*PROCEEDINGS : PROF-97*
*©NML, JAMSHEDPUR; pp.149-155*

# Beneficiation of low grade kyanite from Sirboi Mines of Singhbhum District

R. K. KUNWAR, S. C. MAULIK and N. CHAKRAVORTY
*National Metallurgical Laboratory, Jamshedpur - 831 007.*

## ABSTRACT

*Kyanite is used mostly in the manufacture of high alumina, high performance refractories. The major workable deposits of kyanite occur in Singhbhum District of Bihar. Kyanite from Sirboi mines is however of low grade and need to be beneficiated to achieve the desired specification. The sample assayed 40.43% $Al_2O_3$ and 50.39% $SiO_2$ contained kyanite as mineral of economic interest with quartz constituted the bulk of gangue mineral. The liberation of kyanite from associated gangue was reported to be below -48 mesh size. Gravity concentration by tabling at –48 mesh size were not very encouraging. Froth flotation studies using sodium silicate as depressant and oleic emulsion as collector at alkaline circuit (pH 9.1 – 9.3) did not respond to the desired grade or recovery. Flotation at pH (3.5) employing lactic acid as a depressant and sodium petroleum sulphonate as collector produced a concentrate assaying 60.3% $Al_2O_3$, 33.8% $SiO_2$ and 0.38% Fe with 55.0% $Al_2O_3$ recovery. Thus, the flotation concentrate produced in acid circuit (pH 3.5) meets the specifications and is suitable for blending with massive kyanite which is suitable for the manufacture of monolithic refractories.*

## INTRODUCTION

High alumina refractories, which possess high refractoriness, good resistance to spelling, mechanical abrasion of moving charges and corrosive action of slags and gases and good refractoriness underload are used for lining stacks and stoves of blast furnaces, nonferrous metal smelting furnaces, cement kilns and glass smelting furnaces etc. Kyanite is used mostly in the manufacture of high alumina, high performance refractories, especially in monolithic refractory applications. Expansion of iron and steel industries and increase in production of nonferrous metals, cements and fertilisers and fast depleting reserves of high grade lumpy kyanite call for the exploitation of low grade kyanites resources of the country but only after their upgradation through beneficiation.

Huge resources of low grade mica-quartz bearing kyanite deposits over 200 million tonnes occur in India mainly in Bihar (113.5 million tonnes), Karnataka (80 million tonnes) and to a small extent in Maharashtra, Orissa, West Bengal and Andhra Pradesh [1]. These reserves, after beneficiation can be used for making refractory brick and shapes [2].

Kyanite to be used in refractory industry should be relatively pure, as the presence of impurities such as $Fe_2O_3$, $TiO_2$, CaO, MgO, $Na_2O$ etc., affect its refractory properties. Generally kyanite is marketed in three grades. Over 60% $Al_2O_3$, 50–60% $Al_2O_3$ and less than 50% $Al_2O_3$. All the three grades are used in the manufacture of refractories. Indian refractory industry prefers kyanite having specification given in Table 1.

*Table 1 : Specification for kyanite stipulated by Indian refractory industries*

| Constituent | : | Wt (%) |
|---|---|---|
| $Al_2O_3$ | : | 58.0% minimum |
| $SiO_2$ | : | 39.0% maximum |
| $Fe_2O_3$ | : | 2.0% maximum |
| $TiO_2$ | : | 2.0% maximum |
| $Fe_2O_3 + TiO_2$ | : | 2.5% maximum |
| $Na_2O_3 + K_2O$ | : | 0.5% maximum |
| All impurities ($Fe_2O_3 + TiO_2 + CaO +$ MgO + Alkali's | : | 3.5% maximum |
| Physical size | : | Lumpy (25-300 mm), as it yields dense, tough and coarse grog. |
| Shape | : | Massive variety preferred owing to its greater strength and relative case of bounding. |
| Refractoriness (PCE value) | : | 35 min and preferably 37 orton cone. |

The production of kyanite in India has gone down considerably. Therefore, beneficiation of low grade ores of kyanite seems to be an essential route for increasing kyanite production meeting the marketable grade specifications. NML has carried out extensive beneficiation studies on a number of samples of kyanite from several deposits in India [3]. An appraisal has been made in this paper on beneficiation studies carried out at NML on a low grade kyanite sample from Sirboi mines of Bihar.

## Results

About 200 kg. of low grade kyanite sample from Sirboi Mines of Bihar were received for beneficiation studies from the Director of Mines and Geology, Bihar. The sample as received contained lumps (75-100 mm) size with very little fines. A representative portion of the sample was stage crushed to -10 mesh size and used for experimental purpose. The chemical analysis of the as received sample is given in Table 2.

