MAINTAINING CONSISTENT ANODE DENSITY USING VARYING CARBON RAW MATERIALS

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Abstract

First of all, the methods used to characterise the structural properties of calcined carbon raw materials, in particular the apparent density (AD) of coke particles, are described. Thereafter, measures, designed to minimise and to keep constant the total particle porosity of the dry aggregate in the preparation plant, are considered. The effect of mixing and forming conditions on the apparent density of green anode blocks are also analysed. Finally, proposals are made for the adjustment and improvement of the composition and granular structure of the dry aggregate to obtain optimal paste characteristics and its high degree of compaction.

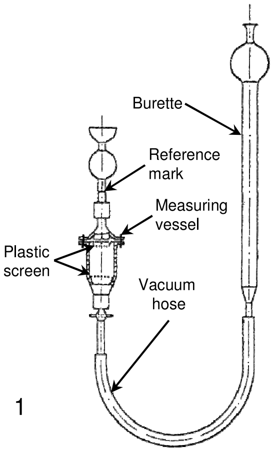
Introduction

In recent years, it has been observed in the anode plants under steady-state operation that the green apparent densities of the formed anodes vary more than in the past. This is mainly due to the supply of a large variety of petroleum-coke grades. A slight decrease in apparent density of green and baked anodes (GAD and BAD) has been recorded and, in some aluminium smelters, this phenomenon has been correlated with the AD of specified coke fractions controlled on arrival. By boosting potline amperage and increasing anode current density, aluminium smelters are still striving to achieve high ADs and low electrical resistivities in their anode blocks without the formation of cracks during the baking process or by thermal shock in the pots. This paper deals with the problems of attaining and maintaining high and consistent BADs in structurally sound and robust anodes on the basis of calcined petroleum cokes from different sources or other solid carbon substitutes with changing materials properties.

Structural Coke Properties

Apparent Density (AD)

Mercury, a non-wetting fluid, has been used and is still used in several aluminium smelters for determining the AD of granular carbon raw materials, especially of calcined petroleum coke. In the former VAW, two mercury methods, adopted from the ceramic and refractory industry, were employed to determine the ADs of coke. These methods are standardised under DIN 51065, Part 2. In the first method, a mercury volumenometer is used under atmospheric pressure with the mercury being displaced by the coke grains in the measuring vessel. The scale in 0.1 ml is read off a vertically adjustable burette (see Figure 1). In the second mercury method, an evacuated pycnometer is used with the displacement of the mercury by the coke grains determined by weight. A very simple gravimetric method with an upside-down glass funnel, shown in Figure 2, was subsequently introduced and employed. In laboratories providing service to anode plants equipped with Pechiney technology, the AD determination of coke is still performed using a pycnometric mercury method on samples of 10 g and 0.85 – 1.7 mm particle size.



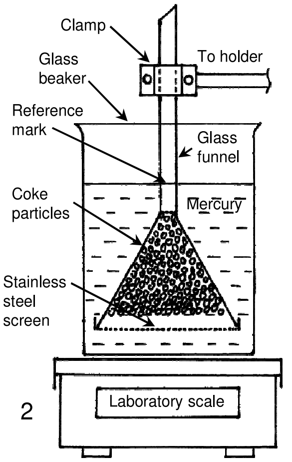


Figure 1: Mercury volumenometer for determining the AD of granular material (DIN 51065, page 2, 1964)

Figure 2: Simple device for the gravimetric determination of the AD of carbon particles with mercury

Using mercury for the determination of the AD has some inherent disadvantages: The penetration of mercury into the entrances of open coke pores is deeper near the bottom of the measuring vessel than at the top. Carbon dust is adsorbed at the mercury surface and a residue of mercury is always trapped in the pores of the coke samples. The handling, cleaning and removal of mercury from the tested coke samples are very laborious and can only fully be accomplished by distillation. Mercury is a toxic substance.

In order to replace mercury for the aforementioned reasons, a safe and harmless water method was developed by VAW at the beginning of the seventies. This method has been used ever since for the determination of the AD of granular carbon materials ranging in particle size from 0.125 to 11.2 mm and with a total porosity of 1 to 40%. The method proved to be very useful and informative in the fields of fundamental investigations and routine control. The use of a wetting fluid, such as water, is based on the following principle: A 100 g sample of the coke sieve fraction is heated to 50°C and then rapidly poured or dropped into a flask containing water at 25°C. The chilling of the coke particles and the contraction of the air in the coke pore volume has a stabilising effect on the interface between the air in the pores and the water at the peripheral pore openings. For a transient time, these fairly stable conditions allow the determination of the apparent volume of the coke particles using a suitable pycnometer. The apparatus and pycnometer employed are shown in Figures 3 and 4.

