Proceedings of the International Seminar on Mineral Processing Technology - 2006, Chennai, India. pp. 21 - 27.

India's Mineral Sands Industry - A Global Perspective

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Abstract

India is in a very fortunate position, poised to become a leader in the global TiO_2 minerals industry. It has ample mineral sand resources, competitive labour costs, improving infrastructure and growing domestic and regional markets. Adopting global standards in assessing markets, establishing modern process flowsheets and above all, knowing the ultimate details of the resource, can push India to the status of industry leader.

INTRODUCTION

India has been blessed with some of the world's best deposits of titanium mineral sands and has a long history of supplying these minerals to the growing world market.

However, the industry in India has not developed into a recognised as a world leader such as Australia and South Africa. Recent regulatory changes have started a process of revitalisation within the Indian mineral sands industry and this paper attempts to put the current state of advancement into a global perspective, by examining the following topics:

- If India is to take its natural place among the world's leaders in this industry, what is to be done?
- What are the natural advantages and disadvantages associated with Indian resources?
- How can India maximise the impact of its advantages and mitigate the inherent disadvantages?
- For globally cost competitive projects, what are typical problems and solutions employed elsewhere?

These four questions are addressed with a technical bias, in accordance with this forum. However, the scene is always set by the markets, and technical responses must logically reside within the market limits. For example, we all know that large scale means lower unit costs – but there is not much point creating huge stockpiles of low-cost product that cannot be sold!

There is a propensity for the governments of emerging economies to wish for maximum value addition and the use of all possible products when permitting exploitation of natural resources. Laudable and understandable, but generally out of alignment with market realities.

Primary industries start out reliant upon export markets. Value addition steps inevitability involve more complex processing steps and often the technology and know-how is closely held in our industry.

So, it is concluded that to advance in international standing in the titanium minerals business, India must first demonstrate its world class ability to supply reliable quality mineral sands, all year around, at large scale, and in a very cost effective manner.

CURRENT SITUATION

TZMI considers operating costs and profitability in one of its annual publications, the latest version entitled *"Titanium Feedstock Producers : Comparative Cost Study"*, published in July 2005. In this study, the relative competitiveness of TiO_2 mineral sands and beneficiation producers is compared on the basis of operating cost margins or "revenue to cash cost ratio". Four Indian operations, representing 6% of world production were included.

These are represented in **Figure 1** below and compared to other operations which together total 82% of global TiO_2 feedstock production.

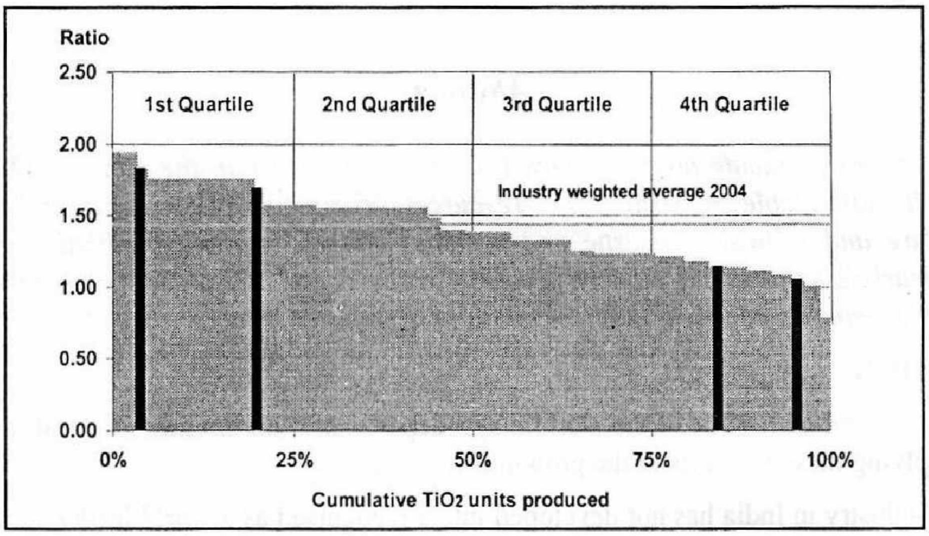

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Fig. 1: Revenue to Cash Cost Curve Showing Four Indian Operations

