New alumina project approach – dedicated design, compact capacity

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1. Synopsis

As discussed elsewhere the design/initial refinery production capacity of greenfield alumina projects outside China has evolved from about 0.5-1.0m tpy 25 to 30 years ago to about 1.5-3.0m tpy for more recently constructed and future planned projects [1]. Despite this large scale increase economics did not structurally improve, mainly as a result of large capital cost increases for alumina projects in this period. The increase in project scale had major consequences:

- Significantly increased project complexity: planning and management, extensive government involvement, huge capital cost (multibillion USD, project financing, multi-party joint ventures).
- Worldwide only a limited number of large companies are left with the resources to develop greenfield projects, and only a few engineering firms with the skills and experience to implement these projects.
- Typically a project life of 30+ years applies to the significant investment of a greenfield bauxite and alumina project. For projects with a captive refinery this means that the bauxite deposit on which they are based should sustain refining operations for such a period of time. Therefore only (very) large bauxite deposits are developed, indicatively 200-300 million tonnes and more.
- Summarising: worldwide only a small number of companies develop mostly very large greenfield bauxite and alumina projects which often takes a decade or more.

This paper describes a new two-stage approach to improve on the state of affairs outlined above: first and foremost base any greenfield project on a dedicated design and layout for a specified production capacity, and secondly apply this methodology to a compact refinery capacity. Objectives are to improve alumina project economics and to develop an option of smaller greenfield bauxite and alumina projects at acceptable economics.

The economic basis of the new approach is discussed in section 3, technical aspects are covered in section 4.

2. Commodities and current refinery design

Commodities such as concrete, steel, mechanical bulks (e.g. valves), piping, wire and cable, etc. represent a significant element (typically ~30%) of a refinery’s capital cost as illustrated in the left-hand column (Current design) of Table 1 (see next page) for a typical current-design 1.5m tpy ‘low-temperature digestion’ alumina refinery.

Importantly commodity amounts and the related capital costs reflect plant design and layout. Current alumina refineries are designed to accommodate additional future digestion units (and all of the other required process units – e.g. precipitation, evaporation), i.e. plant design is not optimised for its initial production capacity. Plant layout is characterised by an ‘open architecture’ as illustrated in Fig. 1 by the main piperack layout of recently designed 1.5m tpy alumina refineries, which represents at best a compromise between the limited layout requirements for the initial/design capacity and the more extensive requirements to accommodate future additional process units. And at worst consists of a large-capacity plant part of which is built, resulting in an inefficient plant layout for the design/initial capacity. In summary plant design is not optimised for its design/initial production capacity.

3. New project approach

3.1 Step 1 – Dedicated design & layout

The new approach is based on a dedicated refinery design and layout for a specified production capacity, i.e. tailoring the design to the equipment and infrastructure requirements (earth works, power, water supply, piperacks, roads, cable trays) of the selected production capacity. This approach enables optimising plant layout for the targeted production capacity e.g. with respect to positioning similar equipment close to each other, and the use of common spares; it impacts positively on commodity volumes, and it focuses on a ‘lean’ design. Consequently the design excludes provisions for future expansions, which should be justified on their own economic merits. This more ‘closed’ layout architecture results in a more efficient plant layout, reflected for example in the design of the main plant piperacks as illustrated in Fig. 2 for a 1.5m tpy refinery (compare with the piperack layouts of Fig. 1 which are on the same scale).

This new approach impacts positively on commodity volumes (refer to [2] for details): for the same production capacity commodity volumes for steel, concrete, piping, etc. for a greenfield plant designed along this approach are similar to that of a brownfield expansion...
Table 1: 1.5m tpy greenfield refinery capital cost comparison (indicative numbers)

<table>
<thead>
<tr>
<th>Cost item in million USD</th>
<th>1.5m tpy production capacity</th>
<th>Dedicated design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment1</td>
<td>244</td>
<td>234</td>
</tr>
<tr>
<td>Commodities2</td>
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<td>474</td>
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<td>Total direct costs</td>
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</tr>
<tr>
<td>Total indirect costs3</td>
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<td>663</td>
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<tr>
<td>Contingency</td>
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<td>150</td>
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<tr>
<td>Total refinery capital cost</td>
<td>1,699</td>
<td>1,521</td>
</tr>
<tr>
<td>USD/annual TA</td>
<td>1,133</td>
<td>1,014</td>
</tr>
</tbody>
</table>

Table 2: 400,000 tpy dedicated design refinery capital cost (indicative numbers)

