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ADVANCEMENTS OF DUBAL HIGH AMPERAGE REDUCTION CELL TECHNOLOGIES

Michel Reverdy[1], Abdalla Zarouni[1], Jean-Luc Faudou[1], Qassim Galadari[1], Ali Al Zarouni[1], Sergey Akhmetov[1], Kamel Al Aswad[1], Maryam Al-Jallaf[1], Walid Al Sayed[2] and Vinko Potocnik[3]
[1]Dubai Aluminium (DUBAL), PO Box 3627, Dubai, UAE
[2]Emirates Aluminium Company (EMAL), PO Box 111023, Abu Dhabi, UAE
[3] Vinko Potocnik Consultant Inc., 2197 rue de Régina, Jonquière, Québec, Canada, G7S 3C7

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Abstract

During the past 10 years DUBAL successfully developed its proprietary high amperage DX and DX+ cell technologies that have shown excellent performance. The 40 DX demonstration cells at DUBAL currently operate at 385 kA and the five DUBAL DX+ demonstration cells have been operating at 440 kA since March 2012. Following the commissioning of a sixth rectiformer, EMAL potlines 1 and 2 have increased the amperage of the DX cells to 380 kA. This paper summarizes the performance of both DX and DX+ cells at DUBAL and EMAL. EMAL Potline 3, currently under construction will total 444 DX+ cells with a potline voltage of 2000 V. DUBAL has recently developed a new pot control system (PCS) based on standard PLC hardware architecture which has been selected for EMAL Potline 3. As part of DUBAL's culture of continuous improvement, further development is in progress towards lower energy consumption, lower PFC emissions and lower capital expenditure.

Introduction

DUBAL has developed proprietary DX and DX+ technology [1-6]. DX cells operate in DUBAL Potline 8 and in EMAL potlines 1 and 2. The DX cells at DUBAL started at 350 kA and now operate at 385 kA. EMAL started the cells at 350 kA in 2010, began increasing amperage in January 2012 and reached 380 kA at the end of September 2012. DX cells at DUBAL and EMAL maintained their outstanding performance at increased amperage. The results are described below.

Five DX+ cells were started in July and August 2010 at 420 kA and achieved steady performance from November 2010. By the end of 2010, DX+ cell technology was chosen for EMAL Phase 2 project (Potline 3). After demonstration of excellent long term results, amperage increase was started at the end of July 2011 reaching 440 kA by the end of February 2012. The operational performance at 420 kA, during the amperage increase period and during steady operation at 440 kA is reported below.

DUBAL has developed its own proprietary cell control system, comprising microcomputer based DCCU (DUBAL Cell Control Unit) and cell control software [7]. DCCU has been progressively installed since 2005 in DUBAL and in DUBAL licensed smelters with 1276 cells equipped as of September 2012. DCCU maintenance is ensured by the DUBAL IT Department. Recently, a further hardware system, based on standard PLC (Programmable Logic Controller), has been developed and installed on the five DX+ demonstration cells. It has been also selected for EMAL Potline 3. The main characteristics of the PLC based control system will be described in this paper.

DX and DX+ Performance at Increased Amperage

The DX and DX+ key performance indicators (KPI's) exceeded expectations at their base and increased amperage. Tables I and II show the KPI's for DX and DX+ technology, respectively.

Table I. KPI's of DUBAL DX Technology.

KPI	Unit	DUBAL Potline 8	EMAL Potlines 1 & 2	
		Nov'10 to March'12	Jan'11 to Dec'11	Jan'12 to Sept'12
Amperage	kA	379.9	351.4	362.8
Current Efficiency	%	95.2	96.1	95.7
Metal Production	kg/pot-day	2911	2717	2795
Volts per Cell	V	4.22	4.21	4.21
DC Specific Energy	kWh/ kg Al	13.21	13.05	13.11
Net Carbon	kg/kg Al	419	416	415
Fe	%	0.042	0.045	0.045
Si	%	0.028	0.032	0.030
AE Frequency	AE/pd	0.054	0.17	0.17
AE Duration	s	10	36	11
PFC Emissions, CO_2 Equivalent*	CO_2 kg/ t Al	10	111	34

* CO_2 equivalent is calculated as in Reference [6], using the Tier 2 method and SAR (Second Assessment Report).

