948
6	30	100	−300	30	7.7	21.9	0.0239	0.1361	0.0158	95.1109
7	30	200	−75	30	7.4	22.1	0.0237	0.1332	0.0162	96.8292
8	30	200	−300	30	7.2	22.4	0.0232	0.1327	0.0155	97.6725

separation from gangue using shaking table under the influence of three important variables which are particle size, shaking speed and slope of deck. The effectiveness of separation which is calculated as Newton's efficiency is obtained using percentage of gold concentration in the feed, concentrate and tailings using Equations (1)-(3) [16]. The respective percentage gold concentrations were obtained from XRFEDX carried out on each fraction.

$$\eta_N = R_c - \left(1 - R_{fa}\right) \tag{1}$$

$$R_c = \frac{C_c W_c}{C_f W_f} = \frac{\left(C_f - C_{fa}\right)C_c}{\left(C_c - C_{fa}\right)C_f} \times 100\% \tag{2}$$

$$R_{fa} = \frac{W_t\left(1 - C_t\right)}{W_f\left(1 - C\right)} = \frac{\left(C_f - C_c\right)\left(1 - C_t\right)}{\left(C_t - C_c\right)\left(1 - C_f\right)} \times 100\% \tag{3}$$

where;

η_N = Newton's efficiency; W_f = weight of feed (gram);

W_c = weight of gold concentrate (g); W_t = weight of tailings (gram);

C_f = conc. of gold in feed (%); C_c =conc. of gold in concentrate (%)

C_t = conc. of gold in tailing (%); R_c = Gold Recovery (%)

R_{fa}: Impurities (%)

Figure 1 shows the trend in the values of Newton efficiency and the increase in gold concentration after it has been concentrated using the shaking table with different experimental variables. The effect of the individual variable on the newton efficiency which is an indicator of separation effectiveness is revealed by making plot of newton efficiency against the variables as shown in Figures 2(a)-(c).

The particles to be separated using the shaking table has transport effect that is significantly influenced by the slope of the deck and the riffle shape. According to Figure 2(a), at lower slope value of 10˚, a higher separation efficiency was observed. This is because the fluid travels at lower speed and lower turbulence thereby giving opportunity for a steady separation of the very fine particles of

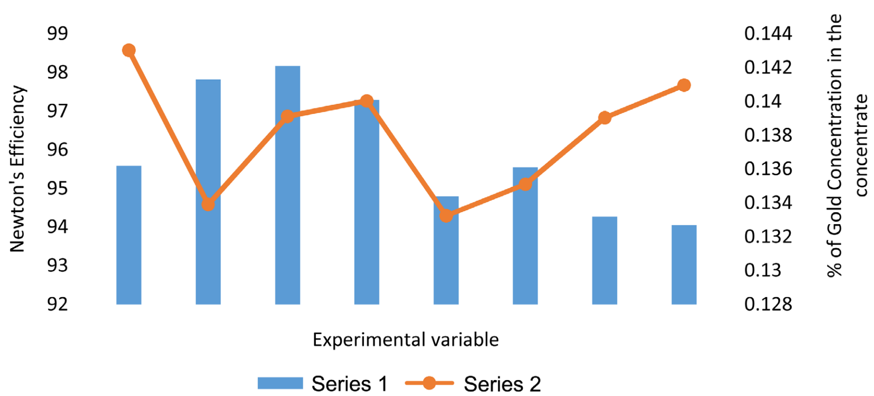

Figure 1. Newton efficiency and percentage of gold in concentrate after separation with shaking table.

