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Effect of Operating Parameters on the Performance of Spiral Concentrator

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Abstract

Spiral concentrator, a critical device in the mineral sand beneficiation circuit, separates minerals based on their specific gravity differences. The effect of different operating parameters on the performance of Spiral has been studied through optimization experiments at different feed flow rates and splitter positions for four feed pulp densities ranging from 25-10%. The raw sand used in experimentation contains 12.5% slimes and 11% heavy mineral .concentrate, out of which 80% was in the particle size range of $-250 + 106$ μm.

It has been observed that with increase in feed flow rate the grade of concentrate increased but as expected the recoveries decreased significantly. Medium feed flow rate, i.e, 3.0-3.5 m^3/hr was found to be optimum in order to obtain the concentrate with greater than 93.5% HMC and high recoveries of >96%. Concentrate grade improved as the feed pulp densities increased. The Spiral concentrator has performed better at feed pulp density of 30% by producing concentrate of high grade (93.5%) and with highest recoveries of 96%. The desliming of raw sand has been done using using hydrocyclone. When the deslimed feed is fed to the spiral, high concentrate grades has been produced with very high recoveries as high as 98%.

INTRODUCTION

Spiral concentrator is one of the simple yet efficient methods of mineral beneficiation which sorts particles according to their specific gravity differences. First commercial spiral concentrator was used to treat chromite ore in 1943. Later in 1943, its use was extended to the mineral sand beneficiation. Since then Spiral design has been progressively modified to improve operational features, extend the range of applications etc (well described by Davies et. al 1991). Design considerations of spirals are further explained by Jing 1994 and Bhatt 1995.

Though the spiral is simple in construction, the fluid flow is complicated by presence of a secondary flow, which operates radially across the trough (Holtham 1990, 1992). This flow is an important part of the separation mechanism. Besides this complex fluid flow, separation mechanism in spiral is further complicated by particle flow, inter-particle forces and their interactions. Particles segregation in the flowing film down the Spiral conduit has been related to the following four sorting processes (Sivamohan and Forssberg 1985) ie., 1) Hindered settling 2) Interstitial trickling 3) attainment of minimum potential energy and 4) Bagnold forces. Thus, Spiral behaviour to different operating parameters has been predicted qualitatively by many authors. Besides it, many authors attempted to predict the performance of spiral quantitatively but the successfulness is limited (Holtham 1992 and Loveday 1994). In the current work, spiral behaviour has been studied subjecting to different operating parameters like feed flow rate, feed pulp density and splitter positions. Also, the efforts are made to quantify the effect of the slimes on the separation efficiency of spirals.

MATERIALS

Mineral sand sample containing 11% heavy minerals (sp. gr > 2.8) and 12.5% slimes (-63 μm) is used for studying the effect of slimes removal on the performance of spirals. The size distribution of mineral sand sample along with the heavy mineral distribution in each size fraction is given the Fig.1. The total heavy mineral content of slimes is very low and is about 0.004%, which accounts to 0.06% of total heavy mineral content. Heavy minerals present in the size range of +100 to -250 μm, accounts to 83% of total heavy mineral content.

EXPERIMENT METHODOLOGY

Pilot scale, Carpco Humphrey Spiral is used for the concentration of mineral sands. For the desliming of mineral sands the Mozley four-inch hydrocyclone is used. Firstly, the mineral sand sample without any slimes removal is processed in Spiral for getting a concentrate enriched with heavy minerals by rejecting low-density minerals like quartz. The effect of different operating parameters like feed flow rate, splitter positions and feed pulp density are studied and the levels of operation of these parameters along with their notations are given in Table 1. The settings of splitter positions are explained in Fig 2.

Table 1: Notation for different operating parameters along with their levels of operation

Splitter Positions			Feed Flow-Rates		Pulp Density	
Notation	Concentrate Splitter	Tailings splitter	Notation	Dry Solids Flow rate (m^3/hr)	Notation	%Wt of solids in slurry
SP1	2	9	FR-1	1.5 – 2.0	PD1	25
SP2	1.5	7.5	FR-2	3.0 – 3.5	PD2	30
SP3	1	7.5	FR-3	4.0 – 4.5	PD3	35
-					PD4	40

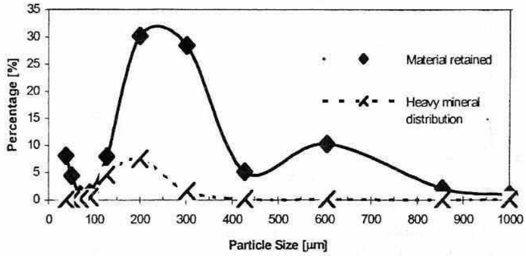

Fig. 1: Particle size distribution of mineral sand feed sample along with %HMC of each size fraction