In addition to the AD, the real density (RD) is normally also determined from a pulverised portion of the tested particle fraction and the total porosity PO_{total} is calculated by equation 1.

$$PO_{total} = \frac{RD - AD}{RD} \times 100 \quad \% \tag{1}$$

A. Tomsett and J. Johnson (Eds.), *Essential Readings in Light Metals*

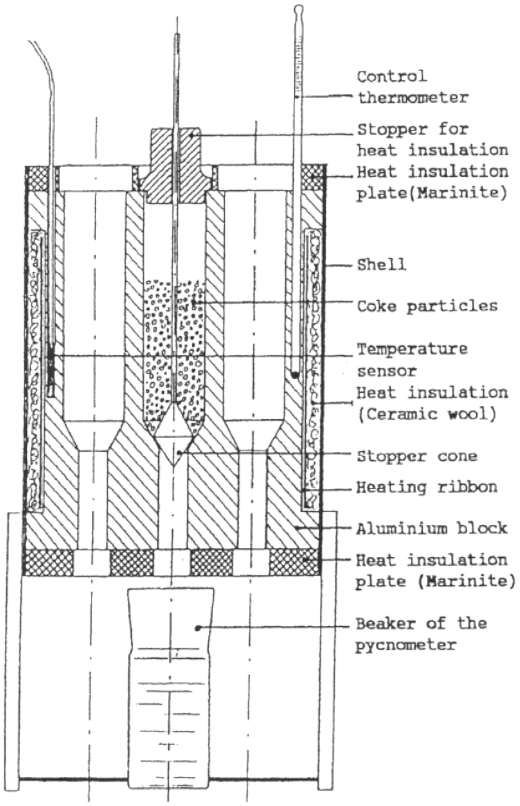


Figure 3: Vertical section of the preheating apparatus for the AD determination of carbon particles by means of the water method

An acceptable relationship was established between the AD and the total porosity PO_{total} of the different types of coke and the AD of the corresponding baked products. The results of these investigations are given in Table I.

Table I: Approximate relationship between the AD of the 1 – 2 mm petroleum-coke fraction and the AD of the baked product

Type of Product	Petroleum Coke Particles 1 – 2 mm			Baked Product
	Real Density g/cm³	App. Density g/cm³	Total Porosity %	Apparent Density g/cm³
Large anode blocks	2.07	1.59	23	1.45 - 1.48
	2.06	1.66	19.5	1.48 - 1.51
	2.08	1.75	16	1.51 - 1.54
	2.09	1.85	11.5	1.56 - 1.60
Cylindrical electrodes (Diameter 500-600 mm, similar recipe)	2.07	1.70	18	1.58 - 1.59
	2.06	1.69	18	1.59 - 1.60
	2.09	1.78	15	1.59 - 1.62
	2.10	1.79	15	1.63 - 1.65
	2.13	1.96	8	1.66 - 1.67
	2.12	1.91	10	1.66 - 1.67
	2.14	1.88	12	1.66 - 1.67
	2.14	1.99	7	1.65 - 1.68

A study of the total particle porosity of calcined petroleum cokes in 1973 and later in 1988 – 1990 (see Table II) reveals that an improvement of coke AD and total porosity took place in the eighties. If lower ADs of coke are encountered today, it seems not to be worse than those of the coke supplied in the seventies.

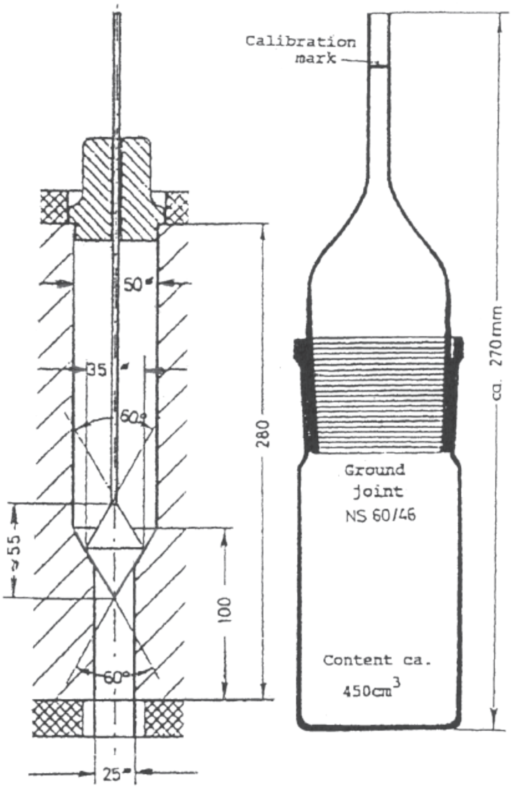


Figure 4: Heating-cell dimensions and pycnometer for the AD determination of carbon particles by means of the water method