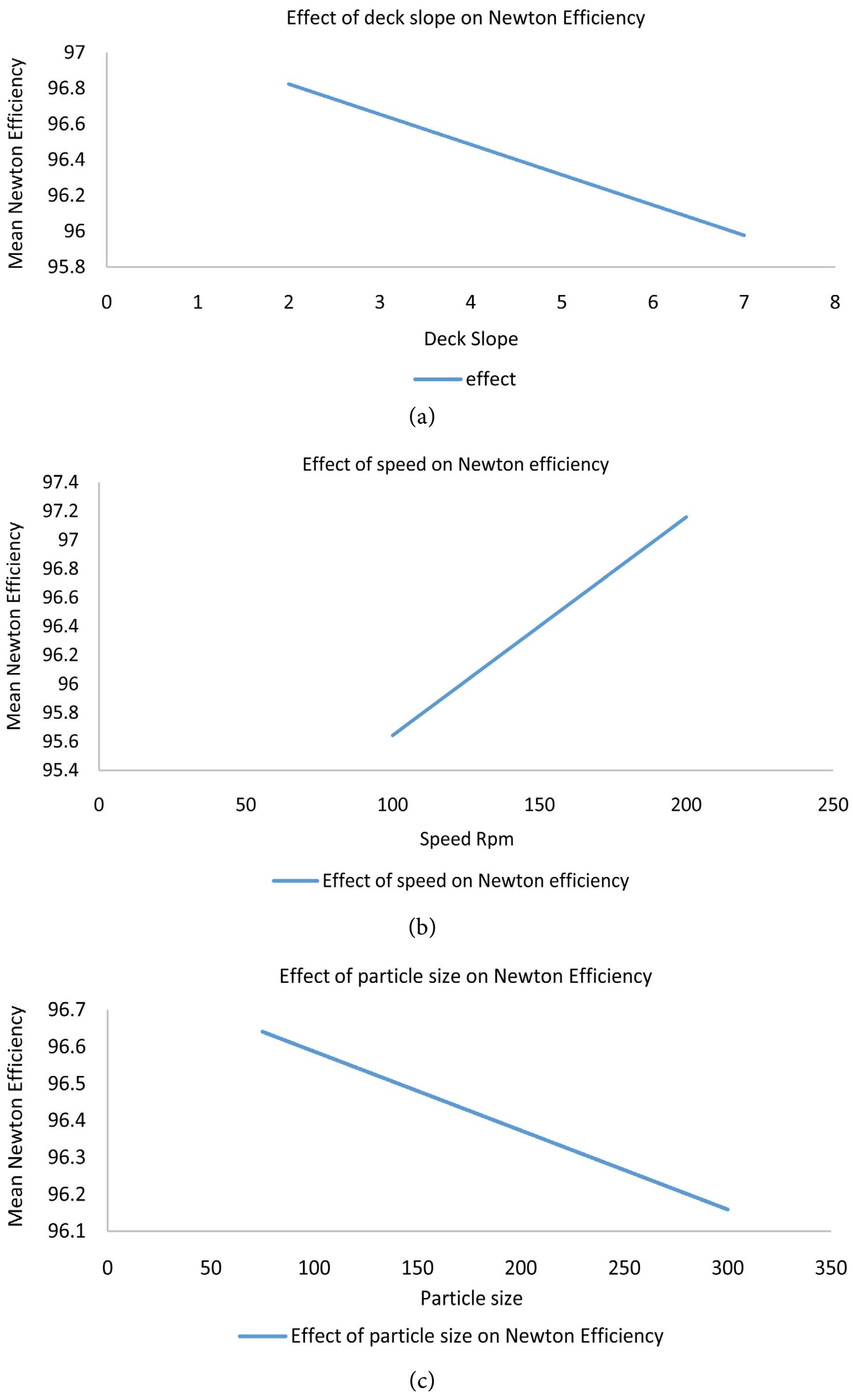

Figure 2. (a) Effect of deck slope on Newton efficiency; (b) Effect of table speed on Newton Efficiency; (c) Effect of particle size on Newton efficiency.

the ore. However, as the deck slope angle increases, there is increase in turbulence and speed of transport of the slurry across the table. This prevented a significant portion of the particle that would have accumulated in the concentrate shelter from doing so. This observation might be reversed if the particle size of the ore is increased.

As observed in **Figure 2(b)**, the shaking speed increased the Newton efficiency significantly. The results of this study did not show significant difference in separation effectiveness as the speed increases from 100 rpm to 200 rpm rather it affected the separation time, because the separation with a higher speed will cause a larger turbulence that makes the separation faster.

Particle size effect on the Newton efficiency is shown in **Figure 2(c)**. The efficiency of separation reduces with increasing particle size. This is because lifting of the particles by the flowing water at the sizes being considered will be more difficult for −75 μm as compared to the particles of −300 μm. Therefore, more particles of the ore will be lifted to the tailings in the larger particle size test.

4. Conclusion

The effect of variables such as rotational shaking speed, particle size and deck slope on the gravity separation efficiency of gold ore samples obtained from an active mine in Imogbara in Osun state, Nigeria using shaking table has been studied. The effectiveness of separation which was calculated as Newton's efficiency was obtained using percentage of gold concentration in the feed, concentrate and tailings with relevant equations [16]. The gold was found to be efficiently concentrated at optimum conditions of a shaking speed of 100 rpm, with a slope of 10˚ and particle size less than 75 μm.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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