

DX cell technology at 400 kA and beyond

Rawa Ba Raheem¹, Arvind Kumar², Sergey Akhmetov³

1. Lead Engineer, Process Control, Reduction

2. Senior Manager, Process Control, Reduction

3. Vice President, Reduction

Emirates Global Aluminium (EGA) Jebel Ali (DUBAL)

Corresponding author: rbaraheem@ega.ae

Abstract

Potline 8 at Dubai Aluminium (DUBAL), which comprises 40 DX Technology pots, was started-up in March 2008 at 350 kA. In June 2014, Potline 8 achieved a major milestone of successfully reaching 400 kA through set of modifications made to the working practices, pot lining material, pot shell and anode designs all of which allow for smooth operation in spite of higher anode current density. Potline 8 has operated at 402 kA since February 2015. This paper summarises the performance of the DX cells during the period of increasing from 390 kA to 402 kA. During the whole period of operation, the metal production per pot day increased from 2 980 kg/pot-day to 3 070 kg/pot-day and the specific energy consumption reduced from 13.24 kWh/kg Al to 13.14 kWh/kg Al, while current efficiency was maintained at almost 95 %. The successful results were accompanied by excellent sustainable performance in the environment aspects as well; necessary changes in the process were induced to prevent any increase in PFC emission with amperage increase.

Keywords: DX pot technology; amperage increase; DX pot performance.

1. Introduction

DUBAL has developed DX Technology in-house, which currently operates in DUBAL Potline 8 (40 cells) at 402 kA and in EMAL Potlines 1 and 2 (756 cells) at 388 kA. Recently the number of cells in DUBAL Potline 8 was increased to 44. Potline 8 is located at the end of Potline 6, which currently operates at 253 kA and supplies the same to Potline 8; the rest of the current is provided by four booster rectifiers with a maximum capacity of 50 kA each. The booster rectifiers were designed to allow for increasing the amperage to the desired level and to explore operation at higher amperages while adjusting the pot operating parameters and operation practices. This paper presents the results for DUBAL Potline 8.

The DX cells in DUBAL Potline 8 were started in March 2008 at 350 kA. The amperage of these cells was increased thereafter, reaching 380 kA on 28 October 2010 and 390 kA on 24 December 2013. In June 2014, DUBAL Potline 8 achieved a major milestone of successfully reaching 400 kA. After a demonstration of excellent results over nine months, amperage was further increased and reached 402 kA by the end of February 2015. Figure 1 shows the history of potline amperage and cell net voltage of DUBAL Potline 8.

2. DUBAL Potline 8 DX performance

The operational performance of DUBAL Potline 8 has been reported earlier [1, 2]. In this paper the performance at amperages from 390 kA to 402 kA is analysed in detail. The DX key performance indicators (KPIs) are given in Table 1. The performance was excellent throughout the whole period. As DUBAL Potline 8 had a combination of different linings and pot shell designs, the KPIs for DX Technology are listed at different stages of amperage increase in Table 1 and for different cathode designs later on in Paragraph 6.