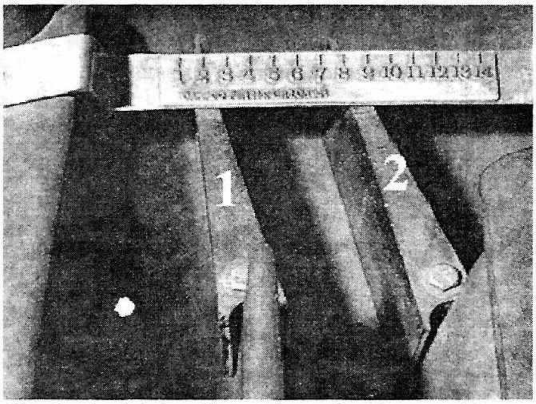

Fig. 2: Explaining the settings of splitter positions - in this figure Concentrate splitter (1) is at 2, and Tailings splitter (2) is at 8

Secondly, 4" hydrocyclone is used for the removal of slimes from the mineral sand without loosing any values in the overflow along with slimes. Optimization of hydrocyclone and the process of desliming is discussed else where (Chandrakala, 2005). Thus, the deslimed product obtained at optimized conditions of hydrocyclone is fed to the spiral and experiments are carried for a feed of 30% pulp density and are repeated for other operating parameters like feed flow rate and splitter positions. Spiral performance in both the cases (feed with and without slimes) is compared in terms of percentage heavy mineral content (%HMC) of the concentrate obtained as well as its recoveries. In all the spiral experiments, the middlings generated are recycled to the same spiral along with the feed.

RESULTS AND DISCUSSION

Spiral is operated at three different sets of splitter positions and at three different flow rates ranging from low to high. These experiments are carried for four feed pulp densities 25, 30, 35 and 40 wt%. Spiral performance is measured in terms of grade of concentrate (%HMC) and percentage of heavy minerals recovered as concentrate. These are shown in figures Fig 3 to Fig 6.

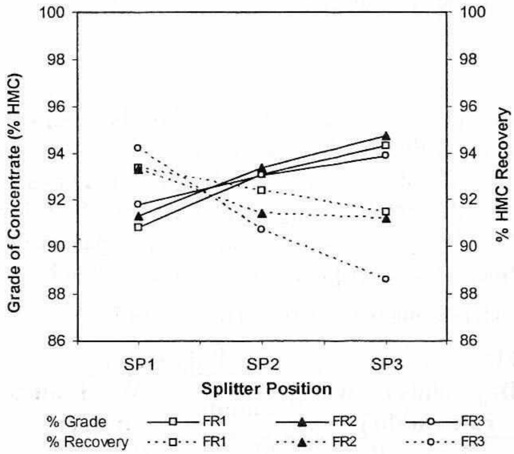

Fig. 3: Comparison of concentrate grade (%HMC) and % HMC recovered as concentrate at different operating parameters for 25% pulp density

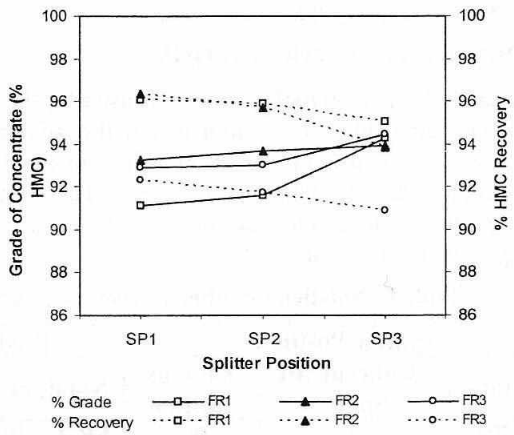

Fig. 4: Comparison of concentrate grade (%HMC) and % HMC recovered as concentrate at different operating parameters for 30% pulp density

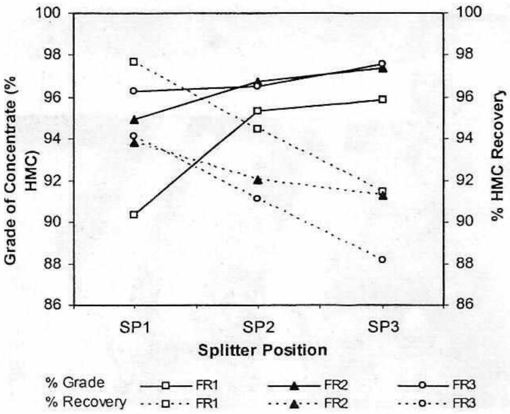

Fig. 5: Comparison of concentrate grade (%HMC) and % HMC recovered as concentrate at different operating parameters for 35% pulp density

