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Various aspects of fines in separation and processing of beach sand minerals in India

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ABSTRACT

In the present study, formation and occurance of beach sand deposits of India and recovery of heavy minerals, viz., ilmenite, rutile, zircon, monazite, sillimanite and garnet have been reported. Separation processes adopted for concentration of heavy minerals at different plants of Indian Rear Earth Limited (IREL) have been discussed.

***Key words** : Beach sand minerals, Gravity separation, High tension separation, Magnetic separation, Froth-flotation.*

INTRODUCTION

Indian Rare Earths Ltd. (IREL), a public sector undertaking under the Department of Atomic Energy is engaged in separation of six heavy minerals (HM), namely; ilmenite, rutile, zircon, monazite, sillimanite and garnet from beach sand deposits of Kerala, Tamil Nadu and Orissa. The raw sand exploited by IREL are available in the form of beach washings thrown by the sea just next to the shore line and as inland deposits formed over the year below and above the ground level in areas away from the shore line.

The beach washings are rich in heavy minerals and less in fines due to repeated washing and concentration by wave action during the rough sea seasons. The inland beach deposits occurring little farther inside the land is formed over years by natural forces acting along the beach. They are leaner in heavy minerals and contain more amount of finer minerals (fines). The general characteristics of these deposits are summarised in Table 1.

Over the years, the quality of beach washings has come down drastically. The limited availability of these seasonal accruals has forced IREL to depend on the inland beach deposits as the primary source of feed material.

Table 1 : Characteristics of beach sand deposits

Deposit	HM%	%Fines	Occurrence	Mining Method	Processing method
Beach	50-70 Washings	<5%	Along the shore line	Surface scrapping	Concentrate upgradation, Dry processing
Inland Beach Deposit	15-40	5-20%	Inland Depth 7-9 metres	Dredging	Pre-concentration, Concentrate upgradation, Dry processing

DEPOSITS

The inland deposits have a complex mineral assemblage compared to the beach washings. The heavy minerals are finer in size. The major gangue mineral quartz is of wider size range and the content of fine quartz is relatively higher in the inland deposits. A typical size distribution of beach washing and inland deposits are given in Fig. 1 for comparison.

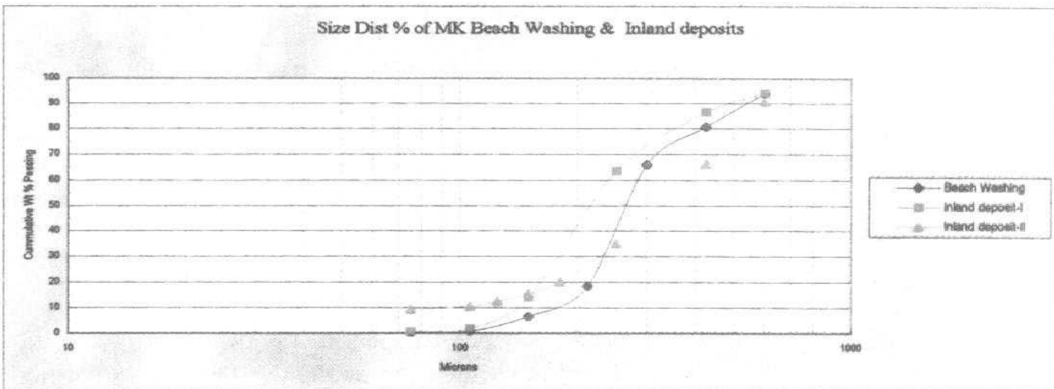

Fig. 1 : Size distribution of beach washing and inland deposits.

The size distribution curves indicate that the inland deposits contain more amount of fines and has a wide range of particle size distribution compared to beach washings.

METHODS

Dredging the raw sand and desliming is the initial operation in recovering the valuable heavy minerals.

Gravity Sepration

The deslimed sand is pre-concentrated to 90% HM using spirals located in a floating/land based concentrator. The rejects mainly silica sand is used for refilling the mined area. The pre-concentrated heavy minerals is then upgraded to about 98% HM in Concentrate Upgradation Plant (CUP) by further stages of spiral/wet table operation. Due to the significant developments in wet gravity separation techniques many types of spirals are available to perform various duty conditions as per the mineral assemblage, size etc. Spiral concentrators have become universally acceptable because of its simplicity of operation, less maintenance requirement and ability to handle large throughput.

Closed circuit tests were conducted using spirals with the representative bulk samples from inland deposits to assess the behaviour of the fine particles and maximise recovery of heavy minerals. The size distribution in the bulk sample from inland deposits and that of ilmenite and quartz in the feed to spiral were as indicated in Fig. 2.

