PROCESS ADAPTATIONS FOR FINER DUST FORMULATIONS: MIXING AND FORMING

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ABSTRACT

Traditionally recipes have used 3000 Blaine dust in the carbon pastes due to limitations that existed previously in the processing equipment particularly in the classifying, weighing, preheating and mixing stages. The optimum processing conditions will change for different recipe conditions and different equipment capabilities. For a given paste plant design, the recipe should be chosen requiring optimum processing conditions as dictated by the plant equipment limitations.

This investigation demonstrates how the paste consistency of different recipes can be altered through adjusting the parameters in the preheating, mixing, forming and cooling stages to produce differing levels of anode quality. This was examined on pilot and production scale, with tests on both vibrated and pressed anodes

INTRODUCTION

Conventional recipe formulations have used a dust fineness of 3000 Blaine and typically 30-40% dust content. Development of the greenmill equipment used to process the dust has paved the way towards more routine usage of finer formulations. The limitations have been in the classifying, weighing, preheating and mixing stages.

In order to maximise the potential of a recipe, the process parameters must to be adapted in parallel with recipe changes. This needs to be made to maximise anode quality and the benefits of different formulations. Adaptation is particularly important for mixing and forming stages of anode production.

A study was made to investigate how the anode quality can be altered through adjusting the parameters in the preheating, mixing, forming and cooling stages for different recipe conditions.

BACKGROUND

Until recently, the manufacturing technology available has restricted the use of certain recipes due to practical difficulties. Equipment development has included the use of dynamic classifiers [1] to allow for sharper cut points, that are not affected by large variations in throughput or primary fines sizing and thus more accurate dust sizing. More accurate weighing systems for fine materials are readily available e.g. loss in weight loadcell feeders with rotary valves. This avoids 'free flowing' problems that can occur with dust above 3500 Blaine with beltscales.

ANALYSIS OF THE DUST COMPONENT

For the purposes of this study, the dust fraction is defined as the combined scale product of the ball mill and filter fines. As in the Cement industry [2], the fineness of the dust content can be conveniently described by the Blaine number (ASTM: C204-84). This is a measurement of the air permeability developed to measure the external specific surface area of fine particles in the 'sub-sieve range' [3]. A worldwide survey of the dust fractions used in industry showed the statistics given in Table 1 [4].

Table 1 Statistical Data from Worldwide Survey

Fraction	Mean Blaine No.	2 σ	n
Mill dust	3051	1497	34
Filter Dust	9986	15064	35
Combined Dust	3586	1872	45

The Blaine number can be related to conventional US mesh sizes by the relationship shown in Figure 1 (a) and (b). Smith [4] showed how the Blaine number correlated to the mean particle size. Thus a higher Blaine number indicates a higher surface area and a finer dust component. A typical dust has a fineness of 3000 Blaine and 2σ of 300 Blaine.

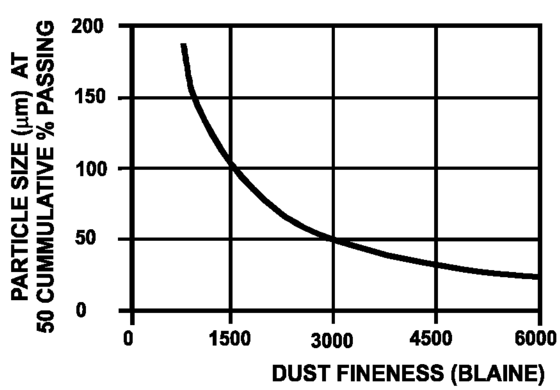

Figure 1 (a) Mean Particle size for different dust fineness

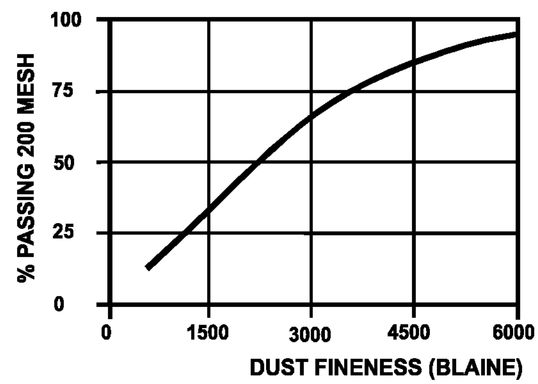

Figure 1(b) Relationship between Blaine and % passing 200 Mesh

FINENESS AND PITCH DEMAND

The value of the Blaine number is to quickly identify the characteristics of the dust component. This is particularly useful as a dominant part of the pitch requirement is to coat the surface of the mix. Thus the surface area that the Blaine number represents is a very important indicator of the paste pitch requirement. Pilot plant trials have shown that, in order to achieve maximum apparent density, increasing the Blaine number by 1000 represents an increase in the pitch requirement of 1% [5]. This is illustrated in Figure 2 on pressed anodes. Previous work by Fischer [6] and Smith [4] agrees with this data.