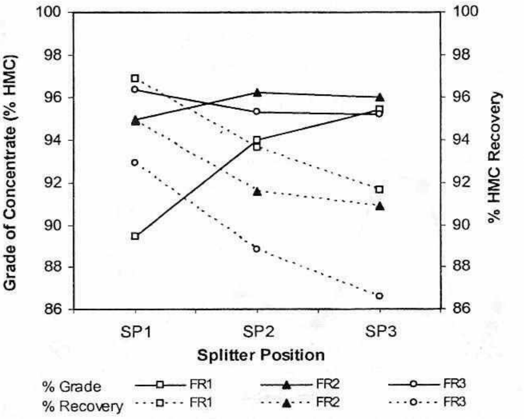

Fig. 6: Comparison of concentrate grade (%HMC) and % HMC recovered as concentrate at different operating parameters for 40% pulp density

Effect of Splitter Positions

As the concentrate splitter (shown in Fig 2) shits from a position of 2 to 1, the concentrate collection zone becomes narrow, there by the concentrate grade increases but recoveries decreases. It has been observed in all the cases from Fig 3 to Fig 6.

Effect of Feed Flow Rate

For the same feed pulp density and splitter positions, it has been observed that grade of the concentrate improved as feed flow rate increases. As the flow rate increases from 1.5 m^3/hr (FR1) to

4.5 m^3/hr (FR3), the concentrate grade increase by 1% to 7.5% depending on feed pulp density. As the feed pulp density increases, the effect of feed flow rate on the spiral efficiency is also increased. At low feed pulp densities (25-30%), as the flow rate incrases from FR1 to FR3, the concentrate grade increased by 1-2% but the recoveries decreased by 3-4%. Where as, at high feed pulp density (35-40%), for same change in the feed flow rate, the concentrate grade improved by 6-7.5% followed by a 3-4% decrease in recoveries. The concentrate grades increases with increase in the feed flow rates since the middlings and fines particles have kept away from the concentrate because of the high centrifugal forces associated with high feed flows. The decrease in the recoveries at higher feed flow rates is because of entrapment of fine heavy mineral particles in the high velocity regions (Sivamohan and Forssberg 1985).

At very high flow rates (FR3), back-mixing of different streams has been observed at the collection box, which drastically affected the concentrate grades and recoveries. Also, the rougher spiral operates with an aim of maximum recovery with optimal grades, so medium feed flow rate (FR2) 3.0 - 3.5 m^3/hr is favourable.

Effect of Feed Pulp Density

Effect of feed pulp density for different flow rates is shown in the Fig 7 and Fig 8. It has been observed that concentrate grade increases marginally (1% max) but with considerable increase in recoveries (~5%) as the feed pulp density increases from 25% to 30%. Hence in all aspects feed pulp density of 30% shows better efficiency than that of 25% pulp density. Further increase in the feed pulp density to 35%, has shown considerable increase in the concentrate grade (~ 3-4%) but with decreased recoveries (1-4%). At feed pulp density of 40%, both the grade and recoveries are low. At a splitter position 2 (SP2), low flow rate (FR1) and 35% feed pulp density or high flow rate (FR2) and comparatively low pulp density 30% gives optimised results. At high pulp densities, the high percentage of solids in the flow improves the concentrate grade by intensifying the hindered settling condition and also it avoids the reporting of middlings into concentrate layer (at low pulp densities, the thickness of the concentrate layer will be less. Hence midllings may admit into concentrate collection zone). How ever, at high feed pulp densities very fine particles finds difficult to settle which would lead to the decrease in recoveries (Sivamohan and Forssberg 1985).

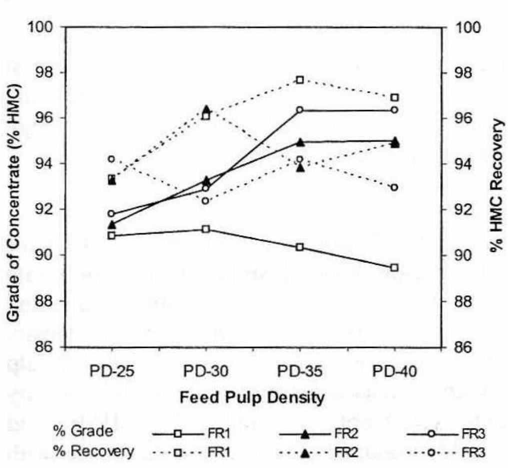

Fig 7: Comparison of concentrate grade (%HMC) and % HMC recovery as concentrate at different feed pulp densities (when splitters are positioned at SP1)