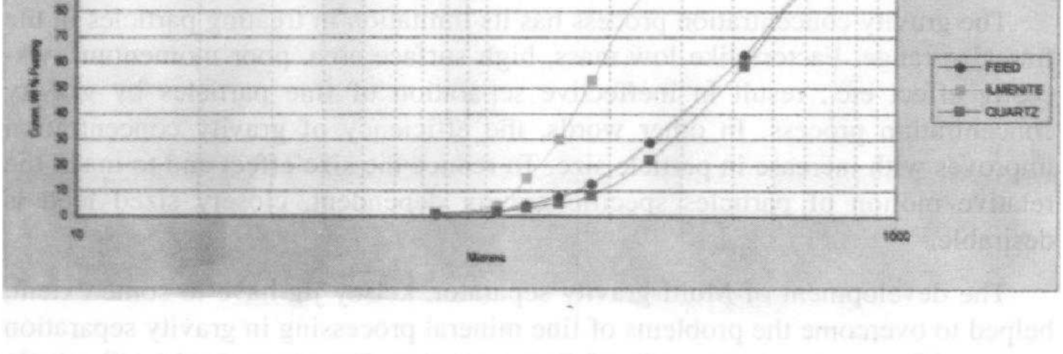

Fig. 2 : Size distribution in the bulk sample

Hydrocyclone was used to reject the slimes in the sample thus presenting a feed material of effective size range coarser than 40 micron. The recovery curves (Fig. 3) indicate that there is loss of fine ilmenite in rejects while fine silica is mostly reporting to the concentrate.

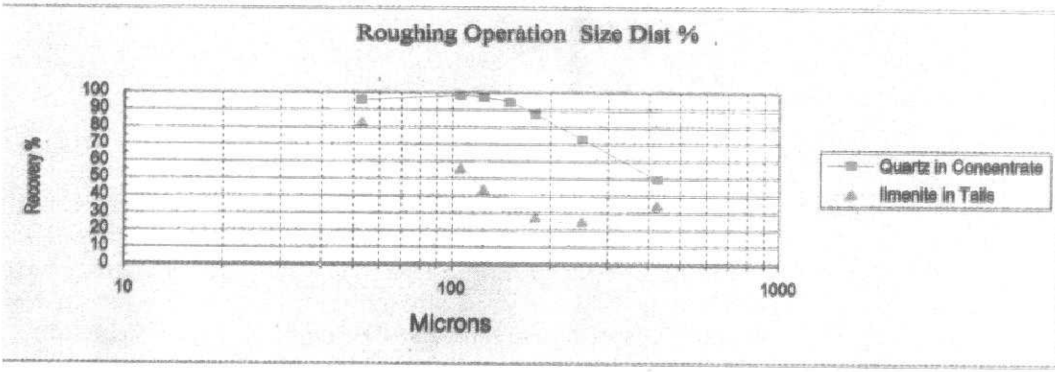

Fig. 3 : Roughing operation size distribution (%)

Even after repeated cleaning of the concentrate using spirals, certain amount of fine silica is still retained in the concentrate product. The study, thus indicate, that while there is loss of fine heavy mineral in the rejects, the fine silica report to the concentrate. The concentrate containing fine silica, was tested in a hindered settling classifier, namely Floatex Density Separator (FDS) and it was found the rejection of fine silica in the overflow was satisfactory.

The gravity concentration process has its limitation in treating particles in the fine size range. Factors like low mass, high surface area, poor momentum, viscosity effect etc., result in ineffective separation of fine particles by gravity concentration process. In other words, the efficiency of gravity concentration improves with increase in particle size. To reduce the size effect and to make the relative motion of particles specific gravity dependent, closely sized feed is desirable.

The development of Multi-gravity separator, kelsey jig have to some extent, helped to overcome the problems of fine mineral processing in gravity separation process. The economic minerals of finer and ultra fine sizes can be effectively separated in Multi gravity separator. The principle of the system consists of wrapping of the horizontal concentrating surface of a conventional shaking table into a cylindrical drum and rotating it. This can exert a force of many times greater than the normal gravitational pull on the particle in the flowing film. This helps to enhance the separation process of fines. Similarly, in case of kelsey jig, it is possible to separate the minerals having difference in specific gravity as low as 0.5, which is otherwise difficult with conventional gravity separators.

For separation of individual minerals contained in the final concentrate, the beneficiation processes adopted by IREL in its plants are high-tension separation, magnetic separation, wet tabling, flotation process etc. Particle size distribution extending over a wide range, presence of fine particles, slime coating over the particles etc., cause difficulties in the beneficiation process, as briefly discussed in the following paragraphs.

High-Tension Separation

The heavy mineral concentrate when subjected to this process is separated into two fractions - conducting and non-conducting, which are further processed to obtain the individual mineral product. In high-tension separator (HTS), when high D.C. voltage is applied, the air surrounding the electrode gets ionized and mineral particles are charged. The conducting minerals after acquiring the charge immediately dissipate the charge to the grounded revolving roll and follow the trajectory due to the centrifugal force. The non-conducting minerals, slow in discharging the charge, is pinned to the roll and are wiped out by the help of A.C. electrode and a mechanical wiper brush. In mineral sand industries, high-tension roll separator and electrostatic plate separators are widely used to separate the conducting and non-conducting fraction. Particle size influences separation behaviour in an HT separator as the surface charge on a coarse grain is lower in relation to its mass than on a fine grain. Thus, a coarse grain is more readily thrown from the roll surface, and the conducting fraction often contain coarse non-conductors. In the same way the non-conducting fraction often contains fine conducting particles because they are most influenced by surface charge. A plate/screen plate separator, where the "lifting effect" by a static electrode is utilised for separation can help in such cases to remove small amount of non-conductors from a predominantly conducting feed (plate separator) and small amount of conductors from a predominantly non-conducting feed (screen plate separator). In an electrostatic separator fine grains are most affected by the lifting force and so fine conductors are preferentially lifted to the electrode whereas in a high-tension separator effective separation of fine non-conductors from coarse conductors takes place. Thus, a combination of these separators are used in most of the flow-sheets.

