Innovative Lining Concepts for Hazardous Waste Incineration

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The environmentally friendly and well-regulated disposal of waste is one of the key factors of conservation of nature in a modern industrialised society. Especially the disposal of so called hazardous waste is a very important issue related to the question of sustainability. Nowadays in a modern technical world guided by consumer products the daily number and amount of critical substances is increased. Therefore we have to focus on this development in response to a growing world population. The environmentally friendly handling of these things is based on two philosophies. One is the discourage of waste which will lead to a lower amount of waste in total and on the other hand a waste management based on thermal treatment of critical residuals. In this paper customised lining concepts for hazardous waste incineration plants are discussed. Based on more than 25 years of experience *STEULER-KCH* shows some examples of lining solutions for the thermal treatment and environmentally friendly disposal of wastes.

1 Introduction

The incineration is a key factor in case of disposal and recycling of hazardous waste. The aim of this process is the disintegration of toxic components, the reducing of amount and volume of waste and the energy recovery. On the next pages we will discuss different types of incinerators for halogenated and alkaline residuals and for mixed waste treated more or less in a randomised process. We will show innovative, wear resistant lining concepts for rotary kilns, fluidised bed incinerators and non rotating incinerators for the treatment of waste water or e.g. halogenated waste.

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2 Mixed waste technology – rotary kiln

Based on the possibility of incineration of high volumes, different types and different physical condition of waste the rotary kiln is the most important system for the use in hazardous waste incineration (Fig. 1). No other kiln is able to burn such a huge amount of solid, liquid and paste-like waste simultaneously. A throughput of up to 60 000 t/a is not really uncommon. These rotating cylinders with a diameter up to 5 m are working with a direct-current heating system. Depending on the diameter the length of the cylinder is in the range of 6 to 12 m, in single cases up to 16 m.

The feeding of the residuals is carried out through different inlet works. For solid waste a chute is commonly used. Liquid and paste-like material is feed through lances. The wear in the inlet area of the kiln is the result of the intake of moisturised waste with a starting vaporisation and the mechanical impact of solid material like e.g. bins. In this area the use of chromium oxide containing lining material is often not necessary due to the missing of slag. Therefore the commonly used lining in this area is a chemically bonded aluminium-silicate based on andalusite. It becomes more and more common to use humps in this kiln inlet zone to optimise the burn-off loss and therefore to enhance the throughput of waste in total (Fig. 2).

Starting with an area where slag can appear STEULER-KCH recommends chromium oxide containing lining material like our well known bricks based on white fused corundum. Depending on the process control and composition of the fed residuals a liquid or friable slag is created which runs through the horizontal rotary kiln into the slag funnel where the hot slag is cooled down with water and than separated into containers. Es-

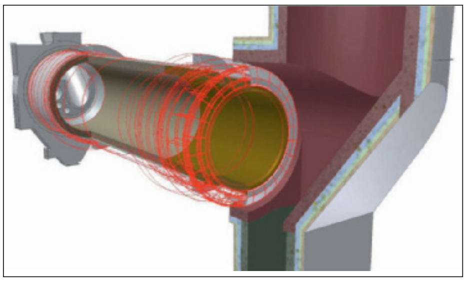

Fig. 1 Hazardous waste incineration complex (schematic)

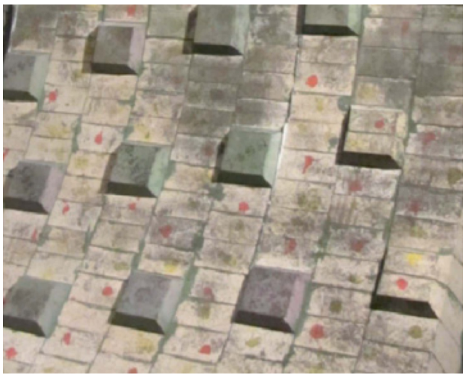

Fig. 2 Hump area in the inlet zone of a rotary kiln

Tab. 1 Properties of different types of chromium oxide containing lining material for rotary kilns

	Suprema CZK 825 P	Suprema CZK 855 P	Suprema CZK 905 P	Suprema CZK 810 P	Suprema CZK 815 P
Chemical Analysis [mass-%]					
Al_2O_3	82	85	87	82	77
SiO_2	8	5	2	2	2
Fe_2O_3	0,4	0,3	0,2	0,2	0,2
Cr_2O_3	5	5	5	10	15
P_2O_5	1,6	1,4	1,5	1,5	1,5
Physical Properties					
Bulk density [g/cm³]	3,14	3,35	3,41	3,43	3,48
Apparent porosity [vol-%]	14	12	12	12	12
Cold crushing strength [MPa]	140	140	150	150	150
Young's modulus [MPa]	41 000	46 000	33 000	31 000	25 000
Linear thermal expansion coefficient [$\times 10^{-4}$/K]	0,75	0,80	0,85	0,85	0,85

