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SØDERBERG PASTE. EFFECT OF FINE FRACTION VARIATIONS

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Introduction

When producing Søderberg paste, the fine fraction is the largest and most difficult fraction to control. The coarser coke fractions have well defined upper and lower limits. The fine fraction in the paste plant at Karmøy Plants has an upper limit of 0.2 mm. The fineness of this fraction is controlled by a simple screening analysis giving the wt% of particles smaller than 74 µm (200 mesh Tyler screen). This fineness control is done at regular intervals. The wt% of particles smaller than 74 µm in the fine fraction is kept within 74.0 ± 2.0%.

Because the fine fraction amounts to 55% of the total aggregate, 40.7% of the total aggregate consists of particles < 74 µm. Variations in the particle distribution below i.e. 50 µm will not be detected with the screening test. At Karmøy Plants paste plant the average particle size of the fine fraction is 38 µm.

To be able to study the complete particle size distribution of the fine fraction, a particle sizer based on laser diffraction was used. With this equipment it could be studied how well the screening analysis at the 200 mesh screen correlates with the total particle size distribution.

Analyses of fine fraction samples with the particle sizer

The particle sizer is based on the principle of laser diffraction (Malvern 2600 C, Malvern Instruments England). Results from the sizer have been compared with results from screening analyzes down to 45 µm. The deviations between sizer and screening results are small, typically 0.5 - 2.0% for the 75 and 63 µm and 1.0 - 3% for the 45 µm screen. Results of a fine fraction sample analyzed by both screening and sizer, is shown in figure 1.

Samples of fine fraction from the paste plants at Karmøy Plants and Sunndal Plants have been analyzed with the particle sizer. Both plants produce the fine fraction in ball mills where the fine fraction particles are separated in an air classifier. The plants use different petrol coke qualities. Figure 2 shows the average particle size (d_{50}) plotted against the amount of particles < 74 µm for 80 samples of fine fraction.

As can be seen from figure 2, there is an exponential correlation between amount of particles < 74 µm and the average particle size in the analyzed samples. The correlation can be expressed with the function

$$y = a*e^{bx} \qquad (1)$$

Correlations were made for the d_{50}, d_{30} and d_{10} diameters, below which 50, 30 and 10 wt% of the particles are found. The constants a and b and determinating coefficient R^2 are shown in table 1. For the analyzed samples the amount of particles < 74 µm varied from 57 to 91 %.

Table I Constants and determinating coefficients

	a	b	R^2
d_{50}	386.3	-0.0320	0.980
d_{30}	174.7	-0.0304	0.975
d_{10}	23.3	-0.0172	0.935

For the two plants where these samples were taken, the results show that the simple screening test of the fine fraction gives a good indication of the particle distribution in the area below 74 µm.

Effect of fine fraction variations on aggregate VBD

To study the effect of varying fineness of the fine fraction on total aggregate vibrated bulk density (VBD), the following was done. Fine fraction from the Karmøy Plants paste plant was screened on a 200 mesh (74 µm) screen. By mixing varying amounts of fractions between 0.2 and 0.074 mm and below 0.074 mm, fine fractions with varying fineness were made. Three different petrol coke qualities were used. Properties of these cokes are shown in table 2.

Table II Coke properties

Coke		:	A	B	C
Real density,	g/cm³	:	2.06	2.07	2.09
Vibrated bulk density,	g/cm³	:	0.832	0.886	0.836
Porosity (0 - 100 µm),	cc/g	:	0.137	0.124	0.136

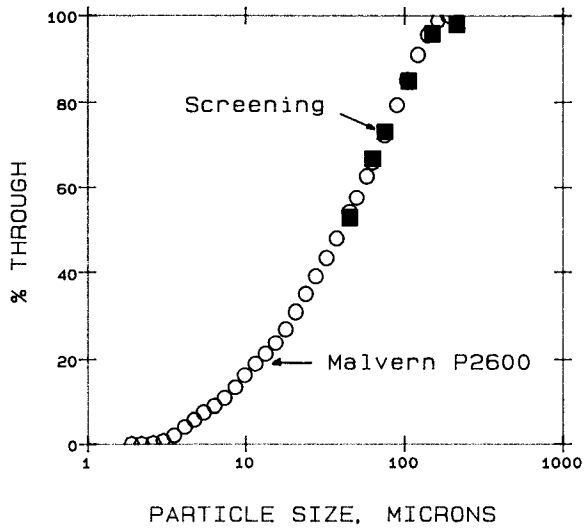


Figure 1: Fine fraction sample analyzed by screening and particle sizer Malvern P2600.

