An Overview of Sohar Aluminium's Anode Baking Furnace Operation

The Sohar Aluminium anode baking furnace was commissioned in 2008, and furnace performance since has remained at excellent levels in terms of gas consumption, baking level, fire productivity, tar emissions and firing cycle range. Some of the challenges in achieving these results are discussed.

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Sohar Aluminium, a joint venture between Oman Oil (40%), Abu Dhabi Water and Electricity Authority (ADWEA) (40%) and Rio Tinto Alcan (20%) operates a greenfield aluminium smelter in the Sultanate of Oman.

This smelter, started in 2008, operates 360 reduction cells using AP 36 technology and produces an Aluminium tonnage of 374kt/y at current operating amperage of 370kA.

Over 200kt/y of carbon is needed to supply the 360 reduction cells. The carbon plant employs the latest AP technology and includes a 52 section gas fired horizontal baking furnace comprising three fires equipped with an Innovatherm firing system and operating at a 24 hour fire cycle at full capacity.

Furnace design characteristics

The Sohar furnace stands out from other furnaces through a number of innovative features that have led to excellent results. The Sohar furnace is characterised by the following specific points, namely:

- A section design with 9 pits and 10 flue walls per section.
- A efficient pit packing geometry to maximise the carbon amount in the pit.
- Innovative headwall expansion joints.
- A fluewall designed using proven modeling techniques.
- The ability to achieve required baking levels by the use of a 4th burner ramp on shorter cycles when necessary.
- The ability to operate at a fire cycle range of 24 to 36 hours by the application of a new process control methodology that favours optimum combustion.

These design characteristics in turn deliver a productivity level of 210kt baked anode with three fires. They reduce the