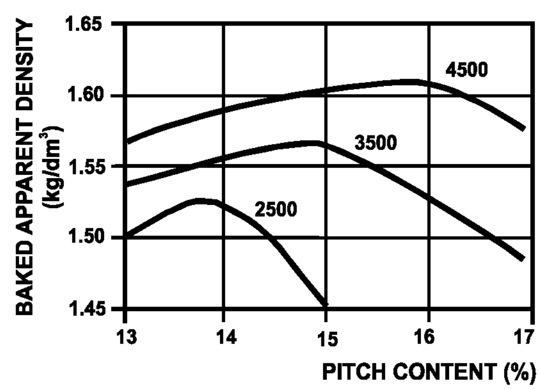

Figure 2 Change in pitch demand for different dust fineness at 35% dust for pressed anodes

These trials have also shown that decreasing the dust content of the dry aggregate by 10% absolute (at 3000 Blaine) reduces the pitch requirement by approximately 1%. The pitch requirement in this paper is defined as the amount required to achieve maximum baked anode density. Figure 3 illustrates this concept.

However very high fines contents reduce the coarse material content of the aggregate skeleton, causing a decrease in cohesion and thus deformation of the anode may occur.

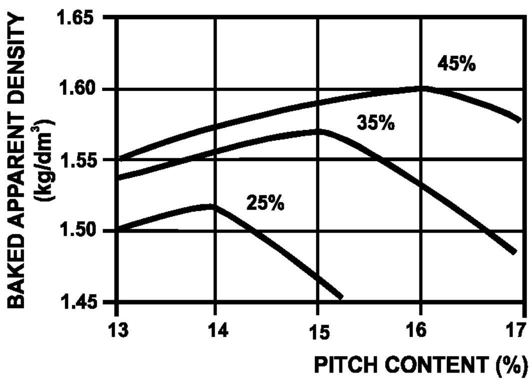

Figure 3 Change in pitch demand for different dust contents at 3500 Blaine for pressed anodes

ANODE QUALITY

Increasing the Blaine number with the appropriate adjustment in pitch content, has the following effects on Anode Quality:

- Decreases the air permeability
- Increases the apparent density

In general this can be represented by the trend shown in Figures 4 and 5. Adaptation of the process parameters is necessary for a substantial impact on the anode quality. This is illustrated for an optimised and unoptimised system where all other parameters are fixed. The air permeability is affected dramatically as illustrated in figure 4.

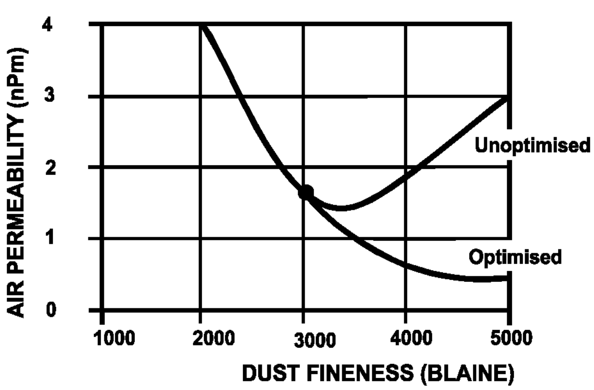

Figure 4 Relationship between air permeability and Blaine for vibrated anodes

Increasing the Blaine number is also beneficial for increasing the anode apparent density. For a standard recipe and adjusting the pitch content (1% for every 1000 Blaine more), the trend shown in Figure 5 is observed.

