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FIELD EXPERIENCE WITH THE BUSS KNEADER TYPE KX: HIGHEST QUALITY AND THROUGHPUT TARGETS ATTAINED

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Abstract

The oscillating screw kneader continues to set dependability and efficiency benchmarks in mixing anode paste. The first of the new-generation Buss Kneaders now in service upholds this reputation. Current and future process technology requirements were analysed together with users and EPCs in order to set realistic industrial targets as follows:

- Fully optimized product flow geometries to ensure dependable, absolutely trouble-free feed of dry materials und binders
- Uniform wetting of coke particles without affecting their structure and size
- Adequate retention time and narrow residence time distribution to ensure homogeneous product characteristics
- Optimal mixing of the various fractions for uniformly high anode densities
- Fast and easy maintenance during long production runs

The new Buss Kneader type KX – with a capacity of more than 60 tons/h – was thoroughly tested for target verification under industrial production conditions. All the requirements listed above have been met in full.

Introduction

Evolving Requirements from the Industry

As smelter outputs become ever larger, with higher pot amperages sought and additional potlines installed, greater carbon anode paste plant throughput is required and the spotlight has turned back to an area in which the original pioneers at Buss AG needed once more to step up to the plate and deliver.
The latest smelters being constructed are 700,000 tpy output with two potlines. In the first ten years of operation, the capacity can be expected to increase by as much as 20 per cent from additional pots and increasing of amperage, whilst Phase II expansions will also come on stream. This pushes the target of metal output up to 1.6 million tpy, requiring up to 1 million tpy of baked anodes, a need which can now be comfortably met by including just two KX kneaders in the paste plant [1] . This article explores both this enhanced solution and the first field experience.

Buss Kneader processing requirements for anode production

The first step in process optimization was to precisely investigate and define the compounding process requirements. While the Kneader is only a relatively small part of the overall anode production chain, it is often regarded as the heart of the process with critical influence on anode quality.

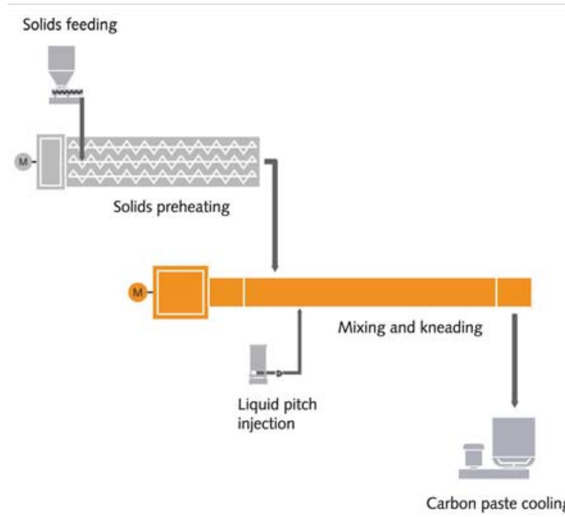

Figure 1: Feasible process layout

The Buss Kneader continuously mixes and disperses the pitch and coke fractions with the object of covering the entire coke surface area with as little pitch as required for filling the pores. During the combustion process this ensures maximum possible anode strength and optimal physical properties.
It is interesting to note that in the same way as with glue, more pitch does not necessarily mean greater strength. K. L. Hulse [2] differentiates between underpitched and overpitched, the optimum being between the two extremes so that the coke particles are fully wetted but still in direct contact. Small cavities are desirable in order to compensate for expansion of the pitch during the combustion process.
The mixing intensity has a significant effect on anode quality. Undermixing causes heterogeneous pitch distribution and partially unwetted surfaces. Overmixing makes the anode paste excessively dry because the pitch penetrates the coke pores too deeply for adequate surface coverage and binding. As a result, the coke particles are broken down by repeated impact and abrasion.

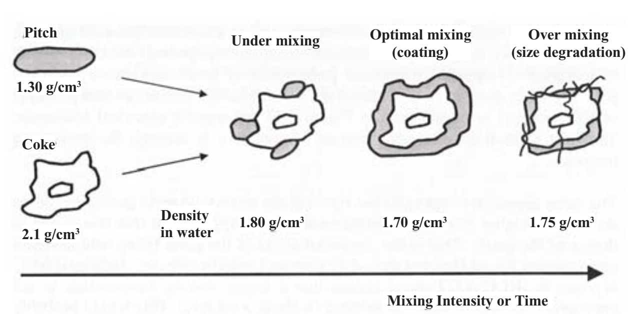

Figure 2: Effect of mixing intensity [3]

The moderate shear gradients in the Buss Kneader, with defined shear gaps between the screw flight and kneading pins, ensure intensive mixing without breaking down the coke undesirably. The typically short product retention time in the Buss Kneader guarantees constant process conditions with precisely controlled mixing time.

