OPTIMUM VIBRATION TIME FOR GREEN ANODE PRODUCTION

Shoulei Gao[1]; Chongai Bao[1]; Shoujun Zhang[1];
Huanxue Wang[1]; Joe Woo[1]; Euel Cutshall[2]
[1]Sunstone Development Co., Ltd, Beijing 100029, China
[2]EC Consulting

Keywords: Anode, Forming, Vibro-Compactor, Vibration Time

Abstract

Anode forming is one of the most important processes in pre-baked anode production, and most modern plants now use vibro-compactors to produce their green anodes. With a vibro-compactor both vibrating time and vibrating frequency can affect anode quality. Sunstone, the largest anode exporter in China, produces many different sizes of anodes, and therefore has to optimize forming parameters for each anode size produced. In this paper, results are given regarding a technique to optimize vibrating time for green anodes. This method can serve as a guide for any anode plant to determine the proper vibrating time for their anodes and therefore to improve their anode quality.

Introduction

In the last ten years or so with the rapid expansion of the aluminum industry and the changing structure of the supply chain for green petroleum coke, a merchant anode market has been established in China. Presently, baked anode production for sale in China exceeds 5 MM mt/yr and is steadily increasing. More than 20% of this production capacity is exported, with this percentage also increasing. Facilities that are producing merchant anodes require the versatility to satisfy many different customers' needs since sizes, shapes, and specifications can be different for each customer. Therefore, the merchant anode manufacturer may have to deal with dozens of different types of anodes, requiring a great deal of flexibility in the production process. For plants that utilize vibrocompactors for forming, vibration time, and sometimes even the vibration frequency, has to be optimized for each anode's size and shape. The proper vibrating time can be determined using the procedure outlined below.

Experimental Procedure

Industrial-scale anodes were produced using a wide range of vibration times. Control anodes were also produced using the plant's "normal" vibration time. These anodes were then baked, cored and analyzed. Optimum vibration time was then determined by evaluating the core data.

First step in the optimization process is to estimate visually the minimum vibration time required for compaction of the anodes. This time was measured by determining the number of seconds required for movement of a small rod fixed to the compaction weight to stop, as referenced to the frame of the vibrator per the photo below.

For a particular anode size the minimum vibration time is determined 10 times and an average calculated. Let "X" be this average value. For the current experiment X = 55 sec with a standard deviation of 1.7 sec. The "normal" vibration time

currently being used by the plant will be designated "Y." For the anode being produced in this experiment Y = 80 sec.
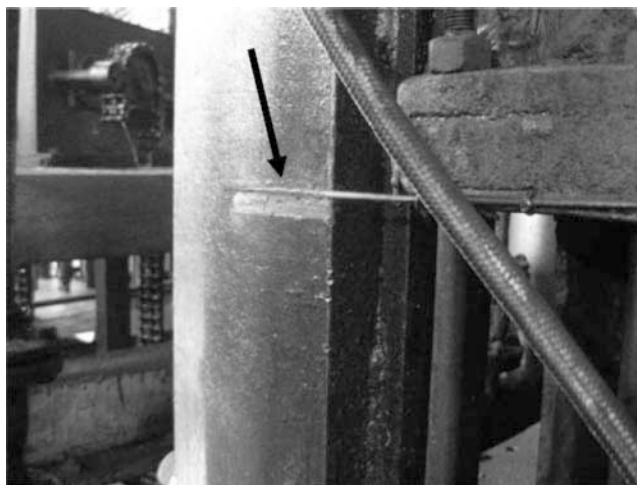

Figure 1. Vibrator fixed rod reference for determining minimum vibration time.

The sequence of data collection for the experiment is shown in Table I below and was selected in order to compensate for any variability in the system.

Table I. Data Collection Sequence

Sequence	Vibration Time, sec	Test quantity
1	Y	14
2	X + 180 sec	14
3	Y	14
4	X – 10 sec	14
5	Y	14
6	X + 60 sec	14
7	Y	14
8	X – 5 sec	14
9	Y	14
10	X+ 20 sec	14
11	Y	14
12	X	14
13	Y	14
14	X + 5 sec	14
15	Y	14

Control anodes using the plant's normal vibration time of 80 sec were produced both before and after each set of experimental anodes. The test quantity of 14 was chosen based on capacities of

the batch mixers. A total of 210 anodes was produced for the experiment.

