Challenges of Anode Spikes in Aluminium Bahrain (ALBA)

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Abstract

Aluminium Bahrain (ALBA) has been improving productivity through increasing potline current and improving current efficiency. The potline current creep has been achieved gradually by multiple changes in the cell components, lining design, cathode design, anode size, and by improvements of the process control and pot operation practices. In addition, operating at reduced anode-cathode distance (ACD) brings up the opportunity to convert the saving in voltage into current increase and to maintain cells in thermal balance. Nevertheless, operating at reduced ACD becomes one of the main challenges to sustain cells productivity and life in modern smelters. The reduced ACD creates anode problems and causes spikes. In order to sustain increased potline current, there are several anode quality parameters that must be kept stable or improved. This paper describes the challenges encountered in anode spike issues in potlines 4 to 6 in Alba over the last three years. It outlines the anode properties with respect to anode spikes issues and the work done to improve anode quality standard through improvements in anode baking furnaces and rodding plant. These improvements in anode properties have significantly reduced spike trends in potlines to acceptable level. The work done and the link between anode properties, along with changes introduced in potlines to resolve spike issues are discussed in this paper.

Keywords: Anode spikes, Anode baking furnace, Baking level, CO_2 reactivity residue.

1. Introduction

Aluminium Bahrain (ALBA), the world's largest single-site aluminium smelter outside China with aluminium production of more than 1.548 million tonnes in 2020 is known for its technological strength and innovative strategies. ALBA always striving to maximize productivity and reduce resource consumption such as carbon and energy in order to continuously reduce impact on environment, improve safety and overall business.

With meticulous approach, ALBA progressively has been achieving its potline current increase plan successfully. Potlines 4 & 5 use AP30 prebake technology. These potlines are presently operating close to 400 kA which is more than 20 % higher than the original potline current [1]. Potline 6 which uses EGA DX+ Ultra technology was commissioned in 2019 with original design current of 460 kA [2]. Presently this potline is operating close to 480 kA which is an increase of more than 4 % from the original design in just two years.

One of most critical elements to operate successfully at higher amperage is anode performance. To avoid overheated cells, most of the efforts have been made to keep the cell internal heat under control. This means lowering the bath resistance, i.e., reducing the ACD. When lowering ACD, the current efficiency may decrease and the pot becomes more sensitive to disturbances. Figure 1 shows the trends of ACD with pot line current increase.

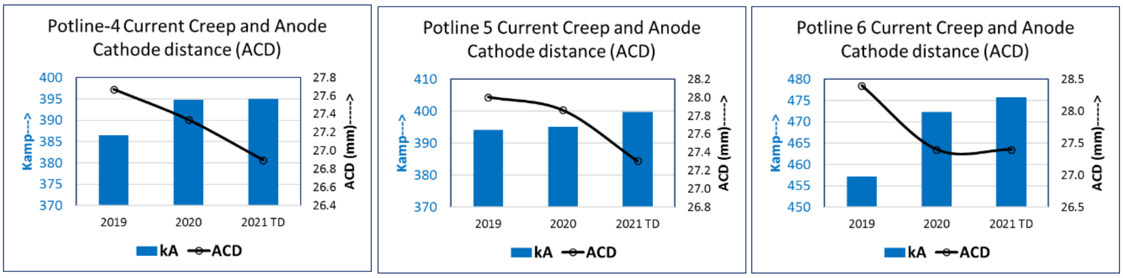

Figure 1. Potline current increase (creep) and ACD.

Increased amperage and low ACD have a tendency to increase the frequency of anode spikes [3]. Furthermore, with increasing amperage the probability of increasing carbon dust increases especially when cells operate outside their operating window. Carbon dust increases electrical resistivity of the bath [4] which further decreases ACD, lowers current efficiency and increases bath temperature. Differences of just 2-3 mm in ACD will have a great impact on the frequency of spikes in the cells when the ACD is close to the operational limit. Therefore, any attempt to reduce the overall cell voltage through squeezing of ACD results in a significant increase in risk of anode spike formation [3]. Other smelters have experienced anode spike crises and have analysed possible causes [5-6].

From the potline perspective, anode quality has a direct impact on current efficiency, pot operation, and carbon dust and anode spike generation. Anode quality dictates how aggressively the pot operating parameters can be pushed. Improving anode quality has been a key challenge during current increase and ACD reduction strategy.

This paper discusses the ALBA's anode improvement initiatives, results and the impact on spike formation.

2. Anode Performance in ALBA Potlines

ALBA has four carbon plants with total gross bake anode capacity of 897 kt/y. These four carbon plants meet the anode requirement of the six potlines. Carbon plants use calcined petroleum coke manufactured in captive calciner located at the marine terminal, 16 km from the main smelter anode plant. Green anodes are made using vibro-compactors, baked in open-top horizontal ring furnaces.

