Complementary Advantages of Steel-Alumina Joint Venture to Achieve Efficient and Low-Carbon Development

Yang Ni[1] and Zhenyong Luo[2]
1. Director, Alumina Engineering Institute
2. Director, Alumina Engineering Institute
CHALIECO GAMI, Guiyang, China
Corresponding author: 66142173@qq.com

Abstract

This paper assesses potential synergies between the co-location of an alumina refinery and a steel mill in coastal China. Steel mills generate excess steam and blast furnace gases, which can be used by alumina refineries, while alumina refineries can supplement raw material supply to blast furnaces in the form of iron concentrate in red mud waste. Co-location can also reduce capital expenditure because the alumina refinery can avoid the cost of building a dedicated thermal power plant or gas station, which not only reduces investment costs, but also reduces both the carbon footprint and the emission of harmful gases. Iron can be extracted and concentrated from alumina refinery red mud for blending into the steel mill feed, which reduces raw materials costs, as well as reducing the cost and volume of red mud to be stored in red mud dams. Furthermore, a co-located steel mill and alumina refinery could share port resources, further reducing both capital and operating costs. In order to maximise the co-location opportunity, capacity matching of both facilities must be taken into consideration.

Keywords: Alumina refinery, Steel mill, Steel-alumina joint venture.

1. Introduction

China's steel output ranks first in the world, however domestic iron supply is of low grade and high cost, so the proportion of iron ore imports is high. In order to minimise transport costs, many of China's steel mills are located close to port areas to be in close proximity to imported iron ore stocks. At present, many port areas along China's coast have steel mills.

Domestic bauxite faces similar resource depletion challenges, as local grades decline and processing costs increase. As a result, the proportion of imported bauxite processed in domestic alumina refineries is also increasing. Replicating the steel mill model, in order to be close to imported raw materials stocks and to minimise transportation costs, China's alumina refineries are also relocating to port areas. As they do, most are finding they have steel mills already located close by. This presents an opportunity to take advantage of synergies between operations, both from a technical and from a geographical perspective.

A 'steel-alumina' joint venture is a collaboration between a steel mill and an alumina refinery in China to achieve complementary benefits to improve efficiencies and reduce the costs of both operations. The alumina production process requires a large steam load and produces a large amount of red mud discharge. Importantly, if bauxite contains a high proportion of iron, after extracting the alumina in the refinery, the iron oxide content of the red mud will be concentrated. The iron ore reduction process consumes large amounts of iron ore and generates a large amount of gas.

New alumina refineries can take advantage of existing port infrastructure originally built for the steel mill to offload and store bauxite. New alumina refineries therefore avoid the costs associated with building new port infrastructure, which reduces project investment and improves the overall utilization rate of the existing wharf.

Waste heat (or gas) generated during the steel production process can be used to generate electricity through boilers, while also supplying steam to the alumina plant, which improves the efficiency of heat utilization. The red mud generated during the alumina refining process can be used to produce iron concentrate by magnetic separation. It can then be blended with imported iron ore, which not only reduces raw materials costs for steel mills, but also reduces the volume of red mud discharge.

2. Coordination of Steel-Alumina Joint Venture

2.1 Steam Demand for Alumina Production and Iron Concentrate Output

Most alumina refineries built in coastal regions process imported ore. A typical coastal refinery processing imported Guinean bauxite and using a low-temperature (LT) digestion process, would have a design scale of 2 × 1.5 Mt/y alumina trains (or modules), with an hourly flow rate of alumina of approximately 360 t/h, and with one tonne of alumina requiring approximately 1.8 tonnes of steam. The steam demand flow rate is therefore approximately 648 t/h, and the annual steam demand would be approximately 5.4 Mt/y.