Table II: Particle densities of various types of petroleum coke in two decades (Particle size 1 – 2 mm)

Year	Type of Pet. Coke	Tamping Density g/cm³	Real Density g/cm³	Apparent Density g/cm³	Total Porosity %
1973	GL 1	0.68	2.07	1.59	23
	GL 2	0.71	2.08	1.64	21
	MHD	0.72	2.10	1.68	20
	MLD	0.75	2.06	1.69	18
	De	0.73	2.08	1.66	20
	Gel	0.80	2.06	1.71	17
	JS	0.68	2.13	1.81	15
1988 to 1990	Ca	0.78	2.09	1.76	16
	Con	0.85	2.09	1.86	11
	Es	0.85	2.08	1.89	9
	Ma	0.84	2.07	1.80	13
	VE	0.79	2.09	1.82	13
	W1	0.80	2.08	1.81	13
	AR	0.83	2.08	1.87	10
	GLP	0.78	2.06	1.75	15
	GL	0.79	2.08	1.75	16
	KC	0.79	2.07	1.74	16
	CS	0.92	2.14	1.99	7

Real Density (RD) and Total Particle Porosity (PO_{total})

Equation (1) describes the interdependence of the RD, the AD and the total porosity PO_{total} and may be rewritten in the form:

$$RD = AD / (1 - PO_{total}) \qquad (2)$$

The AD of a carbon body or granular material expresses how much carbon is contained in a specific volume and the amount that may be consumed in the electrolytic process. The RD reflects how perfect the carbon lattice structure is or its degree of order. The values for a wide range of different carbon raw materials are compiled in Table III. From this, it can be seen that gas-calcined anthracite with a very low RD exhibits the lowest particle porosity, while electro-graphite with a high RD displays the highest particle porosity. It can also be recognized - as is well known - that the total particle porosity of calcined, anode-grade petroleum coke clearly depends on particle size. If a good wetting reagent, such as liquid pitch, is used instead of distilled water for determining the AD and Total Porosity, markedly lower porosity values are obtained (see Table IV).

Table III: Tamping density, RD, AD, and total porosity of various carbon raw materials

Carbon Material	Particle Size mm	Tamp. Density g/cm³	Real Density g/cm³	App. Density g/cm³	Total Poros. %
Gas-calcined Anthracite (GCA)	0.2 - 0.5	0.87	1.74	1.66	4.8
	0.5 - 1.0	0.90	1.74	1.65	1.9
	1.0 - 2.0	0.92	1.74	1.67	1.6
	2.0 - 3.2	0.91	1.74	1.66	1.8
Re-calcined Metallurgical Coke	0.2 - 0.5	0.80	2.02	1.82	10
	0.5 - 1.0	0.69	2.02	1.70	16
	1.0 - 2.0	0.64	2.02	1.52	25
	2.0 - 3.2	0.57	2.02	1.37	32
Petroleum Coke Type A	0.2 - 0.5	0.78	2.08	1.83	12
	0.5 - 1.0	0.74	2.08	1.73	17
	1.0 - 2.0	0.71	2.08	1.64	21
	2.0 - 3.2	0.68	2.08	1.58	24
Petroleum Coke Type B	0.2 - 0.5	0.87	2.06	1.81	12
	0.5 - 1.0	0.82	2.06	1.75	15
	1.0 - 2.0	0.80	2.06	1.71	17
	2.0 - 3.2	0.75	2.06	1.69	18
Petroleum Coke Type C	1.0 - 2.0	0.76	2.09	1.69	19
D	1.0 - 2.0	0.74	2.08	1.71	18
E	1.0 - 2.0	0.77	2.10	1.64	22
F	1.0 - 2.0	0.75	2.08	1.66	20
Pitch Coke	1.0 - 2.0	0.68	2.00	1.66	17
Premium or Needle Coke	0.2 - 0.5	0.90	2.14	1.90	11
	0.5 - 1.0	0.84	2.13	1.85	13
	1.0 - 2.0	0.80	2.13	1.81	15
	2.0 - 3.2	0.75	2.12	1.72	19
Granular Electro-graphite	0.2 - 0.5	0.89	2.22	1.86	14
	0.5 - 1.0	0.86	2.20	1.65	25
	1.0 - 2.0	0.85	2.19	1.62	26
	2.0 - 3.2	0.85	2.20	1.65	25

Table IV: Total particle porosity of various carbon raw materials determined in liquid pitch

Particle Size in mm	Regular Petrol. Coke	Re-calc. Metallurg. Coke	Gas-calc. Anthra-cite	Granular Electro-graphite
2 - 4	12	25	2.7	18
1 - 3	11	20	2.8	17
0.5 - 1	10	15	2.8	14
0.25 - 0.5	9	11	2.4	11
0.125 - 0.25	7	7	-	8
0.090/0.125	4.6	4.3	-	4.4
0.063/0.090	2.7	3.8	-	2.8
Testing conditions: Temperature 175°C, Heating-up and holding time 2 h, Tar pitch softening point 61°C (K & S)				

