“2nd WORKSHOP ON BEST PRACTICES IN ENERGY EFFICIENCY IN ALUMINIUM SECTOR”

Knowledge Exchange Platform 16-17th Dec’16

"Energy For Aluminium- Past, Present and Future"

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ALUMINIUM – The Material of the Future

Buildings
Domestic & Commercial building, Doors, Windows

Transportation
Highly Durable, fuel efficient vehicles – Cars, Buses, Trains etc

Packaging
Beverage Cans, Tetra Packs for perishable products, Medicinal products etc

Electrical
Cables & Conductor Industries for High Transmission lines

Aerospace
With Low Density & High Strength to weight ratio, used in Missiles, Rockets, Air Crafts etc
Market Outlook – Aluminium

- Global demand @ CAGR 4.2% average expected including China
- IMF projected India’s growth forecast as 7.5% vis-à-vis 3.5% global average & 6.2 for China. Majorly driven by consumption.
- Primary Aluminium consumption increased by **23%** & total Aluminium consumption increased by **13%** in last one year.
- Aluminium demand in India is expected to grow at double digit.
- Consumption lead by electrical & Transport sectors & govt. Initiatives on infrastructure~ Smart cities, Railways etc. Make in India to promote domestic industry
Aluminium Evolution

Evolutions in Aluminium industry:

- 1808, Aluminium was first established
- 1890, Aluminium production commercialized using Hall Héroult methods
- 1980’s 175 kA was seen as a challenge and currently 600 KA is the new benchmark
- Improved emissions and efficiency
- Leading Technologies are AP, Pechiney, Hydro, GAMI, SAMI, RUSAL & DUBAL
Smelter Production Process
Inputs to tonne of Aluminium

- Crude Oil
- 4500 kg Bauxite
- 450 kg Green Coke
- 1920 kg Alumina
- 360 kg Calcined Coke
- 180 kg Coal Tar
- 13500 Kwh
- 140 kg Butts
- 560 kg Anode
- 1000 kg Aluminium
- 90 kg Pitch
- 1000 kg Aluminium
- 6 kg Cathode
- 13500 Kwh
- 1000 kg Aluminium

Coal
- 180 kg Coal Tar
- 13500 Kwh
- 1000 kg Aluminium

Anode
- 560 kg Anode
- 6 kg Cathode
- 13500 Kwh
- 1000 kg Aluminium
<table>
<thead>
<tr>
<th>Smelting Capacities</th>
<th>Jharsuguda (Vedanta)</th>
<th>Korba (BALCO)</th>
<th>Angul (NALCO)</th>
<th>Hirakud (HINDALCO)</th>
<th>Renukoot (HINDALCO)</th>
<th>Lapang &amp; Mahan (Aditya Birla)</th>
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<tbody>
<tr>
<td>Potlines</td>
<td>2 + 4</td>
<td>2</td>
<td>4</td>
<td>5(4+1)</td>
<td>11(3+8)</td>
<td>2</td>
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<tr>
<td>Design</td>
<td>325-340 KA</td>
<td>320-340 KA</td>
<td>180 KA</td>
<td>90 KA, 235 KA</td>
<td>65 KA, 70 KA</td>
<td>360 KA</td>
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<tr>
<td>No. of Pots</td>
<td>1952</td>
<td>624</td>
<td>960</td>
<td>780</td>
<td>2139</td>
<td>720</td>
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<tr>
<td>GAP, ABF</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Capacity (KT/Yr)</td>
<td>1750</td>
<td>560</td>
<td>460</td>
<td>200</td>
<td>400</td>
<td>720</td>
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<tr>
<td>Captive Power (MW)</td>
<td>3615</td>
<td>2010</td>
<td>1200</td>
<td>367.5</td>
<td>740</td>
<td>1800</td>
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<tr>
<td>No of TG Units</td>
<td>13</td>
<td>10</td>
<td>10</td>
<td>4</td>
<td>10</td>
<td>12</td>
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<tr>
<td>Technology</td>
<td>GAMI</td>
<td>GAMI</td>
<td>AP</td>
<td>GAMI</td>
<td>Kaiser</td>
<td>AP</td>
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</table>
Focus of Aluminium Industry

**Economy** - Cost Reductions

**Energy** - Energy Consumption Reduction

**Environment** - “Carbon Footprint” Reduction

World’s Aluminium Smelters now use about 3.5% of the total global Electric Power Consumption!