<table>
<thead>
<tr>
<th>Cost item in million USD</th>
<th>400,000 tpy production capacity</th>
<th>Dedicated design</th>
</tr>
</thead>
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<tr>
<td>Direct costs</td>
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<tr>
<td>Equipment1</td>
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<tr>
<td>Total indirect costs</td>
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<tr>
<td>Contingency</td>
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<tr>
<td>Total refinery capital cost3</td>
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</tr>
<tr>
<td>USD/annual TA</td>
<td>1,347</td>
<td></td>
</tr>
</tbody>
</table>

1 Incl steam and power generation, sub stations, residue disposal, water supply, communication and info systems
2 Incl concrete, steel, mechanical bases, piping, wire and cable, etc.
3 Incl freight, EPCM, temporary construction, start-up, commissioning, owner’s engineering

of an existing refinery. In other words per annual TA production capacity significantly lower amounts of commodities are required for greenfield projects based on this approach compared with current, resulting in lower costs. The effect on refinery capital cost is illustrated in the right-hand column of Table 1 for a dedicated design 1.5m tpy ‘low-temperature digestion’ refinery: the capital cost per annual TA capacity improves indicatively by about 10%.

3.2 Step 2 – Compact production capacity

The second step of the new approach addresses the issues of complexity and huge capital cost of current alumina projects: by applying the dedicated-capacity approach to a compact refinery capacity of about 300,000 to 600,000 tpy the resulting project has a simple and limited scope. The higher end of this range is limited by the objective to end up with a total project capital cost well below USD1bn (mega project threshold); the lower end is determined by logistical limitations (e.g. with respect to raw materials shipping). As a result some indirect capital cost items decrease more than proportionately such as costs related to temporary construction and start-up support, camp and other construction related items, and owner’s costs, improving plant capital cost indicatively by an additional 10% relative to a current-design plant of similar size.

As illustration a production capacity for a greenfield 400,000 tpy dedicated design plant is used here, and its related capital cost (indicative numbers) is shown in Table 2. Table 2 shows that the capital cost per annual TA (1,347 USD/AnntA) is higher than that of the much larger 1.5m tpy dedicated plant (1,014 USD/AnntA – refer Table 1), however it is at a level which could result in a project with acceptable economics provided infrastructure capital cost is limited (refer [2] for further details). At the same time a project based on a compact plant capacity has very limited infrastructural requirements and has several advantages over a large plant, particularly if the project is located close to an existing port, e.g. it may be allowed closer to residential areas (i.e. closer to existing infrastructure); the existing infrastructure may be sufficient for a small plant, but not for a big plant; a suitable location for a small residue disposal area is easier to find than for a large one, etc. The table also shows that the total capital cost is at a level which would enable many more companies to develop such a project without necessarily requiring the formation of multi-party joint ventures, simplifying overall project management and thus enabling to decrease the capital cost further.

Note that the new approach is independent of the selected refinery technologies.

4. 400,000 tpy capacity alumina refinery

The above outlined DCS approach (Dedicated Compact Sustainable - this last aspect is not discussed here) has been applied by modelling a 400,000 tpy low-temperature digestion refinery in a benchmark version of the Bayer process (refer [3] for further details). The steam temperature and pressure required for low-temperature digestion enables first using high pressure boiler steam for the co-generation of power. This results in an energy and capital efficient refining process.

4.1 Equipment sparing

- Key role for equipment cleaning/descaling.
- Substantial use of common spare equipment.
- If an outage would result in an immediate alumina production loss, a spare or equipment bypassing facilities are installed or extra capacity in upstream/downstream equipment is included. This also applies to frequently maintained equipment.
- No sparing is included for the bauxite residue washers and flash vessels which can be bypassed, accepting transient process efficiency reductions; a spare precipitator is installed and the third precipitator in line can be used both as agglomerating as well as growth precipitator.
- The refinery operates continuously, with planned outages (accounted for in the overall plant operating factor) being used to service equipment. The sparing philosophy assumes no scheduled extended total plant shutdowns.
- The sparing philosophy may require adjusting to a specific plant location.

4.2 Plant design elements

- The digestion and liquor evaporation areas positioned next to each other, enabling sharing a common spare train of heat exchangers.
- Advantages: equipment standardisation, simplified operations and maintenance, less (types of) spare parts.
- The bauxite residue discharging from the CCD wash train contains less than ~8 g/l caustic soda in the adhering liquor, enhancing disposal options.
- The last two on-line precipitators operate with agitators allowing varying slurry levels, thus accommodating volume take-up when descaling a tank.
- Precipitators are mechanically cleaned/descaled. Main advantages: no major plant volumes/plant liquor caustic concentration fluctuations, i.e. better control of both. Put differently: tank cleaning and plant volume/liquor concentration control have been separated. Other advantages: no further spare precipitators / tanks of similar size are required and steam savings (caustic cleaning).
- The filters for hydration to calcination, for fine seed to precipitation and for oxalate removal are located in one building. Advantages: equipment standardisation, operating procedures, etc.
- A hydrate storage facility between precipitation and calcination, enabling the Bayer circuit to operate independently and as undisturbed as possible from calcination. Two calciners are installed, both normally in operation. By uncoupling the Bayer circuit from calcination, product quality control can be optimised.

