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Short communication

Preliminary studies on teeter bed separator for separation of manganese fines

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ABSTRACT

Teeter bed separators are widely used in different mineral and coal industries for separation at different stages. The teeter bed separator works based on the principles of fluidization and hindered settling. However, the published literature on this separator doesn't demonstrate its use in the separation of mineral fines. In the present article, an attempt has been made to characterize the teeter bed separator (Floatex Density Separator) with respect to its performance at different conditions of operating variables, while treating manganese fines. Also regression models were developed based on statistical design of experiments to quantify the effect of key operating variables on the performance of the separator. The characterization of teeter bed inside the floatex density separator was also analyzed to identify the particle separation behavior while treating manganese fines.

1. Introduction

Teeter bed separators are commonly employed for particle size classification and gravity concentration of coal as well as mineral fines based on their sizes, shapes and densities [1,2] These units, are commercially available at different types, viz.: hydrosizer, floatex density separator (FDS), reflux classifier, cross flow separator, all-flux classifier and hydro float separator. These separators are becoming popular day by day due to their minimum operating and maintenance cost. The working principles of these units are described in the published literature [3–5]. FDS is very successful among the teeter bed separators and are used in the mineral and coal processing industry to classify/beneficiate the fine particles according to size, shape and density. A few applications of teeter bed separator on different mineral fines are reported in the literature [6–8] and also there are several articles narrated on processing of coal fines [9,10].

Most of the published literature on FDS has emphasized on the prominence of the teeter water flow rate on particle separation for treating coal fines. It is also observed that the literature regarding the hydraulic classifier performance is limited to coal fines and it lacks emphasis on the effect of process variables on performance of FDS while treating mineral fines. So, in this article, an attempt was made to characterize the teeter bed inside the separator and to note its behavior during different operating regime. Further, second order quadratic equations were developed to quantify the effects of process variables of FDS on separation of manganese fines. Attempts were also made to provide possible explanations on the observed trends of the data, based on characteristics of teeter bed inside the FDS.

2. Materials and methods

2.1. Manganese fines

The manganese sample (one ton), as obtained from Joda, India was thoroughly mixed and sampled for characterization and experimental studies. Chemical analysis indicated that the manganese ore fines contained 22.42% Mn, 14.46% $Fe_{(T)}$, 35.95% SiO_2, and 3.78% Al_2O_3 with a Mn/Fe ratio of 1.6. From the analysis, it was clear that the manganese fines contained silica as the major gangue content.

A wet particle size analysis was carried out for the sample and the results are tabulated in Table 1. The data of Table 1 shows that about 80% of the sample has a particle size <302 μm and 33.6% of the total wt. has a particle size <25 μm. Further, size wise chemical analysis of manganese fines was carried out and the results are tabulated in Table 2. The X-ray Diffraction (XRD) study was carried out to identify the different mineral phases present in the ore and the XRD pattern is shown in Fig. 1. From Fig. 1 it is evident that, pyrolusite and cryptomelane are the main manganese bearing minerals whereas quartz, hematite and kaolinite are the major gangue mineral phases.

2.2. Floatex density separator (FDS)

The FDS is a teeter bed separator which consists of an upper square tank and a lower conical section. The separation feature of the FDS can

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Table 1
Size distribution of manganese fines.

Size in micron	Cum. Wt% passing
−500+250	100
−250+150	74.28
−150+105	59.53
−105+75	53.13
−75+37	46.8
−37+25	37.53
−25	33.55

be described by dividing it into six main zones, viz: overflow collection zone (A), upper intermediate zone (B), feed zone (C), lower intermediate zone (D), thickening zone (E) and underflow collection zone (F) as depicted in Fig. 2. The detailed working principle of the FDS is described in the published literature [8,10,11].

2.3. Experimental procedure

The experimental campaign was undertaken in a pilot scale floatex density separator (Model No. LPF-0230), of Outokumpu make with dimensions of 230 mm × 230 mm cross section and 530 mm high (square tank height), followed by a 200 mm high conical section. A series of tests were conducted based on the statistical design, by varying teeter water flow rate and set point whereas the other process variables; viz: feed rate (0.5 tph of dry solids) and feed pulp density were kept constant at 25% solids by wt.. The variables and their levels considered during the present investigation are presented in Table 3. The studied variable i.e. teeter water injected through a series of parallel pipes at the bottom of the cylindrical section of the FDS and was controlled through a rotameter. Similarly, set point is another important process variable which is expressed as a unit-less and dimension-less number. Set point of the FDS controls the bed height and bed density/pressure inside the teeter column. The value of the set point was set at 29, while the FDS was filled with water. The change in the bed pressure inside the teeter column could be noted from the PID controller which was above the teeter water pipes. The schematic diagram of the experimental set up at R&D center, Tata Steel Ltd. is shown in Fig. 3. The set up consisted of a 100 liter slurry tank provided with a stirrer and a pilot scale FDS. The required feed rate (0.5 tph) of solids was conditioned with water at pulp density of 25% solids by wt., by adding measured quantity of solids and water in the slurry tank. Initially feed slurry was fed to the FDS continuously till the system reached a steady state condition. Under the steady state condition, samples were collected simultaneously from the overflow and underflow streams. The collected slurry samples were weighed and dried to determine the solids' weights. Representative samples of the products were then analyzed for grade, recovery and rejection. To minimize the error, replication of the test program was carried out and the average values of the result were presented and discussed.