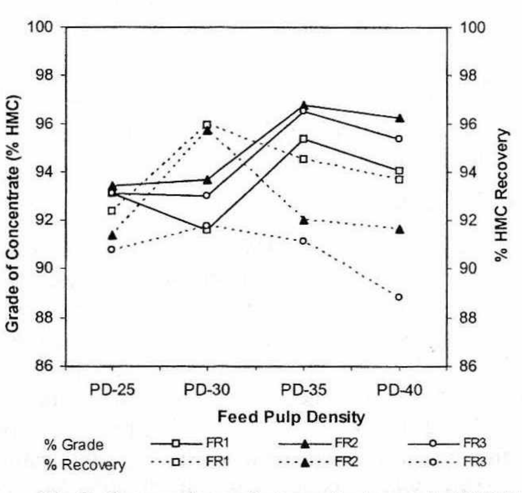

Fig 8: Comparison of concentrate grade (%HMC) and % HMC recovery as concentrate at different feed pulp densities (when splitters are positioned at SP2)

Effect of Slimes (Fines)

For slimes (<63 μm) removal from mineral sand samples, 4" hydrocyclone is used. Its design parameters like vortex finder and spigot diameters are optimized along with the operating parameters like feed pulp density and feed flow rates (Discussed elsewhere, Chandrakala 2005). At optimized conditions, it is able to produce the underflow with very low slimes content as low as 0.02% without loosing +63 μm particles in the overflow at a feed input pressure of 20 psi.

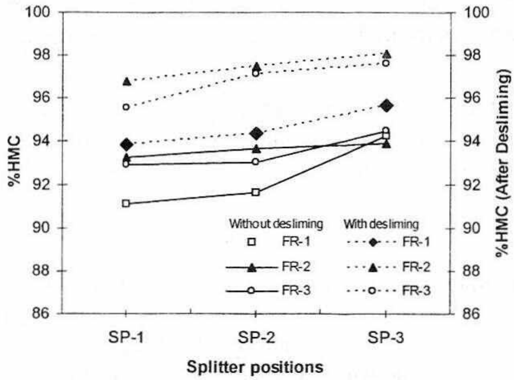

Fig 9: Comparison of %HMC of concentrate obtained in spiral operation using feed with and without slimes (Feed pulp density of 30%)

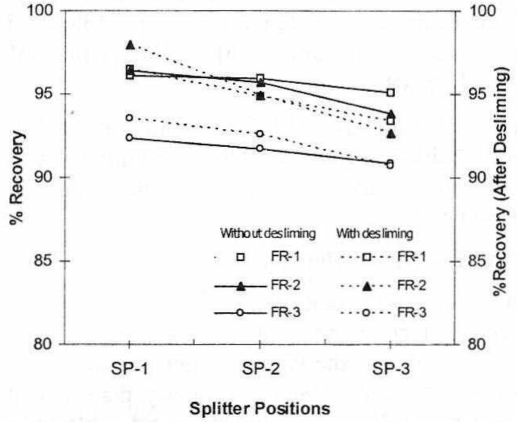

Fig 10: Comparison of %HMC recoveries as concentrate obtained in spiral operation using feed with and without slimes (Feed pulp density of 30%)

The deslimed underflow generated from hydrocyclone at optimized conditions is used for studying its behaviour in the Spiral. Results are plotted in terms of %HMC of concentrate as well as %HMC recoveries and are shown in Fig 9 and Fig 10 respectively for a feed pulp density of 30 wt%. From Fig 9, it is evident that the concentrate grades produced with a deslimed feed are higher (4%) than that of produced with raw mineral sand. The concentrate grade varies from 94% to 97% for the operating conditions of FR2 and SP1. This is mainly because of increase in the fluidity of the film flowing in spiral concentrator with the removal of slimes.

Similarly from the Fig 10, it has been proved that concentrate recoveries are high incase of spiral operated with deslimed feed. Recoveries increased from 92.5% to 98% for the same operating conditions of FR-1 and SP-2 with the use of deslimed feed. Hence, losses of heavy minerals through tailings are decreased to 2-4% from 5-10% by using deslimed mineral sand as feed.

CONCLUSIONS

Mineral sand, containing 11% heavy mineral concentrate and 12% slimes (-63microns) is used for studying the effect of different operating parameters on the performance of Spiral. As feed flow rate increases the grade of concentrate improved but the recoveries decreased. The concentrate grade and recovery increases as the feed pulp density increases from 25% to 35%. With increase in pulp density from 25% to 30%, both the concentrate grade and recoveries are increased. Further increase in pulp density to 35% shows increase in concentrate grade but with decreased recoveries. Feed pulp density of 30% with a flow rate of 3.0-3.5 m^3/hr produced concentrate with optimum grade (93.5% HMC) and with high recoveries upto 96%. Spiral with deslimed feed produced high-grade concentrate with 98.5% HMC where as it gives only 93.5%HMC concentrate when operated with feed containing 12.5% slimes. Also, the heavy mineral losses through tailings are decreased to 2-4% from 5-10% by using deslimed mineral sand as feed.

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