The RD of petroleum cokes increases with the heat-treatment or calcining temperature, as shown in Figure 5. If the petroleum coke supplied has a RD under 2.07 g/cm³, it may undergo a re-calcination during the baking process. This leads to a slight increase in the coke particle porosity and to a slight shrinkage of the geometrical particle shape. The increment in RD is about 2% over a change in the heat-treatment temperature of 100°C. Coked binder pitch behaves differently and increases less in RD.

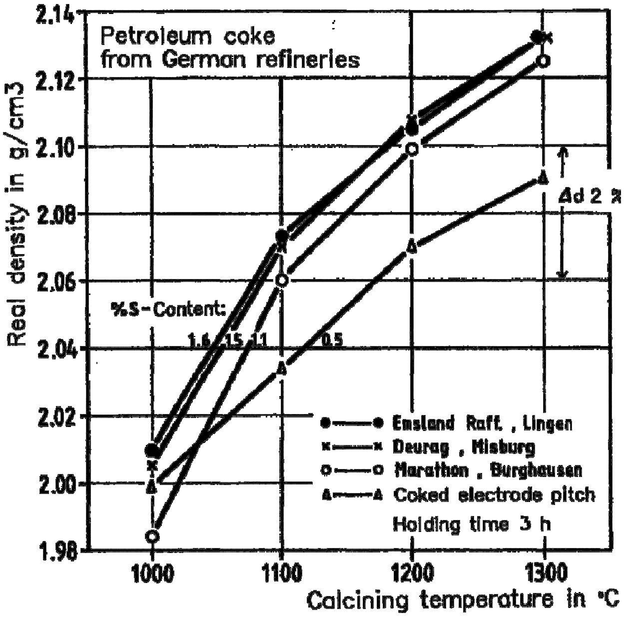


Figure 5: Increase in real density of petroleum coke with the heat-treatment temperature

The total porosity is comprised of open and closed porosity. Most of the coke particle porosity is open. This could be confirmed by the RD determination as a function of particle size (see Table V). It means that the majority of pore channels are accessible from the outside. The percentage of closed porosity of baked anodes is of the same order of magnitude, namely 2 – 3%.

Table V: Closed porosity of an anode-grade petroleum coke as a function of particle size

Particle Size mm	Real Density g/cm³	Closed Pores %
2 - 4	2.029	4.03
1 - 2	2.034	3.78
0.5 - 1	2.042	3.41
0.25 - 0.5	2.062	2.46
0.125 - 0.25	2.077	1.75
0.090 - 0.125	2.087	1.28
0.063 - 0.090	2.087	1.28
< 0.063	2.105	0.43
Extremely fine powder	2.114	0

Tamping Density and Particle Stability

The method for determining the tamping bulk density is laid down in similar DIN and ISO norms and ensures the maximum packing density of coke particle fractions. The tamping density values for coke have already been included in some of the foregoing tables. In Figure 6, tamping or tamped bulk densities of petroleum coke are compared with their total particle porosities as a function of the different size fractions. It can be inferred from this diagram that the particle porosity is more sensitive to particle size than the tamped bulk density.

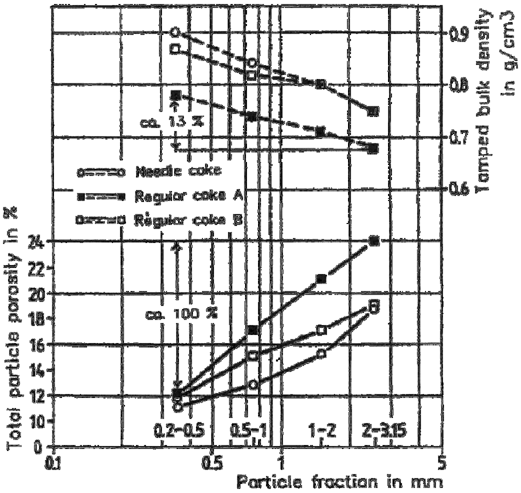


Figure 6: Comparison of the tamped bulk density and total particle porosity of petroleum coke

Particle stability is regarded as a structural coke property and denotes the resistance of coke particles to destruction and degradation during transportation, handling and in discharge systems, as well as to post-crushing in the mixing process. In VAW a Lödige turbulent mixer with plough-shaped blades was used to subject 1 kg samples of coarse coke particle fractions to strong projection movements and impact.