*Table 2 : chemical analysis of the as received sample*

| Constituent | | Percent |
|---|---|---|
| $Al_2O_3$ | : | 40.43 |
| $SiO_2$ | : | 50.39 |
| $Fe_2O_3$ | : | 0.88 |
| MgO | : | 0.085 |
| $Na_2O$ | : | 1.150 |
| $K_2O$ | : | 0.026 |
| LOI | : | 1.930 |

## Mineralogy

The sample consisted of kyanite as chief mineral with quartz constituting bulk of the gangue. The other associated minerals like rutile, corundum, muscovite etc., were present in minor to trace amounts. Fair liberation of kyanite from associated gangue was reported at 48 mesh and below.

## Beneficiation Studies

Bench scale beneficiation studies were carried out employing gravity (tabling) and flotation methods.

## Gravity Separation

Since fair amount of kyanite was liberated at about –48 mesh, two tests were carried out on Wilfley table after wet grinding the representative lots of –10 mesh sample to –35 mesh and –48 mesh size separately. Results of tabling with –48 mesh feed is given in Table 3. The below results showed that table concentrate assayed only 51.44% $Al_2O_3$, 41.07% $SiO_2$ and 0.305% Fe. Results of tabling conducted at –35 mesh size were still less in grade and recovery.

*Table 3 : Results of tabling of –48 mesh feed*

| Product | Wt (%) | Assay (%) $Al_2O_3$ | $SiO_2$ | Fe | Dist. (%) $Al_2O_3$ |
|---|---|---|---|---|---|
| T. Conc. | 50.6 | 51.44 | 41.07 | 0.305 | 64.9 |
| T. Midd. | 9.8 | 31.74 | – | – | 7.8 |
| T. Tail. | 19.6 | 20.63 | – | – | 10.1 |
| Slime | 10.0 | 34.58 | – | – | 17.2 |
| Head | 100.0 | 40.09 | – | – | 100.0 |

**Flotation**

Flotation tests were next attempted for upgrading the sample. A few flotation tests were carried out initially to determine the effect of feed size on flotation. Lactic acid was used as gangue depressant and collector used for kyanite was sodium petroleum sulphonate. pH was maintained about 3.5 with controlled addition of dilute $H_2SO_4$. Initial flotation studies indicated that deslimed feed yielded better results both in terms of reagent consumption and grade of concentrate.

**Effect of variation in grind**

Four representative lots of 600 gm of –10 mesh sample were wet ground in laboratory rod mill for different length of time. The ground samples were deslimed and floated in Fagergren flotation cell. Lactic acid (0.5 kg/ton) and sodium petroleum sulphonate (1.0 kg/ton) were used as gangue depressant and collector for kyanite respectively. pH was maintained around 3.5 using $H_2SO_4$. Three floats were collected and combined floats was subjected to four cleanings using lactic acid. The results of these tests are presented in Table 4.

*Table 4 : Results of flotation tests at different fineness (pH 3.5)*

| Test No. | Grind % –200 mesh | Product | Wt (%) | Assay (%) $Al_2O_3$ | Dist. (%) $Al_2O_3$ |
|---|---|---|---|---|---|
| 1 | 36.2 | R. Conc. | 45.8 | 56.23 | 63.6 |
| 2 | 42.5 | R. Conc. | 48.1 | 57.23 | 68.1 |
| 3 | 47.5 | R. Conc. | 41.5 | 57.41 | 59.2 |
| 4 | 54.1 | R. Conc. | 36.7 | 60.30 | 55.0 |

The results given in Table 4 indicated that flotation test carried out with 54.1% –200 mesh feed yielded a cleaner concentrate assaying 60.3% $Al_2O_3$ with 55%

$Al_2O_3$ recovery. Grinding the material still finer size produced more slime and further loss of kyanite in the slime reported. The completed results of flotation with a feed containing 54.1% –200 mesh, followed by four cleanings are presented in Table 5.

*Table 5 : Results of flotation test at optimum grind*

| Product | Wt (%) | Assay (%) $Al_2O_3$ | Fe | $SiO_2$ | Dist. (%) $Al_2O_3$ |
|---|---|---|---|---|---|
| R. Conc. | 36.7 | 60.3 | 0.38 | 33.81 | 55.1 |
| Cl. Tail (1 to 4) | 15.3 | 51.59 | – | – | 19.5 |
| P. Tail | 20.8 | 3.30 | – | – | 1.7 |
| Slime | 27.2 | 35.30 | – | – | 23.7 |
| Head | 100.0 | 40.46 | – | – | 100.0 |

The results of Table 5 have shown that flotation in acid medium at pH 3.5 followed by four cleanings of rougher floats yielded a cleaner kyanite concentrate assaying 60.3% $Al_2O_3$, 33.81% $SiO_2$ and 0.38% Fe with an $Al_2O_3$ recovery of 55.1.