Table 1: India's Position in Global TiO_2 Industry

	Ranking	
	Position	Global share
Resources	No. 3	18%
Mineral production (TiO_2 units)	No. 6	6%
Ilmenite beneficiation	No. 5	3%
TiO_2 pigment production	No. 19	1%

Table 2: India Supply/Demand for Mineral Sands and Pigment

('000 tonnes)	TiO_2 pigment	Ilmenite	Rutile	Zircon
Consumption	93	189	15	42
Production	52	698	15	22
Exports	12	497	2	0
Imports	53	0	2	20
2004 consumption growth	8%	12%	-9%	24%
2004 production market share	2%	7%	4%	2%

Domestic Market

India is a typical emerging economy, consuming a small fraction "per-capita" of the TiO_2 pigment product compared to the US, Western Europe and Japan. However, by weight of numbers and very high growth rates, the Indian TiO_2 market is of very high importance.

Table 2 Shows the Position of India's Markets for Mineral Sand Products and TiO_2 Pigment.

GETTING THE BEST FROM RESOURCES

Attributes of a "Perfect" Deposit – 3 "Gs"

Geometry :	>10 million tonnes TiO_2
	>10 metre thickness
Geology :	low slimes (<5%)
	high rutile and zircon (>20%)
	no overburden
	sits on water table
	naturally high purity products
Geography :	close to export port
	roads, power, water available
	low value land use
	skilled people and appropriate housing

Indian Deposits

How do India's main areas measure up in these key aspects? **Table 3** shows in simple terms where the strengths and disadvantages appear for the three main producing regions of Orissa, Kerala and Tamil Nadu.

Table 3: Indian Mineral Sands Deposits

	Orissa	Kerala	Tamil Nadu
Size	✓	✓	✓
Grade	✓	✓	O
Assemblage	X	O	O
Slimes/rock	✓	✓	O
Mineral quality	O	✓	O
Accessibility/land use	✓	X	O
Infrastructure	O	O	X
Water	✓	✓	X

Key: = ✓ good O = neutral X = unfavourable

How to Excel Anyway

Provided there are no "fatal flaws" and a number of "good" attributes are present, most deposits are capable of supporting an excellent outcome. Some of the key issues that make the difference between a fairly "ordinary" outcome and a "world class" operation can be summarised below.

Know Your Deposit

The geology, mineralogy, variability and response to process must be thoroughly understood. Almost every mineral sands resource has one or two attributes which sets it apart from others, so it is vital to undertake comprehensive feasibility work. Ongoing detailed discovery of orebody attributes must be done by a team of scientists across the disciplines.

The marketing department must possess an intimate knowledge of the mine plan and process capability, while the process metallurgist and geologist must develop a common understanding of how the minerals exist in the ground and what will then happen on the journey through each process step until the ultimate customer receives the product.

Drive Down the Cost of HMC

The following points are key components involved in minimising the cost of HMC:

- Heavy minerals concentrate (HMC) is the key to an excellent mineral sands mine. The golden rule about HMC is "NEVER RUN OUT". The mineral separation plant (MSP) will always suffer if not fully and consistently fed, potentially impacting on product quality.
- To minimise HMC cost, the operating scheme should seek to reduce ore haulage and concentrator tailings disposal distances. This is why dredging is very popular in the appropriate type of orebody.
- Removal of fines and oversize material should be undertaken as early as possible in the process train. There is no point in transporting non-valuable material from the mine to the concentrator and back again, if it can be conveniently screened out in the pit.
- If attritioning of HMC is required, it should preferably be done ahead of the first drying step, so re-drying is avoided.
- Where possible, reduce the HMC content of minerals that are difficult to market, stockpiling if convenient. East coast Australian operations removed unsaleable ilmenite at the mines for years, before shipping non-magnetic concentrate to the MSP.
- Recovery of valuable minerals into HMC should be kept as high as possible. This requires a robust flowsheet design and good maintenance of desliming and spiral distribution performance. High recovery means lower cost per tonne of HMC.
- Management of maintenance programmes, energy consumption and labour use help keep the costs under control.
- If at all possible, tailings and other waste should be moved only once – to its final resting place.