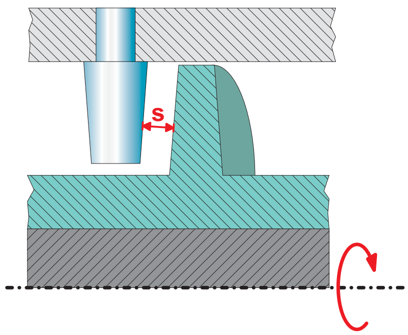

Figure 3: Constant shear gap S along the kneading pin.

In older plants, one or two Kneaders in series were used for melting down the solid pitch. In modern anode production lines this is not necessary because they use tempered liquid pitch. The pitch feeding temperature level is depending on the pitch softening point. Pitch showing a softening point of e.g. 120°C will be stored and fed to the process at 200°C.

System boundaries and limiting conditions

For process optimization, the system boundaries within the complex anode production chain were set between the preheater and Kneader and between the Kneader and cooler. The interfaces with the overall process are therefore located at the Kneader feed and discharge chute.

Located at the heart of the overall anode production process, the Kneader has to meet the following mandatory conditions:

- Vertical process sequence
- Liquid pitch feed at 180-190 °C
- Formulation: 13-18 % pitch
- Coke temperature 170-190 °C
- Least possible use of heat transfer medium

A visionary development

Market specification

A new kneader generation for compounding anode paste cannot be developed on the basis of a vision alone. A specification must first be drawn up based on clearly defined requirements and solutions. After detailed investigations, the resultant market specification can be summarized as follows:

- 50% more specific throughput per machine diameter, but without increasing specific manufacturing costs.
- Dependable and user-friendly machine operation and control.
- Robust enough for highly wear-resistant materials in future without problem.
- The design concept must take into account future throughputs of 20-100 t/h.

Challenge

Meanwhile, findings with other Buss Kneader applications clearly show that for optimal product quality and throughput, the future of intensive mixing processes lies with 4-flight Kneader technology.

Design Tool

A solver-based design tool was derived from those used for plastics processing development (quantec and MX Kneader technology). This enables the comprehensive simulation of anode paste kneaders based on process conditions, geometrical and material data.
This design software centers on the shear model. As the screw flights move sinusoidally past the kneader pins, they generate shear forces in the product. The shear forces are computed by finite element analysis for each flight, and hence for the entire processing zone.

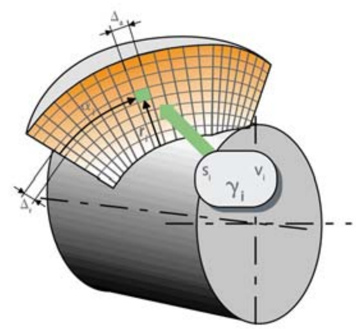

Figure 4: Finite element model for computing shear forces generated by a kneader screw flight.

The numerical simulation model of the Kneader transport characteristics was developed from existing single-screw extruder models by superimposing multiple material flows on the discontinuous flights of the Buss Kneader. Transport is unaffected by the axial oscillation because the forward and backward motions cancel each other out.

Most notably, this simulation model was further developed by fully integrating the process technology data with the mechanical strength computations. This is the only way to find out how changes affect the complex overall Kneader system and thus to show up negative effects in good time. In fact this method is so efficient, that all development possibilities can be rapidly investigated and optimized.

MIX index

Most conclusive among the data generated is the MIX index. This defines the mixing efficiency of a new design compared with the operating data of existing production lines. Comparison with actual data in practice enables easier and faster interpretation of theoretical findings.
The MIX index incorporates two elements. On the one hand the mixing effect of flow separation by the flights on the screw rotating in the product. Hypothetically, these flights separate the product into slices. The thinner the slices, the better the mixing effect. This also takes account of the residal time: the longer the product resides in the Kneader, the more often it undergoes flow separation and reorientation.

The other element of the MIX index defines the axial mixing effect of the reciprocating Kneader screw, which pulls part of the product with it rather like a garden rake.
These two parameters, the axial mixing effect and the theoretical slice thickness, are computed and expressed in terms of actual data measured in practice.

Process sections

The Kneading process zone is divided into four sections, each with a different purpose and geometry (Figure 5).

