Chemically enhanced electrostatic separation

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Heavy minerals separation processes use extensive physical separation technologies such as gravity, magnetic and electrostatic separations. Particularly, electrostatic separation suffers from separation efficiency issues owing to sensitive variables such as humidity, surface contamination, temperature, particle sizes of the feed and other equipment parameters. The variations in the process conditions during separation result in production rate losses and product quality issues suggesting a need for robust technology. Cytec Industries has developed chemical enhancement technologies for physical separation especially for electrostatic and magnetic separation. This paper will discuss chemically enhanced electrostatic separation of rutile and zircon using feed from various parts of the world. The major advantage of our technology is its bolt-on nature to the existing electrostatic and magnetic separation technology. The separation efficiency was increased from 8–11% with the problematic feeds that are not easily amenable to conventional electrostatic separation without reagents. The increase in separation efficiency reduced the recycle load and saved energy.

Introduction

The physical separation processes exploit the differences within gravity electrostatic and magnetic properties in heavy minerals separation plants. While the perpetual challenges rest on selective and efficient separations with difficult orebodies and finer particles sizes, the underpinning sustenance of new technologies depends on their ability to conserve water and energy while minimizing the waste. Many solutions to improve recovery and yield, provide process robustness to beneficiate hard to process ores, minimize carbon footprints and simplify process flow to overall cost-performance effectiveness are being continuously provided.

Electrostatic separation technology

Electrostatic separation is a dry separation technology that is extensively used in heavy minerals separation plants worldwide\(^1\). Separation equipment within electrostatic separator commonly includes a high-tension electrostatic roll (HTR) and electrostatic plate (ESP) separators. Using electrostatic separation techniques the conductors such as rutile and ilmenite are separated from the non-conductors such as zircon, quartz and monazite\(^2\).

A simplified flow diagram (Figure 1) of heavy minerals processing involves a series of pre-concentration steps. Gravity separation is used to separate the heavy minerals such as rutile, ilmenite, zircon and leucoxene from low density minerals such as quartz, clay, etc. This is followed by the magnetic separation to remove all the Fe bearing magnetic minerals from rutile and zircon which is then subsequently dried and heated to 120–180°C to separate using an electrostatic separator.

Separation efficiency and challenges

Subject to the charging mechanisms employed, there are three types of ‘electrostatic’ separators: (1) high tension roll ionized field separators (HTR), (2) electrostatic plate and

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screen static field separators (ESP and ESS, herein called ESP), and (3) triboelectric separators\textsuperscript{3,4}. ESP and HTR separators are the most commonly used today, although triboelectric separators have been developing some interest in recent times. The application remains limited to mineral species that must be contact charged so that they can be separated from the nonconductor species.

A wide variety of electrostatic induced charge and ionized field separators have been invented over the last 90 years. However, the existing commercial designs have undergone little fundamental change in recent years.

The electrostatic separation is an effective process, however, it is not very efficient. The reasons for poor separation, among the other things, are due to fluctuations in ambient conditions such as humidity and temperature of the feed\textsuperscript{5–7}. Higher humidity typically reduces the separation efficiency owing to indiscriminate condensation of a conducting water layer on the minerals, resulting in misreport of nonconductors on to the conductors. Efficiencies averages about 70 per cent resulting in substantial recirculating load. In a 50 t/h feed rate plant, even a 1 per cent improvement in efficiency would improve by 3% the production rate of the product.

One of the major issues related to electrostatic separation, besides the process conditions, is the surface contamination. Shown in Figure 2 a heavy minerals feed containing rutile and zircon minerals that are with and without cross-contamination. The loss in separation efficiency due to misreporting of the minerals, such as non-conducting zircon with titanium species coating to conducting fraction, result in poor grade quality of the final product.

The other types of contamination include the indiscriminate coating of clay or other species such as aluminum, titanium and iron, once again, resulting in poor separation. Figure 3 shows aluminum and iron silicate as inclusions in zircon and aluminum, iron silicates as impurity coatings on rutile sample.

Electrostatic enhancer technology
Designing specific reagents for improving in-process separation efficiencies has remained one of Cytec’s core strengths for several decades. The chemical enhancement of electrostatic separation technology is developed by embracing the best attributes specific reagent chemistries to enhance surface conductivity and/or nonconductivities of the targeted particles considered for separation with the robustness to endure the thermal cycle and the induced surface charging by external charging devices. Its readily applicable nature works with existing electrostatic equipment and requires minimal capital investment. In a very simple way, chemical enhancement of electrostatic separation technology can be described as an enhanced electrostatic separation technology facilitated by tailor-made functionalized reagents that selectively increases the conductivity or nonconductivity of the rutile or zircon particles respectively. The enhancer technology is applied under wet conditions before drying the feed (as described in the experimental section).