In Table II, the actual cell voltage and corresponding specific energy consumption are corrected for the expected improvements due to design changes in the industrial DX+ cells with respect to demonstration cells, which include larger cross-sections of busbars and of cathode collector bars. A substantial voltage gain has been obtained with the introduction of four-stub anodes at the end of 2011 with respect to three-stub anodes used previously. This clarifies a different voltage correction for DX+ industrial cells for the three periods given in Table II.

Excellent performance has been maintained with amperage increase in DX and DX+ cells. Current efficiency has somewhat decreased with amperage, but it is difficult to tell if different ages of the pots also contributed to this. Nevertheless, amperage increase has given a significant increase in metal production. As per normal procedure at DUBAL, the metal purity is excellent in

DX potlines at DUBAL and EMAL and DX+ demonstration cells at DUBAL, with low iron and silicon content, which did not deteriorate with amperage increase. Low iron content shows excellent bath height control, appropriate anode butt height and good anode cover practices. Anode effect frequency and duration are excellent in DX Potline 8 and DX+ cells and are still improving. In EMAL, the anode effect frequency improved significantly after implementation of the same control system improvements as in DX and DX+ at DUBAL in May/June 2012. During the past three months (July – September 2012), the anode effect frequency and duration at EMAL were 0.07 AE/day and 11 seconds, respectively. This gives outstanding CO_2 equivalent of PFC emissions for DX and DX+ technologies [8].

Table II. KPI's of DUBAL DX+ Technology.

KPI	Unit	Dec'10 to July'11	Aug'11 to Feb'12	Mar'12 to Sept'12
Amperage	kA	419.6	430.2	439.7
Current Efficiency	%	95.1	94.9	94.5
Metal Production	kg/pot-day	3214	3291	3345
Volts per Cell	V	4.22*	4.22**	4.24***
DC Specific Energy	kWh/ kg Al	13.22*	13.25**	13.37***
Net Carbon	kg/kg Al	407	412	404
Fe	%	0.040	0.039	0.043
Si	%	0.028	0.029	0.028
AE Frequency	AE/pd	0.191	0.085	0.071
AE Duration	s	9.6	10.3	10.1
PFC Emissions, CO_2 Equivalent****	CO_2 kg/ t Al	33	16	13

*Based on 4.35 V actual minus 0.13 V for design changes in the industrial version of DX+.
**Based on 4.32 V actual minus 0.10 V for design changes in the industrial version of DX+.
***Based on 4.31 V actual minus 0.07 V for design changes in the industrial version of DX+.
****CO_2 equivalent is calculated as in Reference [6], using the Tier 2 method and SAR (Second Assessment Report).

Further Improvements of DX and DX+ Technologies

DX Potshell Optimisation

The purpose of optimising the DX potshell was to increase the sidewall cooling and to decrease the potshell weight without any decrease of potshell strength. Sidewall cooling was increased through enhanced air circulation by using a narrower deckplate and by welding the cradles to the potshell. The mass of the DX optimized potshell was reduced by 21 %; nevertheless, the strength was not decreased due to improved mechanical characteristics of the fully welded potshell when compared with the previous potshell using tack welded cradles and a bolted deckplate. This potshell was designed using mathematical models [9] and initially tested on one modified DX cell in DUBAL Potline 8 under the project name 'DX Step 1'. Subsequently the same design was used on the DX+ cells but with additional cooling fins than on the original DX standard and DX Step 1 cells. In spite of increased potshell area by 12 % in DX+ cells, the potshell mass decreased by 17 %, compared to the original DX potshell.

Measurements confirmed the decrease of the sidewall temperature of the new potshell design. Figure 1 shows the average maximum sidewall potshell temperature for an original DX cell and an optimized one with the same number of cooling fins. The maximum potshell temperature, which occurs at metal pad level, decreased by 18 °C and by more than 50 °C at other specific times. The high potshell strength was confirmed by small deformation, which has been reported in a separate DUBAL paper [9].