Simplify the Mineral Separation Plant

Where possible, the use of magnetic separation should be early in the flowsheet. This can be one of the most effective processes, handling high tonnages over each unit and potentially giving quality final products for very low unit costs.

Minimise the tonnages of material that need to be dried more than once, but do not skip steps in the process of ensuring the mineral surfaces are properly cleaned. Even micron-thick coatings can cause incorrect electrostatic responses, as well as contributing to chemical specification contamination.

The last decade has produced several major advances in physical separation technology that have progressed to fully commercial status. These include high performance electrostatic roll separators, rare earth permanent magnetic separators and centrifugal jigs.

The use of on stream product analysers is also a feature of high performance MSPs.

Finally, prospective mineral sands producers should be very wary about leucoxene. While this spectrum of altered ilmenite minerals can sometimes improve yields to high value products, more often than not, it can detract from the quality and recovery of other minerals. Getting troublesome minerals out of the circuit early – either into a product or into the tailings – is a good practice.

Infrastructure

Mineral sands operations produce high volumes of relatively low unit value products, so the connection between production and export carriers must be highly efficient. Automatic bulk handling systems of high capacity, sufficient bulk product storage at the port and product quality integrity are essential. Smaller quantity products can be shipped "bulk in container", although producers can also supply local markets with palletised bagged material.

The mode of transporting HMC and final products from plant to port must not be underestimated. This is a specific issue in India, where high annual tonnages, small trucks and extremely busy roads do not constitute an ideal scenario.

If possible, rail should be considered, along with special road haulage equipment and even dedicated private roads. In any case, a world-class producer will provide sufficient stockpiles at both ends of its transport line.

All mineral sands operations require the supply of large volumes of water, particularly for the primary concentration stage. Recovery and recirculation of fresh water is required where little or no water supplies are available, although good operations can make use of brackish and sea water. Some even recover water from coarse sand tailings by filtration.

Operations

The best operations strive to have a shared understanding of all aspects across disciplines. The old adage "Knowledge is power" has been replaced with, "Shared knowledge is more power". You should not be scared to share controllable cost data with your staff – otherwise they can only have a slight influence on costs. Make it the marketing department's business to understand the geology and operations, and vice-versa. Maintenance is a part of operations and therefore should conduct its business as part of the production team.

Each operation should recognise its inherent advantages and ensure these are maintained and fully exploited. In India, one such advantage is labour cost, while others are high grade ores and lower construction costs. Conversely, each operation should understand its relative disadvantages and seek to continuously mitigate them. Securing the correct advice and then taking appropriate, timely action will help reduce the impact of natural disadvantages. Usually there are only four to five key performance drivers that have major significance to an operation and these should be used to focus behaviour and effort.

The well-run Indian operation should expect global standards of performance and maintain up to date knowledge of industry benchmarks. In particular, these relate to unit energy consumption, mineral recovery and product quality, and operating hours.

EXAMPLES OF TYPICAL PROBLEMS AND SOLUTIONS

There are no high-tech processes in the production of mineral sands products, only a lot of details. Therefore, problems generally arise due to a combination of relatively simple factors, rather than anything difficult to grasp.

By far the most effective solution to poor operational performance is the diligent application of experience. A broad exposure to multiple operations and sharing of craft and technique with fellow industry participants at all levels should be encouraged, for this is the most powerful problem solving tool. Proprietorship, secrecy and pretending to be better than the rest are enemies of good industry results and give rise to repeated invention of the same wheel.

Examples of problems experienced in the mineral sands industry include:

- low productivity;
- poor product quality;
- legal uncertainty;
- export delays, poor shiploading performance;
- tailings spills;
- water shortage;
- workforce unreliability/skills shortages.

Most of these are management issues and result from not paying enough attention to detail, or leaving things too late!

Some of the more chronic problems may have an underlying technical reason, with examples being poor product quality and low production output.

Low Mine Production

A dredge mining operation in Australia (now closed), was not producing at the design rate. Ore excavation was much more difficult than anticipated and plant reliability was down. Mineral recoveries were several percentage points below the "performance guarantee", and the "Golden Rule" was broken on a weekly basis – no HMC stocks!