ALBA has five anode baking furnaces (ABFs). These furnaces bake four different sizes of anodes to cater the potlines. ABFs are equipped with latest Innovatherm firing control system. Over the years, anode sizes have been increasing to support potline current increase. The baking, process and the ABF condition are crucial for maintaining good baking quality with increased anode size. Anode performance in potline largely depends on baked anode quality and its consistency. Final anode baking temperature, or anode baking level monitored with the parameter Lc (crystal length) in ALBA, is one of the key anode quality parameters, which must be maintained within the target range. Underbaked anodes can cause carbon dust and spikes which lead significant deviations in potline operation. The baking level is being continuously improved through optimization of the baking curve and improvement of the furnace condition. Another important parameter is the anode reactivity; increasing the anode reactivity increases carbon dust generation which leads to anodes spikes formation.

Alba has had a few periods of anode spike problems in Potlines 4, 5 and 6 for the last three years. The causes, impacts and corrective actions vary from one potline to another as it will be illustrated in this paper.

2.1 Anode Spikes in Potline 4

The number of anode spikes in Potline 4 increased significantly from July to December 2019. The main reason behind this increase was insufficient anode baking level in the ABF. This was the result of premature failure of the ABF refractory flue walls. Refractory flue wall condition deteriorated significantly with cracks, pinching, S-shaped deformation, O-type deformation (the flue wall is bulged from both sides – this usually happens near peephole 1), and bending. This caused packing coke infiltration into the flue walls and subsequently significant deterioration in the process, resulting in reduced anode baking quality and increased anode rejection. It became critical to operate furnace in a safe manner to meet Potline 4 needs.

ALBA carbon team has overcome this critical ABF situation with meticulous approach, planning and implementing innovative ideas. The strategy of step-by-step repair of the flue walls was adopted as a temporary solution. In addition, to avoid stress in zone 1 (under peep hole 1), burner configuration was changed to counter flow instead of co-current flow. Furthermore, the fourth burner ramp was introduced to bring the required additional heat. The baking curve and parameters were optimized for the new burner configuration.

The significant deterioration of the anode baking level increased spike formation and baking level (Lc) variations in the period August to December 2019 as shown in Figures 2 and 3. This led to average monthly spike generation as high as 63 per day during September 2019.

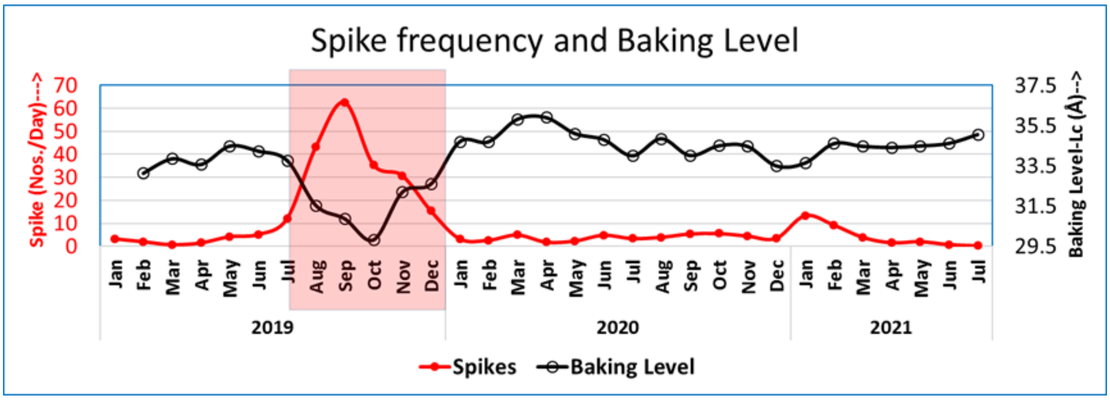

Figure 2. Anode spike frequency with respect to anode baking level (Lc) in Potline 4.

