IMPROVED ANODE BAKING FURNACE COVER MATERIAL

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Abstract

The paper describes a new type of anode baking furnace cover material which replaces more traditional metallurgical or petroleum coke in closed baking furnace designs. The new granular material is a SiO_2-CaO based ceramic which has been used routinely at the HAW smelter for the last two years with excellent results. The material is used as a cover layer on top of a thin coke layer and has resulted in the following improvements: lower packing coke consumption and reduced furnace operating costs, cleaner flue walls as a result of distinctly lower slag formation and caking on the refractory brick lining, and improved quality of anodes due to thermal insulating of the re-usable cover material. The paper discusses the composition and practical application of the new material.

Introduction

Anodes for aluminium electrolysis are baked in annular (ring) furnaces at temperatures up to approximately. 1350 °C. In terms of flue wall construction, flue gas passage and firing procedures, a differentiation is made between the open horizontal flue furnace and the closed vertical flue furnace. Furnace installations of these types contain a multitude of sections arranged in series which in turn, are comprised of several chambers (pits). Two or three circulating fires are generally arranged above these sections, consisting of a burner unit and a cooling device [1]. Shaped, green anodes are placed in several layers into these chambers and surrounded and covered by a granular packing material in order to achieve the following:

- protection of anodes against airburn-from oxidizing gases,
- prevention of anode deformation during heatup,
- efficient heat transfer from flue walls to anodes.

After the baking process, the packing material is removed by vacuum and the anodes are taken out. Petroleum and metallurgical cokes are used as the packing material and typically also as a cover material(grain size 1 to 20 mm). During anode baking, these cokes combust or slag to varying degrees. Taking the same coke type, the consumption per ton of baked anode in an open furnace is notably lower than in a closed furnace (3-fold difference). The uppermost anode blocks are particularly susceptible to air-burn hence the cover layer must be sufficiently thick. When anode sizes are increased, efficient baking can frequently only be achieved by costly chamber modifications.

In closed furnaces, the cover material is directly exposed to the hot flue gases, resulting in a correspondingly high consumption of coke. Consequently, it is common to counteract this problem by use of an appropriate cover material.

Overview - Cover Materials for Closed Furnaces

If only metallurgical coke is used as the cover material, the thickness of the cover layer is approximately 40 cm. This layer thickness is sufficient because metallurgical coke, due to its high ash content, forms an iron-rich aluminosilicate slag. The slag layer acts as an additional protection against air-burn of the uppermost anodes as well as of the coke. After the baking process, the slag must be removed separately. Its disadvantage is that in the upper chamber wall area, the slag reacts with the refractory brick material, sticking firmly to it, Figure 1. With increasing fire cycles, more and more slag is enriched. In older chambers, a run-off of thin-liquid slags down into the floor area is occasionally observed. Ultimately, sticking of coke particles to the slag-covered refractory brick walls leads to caking. As a consequence of mechanical cleaning to remove the coke layer, the

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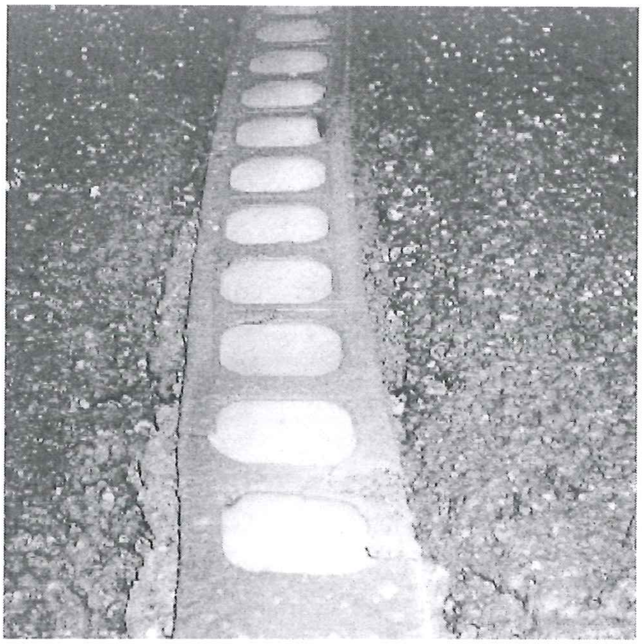

Figure 1: Heavily slagged heating wall, cover with metallurgical coke.

sagger brick walls get quickly destroyed and must be repaired frequently.