Properties of the calcined coke and the pitch used are listed in Tables II and III below.

Table II. Calcined Coke Analyses

Ash, %	0.21
RD, g/cc	2.092
ER, mΩm	482
S, %	2.55
V, ppm	169
Ni, ppm	205
Si, ppm	124
Fe, ppm	167
Ca, ppm	179
Na, ppm	72

Table III. Pitch Analyses

Ash, %	0.08
SP, °C	103
Coking Value, %	57
VOM, %	55
TI, %	30.1
QI, %	9.4
β Resins, %	20.7
Viscosity 160 °C, cP	1405
S, %	0.51
Fe, ppm	91
Si, ppm	30
Na, ppm	59
Ca, ppm	46

During the experiment, all Green Mill and Baking Furnace variables should be as stable as possible. Stability of the fines fraction as measured by Blaine is especially important. Additionally, all the green anodes should be baked in inside pits of the baking furnace, since it is more difficult to maintain proper baking temperatures in the outside pits.

Pitch is just below 15%, in slight excess, as is common at many Chinese anode plants today. Due to this excess some packing coke sticking to the surfaces of the baked anodes is common.

After baking, four of the anodes from each experimental time and each control group were cored and the following analyses conducted:
- Baked apparent density (BAD)
- Compressive Strength (CS)
- Flexural strength (FS)
- Air permeability (AP)
- Electrical resistivity (ER)

Experimental Results

In order to determine the amount of variability in the system during the period that the vibration time experiment was being conducted, the GAD and BAD results for the 80 sec control samples were analyzed. See Figures 2 and 3 below. Note that GAD is the average for all anodes produced in each set of controls and that BAD is the average of the 4 cores analyzed for each control set.
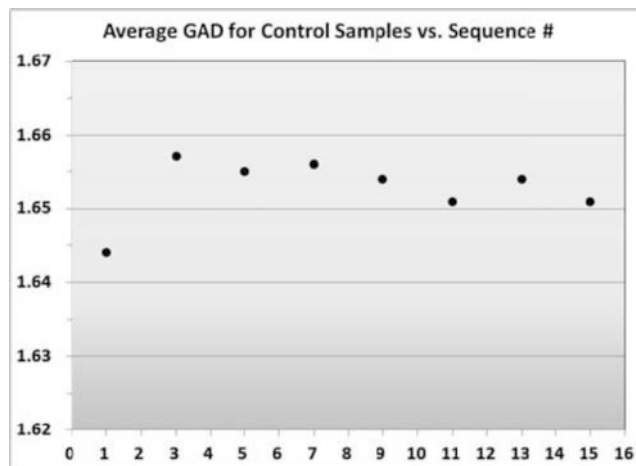

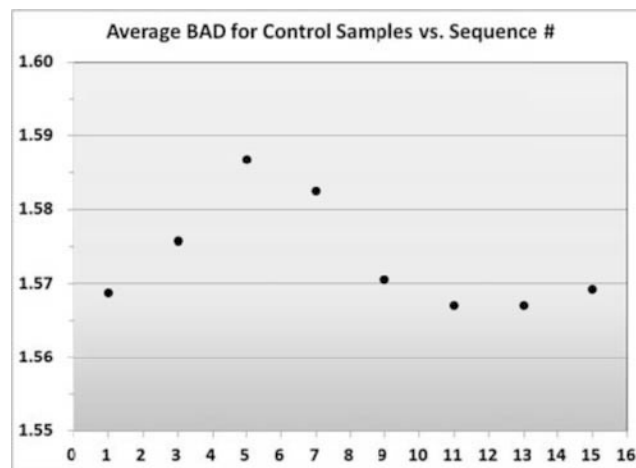Figure 2. Average GAD for 80 sec control samples vs. sequence number.

Figure 3. Average BAD for 80 sec control samples vs. sequence number.

Figures 2 and 3 show that there is variability in the process during what was considered "normal" operations. Therefore any standard data analysis vs. time for changes in properties of the experimental anodes (produced with different vibration times) will not be appropriate. The peak in BAD for sequence number 5 was caused by increasing Blaine of the fines due to the operating practice for metering the dust fraction back into the ball mill product fraction.