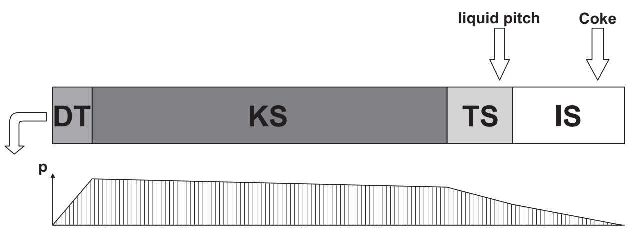

Figure 5: Process sections with pressure graph

Intake Section (IS):

Coke falls through the feed chute into the intake section, from where it is transported into the process zone by powerful screws with continuous flights. The intake section also incorporates well-proven backward venting toward the feed chute.

Transition Section (TS):

In the transition section liquid pitch is fed directly into the product through up to two hollow kneading pins. This avoids pitch flooding and ensures optimal conditions for rapid coke surface wetting. Furthermore, at the end of this section the screw configuration adapts to the change in priority – from powerful transport in the feed section to efficient distributive mixing in the kneading section.

Kneading Section (KS):

The kneading section is the longest in the entire Kneader processing zone. Here, where the focus is on optimal mixing, innumerable flow separations and reorientations with only moderate shear forces ensure maximum homogeneity without breaking down the coke undesirably.

Dynamic Throttling (DT):

Dynamic throttling replaces here the flap-dies previously used. Kneader screw flights with reduced feeding effect decelerate the mass flow to increase the filling degree, thus enabling optimal functioning of the mixing elements in the kneading section. The working principle has been described in [4] in detail.

More efficient mixing

As a rule with 3-flight Kneader technology, the specific energy (compounding energy in kWh per ton of anode paste throughput) required for optimal mixing is about 8 kWh/t. While this rule corresponds well with experience and empirical data, 8 kWh/t covers losses as well as the actual kneading energy required.
For the improved process geometry with 4-flight Kneader technology, this rule of thumb has to be corrected because less specific energy is required. The reasons are as follows:
Coolers between the Kneader and anode mold (vibrator / press) enable higher Kneader output temperatures. The mixing process can therefore take place at a higher temperature, with lower pitch viscosity accordingly. This improves the coke surface wetting and reduces shear force generation.
Systematic coordination of the material transport rates in each process zone section, by numerical simulation, enables a higher filling degree without abruptly decelerating the product flow against flap-dies. This dynamic throttling therefore improves Kneader efficiency by reducing overall power consumption for the same mixing energy.

Table 1: Key data of medium-size-Kneader

Parameter	Medium-size Kneader	Difference compared with existing technology
Throughput	60 t/h	+ 50 %
Screw Speed	60 rpm	+ 11 %
Diameter	650 mm	+ 8.3 %
Number of Flights	80	+ 33 %
da/di	1.97	+ 16 %

First field experience

Recently, the first Buss Kneader type KX went into commercial operation. The procedure adopted can be summarized as follows. This line, at the heart of a complete new green anode plant, was commissioned according to the normal industrial methods. After some intensive dry-run testing, the Kneader was loaded to about 50% of rated throughput, a smooth and trouble-free procedure that enabled dependable startup of the upstream and downstream systems. Afterwards, throughput was increased to the rated value of G = 55 t/h based on the mathematically simulated specific energy consumption in terms of speed/throughput. This enabled efficient and precisely targeted balancing of throughput measurements to the theoretically determined values. Here again, commissioning proceeded according to expectations, and the rated throughput was rapidly attained. The specific energy input as a mixing quality criterion, specified by the customer as espez = 7-8 kWh/t, was likewise attained without problem. And since the line is designed – with generous safety margins – for specific energy inputs up to espec= 10 kWh/t, it never has to operate near the limit. The final result is full compliance with the strict quality standards set for anode production. Furthermore, the line supplier and customer very soon attained their output figures targeted for dependable production in the startup phase. In end effect, this has proved in practice the success of separate process modules used in this combination for the first time – pitch and dry batch feed, kneading screw with optimized geometry, dynamic material flow throttle.

Conclusions

The Buss Kneader KX generation has now passed an important realization milestone. These findings in practice constitute a valuable feedback for the further development of this series¬. The medium size Buss Kneader KX650DT together with the smaller KX540DT and larger KX750DT versions cover a throughput range of 20-90 t/h. Thanks to this successful technology, future industrial demands – both for throughput rates and for anode quality – will be met by well-proven production systems that are cost-effective, maintenance-friendly and long-lived.

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