To conclude the above discussion on the various structural properties of coke, a set of relevant data is displayed in Table VI. Since recycled, crushed and screened butts also represent an essential feed material to the paste plant, an example of their granular properties is presented in Table VII.

Table VI: Example of basic structural properties of high-grade petroleum coke over an extended range of particle size

Particle Size mm	Tamp. Density g/cm³	Real Density g/cm³	App. Density g/cm³	Total Poros. %	Stability (Strength) %
0.08-0.125		2.091			
0.125-0.25	0.96	2.089	2.03	2.9	
0.25-0.5	0.97	2.086	2.02	3.2	
0.5-1	0.97	2.088	1.97	6	93
1-2	0.92	2.099	1.91	9	94
2-4	0.83	2.108	1.87	11	89
4-8	0.74	2.109	1.78	16	81
8-11.2	0.69	2.107	1.73	18	69
11.2-16					62

Table VII: Structural properties of classified butt material

Particle Size mm	Tamp. Density g/cm³	Real Density g/cm³	App. Density g/cm³	Total Poros. %	Stability (Strength) %
0.08-0.125		2.091			
0.125-0.25	0.96	2.089	2.03	2.9	
0.25-0.5	0.97	2.086	2.02	3.2	
0.5-1	0.97	2.088	1.97	6	93
1-2	0.92	2.099	1.91	9	94
2-4	0.83	2.108	1.87	11	89
4-8	0.74	2.109	1.78	16	81
8-11.2	0.69	2.107	1.73	18	69
11.2-16					62

Balancing out AD and Porosity of the Dry Aggregate in the Process Groups of Crushing, Screening and Proportioning

Online Screening Control of the Particle Fractions Combined with the Determination of Packing Density

The vibrated or tamped bulk density of the particle fractions in the paste plant denotes the degree of packing density of the dry aggregate that can ultimately be expected. The corresponding method is outlined in the flow sheet in Figure 7. Samples of the granular particle fractions are automatically taken from the ducts after the screening decks or from the fraction bins and passed to a vessel of defined volume in the tamping device. The vessel is tamped or vibrated to obtain a dense packing of the fraction material. The vessel is then emptied into an automatic screening machine where the screening analysis and the weight determination of the vessel's content are carried out. The results of the vibrated bulk density and the screening analysis are transmitted to the control room. If the packing density of the coarser particle fractions decreases due to the increased porosity of the coke grains, their percentage in the dry aggregate will be reduced and offset by the smaller particle fractions. It is assumed that the overall porosity or packing density of the dry aggregate will remain approximately unchanged by taking appropriate corrective action in the control room. At VAW, a fully automatic analysis screen delivered by the company RHEWUM was installed. In Figure 7 reference was made to the particle fractions best suited to the VAW/KHD paste plant technology but the described method can easily be transferred to other plants.

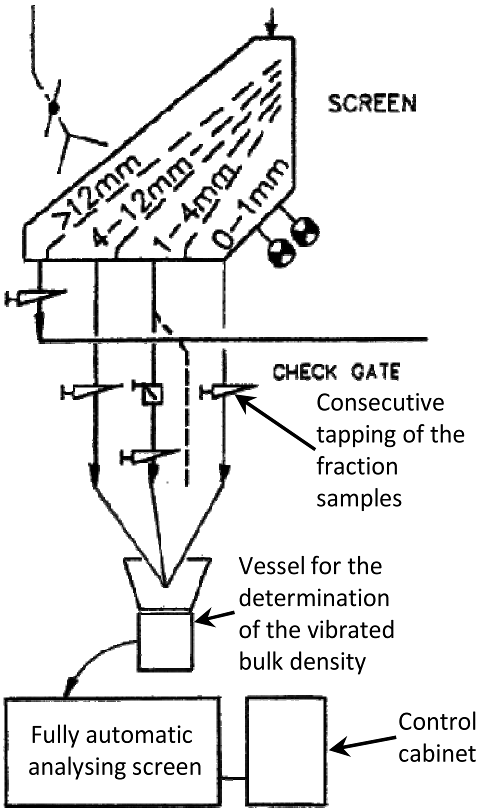


Figure 7: Determination of the vibrated bulk density combined with the automatic screening analysis of the granular particle fractions in the paste plant

