Designing new pot design using Ansys steady state thermal to reach 215 ka pot technology

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Abstract. In the present, Inalum has been operating D3-3, D5-1, D5-2 pot design in 196 kA line current and reach 250 ktpy production. Inalum has vision to reach production to 300 ktpy with one of strategy is designing new pot technology to reach 215 kA line current. Some simulation should be carried out before the application test is done using Ansys to observe thermal balance and material balance or with this case using the Steady State Thermal Analysis, Thermal Electric and Magnetohydrodynamic Analysis. Simulation with Steady State Thermal Analysis for new design is doing with some modification with pot lining material, shows new pot design has side ledge temperature higher than existing pot design D5-1. The result is also shown the side wall temperature of new pot design is lower than existing pot design D5-1 with the higher cathode bar temperature in new pot design.

1. Introduction
PT Indonesia Asahan Aluminium called “Inalum” was established on January 6, 1976 as Joint Venture Company between the Government of Republic of Indonesia (GOI) and 12 Japan investor company. Inalum has become state owned enterprise (SoE) with 100% shareholding by GOI since December 19, 2013 and the company name officially changed to become PT Indonesia Asahan Aluminium (Persero).

Inalum operates 2 (two) hydroelectric power plant (HEPP) at Siguragura and Tangga and an Aluminium Smelting Plant in Kuala Tanjung, all in North Sumatera Province, Indonesia. The Installed capacity of HEPP is 603 MW. The aluminium smelter consists of 3 pot-lines with 170 pots side by side arrangement in each pot-line. The pots are prebaked or improved Sumitomo’s SM-17 technology and the capacity has been improved from initial 225,000 tons of aluminium per year (tpy) to 250,000 tpy. In the future Inalum has plan to increase the production capacity up to 300 tpy by upgrading 1 potline joining with technology provider to reach 235 kA line current and optimize the existing reduction cell in 2 potline to reach 215 kA current by new pot design.

Since first production on 1982, Inalum has been done lots of improvement related to increase line current which significantly increasing metal production, with amount of produce metal can calculate by theoretical production based on Faraday’s Laws with:

\[ TP_{Al} = 0.3356 \cdot I \cdot t \]  

with the meaning of symbols:

TP is theoretical consumption (kg), I is electric current (kA), t is time (h)
 Normally Inalum has been operating reduction cell in 196 kA with latest pot design D3-3, D5-1 and D5-2 with molten production up to 250 ktpy. New design is considered to increase production capacity by increasing the line current by new pot design and reach stable operation in 215 kA line current. Using Ansys software, thermal behavior of new pot design can be observed and seek for potential improvement related to exiting design with some software simulation before doing some test to see the feasibility of new design.

2. Proposed improvement for new design
Some modification with existing D5-1 pot design to improve new design with modification

2.1. Split half cathode bar

Stability in the pot is related to interaction between the horizontal current and the magnetic field, which produces the electromagnetic force and promote the fluctuation of liquid aluminium. Horizontal current affect the metal movement in pot and cause the bad stability. When pot started in noise condition, voltage...
will up to countermeasure noise in the pot. The consequence of additional voltage is more heat generation in the pot and melts crust in side ledge. Bad effect of the melting side ledge can trig the bath/metal leakage [2]. To prevent the horizontal current, the cathode bar is split into 2 pieces with dimension 2285.2 x 220 x 155 mm/piece in the middle of cathode block and fill the ± 170 mm empty gap by cast iron.

2.2. Change some ramming paste to SiC ramming block
SiC ramming block has higher thermal conductivity than ramming paste which can conduct heat in reduction cell better. Increasing of heat loss from sidewall will form the better side ledge and prolong pot life. The dimension of SiC ramming block for pot design is 400 x 252 x 445 mm.

Figure 3. Existing cathode and new design.
2.3. **Longer castable C13N at cathode edge**

Horizontal current is minimized by removing the electric current from edge of cathode through the addition of the length of the C13N castable insulator. The dimension of castable C13N for pot design 200 x 270 x 170 mm.