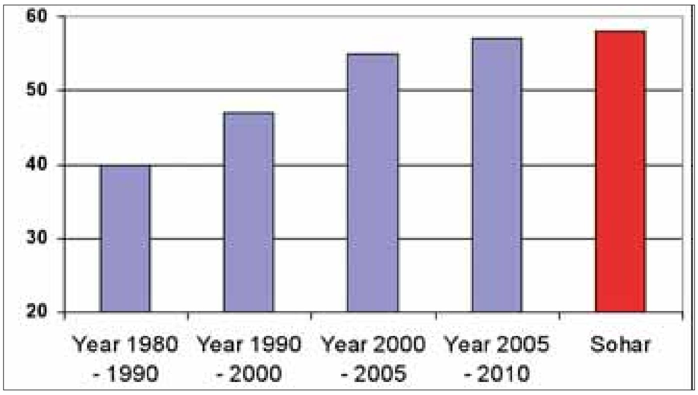

Fig 1 Ratio anode weight/refractory and insulation weight

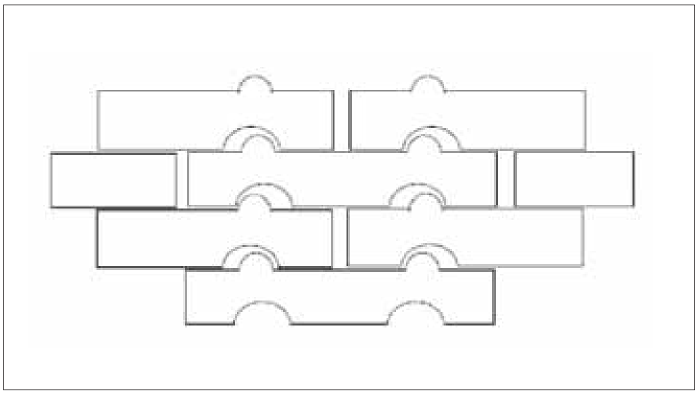

Fig 2 Headwall expansion joint design concept

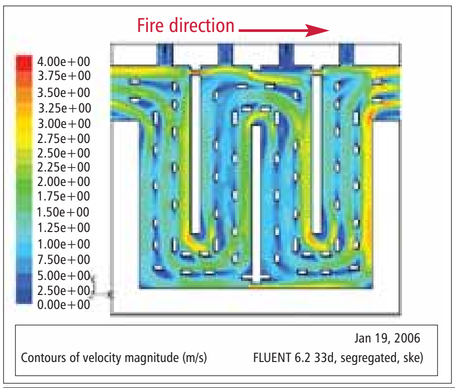

Fig 3 Sohar Modeled Flue Design

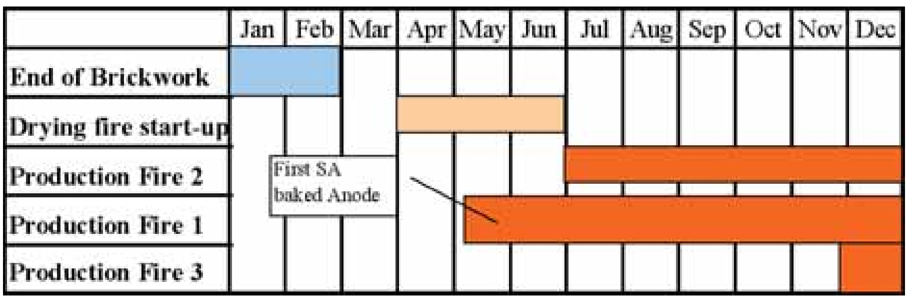

Fig 4 (above) Planning of the furnace start-up

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Fig 5 (above) View of the Sohar baking furnace

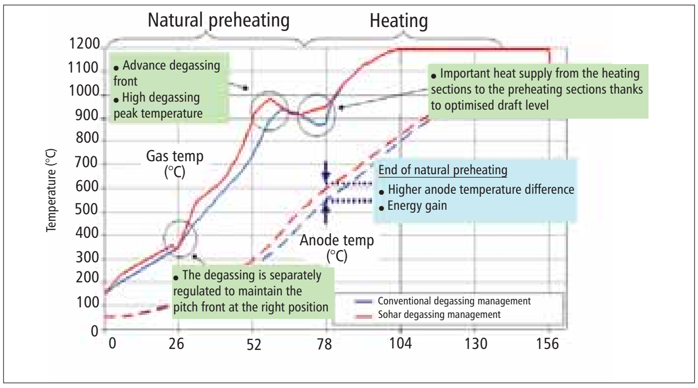

Fig 6 Comparison of heating curves to the new methodology

Fig 7 Volatile matter combustion

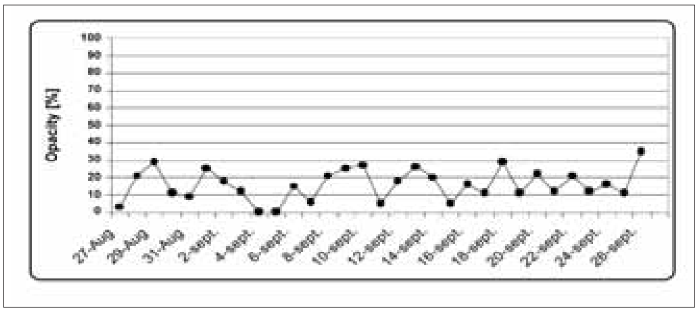

Fig 8 Exhaust ramp opacity results

Fig 9Internal condition of collector duct

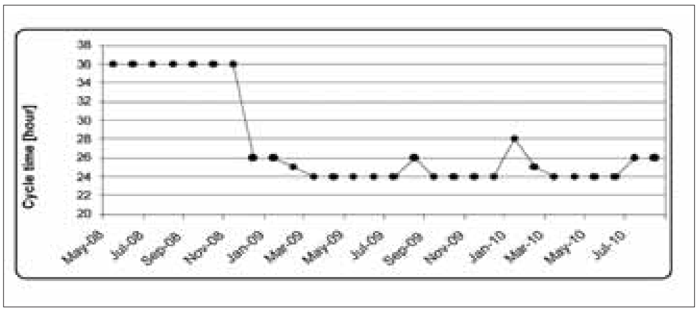

Fig10 Firing cycle evolution

Fig11(right) Refractory condition after 40 fire cycles

ground surface area to approximately 150m by 35m and minimise the capital expenditure.

The 9-pit configuration and the optimized pit sizes lead to a high anode/refractory ratio. This ratio is a measure of the refractory impact on energy consumption[1].

Fig 1 presents the evolution of this ratio from 1980 until today for open type AP baking furnaces. Sohar has the highest ratio, which contributes to low energy consumption in the furnace.