**We are Significant GHG Emitters**

- Globally the aluminium industry emits over 400 million tonnes of CO\(_2\)-equivalents annually.
- This is about 1% of the world’s total emissions.
- The emission is growing not only because the consumption of aluminium is growing, but because an increasing share of the aluminium production is derived from electricity from fossil fuels.
### Aluminium Sector

<table>
<thead>
<tr>
<th>Cycle</th>
<th>No. of DCs</th>
<th>Annual Energy Consumption (MTOE)</th>
<th>Target Reduction (MTOE)</th>
<th>Actual Saving (MTOE)</th>
<th>% Achievement</th>
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<tbody>
<tr>
<td>PAT Cycle 1</td>
<td>10</td>
<td>7.71</td>
<td>0.46</td>
<td>0.73</td>
<td>159%</td>
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<tr>
<td>PAT Cycle 2</td>
<td>12</td>
<td>10.66</td>
<td>0.57</td>
<td></td>
<td>&gt; 159%</td>
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</table>

Aluminium sector is committed to exceed the past performance
Energy Consumption (kWh/Kg Al) = 2.98 \times \frac{\text{Voltage (V)}}{\text{Current Efficiency}}
Traditional view for minimizing Energy Consumption

1. Reducing cell voltage by Anode-cathode distance (ACD) minimization

   Cell noise is usually used as the indicator for the lower ACD limit
   Historically a tendency to individualize cell voltages

2. Maximizing current efficiency (CE) - Focusing on the back reaction between Al and CO2

   Reducing the metal solubility by improved temperature and bath chemistry control

   Concerns with this approach - Impurity reactions, anode spikes, current shorting and carbon dust

Modern prebake cells

   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.
Energy Reduction Initiatives - Present

Voltage drops across electrolytic cell

- Decomposition Voltage Drop 41%
- Bath Voltage Drop 37%
- External/Bus Bar Drop
- Cathode Voltage Drop 6%
- Anode Voltage Drop 8%

Typical heat Loss from electrolytic cell

- Reducing Cell Voltage
- Slotted Anode & Anode Quality
- Anode Stem Voltage Drop Reduction
- Collector bar modification
- Low resistivity Cathode (Graphitized)
- Improved Thermal & Magnetic Balance
- Maximizing Current Efficiency

Focus has been process optimisation and elimination of process losses
Bath drop reduction - Implementation of slotted anodes

Observed benefit in the range of **20-30 mV** which reduced energy consumption by **96 kWh/MT-Al**
Cathode voltage drop - Opportunities

Increase in % graphite

From 30 % to 50 % graphitized & move towards 100 % graphitized cathodes

Cathode Voltage Drop

Gain: 34mv=108 units
Cathode voltage drop and Current distribution- Opportunities

Collector bar geometry and composition change

\[ R = \rho \frac{l}{A} \]
\( \rho \) resistivity, \( l \) - length, \( A \) - area

- Increase in height of collector bar
- Change in composition of collector bar

Advancements

- Copper inserts in collector bars
- Variable slot dimension collector bars
- Insulated collector bars

Advantage:

- Reducing the CVD
- Reducing the current density at cathode surface
- Reducing the metal velocity field
- Reducing the cathode erosion
- Reducing the metal deformation
- Improving MHD cell stability

Bottom line

- Low specific energy consumption.
- High Current Efficiency
Thermal and magnetic balance improvement - Present