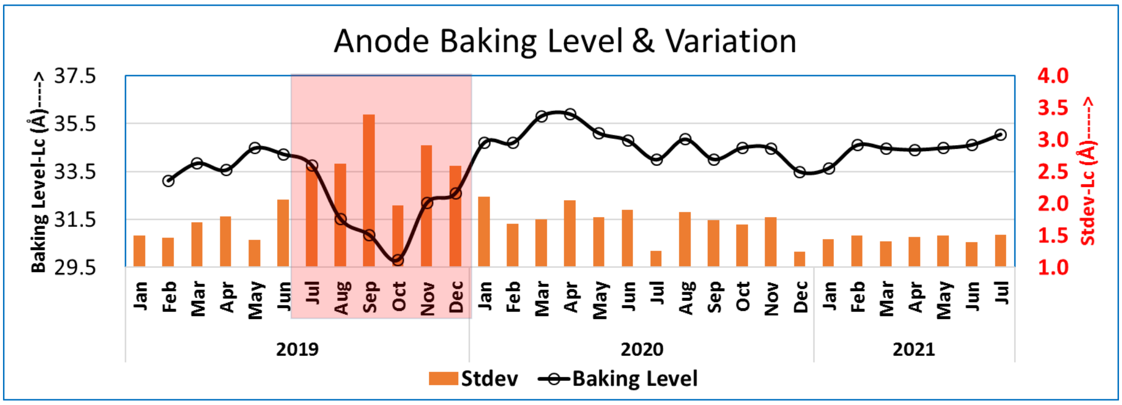

Figure 3. Anode baking level and variation in Potline 4.

In parallel to the immediate measures, a detailed plan was made to replace the bad refractory flue walls within a short term of 5 months. This required meticulous planning for refractory material, flue wall mapping and prioritizing, along with innovative ideas to reduce times for flue wall replacement. ALBA refractory team was able to replace 62 flue walls in a month which is the highest achieved in the past years. All the 408 internal flue walls were replaced and the furnace operation and process improved. Spikes have been reduced significantly to below 5 per day (acceptable level), and currently they are below one per day.

2.2 Anodes Spikes in Potline 5

Potline 5 was commissioned in 2005 with AP30 Technology. Potline 5 originally started at 330 kA and is presently operating at 400 kA with a total amperage increase of 70 kA, more than 20 %, without implementing forced cooling network [1]. Potline 5 performance has been outstanding in comparison with other AP30 smelters.

The anode spikes in Line 5 increased from July 2019 to January 2020 due to variation in anode baking as shown in Figure 4. During 2019, anode baking process was not stable due to lack of draft and pitch deposition in the main duct of fume treatment plant. A major campaign was carried out to clean the main duct and seal all leakages in the furnace. The baking curve was optimized further to improve the process and baking level.

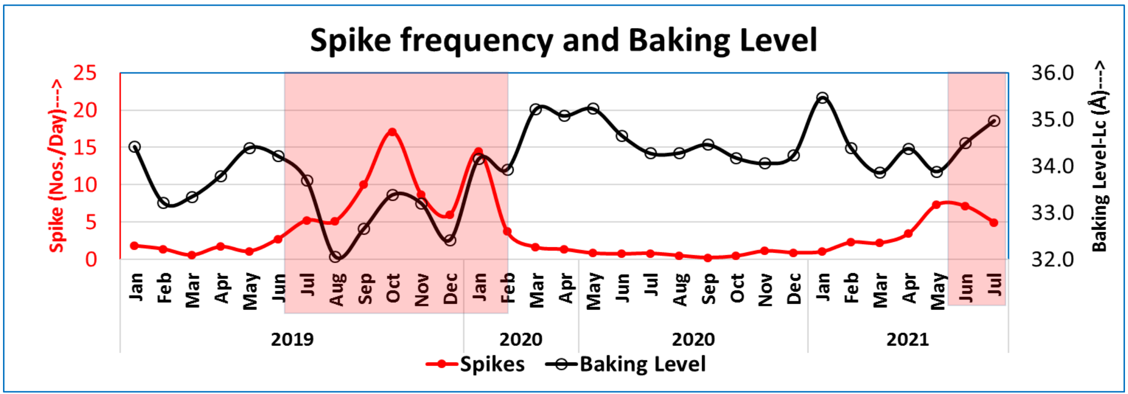

Figure 4. Anode spike frequency and anode baking level in Potline 5.

The anode spikes increased again in 2021 due to squeezed ACD, which was required to balance the cell internal heat at higher amperage as shown Figures 5 and 6.

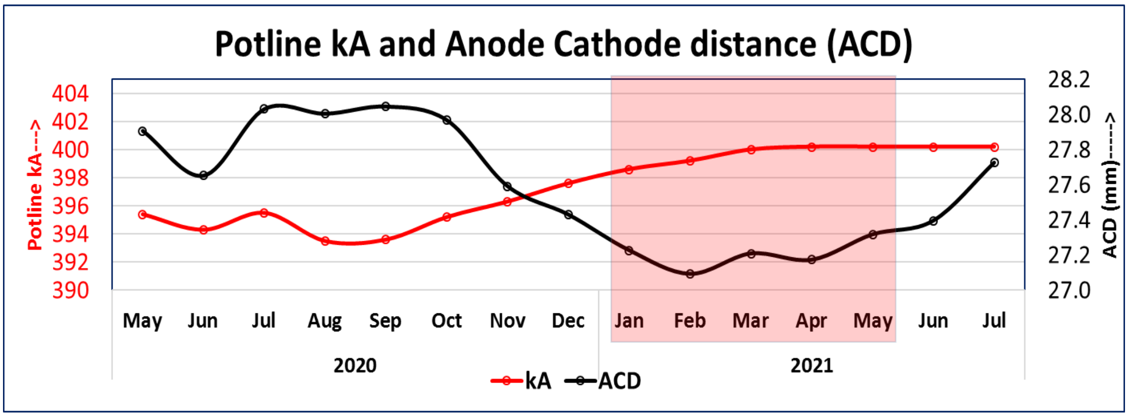

Figure 5. ACD with respect to potline amperage.