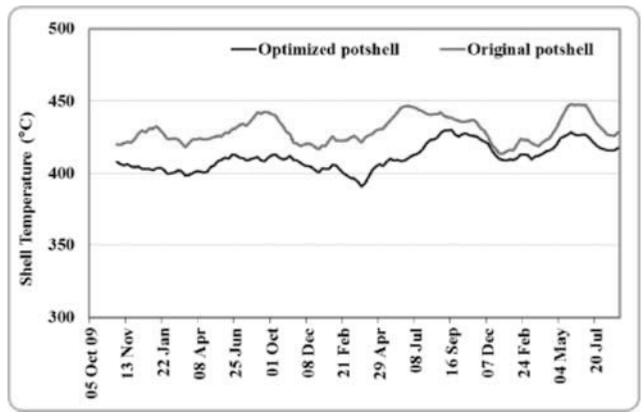


Figure 1. Maximum sidewall potshell temperature of an optimized DX potshell, compared to an original DX potshell.

Following the successful design of the DX+ potshells, a second generation of the DX potshells was also designed and tested in Potline 8. In this design the modifications to the original potshell were made only to the upper part of the existing potshell and the deckplate including additional cooling fins. The benefits in terms of heat loss and potshell temperature on the upper sidewall are even greater than described above for the DX Step 1 potshell because of the additional cooling fins; the maximum potshell temperature decrease is 51 °C with respect to a standard DX potshell. These modifications can be implemented at the time of potlining replacement.

Busbar Optimisation

The purpose of the busbar design optimisation of DX and DX+ cells was to accommodate smaller cell-to-cell distance and to decrease busbar weight and busbar voltage drop. In this process, the busbar arrangement was not changed and the busbar current distribution was kept the same as in the current design, in which it is well balanced, resulting in good cell stability. The results of busbar optimisation are: decrease of cell centreline distance by approximately 5 %, reduction of busbar weight by 20 % and reduction of busbar voltage drop by 26 %.

Superstructure Optimisation

The DX+ superstructure was redesigned due to a greater cell size compared to DX and was also optimised. The space occupied by the superstructure was better utilised for alumina bins and for cell gas collection and suction. The superstructure height was lowered by more than 400 mm and in spite of its increased size, its mass was decreased by 12 % with respect the original DX cell superstructure.

Busbar and Potshell Supports
DX+ potshell and busbar supports were redesigned. The optimised potshell supports allow for better air circulation from below the potshell. The overall volume of the concrete in potshell and busbar supports was reduced by 35 % with respect to the original DX design.

Potroom Building
The DX+ cells were placed in the same potroom building size as DX cells. Considering the amperage increase to 440 kA, the productivity of potroom in tonnes of aluminium per square meter of covered building was increased by 16 % at 7.12 tons of aluminium produced per square meter of covered building, calculated for 360 cells and one central passage per potroom. The potroom building was also reviewed in order to minimise its dimensions while keeping the necessary clearances for safe movement of pot operation equipment. This gives 1.7 % increase in potroom building productivity. An additional 4.6 % increase will be obtained with the reduction of cell-to-cell distance, described above. These improvements together give a potroom productivity of 7.57 tons per square meter of covered potroom building.

CAPEX Optimisation
CAPEX improvement is the result of cell productivity, which is proportional to amperage and of the increase of number of cells per potline as the result of higher rectiformer capacity of 2000 V DC. Figure 2 shows relative decrease in total installed cost with respect to smelter capacity in thousands of tonnes per year (ktpy)

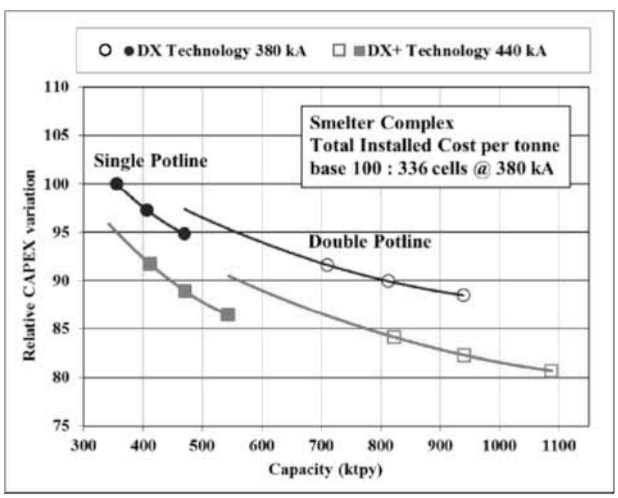


Figure 2. Total installed cost per tonne of smelter complex.