Analysis of Results

There is too much variability during the experiment to simply plot charts of properties vs. vibration time and expect to see actual changes in anode properties. This variability was expected and is the reason why the 80 sec control samples were run both before and after each of the experimental vibration times. For each anode property, the average of the 80 sec control data sets both before and after an experimental data set was calculated and then subtracted from the average of the experimental data set to determine whether there has been a change in the property at this vibration time. Results are given below.
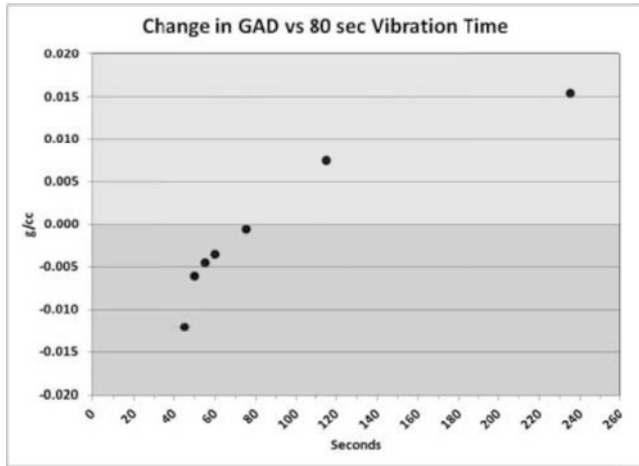

Figure 4. Change in green anode density vs. vibration time.

The GADs increase almost linearly as the vibration time increases up to about 120 sec. However, continual increases in GAD are not always indicative of improvements in baked anode properties. When speaking of anode density what's always most important is the baked density.
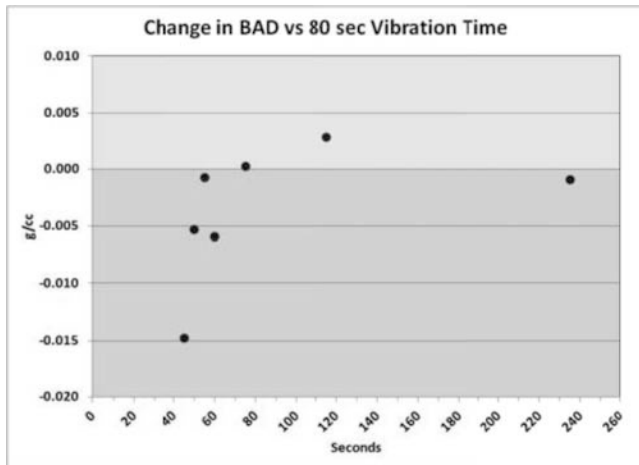

Figure 5. Change in baked anode density vs. vibration time.

In very general terms low vibration times of about 60 sec or less produce baked densities lower than the normal 80 sec vibration time. At or above a 75 sec vibration time baked density is not significantly different than the normal 80 sec vibration time, even though the green density continues to increase.

It should be emphasized that the vibration times discussed are specific to this particular Sunstone Green Mill. Other Green Mills using different equipment and operating procedures and producing different anode sizes may have different optimal vibration times.
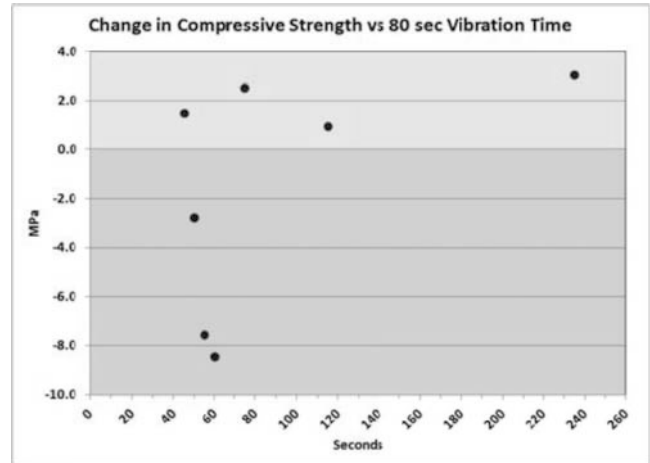

Figure 6. Change in compressive strength vs. vibration time.