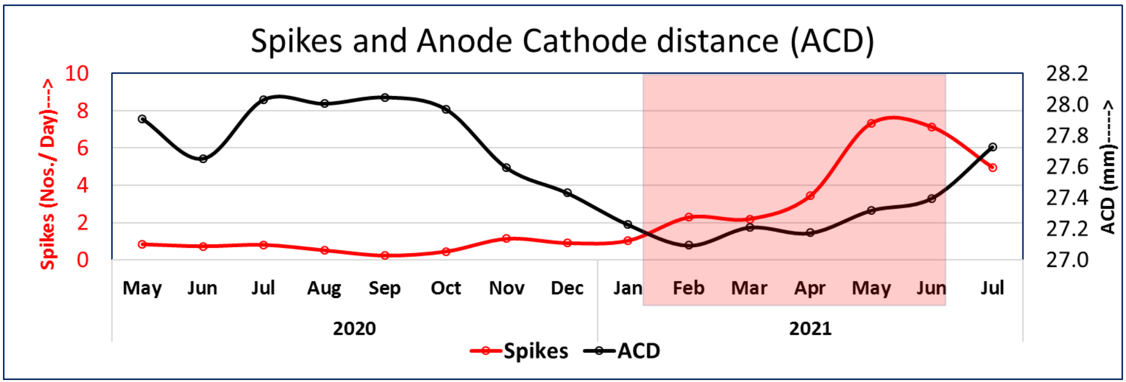

Figure 6. Number of anode spikes with respect to ACD in Potline 5.

In order to reduce the number of anode spikes, the ACD was increased back to optimum level. Nevertheless, the increase in the cell internal heat due to higher ACD was compensated by other means, such as reducing anode top cover thickness, higher metal level and increased anode slot height. These changes were successful in reducing spike formation to an acceptable level of less than 5 per day.

2.3 Anodes Spikes in Potline 6

In 2018, Reduction Line 6 was built using EGA DX+ Ultra Technology with a total of 424 pots at line amperage of 460 kA [2]. Currently the amperage is close to 480 kA. During the current increase, the number of anode spikes was high in November and December. Two main causes for spike generation in Line 6 were: The reduced ACD which was part of current increase and secondly lower baking level illustrated in Figures 7-9.

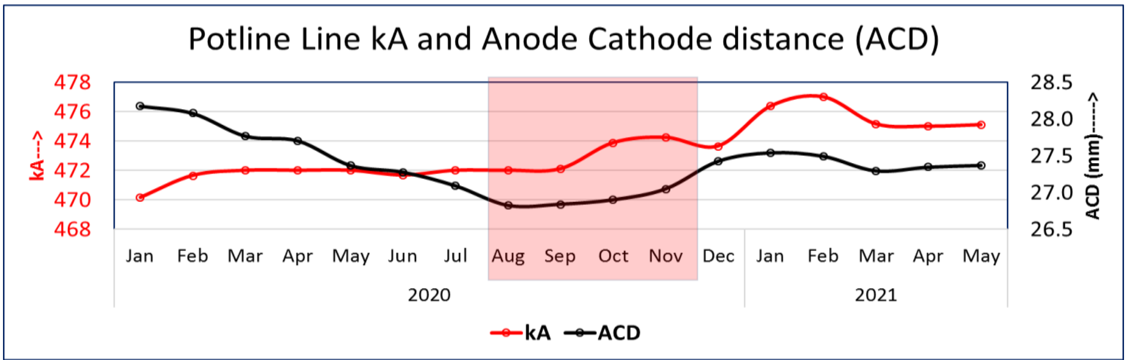

Figure 7. ACD with respect to potline amperage in Potline 6.