The 9-pit configuration also results in a long headwall which increases the risk of distortion in the event of uncontrolled expansion. An innovative headwall expansion joint design[2] (**Fig 2**), limits the

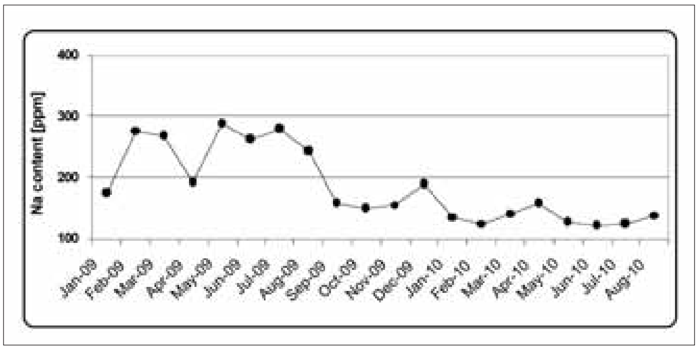

Fig 12 Sodium content in baked anodes

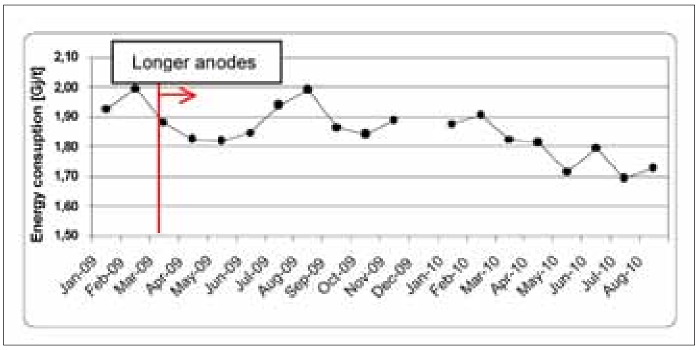

Fig 13 Furnace energy consumption

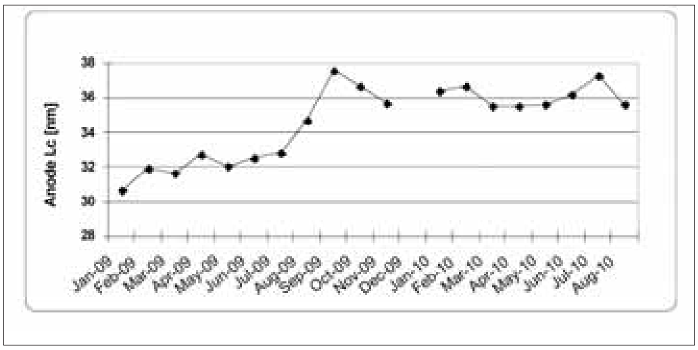

Fig 14 Baking level results

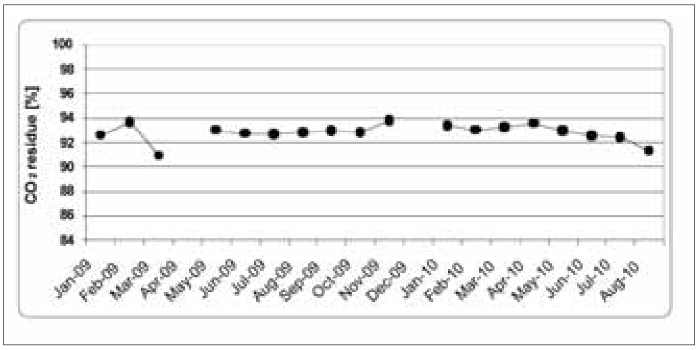

Fig 15 CO_2 reactivity residue

elongation of the headwalls, while at the same time allowing for brick expansion. Moreover, these joints are designed to protect against the infiltration of packing coke. The fluewall design was developed using a computational fluid dynamics model[3] to ensure baking level homogeneity (**Fig 3**).

Furnace Start-up

Furnace drying commenced in the April 2008 and was immediately followed by the start-up of the 1st production fire. The drying fire was then converted into the 2nd production fire.

The final fire was started in November 2008 in accordance with line needs and at the end of 2008 all three fires were in operation (**Fig 4**).

An overall view of the furnace is shown in **Fig 5**.

Operational Overview

The Sohar Anode Baking Furnace is one of the most efficient and environmentally friendly furnaces in operation. Application of a new fire process control methodology ensures quicker and more long-lasting achievement of performance levels, superior to that of other furnaces with the same characteristics.