Some very costly retro-fits were made to toughen up the dredge and increase winching power. Dredge pond cleaning devices were invented to suck out thickened slimes, which were interfering with recoveries. Managers were replaced. Still no HMC stocks.

A clever mining engineer reviewed the resource, bearing in mind that "ore" is material that can be economically mined. It was decided to remove the top half of the old orebody as "overburden" and only mine the lower half, which contained a higher HM grade and lower clay content. The HMC pumps had to be upgraded from 50 tph to 80 tph, but otherwise, no further changes. This might seem obvious in hindsight, but other operations with similar issues have closed rather than change the mine plan or mining method.

Low MSP Throughput

Designed to treat 60 tph of ilmenite-rich HMC, this operation regularly produced throughputs to as low as 40 tph, due to high recirculating loads of altered ilmenite. The usual short term tactics of dumping "middlings" to the floor, increasing magnetic separator settings and even installing additional equipment failed to resolve the problem. Interestingly, for no apparent reason the feed rate would pick up for weeks at a time and then fall back. Geology was blamed and then the primary concentrator suspected of not cleaning the HMC properly .... nothing seemed to work!

HMC was dried at the primary concentrator before being transported for a considerable distance to the MSP. One year, an energy-conscious process engineer devised a method to reduce the fuel consumption at the HMC dryer and in the process, monitored and controlled the HMC product temperature. At the MSP, throughput rates increased to 60 tph, almost causing the "Golden Rule" to be broken.

It is well known that higher temperatures affect the magnetic susceptibility of ilmenite and the "hot" mineral would simply circulate through the MSP until it cooled enough to report into the correct product.

Electrostatic Separator Poor Performance

After a terrific start-up, a new MSP experienced significant reduction in dry plant separation efficiency, which was traced to a build up of material on the surface of HT rolls. Vigorous roll cleaning, changing surfaces to high-polish chrome and installation of supplementary roll cleaning protocols were all observed to initially improve separation, but this improvement declined within about two weeks.

Additional sand cleaning (attritioning) equipment was installed at the front of the MSP and separation efficiencies improved to match the "clean roll" start-up conditions.

Similar experience has been noted elsewhere when deteriorating HTR separation efficiency is traced to improperly operated attritioners.

The conclusion is that an equilibrium is established between deposition of surface contaminants from sand to roll surface, and the action of cleaning the rolls by the brushing mechanism. It is probably the sand in the brush bristles that do most of the cleaning! The answer to dirty rolls is more likely to be initial cleaning of sand, rather than putting more effort into cleaning the rolls.

Poor Quality Products

An ilmenite producer was intermittently hit with high calcium contamination in the product. Garnet was found to be the cause, but was not always present in the ore fed to the concentrator. Previously, the orebody was considered to be relatively homogenous. Although the HM grade varied, mineral assemblage was assumed to be "average".

Following more extensive geological/metallurgical testwork, it was determined that multiple episodes of deposition had contributed to the dune mass and that distinctly different "domains" existed. One of these had a high garnet component in its heavy minerals and had just recently been encountered by the mining sequence.

It was found to be a practical proposition to adjust the mine plan, avoiding this particular domain for a year or more and re-establishing good quality production. Meanwhile, the MSP flowsheet was retrofitted with electrostatic separators to clean up any garnet that reported to ilmenite. After this, the mine sequence returned to normal.

As can be seen from these examples, there were no "high -technology" solutions to these problems. Typically, they were solved after paying attention to detail.

BENEFICIATION

India has only a modest ilmenite beneficiation industry and a small pigment production capacity. These sectors are growing, but both government and industry participants need to be realistic about what is possible, and focus on developing projects which can result in world class performance.

For example, the global sulfate process TiO_2 pigment industry is currently undergoing rejuvenated growth due to China's domestic production. Some of the most cost competitive pigment producers employ the sulfate process and until there is a deliberate technology transfer to India, the chloride process is unlikely to contribute to significant pigment capacity increase here.

CONCLUSIONS

India is in a very fortunate position, poised to become a leader in the global TiO_2 minerals industry.

It has ample mineral sand resources, competitive labour costs, improving infrastructure and growing domestic and regional markets.

Adopting global standards in assessing markets, establishing process flowsheets and above all, knowing the ultimate details of the resource, can push India to the status of industry leader.