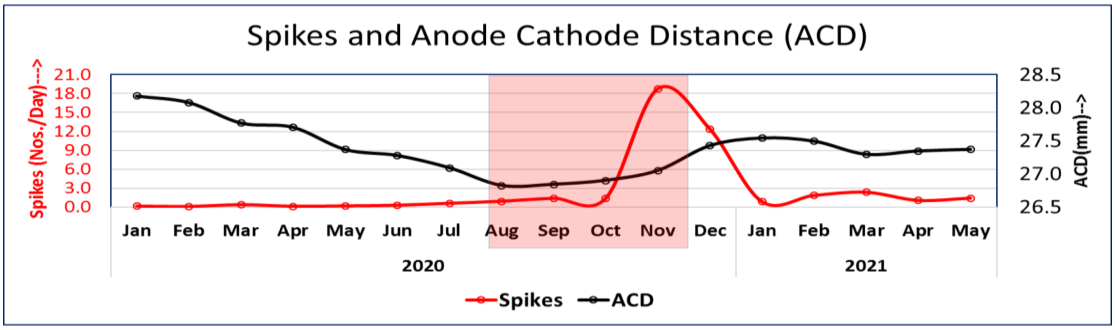

Figure 8. Anode spike formation with respect to ACD in Potline 6.

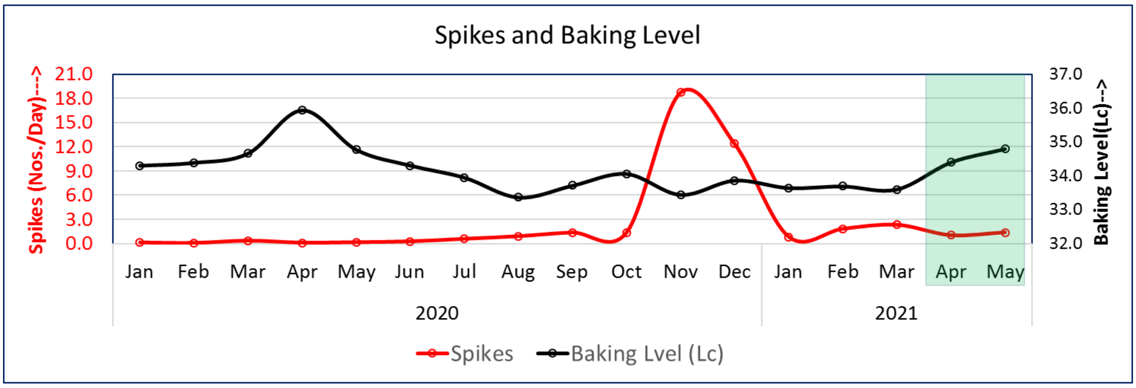

Figure 9. Anode spike frequency and anode baking level in Potline 6.

In order to reduce the number of anode spikes, the ACD was increased which in-turn increased pot internal heat. This increase in internal heat was compensated through lowering the anode cover thickness and increasing the metal level. In addition, the baking level was increased to ensure the crystal length (Lc) to be above 34 Å. Currently, the number of anodes spikes in Line 6 is below 1 per day.

2.4 Overall Anode Quality Improvement

Improving anodes properties has been a major enabler of amperage increase in ALBA potlines and the key to achieve target metal production. Optimizing baking level, reducing anode reactivity, reducing impurities and maintaining low air permeability were top priorities as shown below.

2.4.1 Baking Level (Lc) Optimization

Anode baking level optimization is a continuous approach based on anode performance with potline current increase. Prior to year 2020, baking level Lc was maintained between 32 Å to 34 Å. During last 3 years of current increase, it has been established that the tendency of spike formation significantly drops (< 5 per day) if the anode baking level Lc > 34 Å as is evident from Figure 10.

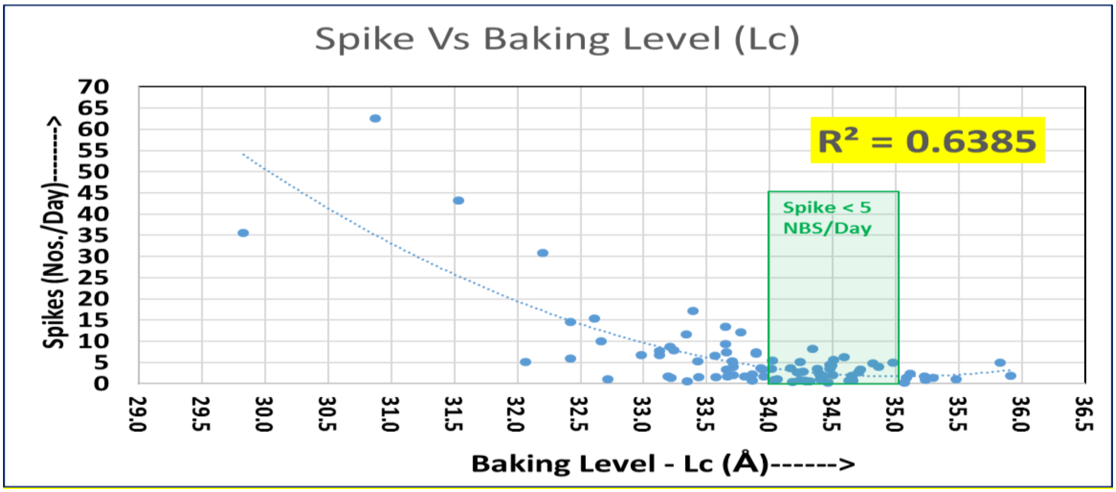

Figure 10. Correlation trend for anode spike frequency vs anode baking level Lc.