Magnetic Separation

In mineral san beneficiation, magnetic separators of different magnetic intensities are used depending on the nature of the feed material and the operational requirement. These include induced roll magnetic separator, lift roll magnetic separator, cross belt magnetic separator etc., to separate magnetic and non-magnetic minerals. In this process, the equipment is operated at a particular roll speed and magnetic intensity. The presence of fine to ultra fine non-magnetic material in the feed causes problem in magnetic separation as well. In order to separate maximum magnetic mineral, a particular rpm and magnetic intensity is applied to the equipment which in turn, entraps the finer non-magnetic particles in the magnetic fraction. If the non-magnetic particles are to be completely separated, then the rpm of the roll is to be increased to develop more centrifugal forces on the fine particles and in doing this more magnetic minerals report to the non-magnetic fraction, thus reducing the recovery of magnetic minerals. Lift type induced roll magnetic separators, where the feed is led to the bottom side of the roll using a vibratory feeder, is effective in picking up fine magnetic particles, to get a good magnetic product.

The introduction of wet high intensity magnetic separator (WHIMS) and rare earth drum magnetic separator (REDMS) providing high magnetic field gradient have improved the scope of magnetic separation of fines. Fig. 4 indicates the size distribution of magnetic separated using REDMS.

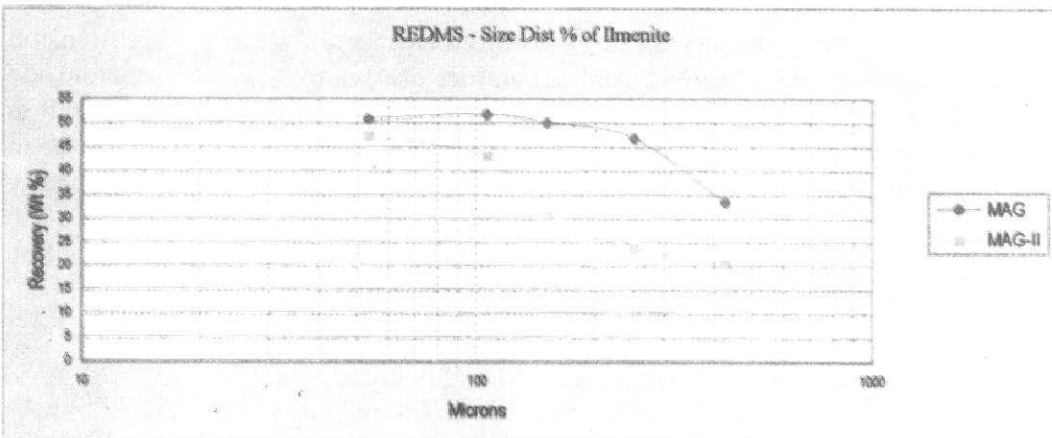

Fig. 4 : Size distribution of ilmenite separated using REDMS

The recovery of finer ilmenite is high in Mag-I and Mag-II fraction with very low loss of fine ilmenite in the non mag circuit. The advantages in using high gradient (REDMS) in beach sand industry will help in the separation of finer magnetics/non-magnetic minerals.

Froth Flotation

In the froth flotation circuit too, the fine minerals cause process problems. Apart from the difficulties of conditioning to be done at higher solid percentage, there are number of factors contributing to this problem, such as high specific surface area of particle, low specific mass, morphology of grains etc. The hydrophilic finer particles (unwanted/gangue) very often report to the froth in flotation cell which needs further cleaning to improve froth grade. In sillimanite flotation circuit, the finer zircon, quartz and rutile have a tendency to report in sillimanite froth due to entrapment, thus, requiring further cleaning of froth.

Column flotation can be used to effectively handle the fine particle processing for beneficiation of sillimanite in beach sand mineral processing unit. Generation of fine air bubble, large residence time of particle and air bubble due to counter current flow of particles and air bubble, long cleaning zone, deeper froth bed and wash water arrangement to clean froth are some of the important factors that contribute for the better performance of column flotation while dealing with fine particles. In single stage operation, the grade and recovery of minerals in column cell is higher than the conventional cell.

CONCLUSION

In mineral processing, fine minerals cannot be avoided. Fine size materials often report in middlings and tailings as the technology for treating fine sized minerals is not well developed. Most mineral processing treatment including gravity separation, flotation, magnetic separation, electrostatic separation have a limiting minimum particle size beyond which the separation is not effective. The inherent difficulty in recovering very fine particles is to be properly addressed and it is expected that the new ideas and improved technology will enable the mineral engineers and allied technologists in meeting the challenges of fine mineral processing.

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