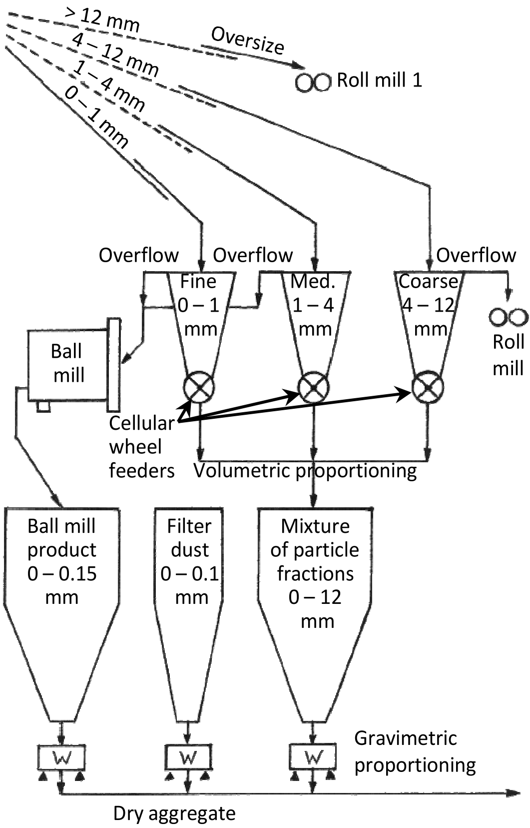


Figure 8: Volumetric proportioning of the granular particle fractions in the paste plant

Volumetric Proportioning

When aiming at high packing densities in the dry aggregate, the theoretical point of view is that it is more a matter of volumetric composition than of weight. A draft flow sheet about volumetric proportioning (see Figure 8) was re-discovered in the files of the author. The dosing of the particle fractions in this system is effected by means of cellular wheel feeders or air locks. The system is self-regulating with respect to the packing density of the particle fractions. If, for instance, the coarse 4 – 12 mm fraction becomes lighter, its weight percentage in the filler material decreases. This loss is then made up by the weight percentages of the smaller size fractions to reach the 100% level again. A special cellular wheel feeder was designed to combine the volumetric proportioning with a direct weight control. For this purpose, one half of the cellular wheel sluice sits on load cells (see Figure 9).

Density Improvement by Sifting

To prepare the dust or powder fraction according to the recipe, the excess quantities of the fine fraction (0 – 1 mm) or medium fraction (1 – 4 mm) are fed into the ball mill or roller mill circuit. Even the small coke grains of the fine fraction, are not free of porosity. After screening, this fine fraction may be passed through a cyclone or static classifier where the portions of fine dust and light and highly porous particles are separated from the portion of heavy and dense particles. The light dusty material is then conveyed to the ball mill feed silo for subsequent grinding.

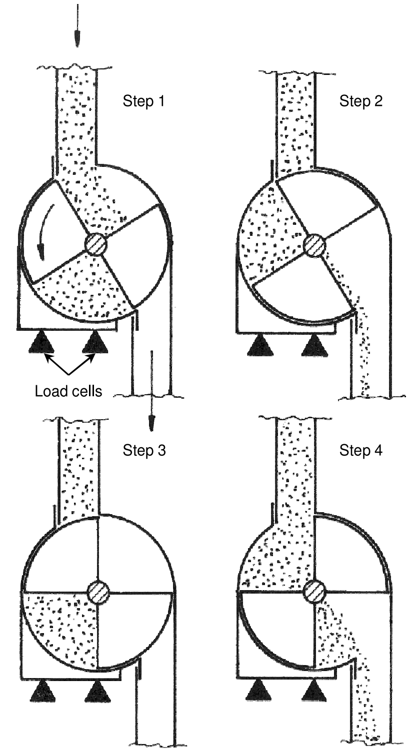


Figure 9: Cellular wheel feeder for the volumetric proportioning of particle fractions combined with weight control

A similar separation of the "wheat from the chaff" may be devised for the medium fraction. Denser and heavier dry aggregates, and hence better compacted anodes, can be expected if the light and more porous coke grains are sorted out and ground to a fine powder almost free from pores.

Blending of Different Types of Coke

If facilities for coke blending are available and if different grades of coke can be procured, blending of coke is one possible way of optimising the AD of the dry aggregate. This, however, depends on the precedence given to the respective coke property. High-sulphur and low-sulphur cokes are frequently blended to meet the official limits of SO_2 emissions. In contrast to this, the blending of high-porosity and low-porosity coke types is rarely given top priority. Commercial barriers, such as price and material shortage, also impose constraints on optimal blending. For this reason, it is deemed better to install technical equipment in the paste plant to cope successfully with a wide range of coke grades.

Effect of Mixing Conditions

Change of Recipes in the Mixing Process

In the seventies trials were conducted in a VAW paste plant to improve the thermal shock resistance of electrodes by substantially increasing the coarse fraction of needle coke. The end effect turned out to be negligible but the reason for this was identified. The filler coke size distribution in the electrode paste that came out from the BUSS mixer was almost the same despite making major changes to the coarse fractions of the dry aggregate. Most of the coarse particles were crushed during the mixing and kneading process.

Similar observations were made in the production of paste at several other anode plants. The particle size distribution of the coke filler in the green anode can deviate dramatically from the planned granular formulation. A change in the particle size distribution leads to higher green apparent densities, which may result in adverse or even disastrous effects, such as anode cracking during baking or thermal shock in the reduction cells.