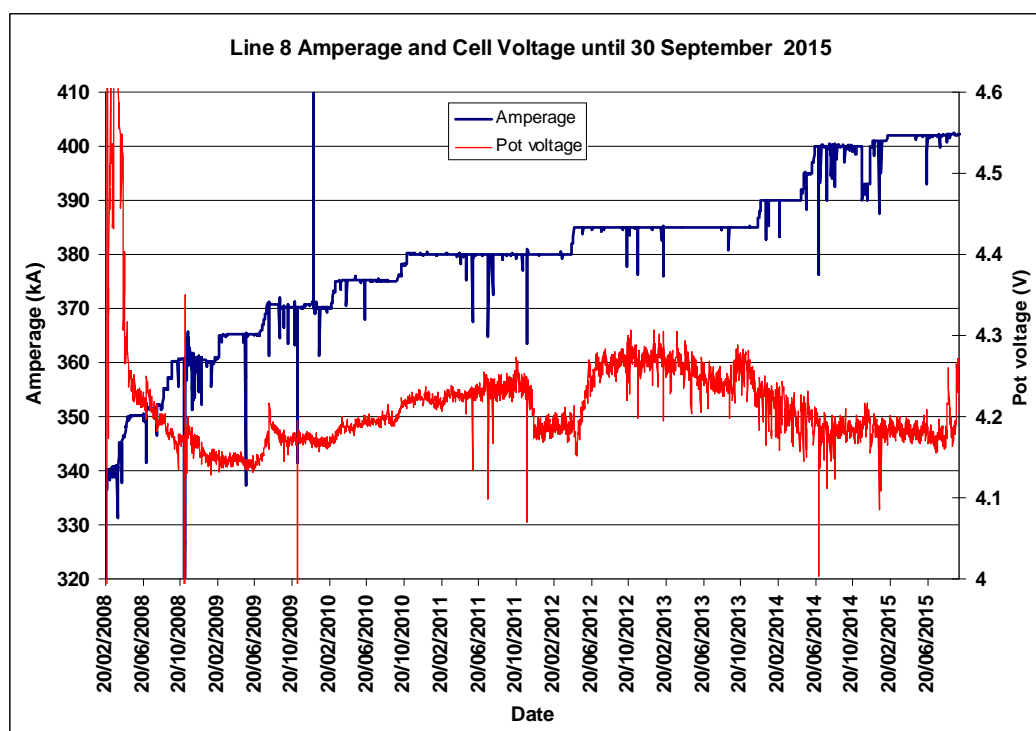


Figure 1. Historical evolution of DUBAL Potline 8 amperage and net cell voltage.

Table 1. Key performance indicators for DUBAL Potline 8 DX cells.

Parameter	Unit	Jun '08 to Sept '15	Jan '14 to May '14	Jun '14 to Feb '15	Mar'15 to Sept '15
Amperage	kA	380.9	390.6	399	401.9
Current efficiency	%	94.9	95.1	94.9	94.3
Metal production	kg/pot-day	2 912	2 991	3 048	3 051
Cell voltage	V	4.20	4.20	4.18	4.18
DC net specific energy	kWh/kg Al	13.19	13.21	13.13	13.20
Net carbon cons.	kg/t Al	414	416	402	407
Gross carbon cons.	kg/t Al	534	559	509	521
Fe	%	0.046	0.067	0.039	0.041
Si	%	0.026	0.026	0.024	0.025
Bath temperature	°C	961	964	962	966
Excess AlF ₃	%	9.9	10.4	10.1	10.1
AE Frequency	AE/pot-day	0.057	0.070	0.083	0.094
AE Duration	s	18	7	10	9
PFC Emission, CO ₂ Equivalent*	kg/tAl	19	9	15	15

*CO₂ equivalent is calculated as in [3], using the Tier 2 method and SAR (Second Assessment Report) of Intergovernmental Panel on Climate Change (IPCC).

3. Modifications for further improvement and amperage increase of DX Technology

3.1. DX Technology potshell design modifications

The objective of modifying the DX Technology potshell was to allow for further amperage increase by increasing the sidewall heat loss and reducing the pot shell weight. The

Generation 1 (G1) potshell had I-beam cradles, spot-welded to the shell and bolted to a wide deckplate. There were two short cooling fins between the cradles. With initial amperage increases, some holes were made in the deckplate for better air circulation, but this was not enough for further amperage increases. The modified potshell, called Generation 2 (G2), had the following features:

- The I-beam cradle was made a T-beam at the metal and bath level by cutting off the inner wing of the I-beam. The cradle was then welded to the shell and to the deckplate in the modified part. The rest of the cradle remained as in the G1 potshell.
- The deckplate was made narrower than G1 potshell.
- The two short cooling fins were replaced by five longer ones.

DUBAL pot replacement is very rapid, with minimum time between the cut-out and replacement with a new cell. The G2 potshells were not all ready at the time when they were required. Therefore, with the objective of not losing metal production, some G1 pot shells were used. Some of these underwent a quick fix of replacing the two short fins with three longer ones, but retaining the G1 cradles and deckplate with some additional holes cut in the deckplate; these are called modified G1 potshells.

All these potshell designs are now in operation in DUBAL Potline 8. 30 cells have G2 potshells and 14 cells have G1 or G1 modified potshells, with a few variations within the latter group.

Modelling analysis determined that the G2 potshells lose 18 kW more heat per pot than G1 potshells, but they primarily lower the potshell temperature. Figure 2 shows the measured maximum potshell sidewall temperature, which is at the metal level, for the different potshell designs. G2 potshells have 58 °C lower maximum sidewall temperature than G1 potshells and 9 °C lower than G1 modified potshells. The number and design of the cooling fins clearly fulfil their role of lowering the potshell temperature.