**Flotation with Fatty Acid as Collector**

Attempts were made to upgrade the kyanite sample by flotation in alkaline circuit at pH of (9.1–9.3) employing sodium silicate as gangue depressant and oleic acid emulsion as kyanite collector. Sodium carbonate was used for raising the pH. Three rougher floats were collected and the combined floats were subjected to four cleanings. The results of flotation tests in alkaline circuit is given in Table 6.

*Table 6 : Results of flotation test in alkaline circuit (pH 9.1–9.3)*

| Product | Wt (%) | Assay (%) $Al_2O_3$ | $SiO_2$ | Dist. (%) $Al_2O_3$ |
|---|---|---|---|---|
| R. Conc. | 35.8 | 52.64 | 40.14 | 46.5 |
| R. Tail (1 to 4) | 30.8 | 37.44 | 57.19 | 28.5 |
| P. Tail | 5.0 | 10.52 | 86.82 | 1.2 |
| Slime | 28.4 | 33.90 | 54.24 | 23.7 |
| Head | 100.0 | 40.53 | 51.72 | 100.0 |

From Table 6, it is apparent that kyanite could be floated in alkaline circuit also. However, concentrate assayed only 52.64% $Al_2O_3$ with 40.14% $SiO_2$ with $Al_2O_3$ recovery of 46.5%. The weight yield was also 35.8% only. Therefore, performance of flotation at alkaline pH was inferior to that of acid circuit.

## CONCLUSIONS

A sample of low grade kyanite from Sirboi Mines, Singhbhum District, Bihar was received for bench scale beneficiation studies. The sample assayed 40.43% $Al_2O_3$, 50.39% $SiO_2$, 0.88% $Fe_2O_3$, 1.15% $Na_2O$, 0.026% $K_2O$ and 1.93% LOI.

Kyanite was the chief mineral with quartz constituting the bulk of the gangue. Gravity concentration method viz., tabling at different size of feed did not give satisfactory result.

Flotation employing lactic acid and sodium petroleum sulphonate as gangue depressant and kyanite collector respectively at a pH of 3.5 produced a marketable grade kyanite concentrate assaying 60.3% $Al_2O_3$, 33.81% $SiO_2$, 0.38% Fe with $Al_2O_3$ recovery of 55.1%. The weight yield was 36.7%. The recovery is expected to improve further if the middlings are recirculated within the circuit as is the case in plant practice.

Fatty acid flotation in alkaline medium at pH (9.1–9.3), employing sodium silicate as gangue depressant and oleic acid emulsion as kyanite collector could yield a kyanite concentrate analysing 52.64% $Al_2O_3$, 40.14% $SiO_2$ with an $Al_2O_3$ recovery of 46.5% only.

Desliming of the ground product before flotation was essential in order to make the flotation process more effective in terms of (1) improvement in concentrate grade and (2) decreasing the reagent consumption. Loss of kyanite in slime was responsible for low recovery. Attempts to recover kyanite from slime employing gravity method was not satisfactory.

The studies indicated that low grade kyanite from Sirboi Mines, Singhbhum District, Bihar are amenable to beneficiation and it is possible to obtain refractory grade kyanite concentrate with a reasonable good recovery.

## ACKNOWLEDGEMENTS

The authors are thankful to prof. P. Ramachandra Rao, Director, National Metallurgical Laboratory, Jamshedpur, for kindly permitting to publish the paper. They also wish to thank to Directorate of Mines and Geology, Bihar for providing the sample for this investigation.

## REFERENCES

[1] Indian Minerals Yearbook, (1992), Published IBM, Nagpur.

[2] G. M. Rao, Amanullah, K. Satyanarayana, (1991), 'Beneficiation of Mica-quartz bearing Indian kyanites, XVII Internationalize Mineral Processing Congress, Dresden, Sept. 23-28.

[3] T. C. De, P. Bhattacharya, S.K. Sengupta, B. Banerjee and N. Chakravorty, (1992.), 'Upgradation of low grade kyanite-sillimanite resources for high alumina refractory manufacture', National Seminar on Research and process Development in Mineral Processing, National Metallurgical Laboratory, Jamshedpur, April 14-15.