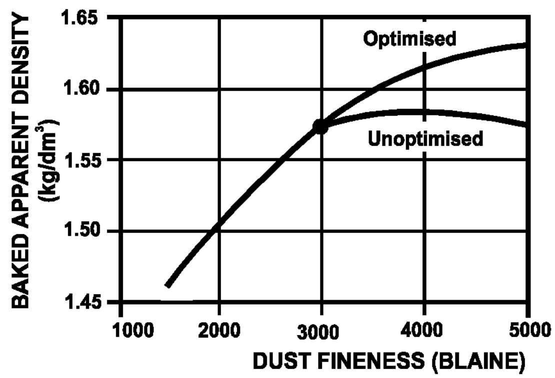

Figure 5 Impact of different dust fineness on the baked apparent density for vibrated anodes

Increasing the Blaine number above 5000 Blaine under these conditions and with conventional equipment does not appear to have any significant benefits. By optimising the processing parameters, this can also have a positive impact on other anode quality figures such as specific electrical resistance, compressive and flexural strength.

PROCESS ADAPTATIONS

Increasing the dust fineness has the following direct effects on the paste plant:

1. Formulation:
   - Increases dry aggregate surface area
   - Increases the material bulk volume
   - Alters particle size distribution
   - Increases the pitch demand
2. Processing Parameters
   - Decreases ball mill capacity
3. Paste Characteristics
   - Increases the viscosity

Tests have shown that when decreasing the average particle size of the dust fraction, the actual dust content can be reduced without adverse effects on most of the anode properties when powerful densification machines are used. This reduces the increase in surface area and thus limits the required increase in pitch content. Practically, in the paste plant, a decrease in the dust content is desirable for the ball mill circuit. The ball mill throughput is a function of the fineness required and will decrease as the fineness increases.

An increase in the paste consistency is also observed. This is due to the increased width of the particle size distribution as well as the increased dust fineness. By reducing the dust content, this also helps to reduce the paste viscosity level. The paste viscosity can also be altered by the shear rate imposed on the paste (mixing speed and motion) and the temperature of processing. Therefore the preheating and mixing play an important role in changing to anodes with a finer dust fraction.

Preheating and Mixing

Regardless of the aggregate formulation, it is important to achieve a certain consistency level during mixing, due to the sensitivity of the anode quality to the paste rheology. As the paste viscosity has increased due to the increase in dust fineness, an appropriate increase in mixing temperature is required to achieve a similar consistency level. Maintaining the paste consistency and formability is particularly important for the strength and the resistivity of the baked anode block.

By the same reasoning, in a normal recipe, a small decrease in pitch content can be compensated by an appropriate increase in the mixing temperature, which will maintain a similar level of viscosity.

If no pitch adaptation is made i.e. pitch content is maintained constant, and the dust fineness is increased this is effectively like decreasing the pitch content as the pitch demand has increased. In this situation, to keep the strength and the electrical resistivity at a satisfactory level, an increase in the mixing temperature is also required. This is illustrated in Figure 6.

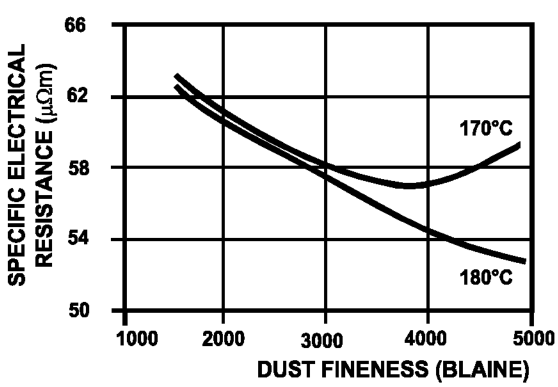

Figure 6 The change in specific electrical resistance with different dust fineness and mixing temperature

Figure 6 demonstrates how increasing the mixing temperature is required to realise the potential of certain recipes. The best method of increasing the mixing temperature is through efficient preheating. A high temperature is required to ensure that the pitch is evenly distributed through the finer dust.

Cooling

It is imperative that there is a form of controllable cooling between the mixing and forming stages if these are to be optimised separately [7,8]. This is particularly important for controlling the lamination and deformation issues potentially generated by mixing temperature levels [9].

Forming

The changes in recipe and processing conditions do not impact the two forms of compaction: vibrating and pressing, in the same manner. The vibroformer [10] is very sensitive to the paste viscosity due to the method of compaction. The frequency of vibration is a form of shear and the paste viscosity is sensitive to the shear rate. Figure 7 illustrates the impact of temperature on the baked anode density.