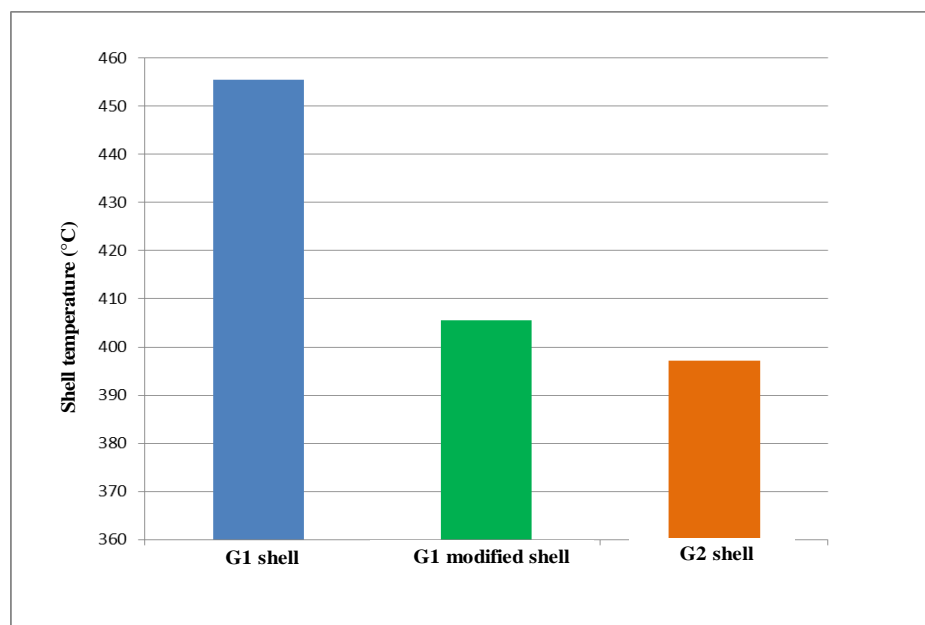


Figure 2. Average maximum sidewall potshell temperature for different potshell designs.

3.2. DX Technology potlining modifications

Potlining designs were also optimised for higher amperage and lower energy consumption. New ideas and a tight cell replacement schedule resulted in several potlining designs. The

most common, G2 lining (32 cells) has the following differences compared to the original G1 lining:

- Collector bars are rectangular instead of round in G1 lining,
- Along the blocks, some cells have a split collector bar with a no-steel gap near the centre axis of the cell; some cells retained the continuous bar of G1 lining.
- The thickness of the sidewall and endwall SiC block was decreased by 16 mm; this enabled an increase in anode length.
- The height and thickness of the side and endwall carbon insert was modified.
- A few cells have copper inserts in the collector bars, designed in a novel way, as part of low voltage initiatives discussed in an earlier paper [4]. These cells have G1 or G2 potshell, G2 lining or modified G2 lining. The latter have more sidewall insulation and a one-layer bottom insulation slab, instead of the more common two layers of high density and low density vermiculite.
- A few cells have profiled cathode blocks, where some blocks are taller than others.

Various combinations of different potshell designs and lining designs are operational in DUBAL Potline 8. The facility continues to be a test bench for amperage increase and low energy consumption for DX Technology in EMAL's Potlines 1 and 2.

3.3. DX Technology anode size modifications

The purpose of optimising the anode size in DUBAL Potline 8 was to support amperage increase as well as maintain gross carbon consumption. The anode length was increased several times coincident with amperage increases, altogether by 2.8 % in one half of the potline and on trial basis by 3.7 % in the other half of the potline, somewhat more towards the sidewall than towards the centre channel. Top anode chamfer was also introduced for longer anodes. This gave better distribution of anode cover material across the anode surface and better protection of the stubs and cast iron. Additionally, anode slot heights were increased coincident with amperage increases.

4. Work practices

The anode setting pattern was changed during 2012 from a double-step pattern to a single-step pattern. This allowed for a more uniform material distribution on the top of the anodes and also contributed to better control of the thermal balance. At higher amperages, the bath height was also strictly controlled, which is clearly reflected by the consistency of iron concentration in the metal (as shown in Figure 3). The iron concentration in early 2014 was above the upper control limit of 0.06 % because the potline still had first generation pots, which were cut out only when the iron concentration in the metal was typically 0.3 to 0.4 %. These pots contributed to higher overall average of iron concentration in the metal.