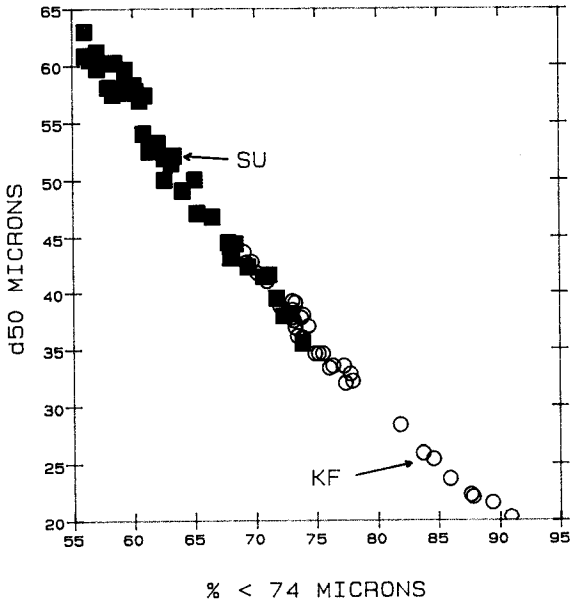


Figure 2: Average particle size and percent of particles < 74 µm for samples from Karmøy Plants (KF) and Sunndal Plants (SU).

The vibrated bulk density in table II is -8 + 14 tyler mesh, Kaiser procedure. Fine fractions with d_{50} in the 30 to 100 µm area were made using these cokes. In the fine fractions made in the laboratory the correlation between d_{50} and d_{10} and amount of particles < 74 µm were close to the values observed in the plants. The deviation was less than 5 µm for the d_{50}, and 1 µm for the d_{10}.

The aggregate used was: 21 % -12 + 5 mm, 11 % -5 + 1 mm, 13 % -1 + 0.2 mm and 55 % -0.2 mm.

The VBD was measured for this aggregate with the three different coke qualities and the fine fractions made in the laboratory. The three coarsest fractions for the different coke qualities came from the paste plant at Karmøy Plants. The analysis of VBD was done by putting the 4 fractions (total 900 grams) in a plastic bag, fill the bag with air and then shake it thoroughly for 5 minutes. The sample was then transferred to a reservoir funnel. From this funnel the sample was transferred to a 1000 ml glass-cylinder by means of a vibrating spatel (modified Mettler LV2). A funnel was also placed in the top of the cylinder. The cylinder was mounted on a vibratory table (Syntron Elec. Jogger). With the sample in the reservoir funnel, both the vibro-spatula and the vibrating table were started simultaneously. Within 90 ± 15 seconds the sample was transferred to the cylinder and after a total vibration time of 4 minutes the cylinder vibration was stopped. After the vibration, a cork lever cup was added before volume of the sample was recorded. Between 1 and 2% of the sample was lost as dust during the vibration. The repeatability of this method was within ± 0.010 g/cm^3.

Figure 3 shows the effect of varying fineness of the fine fraction on the total aggregate VBD. As can be seen from the figure, the fineness of the fine fraction has a significant influence on the VBD of the whole aggregate. The three coke qualities all have their maximum value when 62 - 65 % of the particles in the fine fraction are < 74 µm.

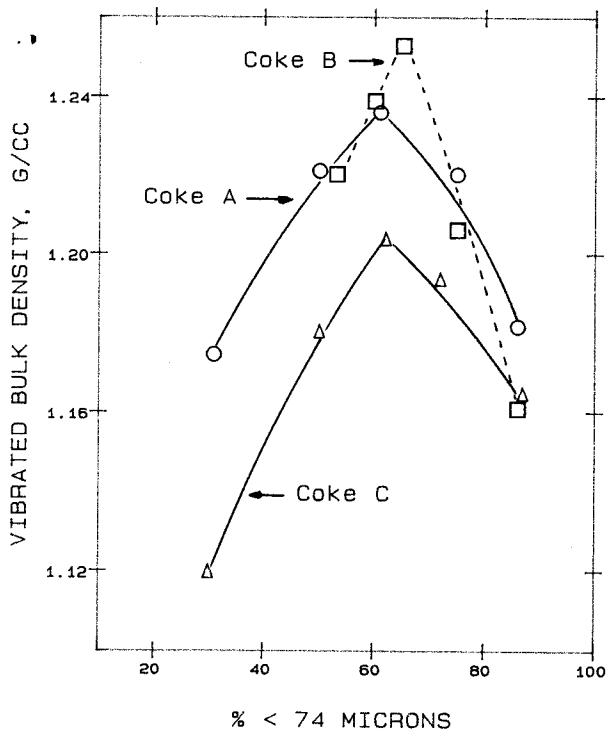


Figure 3: VBD of the aggregate as a function of amount of particles < 74 µm in the fine fraction.