The new methodology developed at Sohar ensures a complete and effective combustion of the volatile matter and injected fuel. The entire energy potential generated by volatile matter and injected fuel is recovered regardless of the cycle (24 to 36h).

This methodology demonstrates significant advantages when compared to furnaces applying a conventional process. These advantages are detailed as follows.

Principle

In a conventional horizontal baking furnace process, irrespective of the technology used, part of the volatile matter from the anodes and, in some cases, injected fuel partially escapes with the fumes.

Residue of the unburnt matter may then be deposited on the collector walls, and there is a loss of potential heating value requiring compensation by the amount of injected fuel necessary to reach final anode temperatures and soaking times.

Optimum operation of the conventional process depends on a sensitive balance of the combustion of the volatile matter in the preheat zone and the injected fuel in the forced heating zone of the furnace

The methodology applied to the Sohar furnace allows the control of both combustion zones separately. This separation makes it possible to:

- Ensure sufficient oxygen level for both combustion zones at all times regardless of the duration of the firing cycle
- Ensure complete combustion of the volatile matter released by the anodes from a temperature of >200°C by having the circulating gas in the flue walls at temperatures >700°C in the preheat zones.

A comparison on the conventional heating curves to the new methodology is shown in **Fig 6**.

The sustainable complete combustion of the volatile matter achieved by the new methodology (**Fig 7**), as opposed to a conventional methodology, results in the following benefits:

- Improved furnace energy efficiency, leading to a reduction in the fuel quantity needed to achieve the same anode baking level.
- Improved environmental performance by ensuring that volatile matter is completely burnt inside the flue walls, thus reducing emissions limiting carry over and condensation of volatile matter in the collector duct work and fume treatment centre.

A complete inspection of the fume treatment centre completed every 6 months confirms this satisfactory control of the process. Minimal combustion residues or soot has been detected since the start up of the furnace. **Fig 8** shows the good opacity control measured at the exhaust ramp on one of Sohar fires.

Fig 9 shows the condition of the collector duct leading to the fume treatment centre after two years of operation with no requirement to perform regular cleaning.