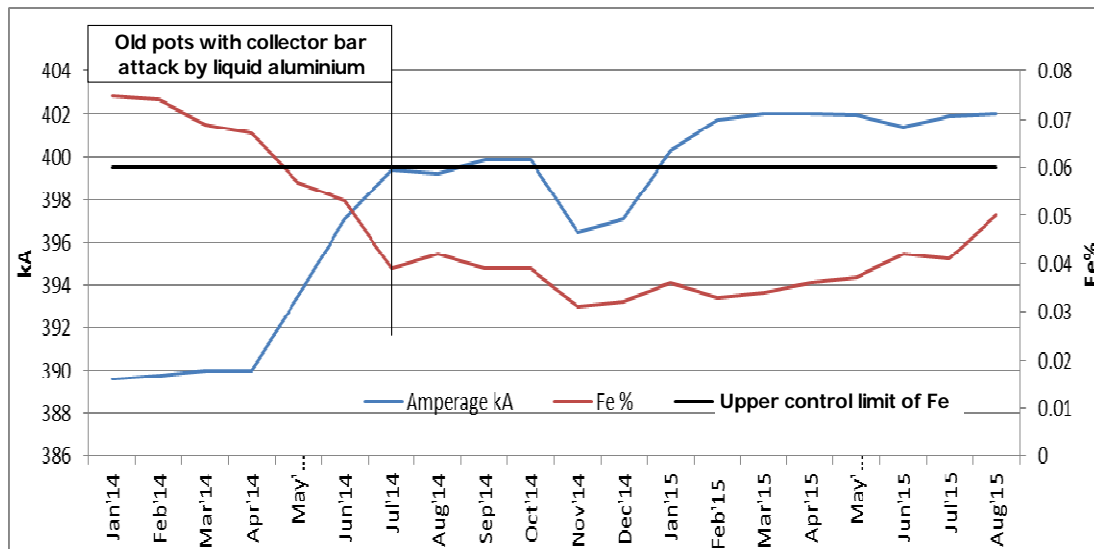


Figure 3. Amperage vs. iron content in metal.

5. Strategy for amperage increase in DX Technology cells

The strategy for the amperage increase from 390 kA to 402 kA was based on one of the following approaches:

- Constant anode-to-cathode distance (ACD);
- Constant voltage;
- Constant internal heat (net heat in the cell).

The decision on the approach applied was based on the freeze thickness according to the different lining and pot shell designs in DUBAL Potline 8.

The amperage increase from 390 kA to 400 kA was done in a series of steps, starting with a 2 kA increase from 390 kA to 392 kA with constant voltage for all the different designs. The internal heat was increased by 3 kW and henceforth this would be compensated by the changes in the freeze thickness. The second step involved increasing the amperage from 392 kA to 395 kA. In this step, the cells' G1 lining was kept at the same voltage as before, but for the G2 lining the constant ACD strategy was followed. During amperage increase from 395 kA to 400 kA, longer anodes were introduced and the constant ACD strategy was adopted. The challenge was to adjust for the thermal parameters of the different designs. Therefore, for ease of operation, the designs were grouped in three categories with different anode cover thickness targets.

6. Performance of different cell designs.

The pot performance parameters for the three different cathode design groupings are given in Table 2. The performance of the groups is similar, except for specific energy consumption which in the third group is 0.45 kWh/kg Al lower than the other two groupings. The lower voltage of Pot 41 takes full advantage of the cathode voltage drop reduction due to the copper insert and additionally has the ACD squeezed by slightly more than 2 mm with respect to the G2 lining + G2 shell pots; yet the current efficiency is only marginally lower. This shows the potential for lowering the pot voltage and energy consumption on other pots, too.

The minimal difference between the G1 and G2 pots shows that the pot operation and control parameters were well adjusted for optimal performance in each group. The G2 pots are, however, able to sustain higher amperage than G1 pots, which will be an advantage when the amperage is increased further. The next step is to increase the amperage to 405 kA before the

end of the year 2015. At the same time, the full potential of reduced cathode voltage drop will be implemented on G2 lining + G2 shell pots and copper insert pots.

Table 2. Key performance indicators for DUBAL Potline 8 DX cells by cathode design groups from 1 October 2014 to 30 September 2015.

Parameter	Unit	G1 lining+ G1 shell	G2 lining+ G2 shell	Pot 41 (Cu insert)
Number of cells		4	21	1
Amperage	kA	400.7	400.7	400.7
Current efficiency	%	94.80	94.7	94.5
Metal production	kg/pot-day	3 058	3 057	3 050
Cell voltage	V	4.19	4.19	4.04
DC net specific energy	kWh/kg Al	13.19	13.19	12.74
Net carbon consumption*	kg/t Al	405	405	405
Gross carbon consumption*	kg/t Al	512	512	512
Fe	%	0.034	0.039	0.052
Si	%	0.024	0.026	0.027
Bath temperature	°C	964	964	961
Excess AlF ₃	%	9.9	9.9	10.5
AE Frequency	AE/pot-day	0.13	0.07	0.12
AE Duration	s	5	8	8
PFC Emission, CO ₂ Equivalent**	kg/t Al	12	10	17

*Gross and net carbon consumption is not followed separately by cathode design groups. The values given are for the whole potline.

**CO₂ equivalent is calculated as in [3], using the Tier 2 method and SAR (Second Assessment Report) of Intergovernmental Panel on Climate Change (IPCC).

7. Conclusions

In DUBAL Potline 8, the amperage of the DX Technology cells has been successfully increased to 402 kA while maintaining excellent pot performance. Different cathode designs did not affect the performance, since the pot operation and control parameters were properly adjusted for each group. Increasing anode length helped the amperage increase. The new cathode designs will have an advantage when amperage is increased further in the near future.

8. References

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