Effect on paste elongation

The mixing of the pastes was carried out in an oil heated 15 liters sigma blade mixer. Before adding the liquid pitch, the coke was preheated to 180 °C. For all pastes the mixing temperature was 192 ± 3 °C, the pitch content 31.0 wt% and the mixing time 15 minutes. The coal tar pitch used had a softening point (Mettler) of 120 °C and quinoline insoluble content of 8.5 wt%. All the pastes were made with the same aggregate, only the fineness of the fine fraction was varied.

When varying the fineness of the fine fraction, the amount of pitch necessary to fill the voids between the coke particles will have a minimum value at optimum VBD for the whole aggregate. The fineness that gives the optimum VBD for the whole aggregate will have the highest amount of pitch in excess when the voids and pores are filled. The more pitch in excess when mixing with the same mixing temperature and pitch %, the higher the elongation number. This correlation between the fineness of the fine fraction and elongation is shown for coke A in figure 4.

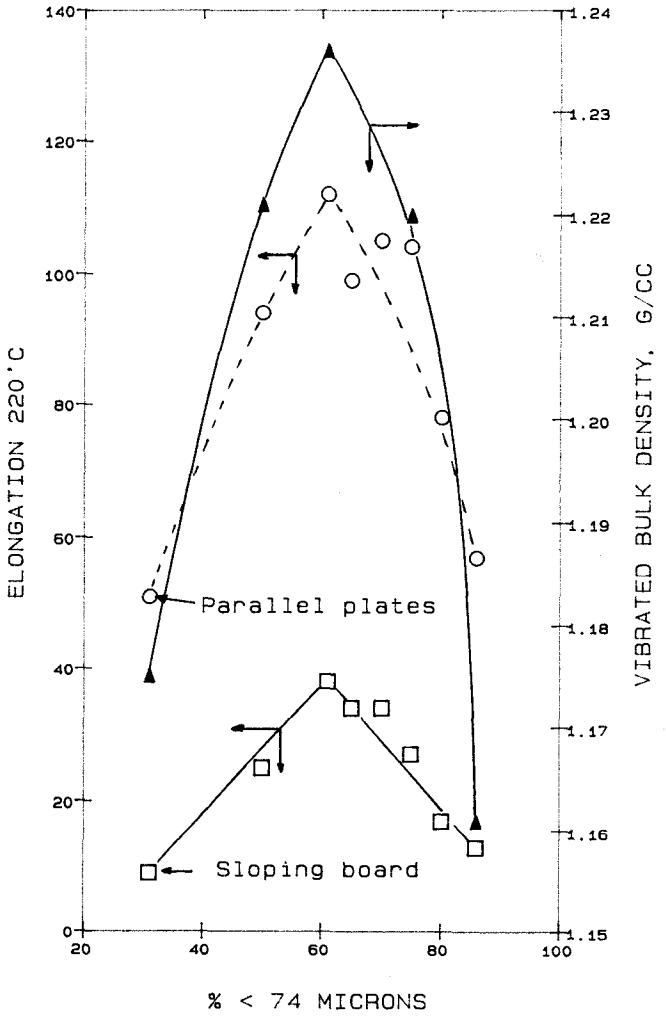


Figure 4: Aggregate VBD and paste elongation at 220 °C as a function of amount of particles < 74 µm in the fine fraction.

The elongation number was measured in two ways. The sloping board where the elongation number is the percent increase in cylinder length (1). The parallel plates where the percent increase in cylinder diameter gives the elongation number (2). For both methods the measuring temperature was 220 °C.

Increase in fineness can result in both increase or decrease in elongation number when mixing with a fixed pitch % depending on the starting fineness of the fine fraction. Plant measurements normally show a decrease in elongation number with increasing fineness of the fine fraction. This because the target fineness is 74 wt% < 74 µm. As can be seen from figure 4, this is on that part of the curve where increased fineness results in decrease in elongation number. If the plant had operated with the same aggregate, but a target fineness of the fine fraction of 50 wt% < 74 µm, the conclusion from plant measurements would have been the opposite. Increase in fine fraction fineness increase the elongation number.