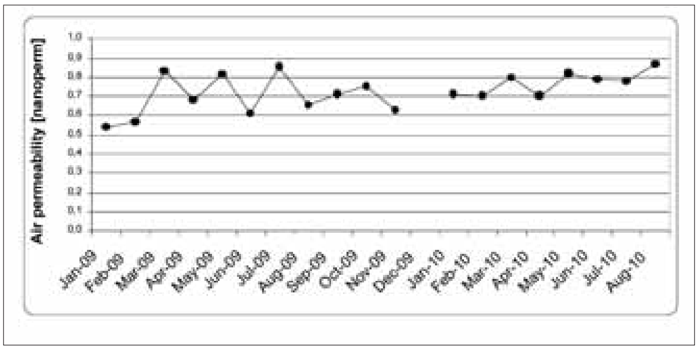

Fig 16 Air permeability

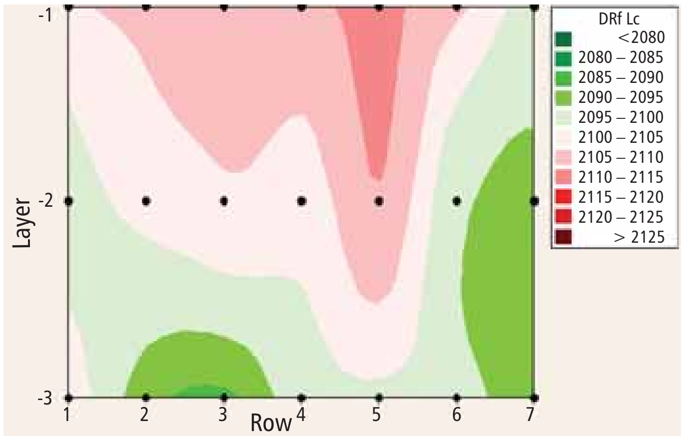

Fig 17 Baking level pit profile

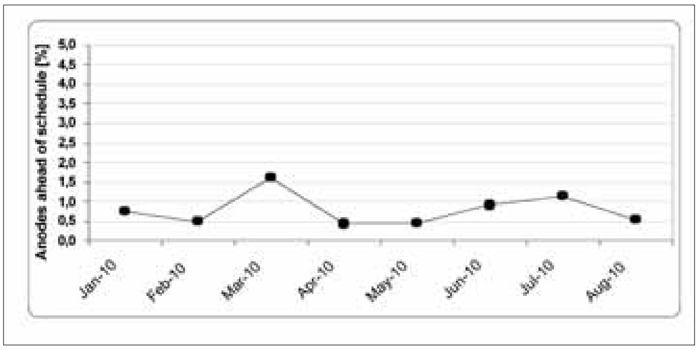

Fig 18 Anode ahead of schedule results

Reduction line performance

The anodes have performed very well in the reduction lines with an absence of dusting since the beginning at high amperage and very low ahead of schedule rates <1% (**Fig 18**). Net carbon consumption is consistently <415kg/t.

Firing Cycle Flexibility

The baking cycles have been adapted to satisfy the reduction line start up needs from the 1st to the 360th cell. **Fig 10** shows the evolution of the firing cycle times since start up. The Sohar operation is not limited by firing cycle duration with the flexibility to operate at either long or short firing cycles. The degassing front position was perfectly controlled while guaranteeing the combustion of the volatile matter and of the fuel injected by the ramps.

This is due to be able to combine the new process control methodology and to make targeted use of a 4th burner ramp for a few hours at the end of the cycle for the shorter cycles to ensure that final anode baking temperature and corresponding baking levels are achieved.

Refractory

The current flue wall age currently is in the vicinity of 40 fire cycles (August 2010). The condition is shown in **Fig 11**. At present there are no signs indicating any early deterioration of the furnace, leading to a predicted life expectancy beyond 170 fire cycles.

A number of factors contribute to the increasing flue wall life span. The first factors are furnace design and the quality of the bricks used.

This is followed by the low sodium level in the anodes, which has been consistently maintained below 200ppm (**Fig 12**), homogenous combustion in the flue walls eliminating localised over heating, and sealing carried out after each fire move.

Energy consumption

All these elements have resulted in the Sohar furnace achieving an average energy consumption level of 1.9 GJ/t baked anode despite a high baking level (Lc >34 A). Further improvement in 2010 has reduced the consumption to 1.8 GJ/t baked anode (**Fig 13**).

The current gas consumption is close to the theoretical gas consumption calculated with a thermal balance model[1].

The theoretical gas consumption considers that all volatile matter has burnt and has recovered this energy to bake the anodes.

Technical Performance Overview

The Sohar furnace has achieved world class performance on a number of technical indicators detailed as follows:

Baking level: Baking levels (**Fig 14**) have been maintained at a level comfortably above the minimum required to ensure a high anode quality resulting in good performance in the cell.

Anode reactivity: Anodes exhibit excellent reactivity. Carbon dioxide (**Fig 15**) and air reactivity residues are above 92% and 80% respectively. The electrical resistivity is lower than 54.5μΩ.m and the air permeability (**Fig 16**) is very good and had an average of <1 nanoperm.

Baking homogeneity is excellent. The modeled flow patterns for the flue design shown in **Fig 3** results in a homogeneous pit profile expressed in real density from the operating furnace (**Fig 17**).

Conclusion

A combination of design, operational and process performance has demonstrated the capability of the Sohar Aluminium anode baking furnace to:

- Deliver a furnace capable of productivity level of 70kt baked anode per fire group.
- Control both combustion zones to ensure complete combustion of all volatile matter coming from the anodes and the injected natural gas at long and short fire cycles.
- Deliver a high standard of baked anode quality with benchmark gas consumption.

The quality of the baked anode supplied to the reduction line has ensured that no dust generation has occurred so far in the cells. This excellent performance and production capacity opens a new way forward to meet the needs for large and efficient furnaces necessary for high amperage reduction cell anodes.

References

1: J.Bigot, M.Gendre, JC. Rotger, "Fuel Consumption : a key parameter in anode baking furnace" Light Metals (2007).

2: International Patent Application WO 2007/006962, "Chamber setting with improved expansion joints and bricks for making same".

3: J.C Thomas, P. Breme, J.C. Rotger, F. Charmier, "Conversion of a closed furnace to the open type technology at Aluminium Bahrain", Light Metals 1999