Can Hydrocyclone be an Alternative in solid-liquid Separation Process?

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Abstract

In mineral processing industry, most of the separation processes involve substantial quantities of water. The final concentrate generated has to be with low moisture content and recovery of water from the tailing stream has to be recycled. So dewatering i.e., separation of liquid from solid is an important step in mineral processing. As dewatering processes are expensive and inefficient in general, these need focused attention. In case of fine and ultra-fine particles, (fine <100μm, ultra-fine < 5 μm) screening, even if in wet condition, is not effective. As there are many limitations associated with thickeners and filtration units, hydrocyclone can be thought of as an alternative in the solid-liquid separation process. Because of the design and operational simplicity, high capacity, low maintenance and operating cost, hydrocyclone is found to be very attractive for dewatering purpose. So, if hydrocyclones can be used efficiently at this stage, then the load on filtration units or thickeners can be reduced.

This paper is aimed at understanding the most important factors that are affecting the separation of solid and liquid in a hydrocyclone for dewatering application i.e., recovering maximum solid and minimum water in the underflow which means maximum water recovery in the overflow. In this study the effect of three parameters on dewatering efficiency was studied in a 2″ hydrocyclone keeping at maximum pressure to achieve the objective. From the experimental results on silica sand, it was found that maximum 98.6 % solid can be recovered with 42.6 % water in the underflow.

Keywords: Dewatering, thickening, fine particle, hydrocyclone, silica

1. Introduction

In mineral processing industry, most of the separation processes involve substantial quantities of water and the final concentrate generated has to be separated from pulp in which water-solid ratio is high. So dewatering i.e. separation of solid from liquid, is an important process in mineral processing. For large particle separation, screening is an efficient process for solid-liquid separation. However, in case of fine and ultra-fine particles i.e. particles in few micron sizes, [fine (< 100 μm) and ultrafine ranges (< 5 μm) (Shiao-Hung Chiang, 2000)] screening, even if in wet condition is not effective. The screening efficiency decreases with fineness. Therefore, there are gravitational and centrifugal systems and the deciding factor for particle settling to take place in either of the two systems is the difference between the density of the solids and that of the suspending liquid. Gravitational sedimentation is an age-old process, which is used for solid-liquid separation purpose. Due to much higher acceleration of suspension, centrifugation is regarded as extension of gravity sedimentation to finer particles and it can be applied to separate emulsions, which might normally be stable in gravity field. Keeping the advantages of hydrocyclone in view, its potential in dewatering application was investigated. Hydrocyclone has relatively low capital cost with small footprint. It has no moving part and high throughput. It has low maintenance and operational cost.

In this paper the effect of various factors that are affecting most the separation of solid and liquid in a hydrocyclone for the dewatering application was investigated.

2. Experimental

In this study experiments were conducted in a 2" Mozley hydrocyclone using silica sand (top size 150 micron, specific gravity 2.65 gm/cc). Here in this study, Box-Behnken response surface method of Stat-Ease design expert 7.0 version software was used. The three variables such as vortex finder diameter (VFD), spigot diameter (SPD) and solid concentration (% solid w/w) were varied at three levels keeping pressure constant (30 psi) (Table 1).

Table 1: Experimental variables

Sl. No.	Parameter	levels	Range of variable
1	VFD(mm)	-1,0,1	8,11,14,
2	SPD (mm)	-1,0,1	3.2,5,6.5
5	%Solid conc. (w/w)	-1,0,1	20,30,40

3. Results and discussion

3.1. Quantification of dewatering performance

The experimental results are shown in table 2 as given below. The objective of this study was to achieve at maximum solid recovery (Rs) in the underflow stream and along with this the water comes along with the solid in the underflow stream (R_w') should be as low as possible. In order to assess the dewatering performance of a hydrocyclone the following parameters are required to know (Pasquier et al. 2008; Rizk et al. 2010).