The corresponding discharge of red mud is approximately 396 t/h (dry red mud), with an annual discharge of 3.3 Mt/y. The estimated composition of red mud is shown in Table 1:

Table 1. Composition of red mud

Composition	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	LOI	Other	Total
%	16.59	4.21	56.33	4.47	8.67	7.81	100

Once the magnetic separation process is applied to the red mud, the resultant composition of iron concentrate would be approximately 45 % iron, as shown in Table 2:

Table 2. Composition of iron concentrate

Composition	Al_2O_3	SiO_2	Fe_2O_3	Na_2O	CaO	LOI	Other	Total
%	10.80	3.26	65	1.98	1.29	5.57	12.1	100

The yield of iron concentrate is therefore around 50 %, and the annual yield of iron concentrate in the alumina plant is approximately 1.65 Mt/y.

2.2 The Current Situation of Waste Heat Utilization in Steel Mills and the Use of Red Mud Iron Concentrate

Taking a typical steel mill with an annual output of 10 Mt/y of steel as an example, the waste heat blast furnace gas volume is estimated to be 1.28 million Nm^3/h, corresponding to a steam output of around 1,577 t/h, which is well-suited to meet the demand for a 3 Mt/y alumina operation.

Iron concentrate in red mud has a low iron content and high impurity content, which is unsuitable for direct ironmaking. This material needs to be blended with high-grade iron ore. The proportion of iron concentrate with an iron content of 45% to 48% is only around 3-5%, while the annual demand for iron ore in steel making plants with an output of 10 Mt/y is approximately 16 Mt/y, corresponding to a red mud iron concentrate requirement of between 480 000 and 800 000 t/y.

2.3 Coordination of Steel-Alumina Joint Venture

The content of Al_2O_3 and Na_2O in the iron concentrate produced by red mud iron beneficiation is considered too high and the particle size too fine, so it cannot be directly used in ironmaking. It needs to be blended with high-grade iron concentrate, with a blend rate of around 3–5 %. The ore consumption for ironmaking is approximately 1.6 tonnes of ore per tonne of iron. The annual iron concentrate production of alumina refining is about 1.95 Mt/y, and the corresponding iron smelting capacity of about 24.4 million to 40.6 million per year would be required to consume all the iron concentrate produced by the refinery.

4.8 Emission Indicators

Taking as a further example the operation of a coal-fired thermal power plant for a similar project in a southern port in China (with an alumina production capacity of 2 Mt/y), after preliminary calculations, the annual pollutant emissions, based on the ultra-low emission concentration limit, are shown in Table 8.

Table 8. Emission reduction data.

		Refinery 1	Refinery 2
SO_2	t/y	180.5	324.9
NO_x	t/y	258	464
Dust	t/y	51.6	92.9
Mercury and its compounds	t/y	0.003	0.005

The refinery 1 in the table is the aforementioned alumina refinery with capacity of 2 Mt/y alumina at a port in southern China, this refinery builds its own thermal power plant, the data in the table represents the annual emissions of major pollutants from the thermal power plant. Refinery 2 is an alumina refinery operated in JV mode with a steel mill, with a production capacity of 3.6 Mt/y alumina. The data in the table is based on the emissions of reference refinery 1, calculated based on the production capacity ratio of the two refineries.

5. Conclusions

China's alumina refineries are likely to become increasingly more reliant on imported bauxite over the next decade. As they do, they are more likely to be built (or relocate) to coastal areas, where imported bauxite is delivered and stockpiled. This provides an opportunity to co-locate alumina refineries adjacent to existing steel mills in and around port industrial parks, where they can take advantage of many synergies between operations, including lower capital costs, lower operating costs and an improved environmental performance.

This research concludes that co-location offers comprehensive energy utilization efficiency for both the steel mill and the alumina refinery, while reducing net carbon emissions and reducing refinery capital costs by avoiding the need for a dedicated power plant and sharing port infrastructure and other related facilities. Co-location also meets China’s criteria for high-quality industry development under China’s "carbon peak, carbon neutrality" policy by direct application in the steel and alumina industries.

6. Reference

1. The data used in this paper is sourced from the feasibility study report and preliminary design of the production project of an alumina refinery in Hebei province in China, and the investigation of the iron and steel mills in Tangshan.