PLC-Based Pot Control System

The new DUBAL pot control system uses Programmable Logic Controllers (PLC) to run the cell control software. DUBAL cell control software has been adapted to PLC with the same functionalities as in conjunction with DCCU but with an improved Graphical User Interface (GUI). The main advantage of this system is the standardisation of hardware to the same as used outside the potrooms throughout the smelter and a possibility to obtain maintenance and spare part management from the PLC supplier.

Figure 3 shows an Integrated Pot Control Panel (IPCP). The new Human Machine Interface (HMI) is a ten inch Panel View, integrated in the Control Panel. One IPCP is connected to two cells.

Increased GUI capabilities provide better and more complete information to cell operators than the original control systems, which were mostly text based and black and white. The new HMI provides the operators access to all required supervisory controls, data entries and information about the pots in the potroom. Two sample screen shots from HMI are shown in Figures 4 and 5. The HMI can also display various trend graphs for a period of 30 minutes to 8 hours (Figure 6).

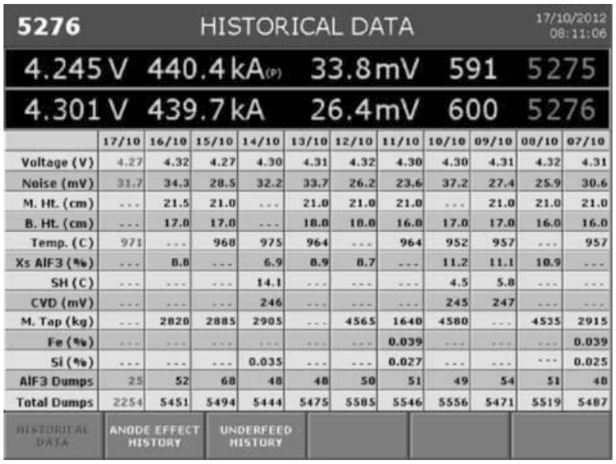
Figure 3. Integrated Pot Control Panel (IPCP) to be installed in EMAL Potline 3.

The PLC data are sent to the potline server where they are analysed and displayed in the same way as with DCCU based control system. Detailed pot traces and command interface can be obtained from "iPots©" system hosted on a network server. In addition, user specified queries can be used in a new web based "Smelter Analytics" platform developed in-house to provide data in an exportable format to programs such as MS Excel. The new iRPMS© reporting system, equipped with a web based interface for ease of navigation, provides information to the user from potlines, carbon plant, casthouse etc, as well as various types of summary overviews to the senior management.

Progress in EMAL Phase 2 (Potline 3) Construction

EMAL Phase 2 construction, which started with the preliminary earth works in October 2011 is progressing well. Figure 7 shows Potroom A building civil and structural steel erection as of October 2012.

First superstructure, potshell and cathode ring busbars prototypes have been approved in June 2012. The mass production is already in progress and some equipment has been delivered to the smelter site. The potlining materials have been ordered and the potline startup is planned for December 2013.



	17/10	16/10	15/10	14/10	13/10	12/10	11/10	10/10	09/10	08/10	07/10
Voltage (V)	4.27	4.32	4.27	4.30	4.31	4.32	4.30	4.30	4.31	4.32	4.31
Noise (mV)	31.7	34.3	28.5	32.2	33.7	26.2	23.6	37.2	27.4	25.9	30.6
M. Ht. (cm)	...	21.5	21.0	...	21.0	21.0	21.0	...	21.0	21.0	21.0
B. Ht. (cm)	...	17.0	17.0	...	18.0	18.0	16.0	17.0	17.0	16.0	16.0
Temp. (C)	971	...	968	975	964	...	964	952	957	...	957
Xs AlF3 (%)	...	8.8	...	6.9	8.9	8.7	...	11.2	11.1	10.9	...
SH (C)	...	...	...	14.1	...	...	...	4.5	5.8	...	...
CVD (mV)	...	...	...	246	...	...	...	245	247	...	...
M. Tap (kg)	...	2820	2885	2905	...	4565	1640	4580	...	4535	2915
Fe (%)	...	...	...	...	...	...	0.039	...	...	...	0.039
Si (%)	...	...	...	0.035	...	...	0.027	...	...	...	0.025
AlF3 Dumps	25	52	68	48	48	50	51	49	54	51	48
Total Dumps	2254	5451	5494	5444	5475	5585	5546	5556	5471	5519	5487

Figure 4. Historical data on HMI.

