Technical Note

**Beneficiation studies on ilmenite rocks of Bhandar mines**

R. C. Behera, P. Rath and G. K. Roy

**ABSTRACT**

Various mineralogical occurrences of titanium with special reference to rock deposits have been briefly reviewed. Method of beneficitation followed for the Bhandar ilmenite rock and the analytical procedure for the concentrate obtained thereof are briefly outlined. Effect of process variables such as particle size of the ore and water flow rate on the beneficitation by tabling has been studied and the results have been codified in the form of a correlation. Experimental findings have been critically interpreted.

**INTRODUCTION**

Chief mineralogical occurrences of titanium are in the form of oxides, titanates and silicotitanates. Some of the common titanium minerals are rutile (TiO$_2$), ilmenite (FeTiO$_3$), arizonite (Fe$_2$Ti$_3$O$_9$), perovskite (CaTiO$_3$) and sphene (CaTiSiO$_5$). However, rutile and ilmenite are the two titanium minerals which are of commercial importance. Rutile analyses more than 95% TiO$_2$ with small amounts of iron, vanadium and other impurities and is comparatively less abundant in nature. Theoretically, ilmenite is ferrous titanate (FeO.TiO$_2$) containing 52.6% TiO$_2$ and 36.8% iron. Although lunar ilmenite is almost pure FeTiO$_3$, the terrestrial ilmenites have wide variations in composition because of partial replacement of the ferrous iron by Mn, Mg and ferric iron during the process of alteration of natural ilmenite. Ilmenite has been mined both from rocks and beach sand deposits. Ilmenite occurs as accessory minerals in igneous and metamorphic rocks which upon weathering, transportation and concentration by wave action yield the placer deposits. These are the secondary deposits of ilmenites.

The rock deposits are the primary deposits of ilmenites. Nearly all the known commercially important rock deposits of titanium minerals are found in anorthositic or gabbroic rocks. These deposits may be broadly classified as (i) ilmenite-magnetite, (ii) ilmenite-hematite and (iii) ilmenite-rutile types.

The titaniferous (ilmenite-magnetite) deposits usually contain ilmenite and magnetite as granular intergrowths which can be readily separated to yield ilmenite and magnetite concentrate. Ilmenite-hematite deposits usually contain these minerals as intimate intergrowths with hematite in the form of lense-shaped masses and are found in anorthosite and nelsonite dikes. Ilmenite-rutile deposits, associated with anorthosite may contain ilmenite and rutile separately of together.

The rock deposits of ilmenites found in Bhandar Mines, Sambalpur (Orissa) belong to the second category of deposit, viz., ilmenite-hematite type. The type of mineralogical constituents present in the ore has been predicted from a ternary phase diagram of FeO-Fe$_2$O$_3$-TiO$_2$ (Fig. 1.) and it is found to be composed of pseudobrookite and rhombohedral phases. The Chemical Composition of this ore is given in Table I.

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**Fig. 1 Phase diagram for the system FeO-Fe$_2$O$_3$-TiO$_2$.**

**TABLE I – Average analysis of ilmenites.**

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Ore</th>
<th>Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>TiO$_2$</td>
<td>32.32</td>
<td>41.20</td>
</tr>
<tr>
<td>FeO</td>
<td>7.83</td>
<td>10.26</td>
</tr>
<tr>
<td>Fe$_2$O$_4$</td>
<td>38.66</td>
<td>33.85</td>
</tr>
<tr>
<td>SiO$_2$</td>
<td>7.38</td>
<td>1.52</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>8.04</td>
<td>6.00</td>
</tr>
<tr>
<td>MnO</td>
<td>0.85</td>
<td>0.98</td>
</tr>
<tr>
<td>MgO</td>
<td>0.54</td>
<td>0.89</td>
</tr>
<tr>
<td>CuO</td>
<td>3.13</td>
<td>3.88</td>
</tr>
<tr>
<td>Loss in ignition</td>
<td>1.21</td>
<td>0.80</td>
</tr>
<tr>
<td>Total Fe</td>
<td>33.15</td>
<td>31.68</td>
</tr>
</tbody>
</table>

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In view of the low TiO$_2$ content of the ore, it is essential that proper beneficiation techniques be employed with a view to enriching the ore, so that commercial exploitation becomes feasible. The enriched ilmenite can be used for the production of low carbon ferrotitanium by the aluminothermic process. With this end in view, beneficiation studies have been conducted on Bhandar ilmenite rock and the effect of different process variables on enrichment has been investigated. An empirical correlation has also been suggested which relates enrichment with various system parameters.

RESULTS AND DISCUSSION

Amounts of TiO$_2$ and total iron in the concentrates obtained at different flow rates and from different feed sizes are given in Table III and presented in Figs. 3 and 4. Table III also indicates the yields of concentrates expressed in percentage with respect to the original feed sample.
It is evident from the above table and figures that enrichment (with respect to TiO$_2$) varies directly with the flow rate of water and inversely with the feed size. The relationship with flow rate was found to be linear. Water flow rate beyond 12 kg/minute was not employed as it resulted in rapid carry over of the materials without bringing about effective separation. A correlation of the following form has been suggested for the prediction of enrichment of a particular feed sample at a definite flow rate of water.

$$E = 0.8W + 38.5 (0.60)^{d_p}$$

Where, $E =$ Enrichment expressed as percentage of TiO$_2$ in the concentrate.

$W =$ Water flow rate kg/min.

$d_p =$ Average particle size, mm.

Enrichment for all the sixteen cases (experimental) has been calculated by the above equation and compared with the actual values obtained from investigations in Table III. The percentage deviations lie within -3.90 to +1.85. The mean and standard deviations are 1.26% and 1.58% respectively. The ranges of applicability of the above correlation are

$$W = 6.0 - 12.0 \ \text{kg/min.}$$

and $d_p = 0.128 - 0.337 \ \text{mm}$. 

The total iron in the concentrates shows decreasing trend for the finer size whereas it has a tendency to increase in the coarser fractions when the flow rate is gradually increased. Moreover a comparison of the composition of the average feed with that of the average concentrate reveals a decrease in ferric iron and an
increase of ferrous iron content. The ferrous iron is generally present in combined form with TiO₂ as ilmenite and an enrichment of TiO₂ by the process of beneficiation will naturally enhance its percentage. On the other hand, ferric iron which is one of the major constituents of the ilmenite-hematite type ore is present in the rock as part of the structure both as a result of solid solubility of Fe₂O₃ in ilmenite and because of the process of alteration of natural ilmenite. The ferric iron formed from altered ilmenite is likely to be present along the grain boundaries which are left free by the process of crushing and grinding and are separated easily by the conventional methods of beneficiation like tabling. Though hematite (ferric iron) has higher specific gravity, it has higher grindability and, hence, in the process of crushing and grinding, becomes very fine. These fines get washed away easily during beneficiation by tabling. However, the ferric iron present in solid solution remains intact and is unaffected by such beneficiation processes. Thus, the total iron gets reduced in the finer size ranges and increases in the case of coarser ones where proper breaking of the grain boundaries does not occur. Also, for the whole range of operation it is the ferric iron that gets reduced.

Thus, it is seen that the process of beneficiation as adopted in the present study can be effectively employed for the rock deposits of ilmenite-hematite type as a primary step of enrichment of the ore.

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REFERENCES

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