![Figure 4](image)

**Figure 4.** Existing pot lining and additional ramming block.

![Figure 5](image)

**Figure 5.** Additional C13N castable.
2.4. Additional 1 layer brick B-1

![Figure 6. Additional brick B-1 layer.](image)

3. Steady state thermal analysis by Ansys R19.1

Bath temperature is assumed with by 960 °C with thermal conductivity value is set according to each pot lining material in table 1.

| Cell Parts                | W/mm.ºC | Cell Parts                | W/mm.ºC |
|---------------------------|---------|---------------------------|---------|
| Pot Cell/Structural Steel | 0.0605  | Cathode Block             | 0.11    |
| Superwool                 | 0.0002  | Cathode Bar               | 0.0655  |
| Solid Bath                | 0.0012  | Cast Iron/Cathode         | 0.046   |
| Fire Brick SK-32          | 0.00141 | Castable CA 13NI          | 0.00089551 |
| Side Ledge                | 0.0012  | Castable CA 13I           | 0.00089551 |
| Rand Block                | 0.12    | Insulation Brick C1       | 0.000314  |
| Ramming Paste             | 0.008   | Insulation Brick B1       | 0.00019771  |
| Ramming Block             | 0.014   | Anode                     | 0.00343   |
| Non Asbestos Board        | 0.00016 | Anode Rod/Aluminium       | 0.14862  |
| Liquid Bath/              | 210     | Anode Stub/Steel          | 0.0605   |
| Liquid Aluminium          | 10      | Alumina Cover             | 0.035    |
| Castable HC-Al            | 0.0010234 |                           |         |

Based on the analysis result of Ansys R19.1 new pot design has side ledge temperature higher 16 ºC than existing pot design D5-1. The result is also shown the side wall temperature of new pot design is lower than existing pot design D5-1 with the higher cathode bar temperature in new pot design. Since the result is assumed by simulation, other simulation with thermal electric and magnetohydrodynamics analysis should be carried out before application test is done to ensure the analysis result and the new pot design pot performance.
Figure 7. Thermal analysis of side ledge existing and new design.
Figure 8. Thermal analysis of sidewall existing and new design.

Figure 9. Thermal analysis of cathode existing and new design.

4. Cost and benefit analysis

| No | Item                      | Unit | Amount (USD) | Remarks                      |
|----|---------------------------|------|--------------|------------------------------|
| 1  | Investment Cost           |      |              |                              |
|    | Additional Material       | USD/pot | 167         | Additional 224 kg Cast Iron  |
|    | USD/pot                   |       | 464         | Additional 601 kg Castable C13N |
|    | USD/pot                   |       | 1,565       | Additional 2800 pcs Brick B1 |
| New Material                | USD/pot | 2,334 | 71 pcs Ramming Block |
|-----------------------------|---------|-------|----------------------|
| New Equipment               | USD/pot | 3,000 | 2 set Magnetic Lifter 3T |
| 2 Potential Benefit         |         |       |                      |
| Production                  | kg/pot/year | 632  | Pot design with line current 215 kA |
|                            |         |       | (Additional production 56 kg/pot/year from pot design D5-1 with line current 196 kA) |

5. Conclusion
New pot design has side ledge temperature higher 16 °C than existing pot design D5-1. The result is also shown the side wall temperature of new pot design is lower than existing pot design D5-1 with the higher cathode bar temperature in new pot design. Other simulation with thermal electric and magnetohydrodynamics analysis should be carried out before application test is done to ensure the analysis result and the new pot design pot performance.

Reference
[1] Peter E 2014 Alcan Alesa Engineering Electrolysis Seminar : Theory of Aluminium Smelting
[2] Wangxing L 2014 Simulation and Optimization of Cathode Current Distribution to Reduce the Horizontal Current in the Aluminium Liquid Light Metal 2014