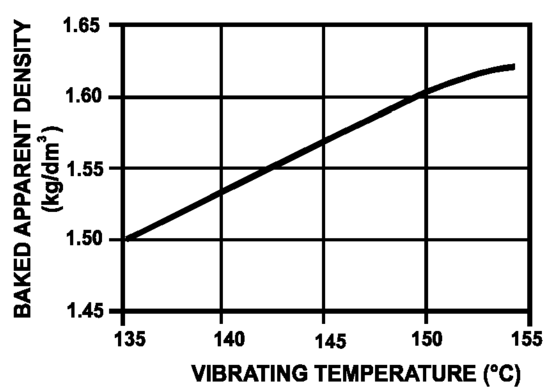

Figure 7 The relationship between vibrating temperature and apparent density

The press by contrast is sensitive to the elasticity of the paste which is a function of the dry aggregate recipe [11]. Higher dust contents and fineness levels increase the elasticity or 'bounce backability' of pressed anodes. To minimise the expansion of the anode following pressing, it is necessary to decrease the dust content when increasing the dust fineness. Failure to do this will cause very high levels of elasticity. This can cause high variability in certain anode properties. High expansion levels occur concurrently with a decrease in flexural strength and an increase in electrical resistance [12]. The elasticity level can also be reduced by decreasing the pressure level during forming without adverse effects on the anode quality providing the appropriate pitch content is used. The change in back expansion with dust fineness and dust content is illustrated in Figure 8. This is practically independent of the pitch content.

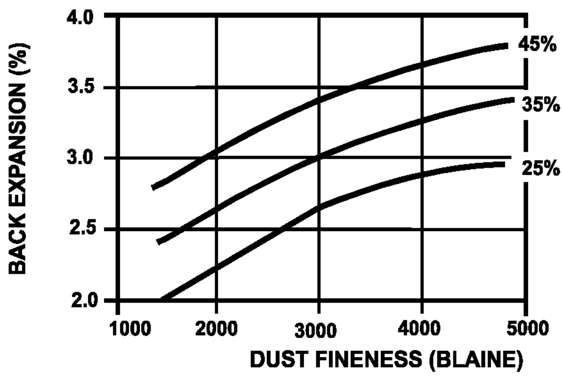

Figure 8 Influence of recipe of the back expansion

Increasing the dust fineness increases the paste viscosity as does increasing the dust content. Therefore by reducing the dust content for recipes with higher dust fineness minimises the change in viscoelastic characteristics. It is well known that increasing the temperature decreases the viscosity of a substance [13]. Therefore mixing and vibrating at higher temperatures when using higher dust fineness is required to achieve an optimum level of paste consistency. Vibrating at higher force levels can have the same effect as increasing the forming temperature but laminations can be an issue.

COMPARISON WITH CONVENTIONAL DATA

Trials conducted in the same plant using a continuous kneader, intensive mixer-cooler and vibroformer (no vacuum) and the same raw materials are compared in Table 2. This data shows the results from two tests illustrating the anode properties of a conventional recipe and the properties for a recipe using a finer dust formulation. Both recipes had the processing parameters appropriately optimised. A comparison between the processing parameters is given in Table 3.

Therefore for a given paste plant design, the recipe should be chosen requiring optimum processing conditions as dictated by the plant equipment limitations. Using an optimised recipe in a plant that can not achieve the target process conditions will adversely influence the anode quality achieved.

Table 2 Comparison of anode properties

Property	Units	Normal Recipe	Modified Optimised	Modified not Optimised
Blaine No.	-	3000	4500	4500
Dust Content	%	33	25	25
Pitch content	%	15.2	14	14
Green apparent density	kg/dm^3	1.630	1.660	1.644
Baked apparent density	kg/dm^3	1.583	1.600	1.586
Spec. electrical resistance	$\mu\Omega m$	55	53	55
Flexural strength	MPa	10.8	11.4	9.2
Air permeability	nPm	1.02	0.78	1.68

Table 3 Comparison of processing parameters

Parameter	Units	Normal Recipe	Modified Optimised	Modified not Optimised
Preheating temperature	°C	160	171	164
Kneader temperature	°C	176	184	177
Mixing Energy	KWh/t	6	8	6.5
Vibrator temperature	°C	143	150	143

CONCLUSIONS

Anode formulations using finer dust components and optimised process conditions show the following advantages in anode quality over conventional recipes:

- lower air permeability
- higher apparent density
- lower specific electrical resistance
- higher strength

The process adaptations required for these recipes are a function of the rheological behaviour. These adjustments are summarised below:

- lower dust content
- optimised pitch content
- higher preheating and mixing temperature
- higher mixing energy
- higher vibroforming temperature
- lower pressing force

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