An experience of this kind was once made at an anode paste plant where the kneading shaft in the Buss mixer was not adjusted properly and the clearance between the flights too tight. Paste extraction analysis is therefore the key control tool. Some testing results are given in Table VIII.

Table VIII: Three examples of paste extraction analysis revealing the post-crushing of the coarse particles in the BUSS mixer

	Example 1			Example 2			Example 3		
	A	B	C	A	B	C	A	B	C
Fraction mm	Dry Aggr. %	Extr. Paste %	Diff. %	Dry Aggr. %	Extr. Paste %	Diff. %	Dry Aggr. %	Extr. Paste %	Diff. %
< 0.5	40.5	43.2	+2.7	39.9	44.9	+5.0	36.9	49.6	+12.6
0.5-1	8.8	9.5	+0.7	9.8	10.3	+0.5	7.0	12.9	+5.9
1-2	9.9	10.6	+0.7	9.2	10.0	+0.8	13.0	13.0	0
2-4	13.9	12.2	-1.7	12.2	11.5	-0.7	12.8	9.9	-2.9
4-8	16.7	15.5	-1.2	18.0	12.9	-5.1	16.7	11.0	-5.7
> 8	10.2	9.0	-1.2	10.9	10.4	-0.5	13.6	3.6	-10.0
1)			4.1			6.3			18.6
2)			Normal			Acceptable			Very high

1) Loss of coarse particles 2) Ranking

A) Dry Aggregate, B) Extracted Paste, C) Difference

The lower the mixing temperature and the higher the specific input of mixing power in kWh/t of paste, particularly above 10 kWh/t, the stronger the post-destruction of coarse particles in the mixer will be. Mixing operations where more than 15% of the coarse particle fraction is crushed and where the crushed material is shifted to smaller size fractions still exist.

Other Aspects of the Mixing Process

If the green anode density (GAD) cannot be kept within the pre-set band because of varying particle density of the processed carbon material, two immediate corrective measures are usually taken in the control room.

If the GAD falls below the lower limit, more pitch is added. If the GAD exceeds the upper limit, pitch addition is reduced. In the first case, mainly associated with light cokes, the anodes may be over-pitched and adherence of sticking packing coke on the anode surfaces may result as one of the consequences. In the second case, which is more likely to occur with the processing of very dense cokes, the anodes may be under-pitched and the bond strength of the binder coke may become insufficient. As a result, horizontal fissures may appear in the baked anode.

The other corrective measure taken in the control room may consist in increasing the mixing power. This action will probably enhance the GAD of the paste and anode which is likely due to the above-mentioned shift to a smaller granulometry of the filler material.

The potential measures outlined above are designed to improve and balance out the dry aggregate and thus minimise the need for online adjustments to the mixing process.

High mixing temperatures of about 200°C are often preferred in order to facilitate fast and thorough wetting of the dry aggregate by the liquid pitch. Agitated cooling of the relatively hot paste is subsequently used in some paste plants to ensure fault-free forming. It has been proven that intensive cooling of agitated paste results in some pelletisation or granulation of the paste, ranging from tiny beads to clearly visible balls. The granulated paste does not affect the GAD of the formed anode block to a great extent but the baked bond structure seems to be weakened.

Attempts have been made to prepare the paste at extraordinarily high mixing temperatures of 300 – 350°C. Extremely low mixing power is required, and coarse dry aggregate particles will not be destroyed. At such high mixing temperatures, the low-viscosity pitch is characterised by strong wetting capacities and capillary forces. Moisture and air are readily desorbed from the large carbon dust surface and pitch creeps into the pores of the coke particles. Following the highly effective and rapid mixing process, the anode paste is subjected to a short vacuum treatment. The light volatiles in the pitch are removed in seconds by the applied vacuum. At the same time, the viscosity is raised to such an extent that no external cooling is needed prior to compaction of the paste. The advantage of the fore-going process is better utilisation of the expensive pitch. The carbon yield from the binder pitch is increased to over 80%. The baking behaviour of the green anode and the AD and strength of the baked anode are greatly improved. In addition, the baked anode will have a 20% lower electrical resistivity. This means an enormous benefit for high anode current densities. It can be further assumed that the mixing and forming process becomes less sensitive to variations in coke quality because open pores are partially impregnated with pitch.