R_s = Recovery of solid from feed to underflow or gross efficiency or solid elimination efficiency

R_w =Water recovery from feed to overflow

R_v = volumetric recovery of slurry to the underflow or flow ratio

R_w' = Water recovery from feed to underflow =1- R_w

E = Hydrocyclone efficiency or thickening efficiency or centrifugal efficiency=(R_s-R_v) /(100-R_v)

Table 2: Experimental results

Expt No.	SPD (mm)	VFD (mm)	% SC	% Rs	% R_w'	% E
1	3.2	8	30	41	8.4	28.1
2	6.5	8	30	98.3	24.6	97.1
3	3.2	14.3	30	0	0.0	0
4	6.5	14.3	30	70.8	12.8	58.9
5	3.2	11	20	0	0.0	0
6	6.5	11	20	97.1	22.1	95.4
7	3.2	11	40	0	0.0	0
8	6.5	11	40	62.4	19.4	41.1
9	5	8	20	98.6	42.6	96.8
10	5	14	20	91.2	13.2	87.6
11	5	8	40	86.6	35.9	69.5
12	5	14	40	31.6	11.2	15.6
13	5	11	30	48	9.6	34.7
14	5	11	30	43.5	8.2	30.7
15	5	11	30	51.7	11.3	37.1

3.2. Effect of parameters on solid recovery in the underflow

3.2.1 Effect of individual parameters

Increase in SPD i.e more clearance in the aperture resulted in more solid recovey in the underflow stream. Increase in VFD may lead to short circuit flow, so decrease in solid recovery. As the solid concentration increases from 20 to 40 wt% (w/w), more hinderance to the flow i.e hindered settling exists. This leads to decrease in less solid recovery in the underflow stream.

3.2.2. Interaction between parameters on solid recovery

3.2.2.1. Interaction between SPD and SC on recovery of solid in underflow stream

As shown in figure 1(a) that at lower value of SPD, change in solid concentration doesn't affect much. Even if the solid concentration decreases from 40% (w/w) to 20 % (w/w) means the slurry is diluted, at smaller under flow opening aperture there is no increase in solid recovery. But as the SPD increases the decrease in SC yields at maximum solid recovery which is most appreciable. As the SPD increases and SC decreases, the free settling condition prevails. leads to increase in solid recovery.

3.2.2.2. Interaction between VFD and SC on recovery of solids in underflow stream

With decreasing VFD and increase in SC and with decrease in SC and increase in VFD yield at maximum solid recovery in the underflow (Fig. 1 (b)). But both at intermediate value shows a decreasing trend in solid recovery. As because slurry is introduced into the cyclone with maximum tangential velocity (maximum possible tangential velocity is provided in all 15 experiments) which leads to generation of high centrifugal force, so it tries to push the particles towards the wall of the cyclone and collected in the underflow.

3.3. Effect of parameters on water recovery in the underflow

3.3.1 Effect of individual parameters

Here the objective is to recover less water in the underflow and more clearer water in the over flow. With increase in VFD, water recovery in the under flow decreases significantly that means larger the vortex finder aperture more water flows through the over flow aperture so less water is recovered in the under flow. SC doesn't have much effect on water recovery.

3.3.2. Interaction between parameters on water recovery

3.3.2.1. Interaction between VFD and SPD on recovery of water in underflow stream

Water recovery in the under flow is affected by VFD and SPD not by SC. As shown in fig. 2, with decrease in SPD and increase in VFD less water is coming to under flow which is the objective. When VFD is bigger with the help of air core mostly water will flow to the over flow and it will favorable by small SPD because there is no chance of water flowing through under flow aperture.

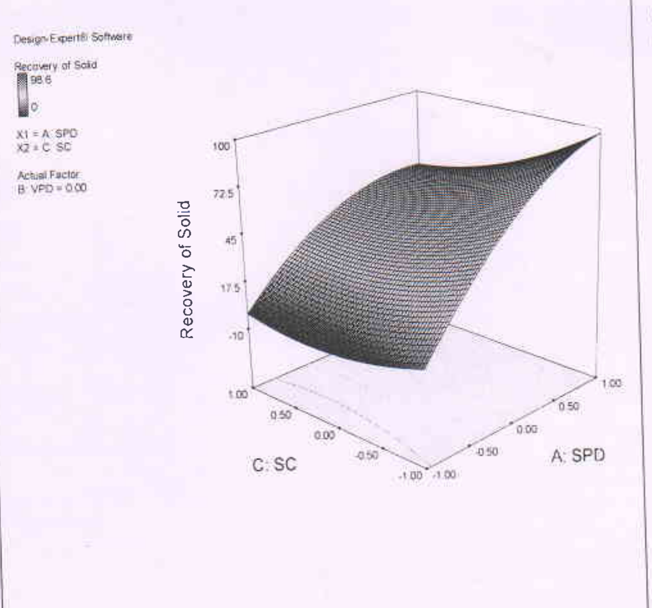

Fig. 1 (a). Interaction between SPD and SC on recovery of solid in underflow (3D Plot)

