Introduction of a Vertical Shaft Kiln Coke at Ma’aden Green Mill

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Abstract

Due to the floating nature of calcined petroleum coke (CPC) in the marketplace globally in terms of supply and quality, it is always discussed to introduce vertical shaft kiln (VSK) CPC for anode manufacturing and to perform several studies based on trials to apprehend the anode quality as an impact to outline the finest or optimum recipe. This study gives CPC behavior and overall performance contrast of CPC produced with different kinds of calcining technologies (Vertical Shaft and Rotary Kiln) from a process performance, system limitation and product quality perspective. It describes the effect of different blending ratios of coke in the recipe and its effect on the quality to meet product excellence. In alignment with the subject, design of experiment (DOE) has been conducted to study newly introduced calcined petroleum coke performance/behavior within Ma’aden Aluminum (MA) green anode plant. green petroleum coke (GPC) batch selected under this study was calcined through a vertical shaft kiln technology against regular coke used at Ma’aden Aluminium, calcined through rotary kiln technology. Under subject study, CPC behavior with green anode plant, process and equipment will be monitored and observation will be made as response amongst raw material, equipment, operation practice and process parameters.

Keywords: Calcined petroleum coke (CPC), Green petroleum coke (GPC), Vertical shaft, blending, Optimization, Rotary kiln.

1. Introduction

To explore CPC supply for green anode manufacturing at Ma'aden Aluminium, we underwent performance evaluation of CPC calcined through the vertical shaft kiln, where most supplies are from China. At Ma'aden Aluminium we aimed to evaluate the performance of the CPC to maximize green apparent density (GAD) in parallel with baked apparent density (BAD), air permeability (AP), and specific electrical resistivity (SER). The study will also evaluate other baked anode properties made by CPC as supportive performance evaluation for example carboxy reactivity residue, air reactivity residue, compressive strength etc.

2. Raw Material Selection and Design of Experiment

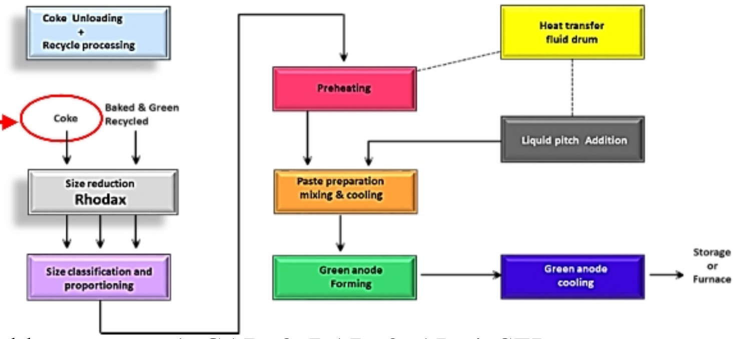
Ma’aden Aluminum typically uses technology recommended CPC specifications, like other smelters. For the specific trials involving vertical shaft calcined CPC, the first task was to measure and compare the specifications of the CPC to be used in the test. The coke selected for testing was within Ma'aden specification (Table 1). Based on experience and understanding, the green anode formulation is a key factor that determines the behavior and performance of CPC within green anode plant (GAP), as well as properties of the baked anode. The CPC is added to the dry aggregate recipe in a specific mixing ratio as a variable input. Figure 1 summaries the process and DOE model that was followed during the trial.

Table 1. CP coke analysis.

Parameters	VBD	RD	SER coke	-50 mm	+4 mm	-0.25 mm	Sulfur	Vanadium	Nickel	Iron	Silicon	Sodium	Calcium	Phosphorus	lead
UOM	g/cc	g/cc	µΩ-m	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
CPC- Vertical	0.92	2.05	510	100	35	9	2.8	296	176	225	231	51	115	8.5	19
CPC- Rotary	0.88	2.062	-	100	36.89	4.02	2.66	326	199	181	193	60	64	7	-

<u>Process and DOE model overview</u>

Coke Blending	
Coke - V %	**Coke - R %**
0	100
50	50
70	30
100	0



Dependent variable response- 1. GAD, 2. BAD, 3. AP, 4. SER.