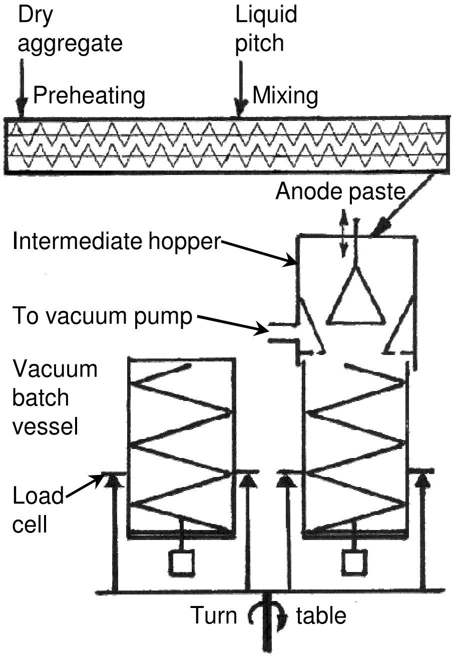


Figure 10: Layout of a compact high-temperature mixing process with subsequent vacuum treatment of the paste

The equipment layout of this high-temperature mixing process is relatively compact and displayed in Figure 10. Electrical preheating of the dry aggregate and mixing of the paste are consecutively performed in one twin screw unit. The two vacuum vessels are filled alternately and also serve as batch-weighing hoppers. The paste is directly discharged from the hopper to the forming mould of the vibro-compactor. The escape of pitch fumes into the environment is avoided by the tight design and construction of the equipment.

Effect of Forming Conditions

The vibratory forming of anode blocks began in the sixties. Vacuum application was introduced in the early seventies.

An elastic load on the cover-weight has been used since the eighties, mainly in the production of carbon lining blocks and arc furnace electrodes. "Stressed" cover weights have also been in common use in anode forming since the mid nineties. Initially, cover-weight pressure systems consisted of hydraulic/pneumatic devices but later of inflatable rubber bellows only. The vibration tables, which are excited by two counter-rotating shafts with eccentric masses, have been equipped with variable drives for the production of carbon lining blocks and electrodes since the eighties. Nowadays, anode vibro-formers also boast variable speed drives. The first generation of vibration tables was mounted on steel springs, the second one on inclined rubber pads and the latest on inflatable rubber bellows. While steel springs and rubber pads have invariable spring constants, the last generation of inflatable bellows allows fine-tuning.

Thanks to these technical developments, modern vibro-formers offer more variables for easy adjustment of compaction and are able of achieving better GAD consistency. Although the eccentric masses or centrifugal forces of the fly wheels can be adjusted as an important vibration parameter, they cannot be varied online by remote control. This vibration variable has to be optimised by carrying out test runs to set the frequency and momentum of the fly wheels. An increase or decrease in the air pressure in the bellows on the cover-weight is regarded as quick and easy way of regulating GAD. As seen from the graph below (see Figure 11), the temperature of the paste is another efficient means of adjusting paste compaction.

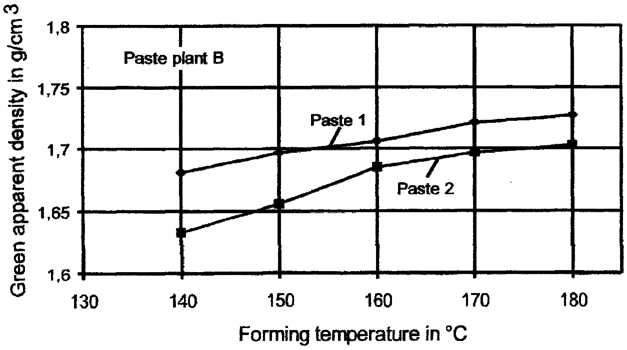


Figure 11: Anode paste compaction as a function of temperature

The new generation of vibro-formers made it possible to reduce the pitch content (freshly added pitch) in the paste to about 13% and the dust content in the dry aggregate to about 28%. A green anode block with the GAD of 1.64 g/cm³ and pitch content of 13.3% – without the pitch content of the green scrap - has a total porosity of about 14%. Approximately 8% of this total porosity can be assigned to the residual porosity in the filler material and about 6% porosity to incomplete compaction of the paste. This estimate indicates that there is still a margin for higher densification of the paste. For this reason, no major AD problems are anticipated to process cokes of varying porosity.

Conclusions

As part of the assessment of structural coke properties, the determination of the apparent density on selected sieve fractions between 0.125 and 11.2 mm provides early and useful information for the processing of various types of coke.

In the preparation plant measures can be taken and means be implemented to offset the influence of varying particle porosity and packing density of different petroleum cokes.

The mixing process may have an unfavourable impact on the pre-set composition and particle size distribution of the dry aggregate. A new high-temperature mixing process is proposed to enhance anode paste quality and baked anode properties.

Remarks are made regarding the use of vibro-compaction in the anode forming process. The densification capacity of the latest generation of vibratory compactors is high and adjustable, allowing good and consistent GADs to be maintained and the problems of varying structural qualities of carbon raw materials to be overcome.