Experimental
A bulk quantity of the feed (25–30 kg) was passed through a riffle splitter to ensure a good representative feed sample.
With a continuous splitting procedure, the sample size was reduced to ~ 500 g. Each of the 500 grams representative sample batches were separately packed and stored. In each test about 166.0 g of water was added to an octagonal shaped tall tubular steel container and was mixed and conditioned using an impeller design that provided countercurrent slurry push. An appropriate amount of electrostatic enhancer reagents was added to this and homogenized for 1 minute. The feed (500 g) was then added to this mixture and conditioned at natural pH for 5–10 minutes. The treated slurry was transferred to a tray and the solution decanted. The tray was placed in an oven at 140°C for ~ 3 hours and the dried sample was mixed well to remove the agglomerates, if any. The sample was reheated to 140°C by replacing it in the oven. Then the sample was quickly removed from the oven and transferred to the feeder to electrostatic separator as shown in Figure 4 (model HTP(25)111-15). The electrostatic separator was operated at a roll speed of 260 RPM, an applied voltage of 23 kV and a feed rate of 50 kg/h/in. The humidity was noted and a control (without reagent) test was conducted with every set of experiments. The separated feed was captured in a continuous train of 18 trays where trays 1–9 were designated as conducting portion (C), trays 10–12 as middling-1 portion (M1), trays 13–15 as middling-2 portion (M2), trays 16 and 17 as middling-3 portion (M3), and tray 18 (NC) as the nonconducting portion. The weights in the above trays were recorded. XRF analysis was then performed on each group (conducting, middlings-1,2,3 and nonconducting portion). The mass recovery (weight of each portion) and grades (XRF analysis) were plotted to evaluate the efficiency curves.

The efficiency improvement is calculated from the cumulative recoveries of individual fractions such as C, M1—NC. Maximum efficiency (ME) is the highest value between cumulative efficiencies CE (C)...CE (M2)...CE (NC).

\[ E = \frac{\text{CRT}i + (100 - \text{CZ}r)}{2} \]

As mentioned before, if the reagent improves the separation then the maximum efficiency (ME) of the separation with the reagent will be higher than the control (no reagent) and the difference (\( \Delta E \)) of 3 to 5% is considered significant in a laboratory operation.

An extensive pilot-plant optimization study conducted using the enhancer technology under plant operating conditions on the rutile–zircon separation achieved 8–11% improvement in separation efficiency. The performance efficiency improvements are represented by efficiency plots as shown in Figures 5 and 6.

![Figure 4 — The electrostatic separator model HTP(25)111-15](image1)

![Figure 5 — Representative efficiency improvement plot](image2)

![Figure 6A — Efficiency plot illustrating improvements in rutile-zircon separation with Aero® EZ-2100/Aero® EZ-1000](image3)

![Figure 6B — Efficiency plot illustrating improvements in rutile-zircon separation with Aero® EZ-2000/Aero® EZ-1000](image4)

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Other potential applications for chemical enhancer technology

The chemical enhancement of electrostatic technology can be applied to a variety of mineral separation including: (a) mineral sand, (b) ilmenite/staurolite, (c) ilmenite/monazite, (d) rutile/zircon, (e) zircon/leucoxene, (f) iron ore—silicate removal, (g) hard rock ilmenite or rutile, (h) metal-plastics recycling, (i) kyanite/zircon, (j) cromite/garnet, and (k) celestite/gypsum.

Conclusion

Chemical enhancement of electrostatic separation can be achieved by judicious combination of surface selective reagents that favourably modify the surface conductivities for improved separation. An improvement of 8–11% in separation efficiency has been achieved between rutile and zircon in the first pass on a laboratory HT separator. We believe, chemical enhancement: (1) can improve the production rate due to the reduction in recirculation load, (2) can translate into energy savings by the elimination of a certain number of cleaning stages, (3) is adaptable to the existing electrostatic separation technology with minimal capital investment, (4) is robust, (5) can be expanded to a platform technology and can be used to potentially separate chemically dissimilar conducting or nonconducting minerals and (6) is easy to use/handle and train operators. Further work is in progress at our lab to study the robustness under plant variations.

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References


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Dr. Ravi Ravishankar is currently working with Cytec Industries Inc. as Manager- Technology and has been with the company for the past 7.5 years. By way of Educational background, Ravi has a Ph.D in Materials Science and Engineering from Virginia Tech, USA and two master degrees in metallurgical engineering and chemistry and. Ravi has been working on the technology development and implementation in Minerals processing and separation areas for the past 25 yrs. Industrial minerals beneficiation & processing and Enhancement of Physical separation have remained major focus for him. Ravi has published several papers in reputed international journals and books and invented many patentable technologies. He is an active member of SME, ACS and serves as a member in President Hoover medal board for engineers. He is currently serving as the program chair for the Industrial minerals and aggregate division in the Society of Mining Engineers technical program in 2010.