The Energy Efficiency Barrier in Aluminium Smelting

2nd Workshop on Best Practices in Energy Efficiency in Aluminium Sector

Hirakud 16-17th December, 2016
Energy Efficiency : A Compelling Global Resource

Globally, energy efficiency represents about 40% of the GHG reduction potential that can be realised at the cost of less than ₹ 5,000.00 per ton of CO₂-eq

Government will play a decisive role in boosting Energy Efficiency

By refocusing energy policies the developing country like India can dramatically reduce the energy demand in coming years without impairing economic growth
Main Challenges for the Aluminium Industry

Global Trends – E^3

- **Economy** - Cost Reductions
- **Energy** - Reduced Energy Consumption
- **Environment** - “Carbon Footprint” Reduction
Global Consumption

The World’s Aluminium smelters now use about 3.5% of the total global electric power consumption.

Rio Tinto Alcan’s website wrote that it uses 325 megawatts of electricity each day - enough to power a city of the size of New Orleans - to produce 193 000 tonnes of aluminium annually.
# Energy Conservation Potential

<table>
<thead>
<tr>
<th>Indian Industries</th>
<th>% share of energy in production cost</th>
<th>% conservation potential</th>
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<tbody>
<tr>
<td>Refineries</td>
<td>1</td>
<td>8-10</td>
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<tr>
<td>Ferrous Foundry</td>
<td>10.5</td>
<td>15-20</td>
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<td>Textile</td>
<td>10.9</td>
<td>20-25</td>
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<td>Petrochemical</td>
<td>12.7</td>
<td>10-15</td>
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<tr>
<td>Chloro-alkali</td>
<td>15</td>
<td>10-15</td>
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<tr>
<td>Iron &amp; Steel</td>
<td>15.8</td>
<td>8-10</td>
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<tr>
<td>Fertilizers &amp; Pesticides</td>
<td>18.3</td>
<td>10-15</td>
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<tr>
<td>Pulp &amp; Paper</td>
<td>22.8</td>
<td>20-25</td>
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<tr>
<td>Aluminum</td>
<td>32</td>
<td>8-10</td>
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<tr>
<td>Cement</td>
<td>34.9</td>
<td>10-15</td>
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<tr>
<td>Ferro-alloys</td>
<td>36.5</td>
<td>8-10</td>
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</tbody>
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Source: Energy Report, UNIDO, 2010
Energy Consumption (AC)

Source: (1) EESL reports 2014
Benchmarking (DC)

Energy, kWh/t, Al

Source: UNIDO report 2014
Energy, kWh/t, Al

Indian Aluminium Smelter

- A: 147
- B: 158
- C: 180
- D: 147
- E: 144
- WWM: 136.5
- BAT: 132
- LTG: 110

Hundred
3 B’s
Energy Reduction

• Best Practice Technology

• Best Available Technology

• Benchmarking
IAI - Mission 2020

- 5% ↓ in energy intensity
- 11 kWh/kg for smelting
- 25% ↓ cost of metal production
- 25% ↓ energy use in melting
- 97% CE at a low energy input
- 13 kWh/kg by retrofit

Source: Aluminium Roadmap, IAI, 2006
Why is it Important for Aluminium Producers to Reduce the Energy Consumption?

- Production & consumption of Al is growing
- Increasing share of global Al production derived from fossil fuels for power
- Global demand for energy increasing
- Rising energy cost
- Increasing greenhouse gas emission

NEA: Energy savings in all parts of the production process will continue to be an important task for aluminium smelters in the coming years
Aluminium Production is Power Intensive
Power Dominates the Cost and Varies the most among Producers

Based on average weighted global aluminium production. Source: CRU.
For minimum and maximum are the ten highest and lowest smelters been left out of each category
Why is Aluminium Smelting not very Energy Efficient?