Figure 1. Process overview with DOE model.

3. Design of Experiment Implementation and Data Collection

To conduct the experiment, it was decided to use each selected blending in a batchwise manner with controlled operation and process parameters and each batch must be tracked with all green and baked anode process parameters having identified storage location at every stage of processing. The following describes the activities and observations made at each stage of the trial.

3.1 Grain Size Distribution (GSD) – CPC

Under this trial, after having selection for coke blending ratio, it was necessary to have coke GSD analysis which can be correlated later with anode properties. GSD is considered one of the key factors in anode manufacturing and it needs to be maintained within control limits. Based on the DOE strategy, Figure 2 represents the actual blending GSD that entered the system. It can be observed from the graph that the increase in percentage of the vertical shaft coke leads to larger particles as compared to rotary kiln coke. Because of the weight load and the compaction in the lower section of a shaft, a degree of agglomeration of the coke grains takes place, increasing the grain size of the CPC produced by vertical shaft kiln [1]. Vertical shaft calcining improves the grain size of CPC produced due to the agglomeration effect and results in lower porosity and higher VBD [1]. GSD comparison of the coke entering green anode plant system shows small variation compared to the CPC supplied as it is very difficult to avoid segregation within the coke storage and handling system which also makes it difficult to maintain the constant GSD throughout the blending. Figure 2 shows the blended CP coke GSD for each blend change.

Table 5. Baked properties with ANOVA comparison for each blending.

Test Rank	Parameter	Blend % (VSK)	Mean	Stdv.	Mean differs from test rank based on alpha (p) value		
1	Air permeability (nPm)	0	0.7	0.2	3	4	-
2		50	0.9	0.6	-	-	-
3		70	1.3	0.9	1	-	-
4		100	2.0	1.6	1	-	-
1	Apparent Density (kg/dm^3)	0	1.589	0.0163	4	-	-
2		50	1.599	0.0176	4	3	-
3		70	1.577	0.0186	4	2	-
4		100	1.55	0.0193	3	1	2
1	Electrical resistance (µΩ.m)	0	51.1	1.7	2	3	4
2		50	54.5	1.9	1	4	-
3		70	54.3	2.3	1	4	-
4		100	59.7	4.5	1	2	3

Based on the trial findings and observations, the following are a few proposed points for future studies that have showed improvements:

1. Reduction in max size of vertical shaft coke as raw material to 30 mm instead of 50 mm respecting all other fraction within Ma'aden specification. This trial also can be taken into consideration to avoid larger vertical shaft coke in system and to achieve more medium and intermediate fraction.
2. Reduction of cone crusher (Rhodax) output crushing size by maintaining the optimum gap of 18 - 19 mm. The recirculation of particle size greater than 25 mm instead of 30 mm for crushing will be the next step as a trial which can minimize deviation within GSD. Such changes will have an impact on crusher output rate, which may slow plant throughput, so an optimum rate needs to be established.

6. Conclusions

It has been observed from above statistical analysis that the introduction of vertical shaft calcined coke on higher ratio with rotary calcined coke during the trial was not able to reproduce the baked anode properties in the range of optimum accepted level as well as in the range of running average. With the current system, every change in coke blending ratio (vertical shaft coke) impacts the baked anode properties, a higher vertical shaft coke % in the recipe further deteriorates the anode property. This study shows that due to the nature of the two different cokes properties and considering green anode plant equipment (technology) which have limited control over fractioning in a recipe, a lower percentage of vertical shaft coke can be used in a recipe, as 30 % on the safer side with limiting to max 50 % having few adjustments on process and recipe parameter. A few more tests can be done with major changes to the system to see the effect of increased vertical shaft coke on the anode quality. It is also important to consider that blending capability limits can be eliminated either by reducing shipment size or by having additional silo capacity installed.

7. References

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