When producing Søderberg paste the aim is to produce a homogeneous paste with small variations in the elongation number. Variations in elongation number caused by variations in the fineness of the fine fraction, will be smallest when the target fineness is that which gives the optimum VBD for the whole aggregate.

To simulate anode top behavior, the pastes were held at 200 °C for 68 hours. The pastes elongation numbers before and after the heat treatment are shown in figure 5. The parallel plate method was used for these measurements.

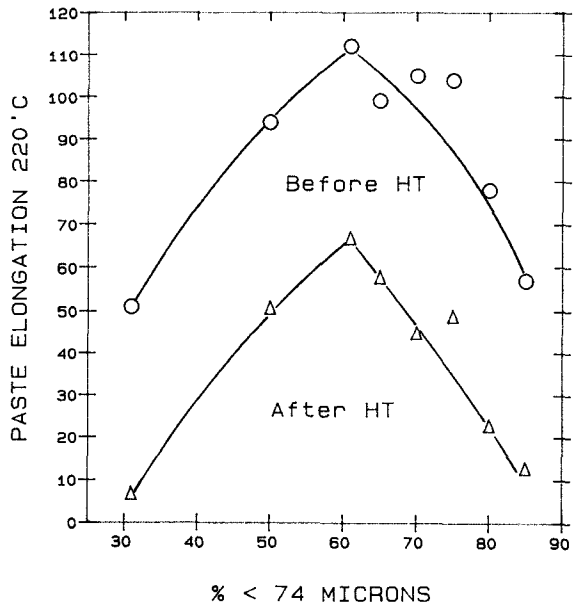


Figure 5: Elongation before and after heat treatment as a function of amount of particles in the fine fraction < 74 µm.

In figure 6 the relative change defined as K is plotted against the fineness. K is defined as:

$$\frac{\text{E.N. after heat treatment}}{\text{E.N. before heat treatment}}.$$

The smallest change in flowability was observed for the pastes produced with a fineness of the fine fraction close to that which gives optimum VBD for the whole aggregate.

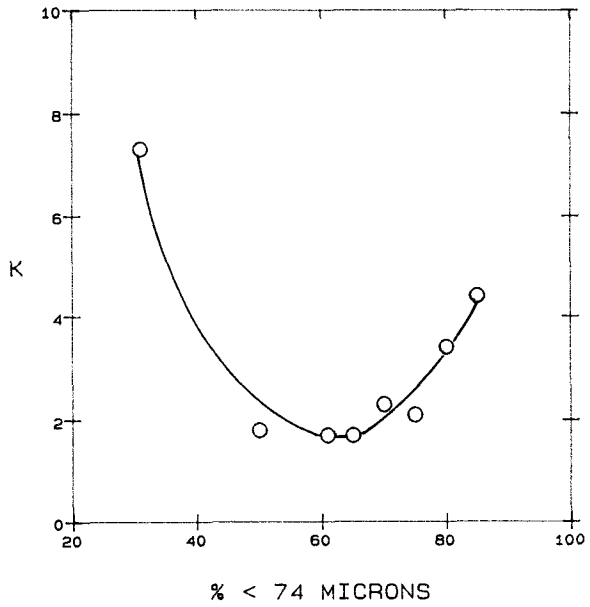


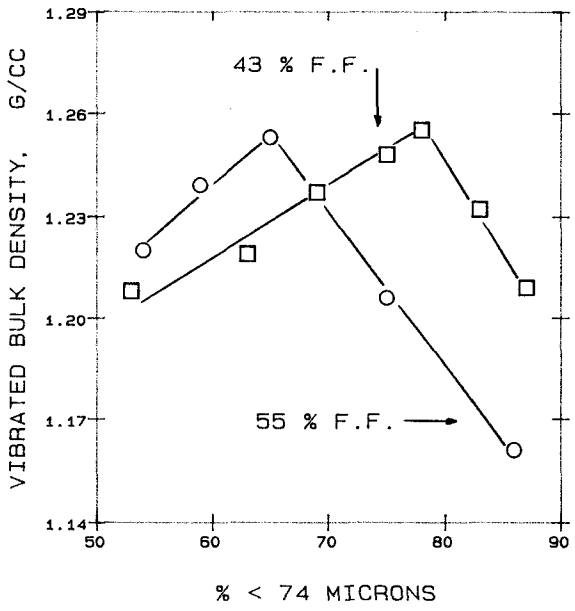
Figure 6: Change in elongation after the heat treatment as a function of amount of particles in the fine fraction < 74 µm.