A characteristic of petroleum coke is its very small ash content, which results in very low slag formation. But to provide sufficient protection of the anodes, a cover layer of petroleum coke must be much thicker than for metallurgical coke (approx. 60 to 70 cm) due to the higher air-burn with petroleum coke Hence, consumption of petroleum coke is much higher than in those cases where much cheaper metallurgical coke is used.

The technical data concerning the advantages and disadvantages resulting from the use of the two. coke types are summarized in Table I. The temperature on removal of the chamber lid also influences coke consumption. If it is notably higher than the ignition temperature of the coke used, further coke burning takes place because of the air supply [2].

Table I Technical Data of Coke Types Used as Cover Material

Property	Met. Coke	Pet. Coke
Ash content (%)	8-11	0.2-0.4
Consumption (kg/t baked anode)*	30-40	55-70
Cover thickness (cm)	approx. 40	approx. 60-70
Advantages	low price thin cover	no slag formation
Disadvantages	slag formation (disposal, difficult handling, damage of flue walls)	high consumption high price thick cover

*packing material included

The benefits of using petroleum coke as a packing material prompted a search for an appropriate material to protect the coke, particularly in the cover layer. The following refractory materials were proposed:

- crushed, spent brick material, e.g. from the anode furnace [3],
- balls made of corundum or mullite [4].

However, on application of these materials, other disadvantages are encountered. Either the material sticks strongly together after its first use, necessitating its replacement, or the material costs are too high or its handling is too difficult.

The New Cover Material

The disadvantages of using coke in the cover layer and the demand for larger anodes led to the development of a new cover material. The following requirements were satisfied:

- no negative influence on the anode quality,
- avoidance of slag formation and strong caking,
- multiple re-use
- substantial reduction of cover layer thickness compared to the use of coke alone,
- simple handling,
- positive economics ,
- no negative impact on the furnace crew and the environment.

. The main constituents of the new cover material are the crystalline SiO_2-phases tridymite and cristobalite and a CaO based bonding phase. The production takes place at burning temperatures above 1420 °C. An overview of the most important properties is given in Table II.

Table II Properties of New Cover Refractory Material (Typical Values)

Property	Unit	Value
CaO	%	3
SiO_2	%	94
Alkalis	%	0.4
Grain size	mm	6-25
Packing density	t/m³	0.8
Melting temperature	°C	> 1650

Since late 1998, the material has been used routinely at the HAW smelter near Hamburg to cover the uppermost anode layers. The closed-type Riedhammer furnace had previously been subjected to a general repair. Furnace data is shown in Table III.

Table III Characteristics of HAW Baking Furnace

Characteristic	Unit	Value
Fire cycle	h	33
Number of fires	-	3
Sections	-	48
Pits per section	-	5
Anodes per section	-	75
Max. flue gas temperature	°C	1250

Before and after the repair, neither changes in the furnace operation nor in the anode production were made. The same metallurgical coke type was maintained as a packing material. A good evaluation of the behaviour in operation of the new cover material was thus given.

A low total thickness of the cover layer was achieved by pouring an approximately 10 cm layer of metallurgical coke at first onto the uppermost anode layers. Subsequently, this was covered with a 15 cm thick layer of the SiO_2-rich material. The total cover layer thickness of 25 cm is approximately 40 % thinner compared to the previous procedure, Figure 2. On account of its chemical- and mineralogical composition, the ceramic cover material can be re-used multiple times. When emptying the chambers with the suction device, a mixing with the metallurgical coke may occur which leads to a weak sticking of the granular constituents upon repeated use (especially with strongly slagging coke types). During suction with the crane however, these contacts are easily broken up again. The cover material is stored in a separate bunker.

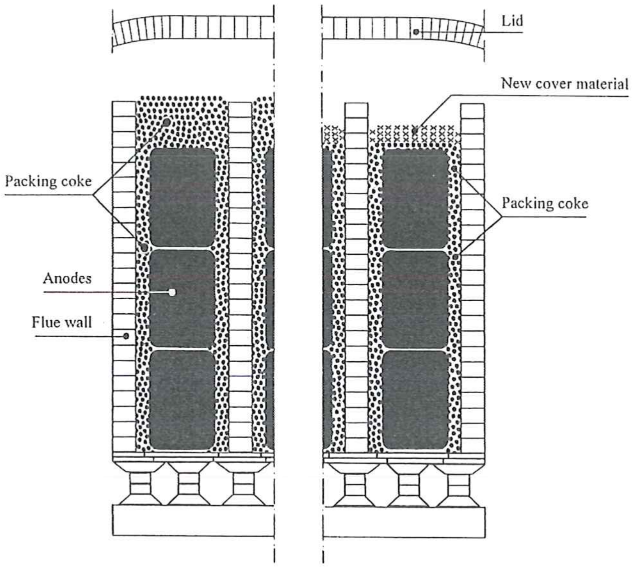

Figure 2: Thickness and structure of the cover layer before and after general repair (schematic view).