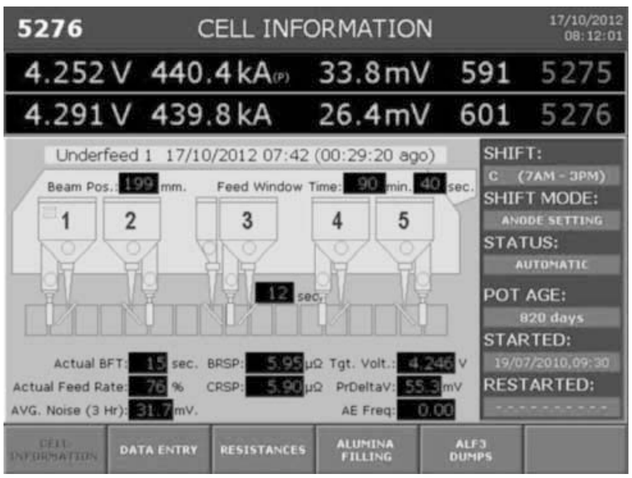


Figure 5. Cell information data on HMI.

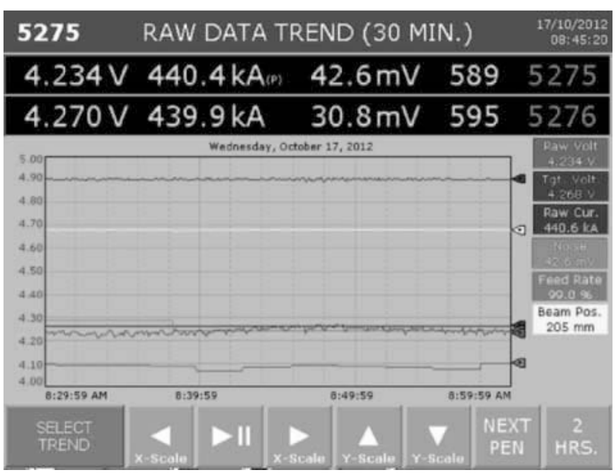


Figure 6. Voltage trend display on HMI.

Conclusions

Both, DX and DX+ cell technologies continue to give excellent performance with considerable amperage increase to 380 kA in EMAL and 385 kA in DUBAL Potline 8 and to 440 kA in DX+ pilot cells.

DX+ cell technology optimisation gives a significant reduction in mass of steel, aluminium and concrete, per tonne of aluminium. Combined with increasing metal productivity in tonnes per square meter of covered potroom buildings, the CAPEX per tonne of installed capacity is significantly decreased.

The new Pot Control System is based upon standard market PLCs, which give increased HMI capabilities and assure easy maintenance and future development.

Figure 7. EMAL Phase 2 construction site (October 2012).

References

1. A.J.M. Kalban et al., "DX Technology, The Development and the Way Forward", Light Metals 2008, 383-388.
2. Marc de Zelicourt et al., "2008: A Milestone in the Development of the DX Technology", Light Metals 2009, 359-363.
3. Ali Al Zarouni et al., "DX Cell Technology Powers Green Field Expansion", Light Metals 2010, 339-343.
4. Marc de Zelicourt et al., "DUBAL DX Cell Technology Successful Path from Prototypes to Industrial Projects", *XVIII ICSOBA International Symposium*, Zhengzhou, China, November 25-27, 2010.
5. Ali Al Zarouni et al., "The Successful Implementation of DUBAL DX Technology at EMAL", Light Metals 2012, 715-720.
6. Ali Al Zarouni et al., "DX+ an Optimized Version of DX Technology", Light Metals 2012, 697-702.
7. Dinkar Vittalapai, Mamatha Shyamala and Florentino Maloto, "Development of DUBAL Cell Control Unit", Light Metals 2007, 429-434.
8. Abdalla Zarouni et al., "Achieving low Greenhouse Gases emission with DUBAL's high amperage cell technology", *19th International Symposium of ICSOBA*, Belem, Brazil, October 25-November2, 2012.
9. Abdalla Zarouni et al., "Mathematical Model Validation of Aluminum Electrolysis Cells at DUBAL, Light Metals 2013.