• The cell resistance is high due to ohmic electrolyte and gas bubble resistances, plus ohmic resistances in the anodes and cathode

• The anode-cathode distance (ACD) must be kept above a certain minimum to avoid back reaction of aluminium with CO₂

• Heat losses are necessary to maintain a frozen side ledge to protect the sidewall, so extra heat has to be wasted!
Forms of Energy Input to Al Electrolysis Cell

1. Electrical energy input = Cell voltage × Line amperage
   - Electrical energy input = Chemical energy to break the bonds (in the form of Al-O-F anions dissolved in the electrolyte) + Heat energy (I² • R)

2. Chemical energy input = Burning carbon anodes
   - Anode reaction is exothermic transformed to heat reducing electrical energy supply to the cell. Saving of electrical energy about 3 kWh/kg Al, which means by nearly 20%

One can therefore say that the thermal energy content of the carbon anode saves electrical energy in the cell
Factors Controlling kWh/kg

- Anode Current density–Design and Operation
- Magnetic fields–only metal heave is affected if current distribution is even and vertical..
- ACD –Operational control related, and about control of heat balance..although cathode design can introduce step changes....
- But is every Pot performing the same in a Potline?
  - Variation between pots is the largest component of the variability.. (Rutledge, Light Metals 2008, pp.325)
Minimising Energy Consumption

1. **Reducing cell voltage**
   Anode-cathode distance (ACD) minimisation
   - Cell noise is usually used as the indicator for the lower ACD limit
   - Historically a tendency to individualise cell voltages

2. **Maximising current efficiency (CE)**
   Focusing on the back reaction between Al and CO$_2$
   - Reducing the metal solubility by improved temperature and bath chemistry control

*Shorting is a major contributor to poor performance in potlines with CE < 93%*

B. Welch, TMS course 2015
Lower Anode-Cathode Distance (ACD) to Reduce Cell Voltage

• Minimise cell voltage, for lowering energy consumption

• The easiest way is to reduce the anode-cathode distance (ACD)

• There are two main constraints:
  – Keep the physical distance sufficient to avoid back reaction between aluminium and carbon dioxide (aluminium layer stability)
  – Keep the electrolyte resistance sufficiently high so that the electrolyte remains molten
To reduce the Energy Consumption we must Lower the Cell Heat Loss!

Or we must use the present heat loss to preheat the raw materials!
Anode Changing - The Greatest Cause of Cell Dynamics and Operating Problems

• Cold carbon anode is inserted in the electrolyte
• Anode set is the major root cause of poor performance
• Reducing the anode changing DISTURBANCE should have top priority!

Can we PREHEAT the anodes?
Work Practices & Energy Consumption

Anode setting
- Need to enhance anode setting precision, including current pick-up rate to keep cell in heat balance
- Need to remove anodes without collapsing crust into cavity
- Need to set the anode reference height more precisely

Anode covering
- Minimise spillage into the cell during anode covering
- This lowers superheat causing alumina solubility problem
- Minimise crust fall into cavity during anode change
- This lowers superheat, making alumina dissolution worse
- This increases heat lost by the material removed
Lower Energy Consumption

• Alouette’s example is to minimise kilowatt hours per kilogram for energy available - not to maximise current efficiency and productivity

• Current AP30 cells are operated at 12.7 kWh/t Al and goal is 12.5 kWh/t Al or lower

• **How to get lower energy consumption:**
  – Lowering the anode - cathode distance (ACD)
  – Better metal pad stability
  – Better cathode and anode rodding procedures (to minimise external voltage drops)
  – Modeling of the thermal balance
Chinalco: A Significant Breakthrough

- 600 kA super-large cells were developed by SAMI in seven years.
- It was designed to solve technical difficulties like magnetic fluid stability as well as operational stability.
- After being tested for 1.5 years the energy consumption is 12.14 kWh/kg Al.

Source: AlCircle.com  Date: 29 January 2014
DC 12.0 kWh/kg Al is achievable

- Partial preheating - alumina & anode
- Sharpen-up work practices – accurate anode change
- Stabilise metal pad for CE gain
  - Voltage savings to give ACD gains
- And the combination of cathode block design, jointing and collector bar design
Future Trend

• Amperage increase has been the trend for many years now. This has implied lower cell voltage to maintain a proper heat balance in the cell

• It may seem to be some opportunity now for gains in cell voltage, which probably will be below 4.0 V in the future

• Lower energy consumption will be required, because the aluminium industry will be expected to save energy in the years to come
Aluminium may become an even greener metal than today. Technically, the aluminium production process can be a close to zero climate gas producer. The aluminum technology of the future will be the world’s most energy-efficient and the one with the lowest CO$_2$ footprint!
Thank You

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