Benefits of the New Cover Material

As a result of using the CaO-containing SiO_2-rich cover material, slag formation was eliminated (no slag disposal). Caking at the chamber walls was thus effectively prevented, Figure 3.

The total thickness of the cover layer could be reduced by approximately. 40 %. Now, HAW is in a position to produce larger anodes without any furnace modifications. Another positive effect is the dramatic reduction in coke consumption (sum of packing coke and anode coverage) by approximately 80 %. Viewed over a long period, consumption of the new cover material was below 5 kg/t baked anode, Table 4.

In operation, the reusable ceramic cover material also acts as a stable heat insulation for the anodes. With respect to anode quality, some improvements could be expected. Comparative investigations of air reactivity (residue, ARR) demonstrate an increase of 2-6 % absolute, Table IV.

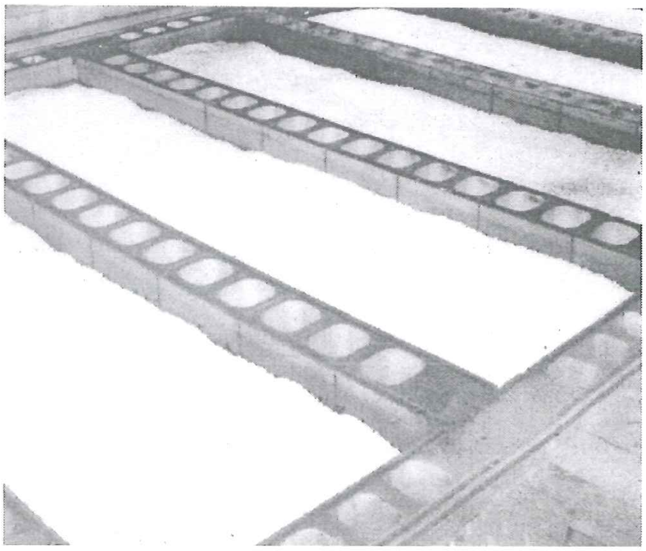

Figure 3: Chamber after several fire cycles using the new cover material.

Table IV Comparative Production Results Before (Old) and After General Furnace Repair (New)

Figure	Unit	Old Value	New Value
Coke consumption*	kg/t b. a.	32.0	6.8
Consumption of new cover material	kg/t b. a.	-	4.4
Anode air reactivity, residue**			
- top layer	%	87	89
- middle layer	%	79	85
- bottom layer	%	80	84

*packing material included, **RDC-method [5]

Conclusions

The granular, refractory SiO_2-rich cover material yields technical and economic benefits:

- Slag formation and incrustation with the use of metallurgical coke were stopped (no slag disposal). The need for extensive cleaning work on chamber walls is eliminated.
- The total thickness of the cover layer can be reduced substantially. Baking of larger anodes is in many cases, possible without any modification of the furnace.
- The material provides better insulationand the operation is more stable. The quality of anodes was thus improved and standardized.
- The cover material can be re-used multiple times and handling is very simple.

Consequently, its use in closed anode furnaces makes particular sense if petroleum coke is used as a packing material.

References

1. J. Hurlen and T. Naterstad, "Recent Developments in Carbon Baking Technology," Journal of Metals, 43 (11) (1991), 20-25.

2. W. J. Negrón et al., "Fire Distribution of a 48 Sections Baking Furnace," Light Metals 1995, ed. J. W. Evans (TMS, Warrendale, Pa), 701-704.

3. A. J. M. Kalban et al., "Baking Kiln Performance Optimization by Retrofitting and Operational Modifications," Light Metals 1994, ed. U. Mannweiler (TMS, Warrendale, Pa), 545-550.

4. T. Tokushi, M. Nagayasu, and E. Niihama, "Verfahren zum Brennen oder Graphitieren von Kohlenstofformkörpern," DE patent 2314391 (23 March 1972).

5. W. K. Fischer et al., Anodes for the Aluminium Industry (Sierre, Switzerland: R&D Carbon Ltd., 1995), 288-289.