Energy saving in existing Potlines

MHD stability and heat balance

- Increase in anode cover height
- External insulation in electrolytic cells

Software up-gradation

- Better AL2O3 concentration control
- Multi-mode Fluoride excessive control
- Multi-stage noise control

Extended ledge in present cells – leading to horizontal current disturbances

Optimized ledge giving better MHD stability
Future Technologies

**Inert anode Cells**

- Non-consumable anodes avoid the formation of carbon dioxide
- Pure oxygen is produced during the reaction which is equivalent to 70 hectares of Forest
- Inert anode does not burn down and need not be replaced saving considerable operational costs

**Drained Cell Technology**

- The key effect of drained cathode is breaking the circulation of liquid metal into pieces and slow down metal flow velocity and its waving
- It removes the metal padding thereby eliminating the magnetic turbulence, enabling the cells to be operated at a much reduced inter-electrode distance

**Irregular Cathode**

- In recent years, a number of patents of “irregular cathode” structures filed in China, application proved it can reduce ACD about 1cm and save energy by 500-1000kWh/t-Al.
Road Map to Benchmark Energy

Short Term
- Reduce pot voltage
- Baking Furnace Preheating Curve Optimization
- Process Optimization to improve current efficiency in pots.
- Reduce external contact drops
- Use slotted anodes
- Alternate energy for replacing Fuel oil usage in Casthouse.
- Use of energy efficient lighting, motors, transformers, pumps, compressors etc.
- Process rejection reduction & control COPQ

Medium Term
- Pot controller up-gradation
- Lining design up gradation
- Ready to Use Cathodes
- Graphitic cathodes
- Thermal Balance control in Pots
- Anode Stem Voltage Drop reduction
- 100% Graphitized Cathodes
- Secondary Producers at near vicinity to Primary Smelters
- Furnace lining up graduation with better insulation

Long Term
- Inert Anodes
- Low temperature electrolysis through chemical additives
- Technological Up-gradation in lining design change to improve magnetic and thermal balance.
- Current ramp up
- Investment in renewable energy sector
- Waste heat recovery from pot fumes
- Use of SPL as alternate fuel
Global Aluminium Technologies

Leading Technologies

- AP
  - AP 18
  - AP 22
  - AP 30
  - AP 60
- RUSAL
  - RA 300
  - RA 400
  - RA 500
- DX+
  - DX(400)
- SAMI
- GAMI

<table>
<thead>
<tr>
<th>AMPERAGE (KA)</th>
<th>POWER CONSUMPTION (KwH/MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300-400</td>
<td>13000</td>
</tr>
<tr>
<td>500</td>
<td>12400</td>
</tr>
<tr>
<td>600</td>
<td>12136</td>
</tr>
</tbody>
</table>
Way forward for smelting technologies in India

In reviewing all new technology and developments since the early 1980s, the following features stand out:

- Current efficiencies in excess of 95% can be achieved.
- The present process energy efficiency is approximately 50%, with the excess energy being dissipated as heat loss from cells.
- The limit to reducing cell voltage is no longer the anode-cathode distance, constraint from the turbulent metal pad that leads to the risk of direct shorting.

Rather, it is to ensure sufficient heat is generated to maintain stable operation.

- Because of constraints through operating procedures and the emphasis on the capture of emissions, there are only limited variations for reducing the top heat loss from the cell. Thus, the present technology is constrained by both upper and lower limits for heat generation.

- Indian smelters need to upgrade themselves and bring in new technologies with Pots operating at Higher Amperage such as AP 60, GP 50, SY 600.
- 100% Graphitized Cathodes, Wet & Curved Cathodes, Non-consumable inert Anodes & Advanced Pot controller are the need of the hour.
Focus on Process optimization.

Building roadmap for technology up gradation.

Focus on implementation of energy management system to achieve energy excellence where ISO:50001, EnMS plays a pivot role.

Collaboration & best practices sharing across the leading Aluminium industry for indigenous development of technology.

Development of in-house research centres in India.
Thank You