Baking at higher level is associated with other challenges such as desulphurization of anodes more stress on refractory flue walls of ABF, and management of oxygen level and pitch burning efficiency. These challenges were overcome successfully with optimization of baking curve along with establishing systems to improve operational and maintenance compliances. The following measures were taken:

- Refractory temperature measurement,
- Flue wall condition monitoring
- Due refractory maintenance,
- Draft / blower pressure optimization,
- Baking curve optimization,
- Monitoring of pitch burning and location,
- Daily kilns operational deviations and compliances,
- Extra sampling at low baking zone of the furnace,
- Firing equipment condition monitoring.

Coke quality also plays a vital role in achieving required baking level. At ALBA, it is observed that the higher calcination level results in higher anode baking level without changing the energy consumption of ABF. It is worth to note that over calcined coke has tendency to desulphurize during anode baking. It is critical to optimize the coke calcination and anode baking in-order to reduce desulphurization. Therefore, the baking curves have been adjusted to the coke quality.

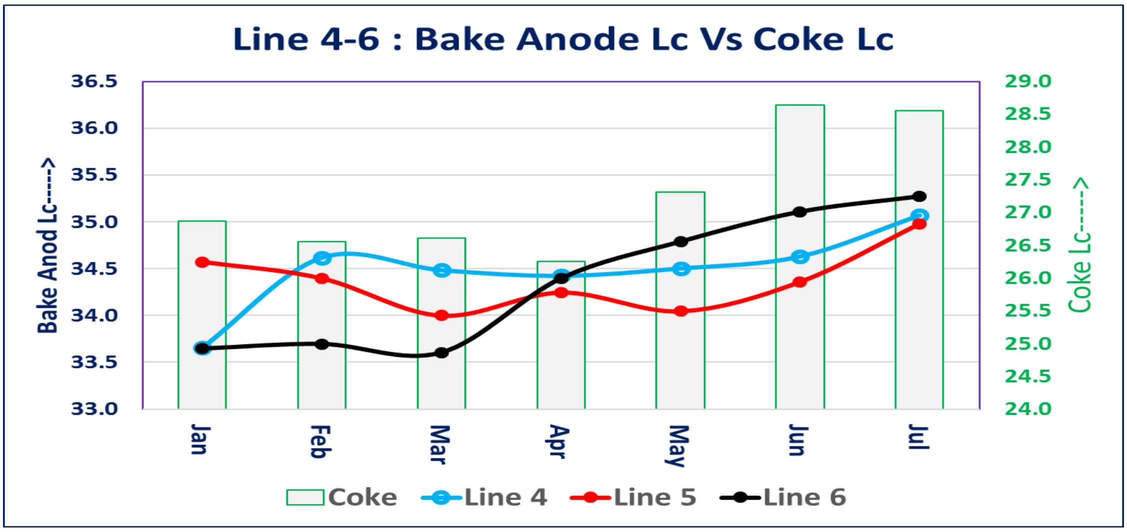

Figure 11. Impact of coke calcination on anode baking level.

2.4.2 Improvement of Anode Carboxy and Air Reactivity

The carbon dust generation in electrolysis cells is caused by selective oxidation, sub surface attack of the anode by air (known as air burn) or carbon dioxide (known as carboxy attack). Therefore, anode reactivities are an important parameter in anode quality. The anode reactivities are a function of optimum baking level, air permeability, sulfur content in the anode and impurities (sodium and calcium). Un-optimized baking level (under baked as well as over baked anode) can increase the anode reactivities and thereby carbon dust generation in the potline. Carboxy reactivity residue (CRR) and air reactivity residue (ARR)improved with lower Na and Ca in baked anodes as shown in Figures 12 and 13.