Table 2
Size wise chemical analysis of the manganese fines.

Mesh size	Assay value (%)			
(Micron)	Mn	Fe	SiO_2	Al_2O_3
+250	26.26	15.44	33.36	1.43
−250+150	19.57	13.08	48.02	1.22
−150+105	18.44	12.63	46.67	1.13
−105+75	19.14	13.33	45.02	1.32
−75+37	19.02	13.68	48.31	1.38
−37+25	17.8	12.9	49.15	1.27
−25	21.6	15.86	30.7	8.41

3. Result and discussion

The experiments were conducted based on the statistically designed (two variables and three levels) program and the results are shown in Table 4. It can be observed that the underflow stream was upgraded up to a maximum of 42.11%Mn and the silica content had reduced to a minimum of 21.15%. It is evident from the result that, with increase in the teeter water flow rate, there is a decrease in yield (%) to the underflow stream of FDS. The yield of the underflow stream varied from maximum 71.9% to a minimum of 32.9%. This could be due to the change in the set point; the yield to the underflow product also changed accordingly. With the increase in set point, the bed height inside FDS also increased and results show a lower yield to the underflow.

It can be noted from Table 4, that Mn (%) content in the underflow stream of FDS has improved to 42.11% from 27.53%. It is observed that the better product quality of underflow stream was achieved at intermediate level of teeter water flow rate i.e. 10 lpm. It is also observed that Mn content in the underflow stream varied from 35.59% to 42.11%. It can be noted that, at lower (8 lpm) and higher (12 lpm) levels of teeter water flow rate, there was an insignificant upgradation in the system (% Mn content in the underflow product). This may be explained thus, with increase in the teeter water flow rate, teeter bed diluted and the density of the bed decreased which allowed the lighter gangue minerals to pass through the teeter bed. Also the particle separation in the teeter bed depends on the slip velocity, and is defined as the slip velocity of the particle which is equal to the interstitial teeter water velocity, where the particle will have a zero velocity with respect to a stationary observer and which will have an equal probability to report either to the overflow or to the underflow stream. If the slip velocity is greater than the interstitial teeter water velocity, the particle will report to the underflow stream and if it is lower, will report to the overflow stream [10]. Similarly with increase in the set point, there is a change in the quality of underflow product. It was observed that Mn(%) content of underflow stream in FDS had significantly improved at higher set points. This may explain thus, at higher set point, the teeter bed height and bed pressure increases which in turn improve the quality of the underflow stream. From the literature, it is revealed that FDS is an effective tool for removing silica from iron ore, beach sand minerals, chromite etc. Similar observation is inferred from Table 4 which is, with the increase in teeter water flow rate, there is a decrease in the silica content of underflow stream of FDS. The silica content in the underflow stream was varied from 21.15% to 31.47% during the experiments. It can be seen that with increase in the set point there is a marginal change in the silica content in FDS underflow stream.

Further, the recovery of Mn in the underflow stream and the rejection of silica to the overflow stream were analyzed and are shown in Fig. 4. From Fig. 4, it is observed that the recovery of Mn in the underflow stream varied from 89.76% to 46.09%. It can also be seen from the figure that the recovery of Mn to the underflow stream is reduced drastically at higher teeter water flow rate (12 lpm) i.e. experiment nos.7, 8 and 9. Similarly the rejection of silica to the overflow stream increased at higher teeter water flow rate. Also, the maximum rejection of silica was reported at higher teeter water flow rate (12 lpm).

Although the results obtained during the experiments are encouraging, it is difficult to analyze the results based on the parameters. In an operating plant, FDS is controlled by teeter water flow rate and set point. These two parameters are fine-tuned and optimized to achieve the required quality and recovery. However, the particle separation inside the separator solely depends on the teeter bed height and teeter bed density. So, for understanding of these controllable parameters of the separator along with the dependent