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Effect of Process Variables on High-Tension Separation – A Statistical Approach

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Abstract

The minerals like ilmenite, rutile and leucoxene behave as conducting minerals where as zircon, sillimanite, garnet and monazite behave as non-conducting minerals when high potential difference is applied. In a mineral processing plants effective separation of the conducting minerals depends on the efficiency of electrostatic separators. The commercial equipment are designed in an electro dynamic and electrostatic operating conditions depending on the process requirement and several stages of such operations are necessary to produce high pure mineral products with good recovery. The separation process becomes relatively more difficult when the particle size distribution is in wider ranging from very fine to coarser along with coated non-conducting minerals. The present study deals with the use of high-tension separator in processing heavy minerals for recovery of conducting minerals. The process variables have been optimized with the help of statistical design of experiments and co-relations have been developed between the operating variables of high-tension separator, yield and the grade of conducting minerals recovered.

INTRODUCTION

Processing of ores depend upon the physical properties of the minerals like size, shape, specific gravity, magnetic property, electrical conductivity and the surface properties of the minerals. High-tension separators are used to separate conducting minerals from non-conducting minerals. Theoretically it represents the universal concentrating method; all most all minerals exhibit some difference in conductivity and is possible to separate two minerals by this technique.

The effective electrostatic separation of particles in an electric field requires moisture free closed sized particles. The three basic types of electrostatic separators are based on the particle charging process such as induction, friction (tribo effect) and ion bombardment.

MECHANISIM OF PARTICLE CHARGING

The maximum particle charge in electrostatic separator is attained by ion bombardment. Due to high voltage, the air between the electrodes is ionized and these ions charge the feed material. The ionization and conductivity of gas/air increases greatly and a corona discharge occurs when the potential difference between two electrodes are raised to a sufficient level. Further increase of the voltage ultimately leads to a disorderly current flow due to arcing. The nature of the corona varies depending on whether the wire electrode is negative or positive. The positive corona has a gentle glow, which is relatively steady and uniform near the wire electrode and can be produced in any gaseous/air medium. A negative corona concentrates as cluster of glowing gas spaced at intervals along the wire, which is possible only with gases such as oxygen that provide electron attachment. Accumulation of dust particles decreases the total space charge between electrodes resulting in indiscriminate separation. This phenomenon could become a problem with electrostatic separators if there is high proportion of dust in the air, or in particles stream of the feed. Presence of humidity is also having a significant affect on the corona. The corona inception voltage decreases with increasing humidity. The charge acquired by a particle depends on its size, its dielectric constant, the field intensity and the concentration of ions in the gaseous medium.

Induction charging is the process where uncharged particles in an electric field assume the field polarity. A charged conducting particle when comes in contact with conducting surface, it conducts charge of one polarity to the surface, leaving the particle with a net charge of the opposite polarity. The charge particle is then repelled by the surface because it has the same polarity. Non-conducting particles does not have any 'net charge' and are neither attracted nor repelled by the electric field.

Tribo or frictional charging is the process whereby a charge exists on a material after parting of a solid/solid or solid/fluid contacts. The magnitude of the final charge will actually be the result of two processes, the charge transfer that occurs during the contact, and the charge back flow that occurs as the materials are parted.

ELECTROSTATIC SEPARATORS

Commercial electrostatic separators are designed based on the above principles and commonly available in the following configuration.

The high-tension separators are conventional ionized field separators utilizing a grounded roll to neutralize the charge of the feed material, which was passed through high voltage ionizing field. The conducting particles loose their charge to the grounded roll and follow a trajectory depending on the centrifugal force developed by the speed of the rotor. The non-conducting particles are pinned to the roll, transported further and removed by mechanical means like brush or by high voltage AC wiper.

The electrostatic separators are available in two configurations namely plate and screen electrode types. The feed particles slide down through a grounded plate into the electric field induced by the large curved electrode, where the particles are charged by induction. The conducting particles, which acquire a charge opposite to the electrode, are thus attracted towards the electrode and give the lifting effect. The non-conducting particles continue to slide down the plate or screen. The equipment is mainly used for cleaning a small quantity of conducting particles from a large quantity of non-conducting.

EXPERIMENTAL WORK

The bulk sample of spiral concentrate was taken as feed material for the study. The feed material predominantly consists of 65-70% Ilmenite, 3-5% Rutile, 1-2% Monazite, 4-5% Zircon, 8-10% Garnet, 5-7% Sillimanite and 1% Quartz. The separation behavior of particles in high-tension separator is dependent on size of the particles. In order to understand the process variable effect on the separation the bulk sample was subjected to 500 micron size mesh and removed the over size. The under size was screen through 125 micron size mesh to remove the fine size material. Only–500+125 microns size material was used for all the experiments. A total of 27 factorially designed experiments were conducted on laboratory model (MDL make) high-tension separator, in which the effects of three important process variables, each at three different levels have been studied. The variables and their levels are given in table 1. All other parameters kept constant through out the experiments.

Table 1

S.No.	Variables	Level		
		1	2	3
1	Temperature in °C (T)	100	120	140
2	Feed rate in tph (F)	1.5	2.0	2.5
3	Roll speed in rpm (R)	120	150	180

For example T1, T2 & T3 are the temperatures at 100°C, 120°C & 140°C respectively.

RESULTS AND DISCUSSION

The results obtained from factorially designed experiments are tabulated in table 2.