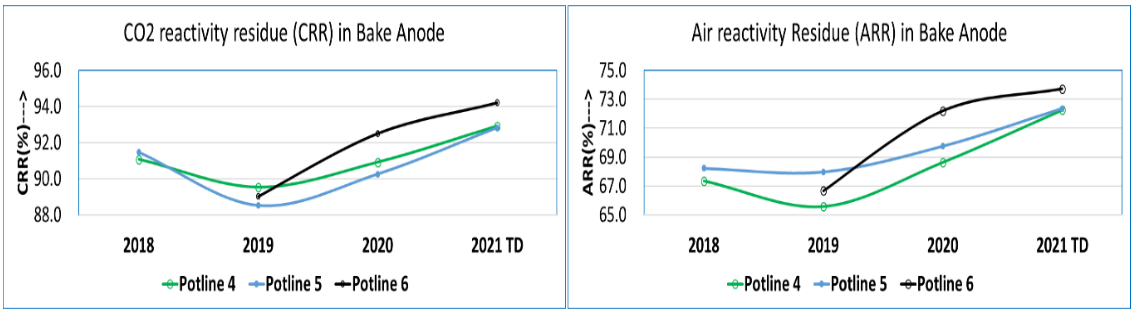

Figure 12. Trend for CO_2 and air reactivity residue.

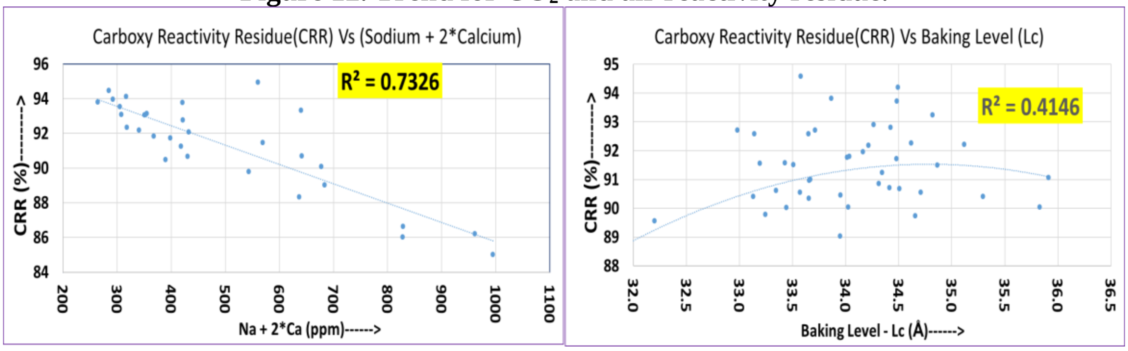

Figure 13. Correlation of CRR with (Na + 2*Ca) and baking bevel

2.4.3 Reduction in Sodium (Na) in Baked Anodes

Impurities in baked anodes such as Na act as catalyst for the air reactivity and CO_2 reactivity. One of the key contributing factors to improve anode quality is the reduction in Na in baked anodes at ALBA. This has become possible through improving butt cleaning efficiency of steel shot blast machine and workmanship in the rodding shop. Many innovative initiatives have been taken to improve cleaning efficiency of butt steel shot blast machine. Some of them are:

- Improve availability of butt steel shot blast machine
- Upgrade blasting wheel
- Interlocking of P & F (power and free) conveyor with steel shots level
- Rotation of butts to have 360° cleaning.

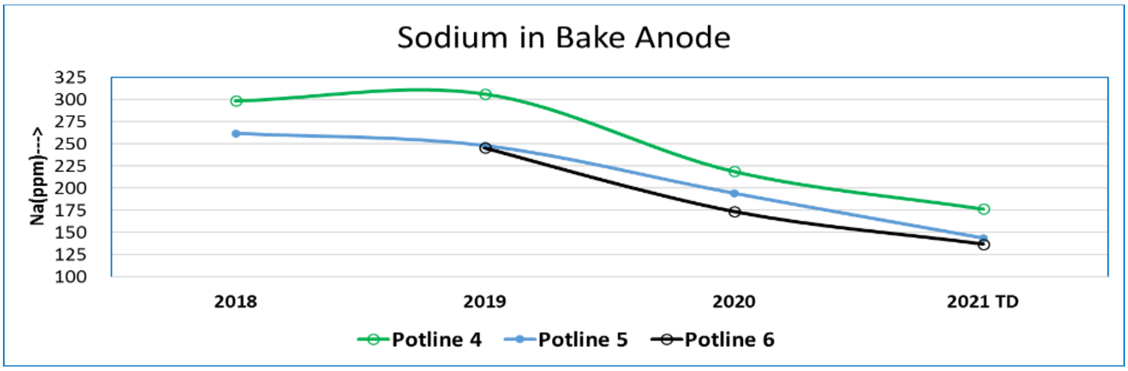

Figure 14. Trend for sodium (Na) in baked anodes.

2.4.4 Maintaining Low Air Permeability with Increased Baking Level

It is critical to maintain air permeability constant while increasing the baking level, otherwise it could have adverse impact, leading to high carbon dusting. The following actions were taken to ensure this:

- Frequent pitch optimization,
- Baking level optimization,
- Ultra-fines in the recipe,
- Optimization of mixing power.