At the paste plant at Karmøy Plants, paste is produced with a fixed pitch percent set according to coke macro porosity measurements. The elongation number is measured and used as a controlling, but not regulating parameter. When producing Søderberg paste with a fixed pitch percent, variations in mixing temperatures may result in variations in the measured elongation. These variations will be strongly reduced at the anode top (3). Variations in the elongation number caused by varying fineness of the fine fraction will not be much reduced. Variations in the fine fraction fineness can therefore result in variable quality of the baked anode.

Other aggregates

For the aggregate used so far (21-11-13-55) the optimum VBD was found for a fineness about 65 wt% < 74 µm. As this is an aggregate relatively rich in fine fraction, another aggregate containing less fine fraction was also studied. This aggregate consists of 16 % -12 +5 mm, 20 % -5 + 1 mm, 21 % -1 + 0.2 mm and 43 % - 0.2 mm. Both aggregates are used at Søderberg smelters.

Fine fractions with varying fineness were made and mixed with the other fractions to measure the VBD. Figure 7 shows the results for both aggregates. The same coke was used, coke B. To obtain optimum VBD for this coarser aggregate it was necessary to have a fine fraction containing more particles < 74 µm.



Figur 7: Aggregate VBD for Søderberg aggregates with 55 and 43 wt% fine fraction as a function of the amount of particles in the fine fraction < 74 µm.

The effect of varying fineness on the VBD of the fine fraction itself is shown in figure 8 for coke B and C. For an aggregate consisting of only fine fraction, the optimum VBD was obtained with 50 to 55 wt% of particles < 74 µm.

The obtained results indicate that the less fine fraction an aggregate contains, the finer the fine fraction should be to obtain optimum VBD for the whole aggregate.

Conclusions

The simple screening test used to control the fineness of the fine fractions in the paste plants of Karmøy Plants and Sunndal Plants, gives a god indication of the particle distribution in the area below 74 µm.

Variations in the fineness of the fine fraction were found to have a significant effect on the total aggregate VBD. For the studied Søderberg aggregate, three different petroleum coke qualities all had the optimum total aggregate VBD with the same fineness of the fine fraction.

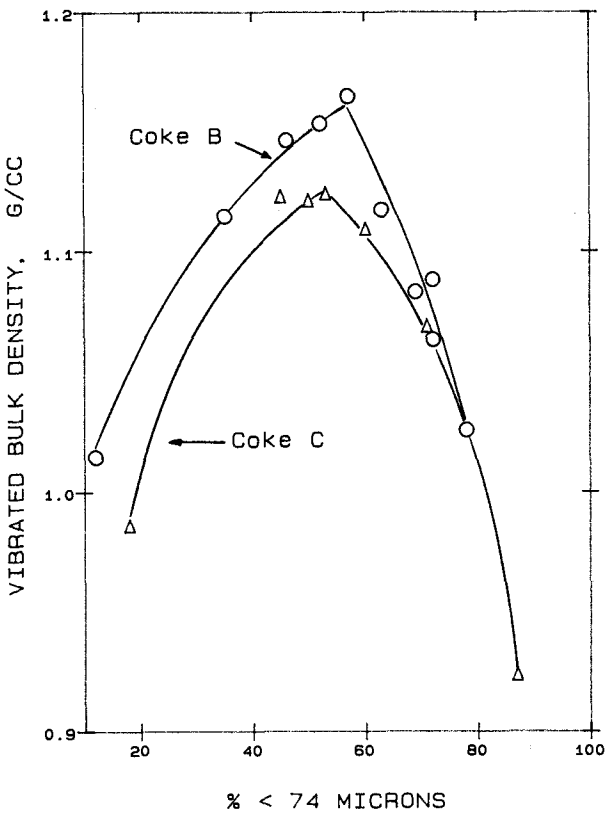


Figure 8: Effect of varying amount of particles < 74 µm on the fine fraction VBD.

With a constant pitch content, the elongation number of the studied Søderberg paste varied with varying fineness of the fine fraction and thus the total aggregate VBD. Variations in elongation numbers caused by varying fineness of the fine fraction, will be smallest with the target fineness which gives the optimum VBD for the whole aggregate. Anode top simulation showed that the difference in elongation caused by variation in fine fraction fineness is not reduced at the anode top.

When testing to find optimum VBD aggregates for Søderberg pastes, the fineness of the fine fraction is an important parameter. The results indicate that when reducing the amount of fine fraction, the fineness of this fraction should increase to obtain optimum total aggregate VBD.

References

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