Table 2

S.No.	Condition	Conducting		Non-conducting	
		Yield%	Grade%	Yield%	Grade%
1	$T_1 F_1 R_1$	76.6	97.8	23.4	20.1
2	$T_1 F_1 R_2$	82.4	95.7	17.6	2.2
3	$T_1 F_1 R_3$	85.8	93.2	14.2	0.9
4	$T_1 F_2 R_1$	79.0	96.7	21.0	12.8
5	$T_1 F_2 R_2$	83.2	95.5	16.8	3.7
6	$T_1 F_2 R_3$	85.2	95.1	14.8	1.7
7	$T_1 F_3 R_1$	78.3	96.8	21.7	24.5
8	$T_1 F_3 R_2$	83.9	95.7	16.1	5.1
9	$T_1 F_3 R_3$	85.1	93.8	14.9	1.9
10	$T_2 F_1 R_1$	79.0	97.0	21.0	12.1
11	$T_2 F_1 R_2$	82.6	95.2	17.4	3.0
12	$T_2 F_1 R_3$	84.1	94.7	15.9	1.3
13	$T_2 F_2 R_1$	78.5	97.1	21.5	16.8
14	$T_2 F_2 R_2$	83.1	96.4	16.9	6.1
15	$T_2 F_2 R_3$	84.3	95.3	15.7	2.9
16	$T_2 F_3 R_1$	74.3	97.6	25.7	34.3
17	$T_2 F_3 R_2$	82.2	96.1	17.8	9.3
18	$T_2 F_3 R_3$	84.8	94.2	15.2	2.3
19	$T_3 F_1 R_1$	78.0	98.5	22.0	20.6
20	$T_3 F_1 R_2$	82.5	95.9	17.5	2.4
21	$T_3 F_1 R_3$	83.4	95.0	16.6	4.1
22	$T_3 F_2 R_1$	71.8	97.5	28.2	33.6
23	$T_3 F_2 R_2$	82.2	95.4	17.8	7.1
24	$T_3 F_2 R_3$	83.4	95.9	16.6	5.5
25	$T_3 F_3 R_1$	71.9	97.5	28.1	34.6
26	$T_3 F_3 R_2$	82.8	95.8	17.2	6.5
27	$T_3 F_3 R_3$	84.7	93.9	15.3	2.3

These results are analyzed statistically to know the true effect of the variables and their interaction on product parameters quantitatively.

STATISTICAL ANALYSIS

One of the most effective techniques in research is the factorially designed test with the analysis of variance. The main advantage of this method is that, it identifies and measures the effect of interaction. Fissure – test has been carried out to know the significance of the effect of variables. The results obtained are given in table 3 and analysed as follows.

Table 3

Source	Yield			Grade		
	Sum of Squares	Mean Sum of Squares	F-value	Sum of Squares	Mean Sum of Squares	F-value
Main Effects						
R	331.58	165.80	71.70	36.29	18.15	81.03
F	2.15	1.08	0.47	0.64	14.39	64.24
T	22.04	11.02	4.77	1.58	0.79	3.53
Interactional Effects						
F X R	12.90	3.23	1.40	3.27	21.05	93.97
T X R	12.07	3.02	1.31	1.15	0.28	1.25
T X F	12.16	3.04	1.32	1.06	0.27	1.21
Residual	18.5	2.31	---	1.79	0.224	---

Main Effects of Variables

The mean sum of square values of the analysis of variance (ANOVA) bring out that, among the main effects of the variables, the roll speed has the maximum effect on both yield (165.80) and grade (18.15) of the conducting fraction. The F-test indicates order of significance is

Roll speed > Feed rate > Temperature (for Grade of the conductings)

Roll speed > Temperature > Feed rate (for Yield of the conductings)

The trajectory of the conducting particle from the rotor is influenced mainly by the rotor speed. The other variables control the separation on the rotor. It may be inferred from the study that the rotor speed should be given prime attention in optimizing the variables.

Interactional Effects of Variables:

F x R Interaction: The results of ANOVA show that the mean sum of square value (3.23 for yield, 21.05 for grade) of this interaction is more than the residual mean sum of square value (2.31 for yield, 0.224 for grade). Both yield and conducting grade are influenced by this interaction. The negligible F-value (1.40) for yield indicates that the minimum effect on yield of the conducting product. Whereas with respect to conducting grade the maximum F-value (93.97) shows that significant effect on this interaction. This may be explained as the feed rate controls the selective charging at the ionising zone at the rotor. If one of the variables is changed with respect to other, it will have a considerable effect on conducting grade.

T x R Interaction: The low mean sum of square values (3.02 for yield, 0.28 for grade) and negligible F-values (1.31 for yield, 1.25 for grade) reveal that the interaction between these two variables has a marginal effect on yield and no significant effect on grade of the conducting fraction. This shows that whatever the temperature level, when the roll speed is increased, marginal increase in the yield and no substantial improvement on the grade of the conducting fraction is observed. This interaction affects the condition of the particles on the rotor but does not influence the selective separation of the conducting particles.

T x F Interaction: The low mean sum of square values (3.04 for yield, 0.27 for grade) and negligible F-values (1.32 for yield, 1.21 for grade) reveal that the interaction between these two variables has a marginal effect on yield and no significant effect on grade of the conducting fraction. This shows that whatever the temperature level, when the feed rate is increased marginal increase in the yield and no substantial improvement on the grade of the conducting fraction is observed. This interaction affects the condition of the particles on the rotor but does not influence the selective separation of the conducting particles.

CONCLUSION

The study reveals that the roll speed, temperature and feed rate are having influence in electrostatic separator with respect to product quality and recovery. The variance in temperature has greater influence on recovery where as the change in feed rate has grater influence on grade of the product. However, the roll speed variance beyond its optimum limit will have adverse effect on recovery and grade of the product.

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