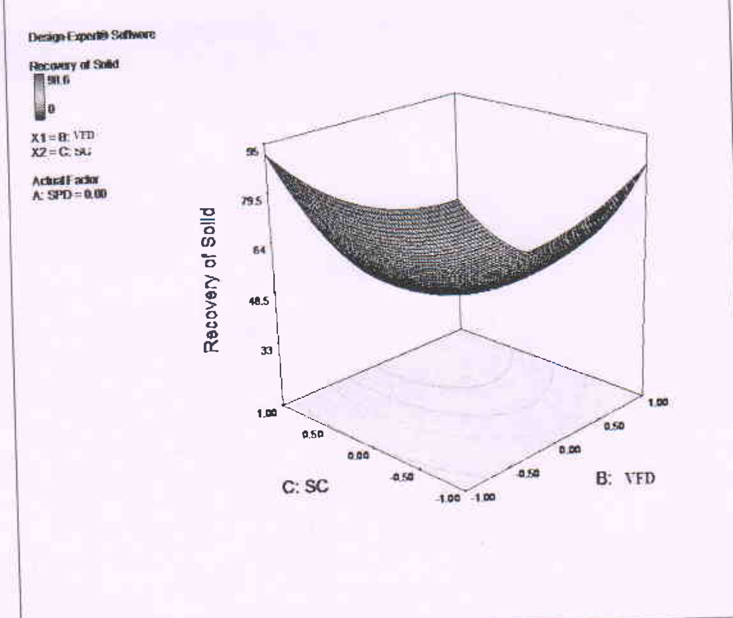

Fig. 1 (b). Interaction between SPD and SC on recovery of solid in underflow (3D Plot)

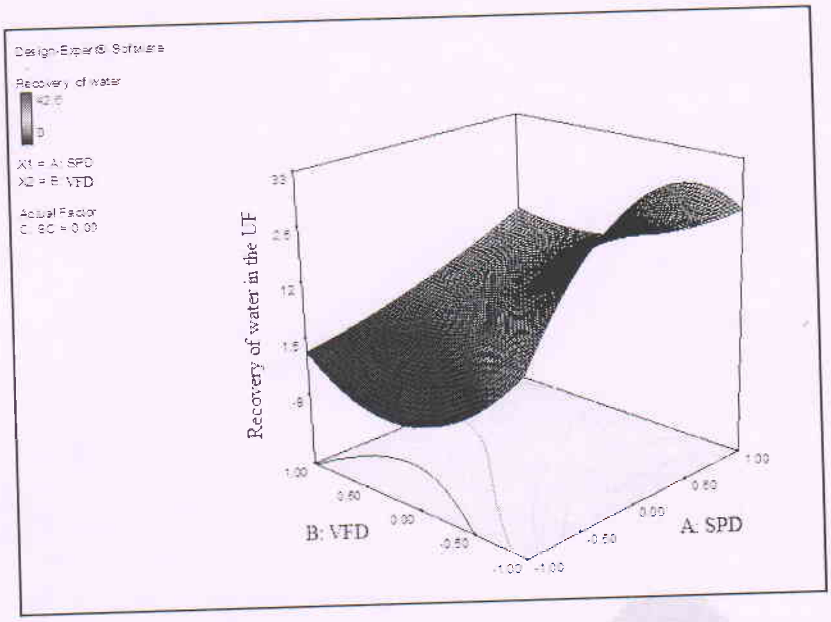

Fig. 2. Interaction between VFD and SPD on recovery of water in underflow (3D Plot)

4. Conclusion

From the experimental results it was found that maximum 98.6 % solid can be recovered with 42.6 % minimum water removal is possible. However, one of the favourable conditions is found to be 98.3 % solid recovery as minimum as 24.3 % water in the underflow can be achieved. Although our data is limited to few experiments and using only one material (i.e., silica sand), this indicates that hydrocyclone can possibly be used as an alternative in solid-liquid separation in mineral-based industries.

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