4.3 Layout considerations

The key advantage of the DCS design is that the plant layout is optimised. This may be realised in various ways, depending on bauxite quality (boehmite, TOC, oxalate, etc.), select-
apply also if other choices are made.
- Position the digestion and liquor evaporation areas next to each other (refer Fig. 3). The causticiser feed heat exchanger is located in the digestion/evaporation area because evaporation export steam and digestion flash condensate is used to heat the CCD-washer overflow to causticisation. Attention should be given to maintain the free caustic concentration in the spent liquor through evaporation at the hot end within acceptable levels.
- Place the bauxite residue settler and washers in a horseshoe shape for easy access to washer overflow standpipes and pumps, etc. (refer Fig. 4). Lime related areas are positioned next to each other (similar operating and maintenance requirements) and close to the washer train.
- Place the filters for hydrate to calcination, fine seed for precipitation and oxalate removal, as well as the cyclone classification areas in one building (similar equipment, operating and maintenance procedures, spare parts, sharing of common spare tanks and pumps, etc.) (refer Fig. 5).
- Position security filtration related equipment close to each other for operating and maintenance efficiency reasons; the heat interchanger, precipitation and interstage cooling close to each other as these have many interactions (minimising liquor/slurry pipeline distances); and the main steam consumers (digestion and evaporation) and the steam and power plant close to each other to minimise energy losses; and place if feasible the bauxite crushing, grinding and pre-desalination areas close to each other and to the digestion area to minimise slurry pipeline distances.
- Construct in the centre of the plant a facility accommodating the plant control room (including control of the steam and power plant), operations office and plant laboratory.
- Create good crane access to all major equipment from 15 m wide plant roads, and if economically justifiable consider pipe trenches instead of piperracks for road crossings (ease of access).

4.4 Overall plant layout
An overall process plant layout for a 400,000 tpy DCS plant is shown in Fig. 6, showing that the new approach leads to a compact, simple and efficient layout with a small Bayer loop, illustrating that the goal to tailor the design to the equipment and infrastructure requirements of the specified production capacity is achievable: most of the infrastructure is integrated in the process areas and only limited infrastructure is required outside those.
5. Advantages of the new approach

The main advantages of the new approach are:
- Reduced capital cost (lower risk) enabling the development of bauxite and alumina projects by smaller companies without a need to form joint ventures, thus increasing the number of companies potentially interested in developing bauxite deposits. More competition, more efficient use of (capital and bauxite) resources.
- Small and simple projects carrying less risk require less time to develop, construct and start-up, positively impacting economics.
- Alumina refining projects based on this approach require a small bauxite deposit (a deposit of about 40m tonnes could support a 400,000 tpy project for 30 years), i.e. worldwide the number of bauxite deposits lending themselves to development increases, again improving the use of resources.
- This new development model may also be applied to the development of part(s) of a large deposit.
- In some cases the new approach enables value creation through alumina refining rather than being limited to bauxite export (attractive to the host country and to companies developing bauxite & alumina projects).
- An adapted version of the new development model may in some cases enable bauxite deposit development even in locations with little existing infrastructure, albeit at a larger than compact scale (see below).

6. Possible project locations

Examples of bauxite deposits that may lend themselves to development via the proposed approach are (between brackets the potential alumina export port):
- Haden, Queensland, Australia (Brisbane)
- Pinjarra, Western Australia (Fremantle)
- Central Northern Tasmania (Devon Port / Bell Bay)
- El Palmar, Venezuela (Ciudad Guayana)
- Trelawny, Jamaica (Discovery Bay)
- Kibi, Ghana (Tema).

In addition some bauxite deposits which in view of their large size could support the current development approach with large-capacity alumina refining projects, may also lend themselves to stage-wise development applying the new approach. In this case these deposits could support several (smaller) greenfield bauxite and alumina projects in an adapted version of this new development model – e.g. a dedicated 1.5m tpy capacity project. Example: some of the Eastern Ghats deposits in Orissa and Andhra Pradesh, India, e.g. the Kutramali deposit (with Visakhapatnam as potential alumina export port).

7. References


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