For compressive strength there's more scatter in the data, but again the data indicates that vibration time needs to be at least 75 sec to consistently obtain the highest values.
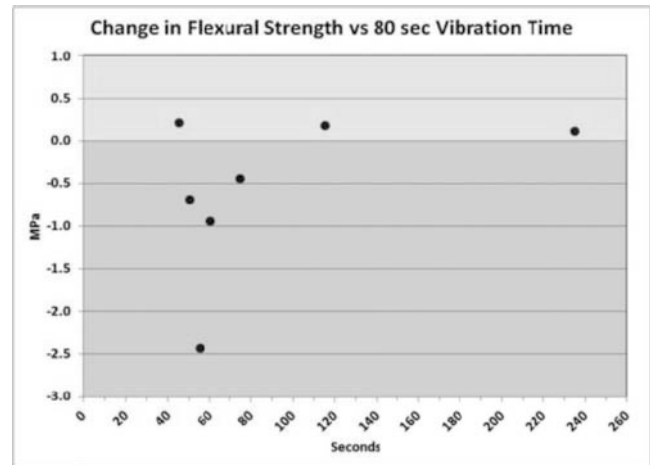

Figure 7. Change in flexural strength vs. vibration time.

The flexural strength data indicates that vibration times longer than 75 sec will be required to achieve maximum values. However, there is quite a bit of scatter in the data, and the pitch % being higher than optimum may have an influence here.

In Figure 8 showing the changes in air permeability only two points are significantly different than the 80 sec control anodes. No trends are seen, indicating that vibration time has little effect on air permeability.
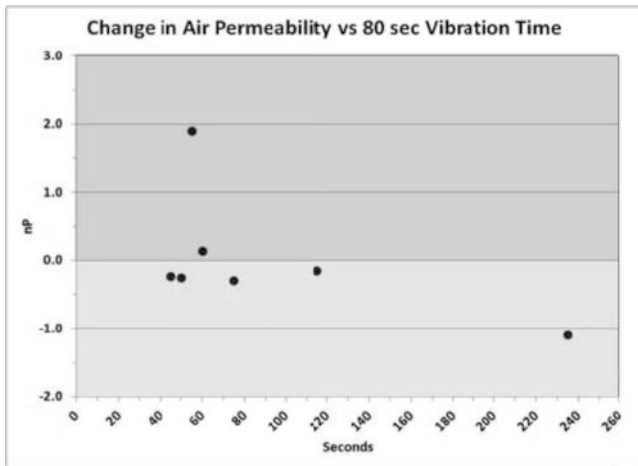
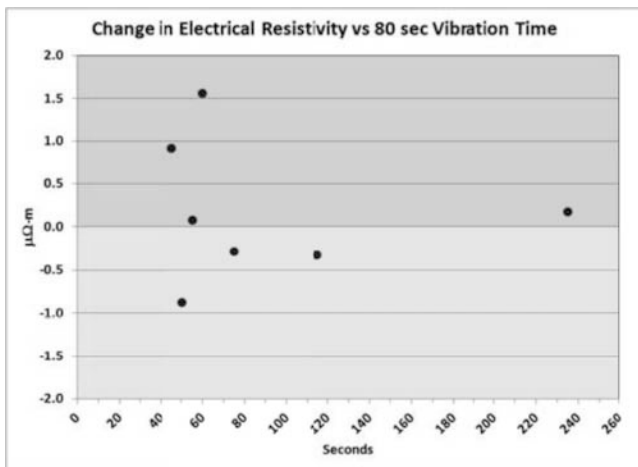Figure 8. Change in air permeability vs. vibration time.

Figure 9. Change in electrical resistivity vs. vibration time.

Electrical resistivity, just as with BAD, CS, and FS, shows quite a bit of variability for the lower vibration times less than 75 sec. For 75 sec and above the ERs are not significantly different than the normal 80 sec vibration time.

Summary and Conclusions

An experimental method has been described that will allow an anode manufacturer to determine the optimum vibration time for each anode size being produced, even if there is significant variability in the process. Using this technique at Sunstone the following conclusions result.

- The 80 sec vibration time used at the plant is appropriate for this anode size.
- Vibration times less than 75 sec result in less consistent and poorer anode properties.
- Long vibration times do not result in poorer anode properties, but do not show improvements either.

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