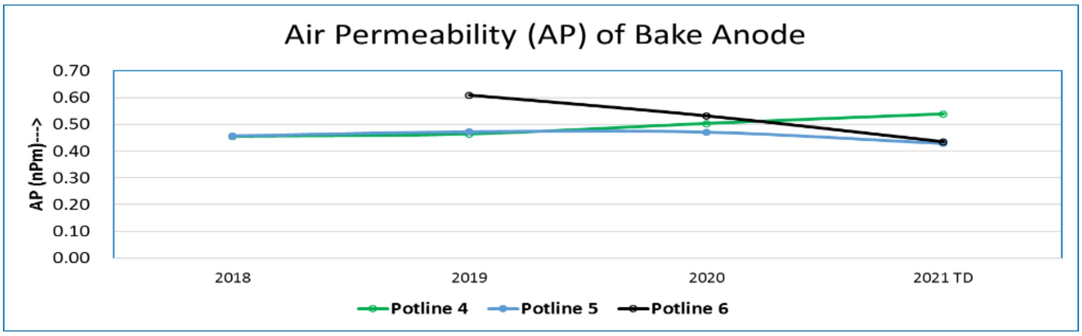

Figure 15. Trend of air permeability.

3. Improvement in Gross Carbon Consumption and Net Carbon Consumption

Despite the increase in amperage in potlines and increase in anode spike frequency, ALBA has been able to reduce gross carbon consumption as shown in Figure 16.

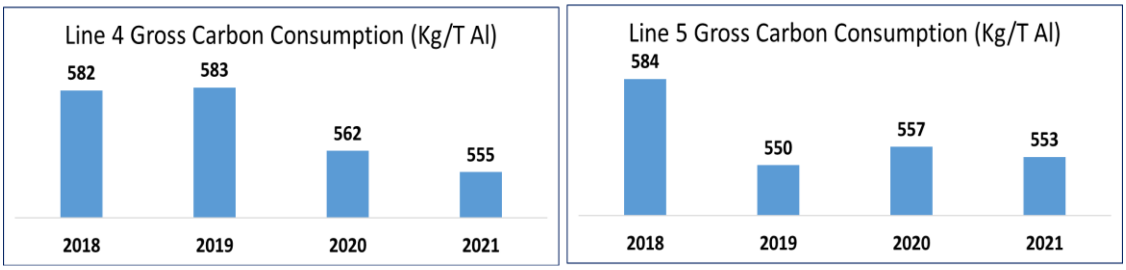

Figure 16. Trend of gross carbon consumption.

In addition, the net carbon consumption has been reduced in all potlines as shown in Figure 17 which indicates both good anode quality and strict potline operation control.

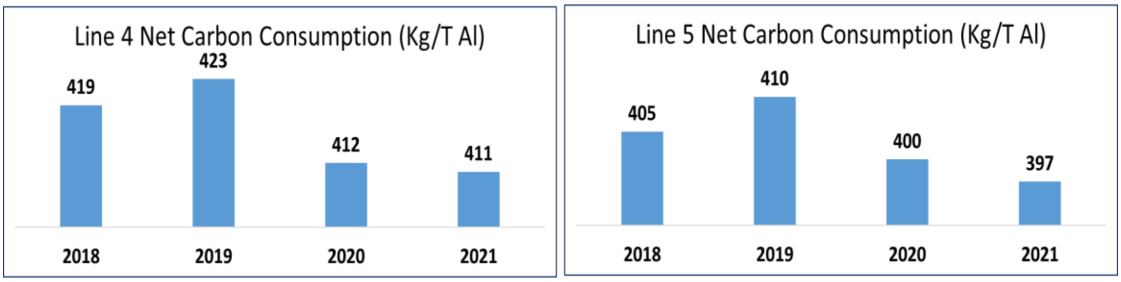

Figure 17. Trend for net carbon consumption.

4. Conclusions

During the last three years, ALBA faced an increase in anode spikes in several periods of time. The causes of spike formation vary from one potline to another. To meet the anode quality and quantity of Potline 4 was a great challenge due to unexpected deterioration in ABF condition. It was handled successfully at with meticulous planning and implementation of innovative ideas.

It was realized that the anode quality needs to match the potline current increase in all potlines. Alba improved anode quality through data analysis and optimization carried out systematically. Baking level is one of the many key parameters which were improved in phases without negatively impacting the other related anode quality parameters such as desulphurization, air permeability and pitch burning efficiency. Carboxy and air reactivity have been reduced significantly through optimizing anode baking and controlling butt cleaning efficiency. Alba implemented many innovative solutions to improve butt cleaning efficiency of butt shot blast machine.

All of the initiatives resulted into overall anode quality improvement and in the reduction of net carbon and gross carbon consumption.

5. References

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