pecially low viscosity and high iron content of the slag is in most cases the condition which results in an extremely high wear of the refractory lining. In this extremely troubled kiln zone only premium bricks based on fused corundum with more or less addition of chromium oxide will keep the lifetime of the lining in an acceptable range. Although depending on the specified operating time the level of addition of chromium oxide is adjusted. Tab. 1 shows some of the well-proven lining material produced by STEULER-KCH. On the right side of Tab. 1 low silica containing refractory material is shown. Such a kind of grade results in very high corrosion and infiltration resistance. Parallel they provide high structure elasticity due to the addition of zirconium oxide which disturbs the structure of the material itself.

For the continuous improvement of lining material or on the other hand simply as test of different material the implementation of test fields in the current or new lining is a suitable method to gain significant results out of the practical use of refractory material (Fig. 3). The aim of this comparison is to point out the most suitable lining material for the operation of the incineration plant.

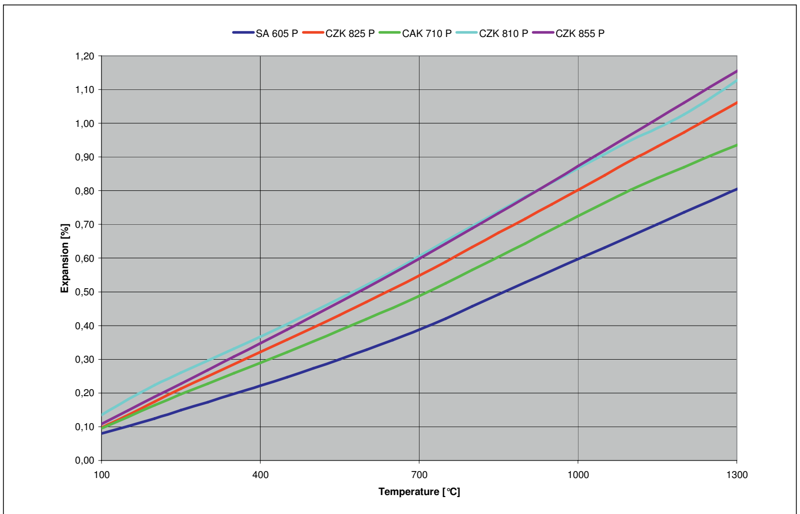

Fig. 4 Thermal expansion of different types of lining material

Fig. 3 Half-shell trial in a rotary kiln

3 Mixed waste technology – post-combustion chamber

The challenging function of the post-combustion chamber at the output connection of the rotary drum is as follows:

- to discharge the inert, off-burned residual products in a solid or liquid form into the slag funnel
- supplementary incineration of liquid and gaseous waste in the lower part of the chamber
- disintegration of toxic components in the flue gas through a suitable residence time in the chamber in the temperature range between 1000 and 1250 °C based on the legal regulations of emissions.

With the start up of the incineration process in rotary drums the post-combustion chamber had a rectangular shape. Nowadays most of the chambers especially the new ones are build up cylindrically. The reason for that is a better behaviour in the case of residence time and flow mechanism. But also some constructive reasons have led to the cylindrical shape of the post-combustion chamber.

The upright standing chambers up to a height of 25 m and a diameter of the steel shell up to 8 m are lined in multilayers with a total thickness up to 600 mm. The thickness of the hot face layer is app. 180 to 250 mm and has the most wear in the lower part of the chamber. Often extreme wear occurs in the arch area at the entrance of the chamber where the end of the rotary drum is connected to the post-combustion chamber. The reason for the high wear in this area is often seen in the high velocity of the flue gas, high incineration temperatures up to 1350 °C and the feeding of liquid and gaseous waste into the lower chamber part.

Tab. 2 Properties of different types of lining material for post-combustion chambers

	Suprema SA 605 P	Suprema CA 705 P	Suprema CAK 710 P
Chemical Analysis [mass-%]			
Al_2O_3	60	70	70
SiO_2	36	20	13
Fe_2O_3	0,9	0,8	0,6
Cr_2O_3	–	5	10
P_2O_5	1,4	1,5	2,1
Physical Properties			
Bulk density [g/cm³]	2,58	2,85	3,00
Apparent porosity [vol-%]	13	14	14
Cold crushing strength [MPa]	110	100	100
Young´s modulus [MPa]	28 000	22 000	20 000
Linear thermal expansion coefficient [× 10⁻⁴/K]	0,55	0,62	0,65

Tab. 3 Properties of different types of lining material for thermal oxidisers and fluidised bed incinerators

	Suprema SA 57 P	Suprema SA 605 P	Suprema CA 705 P	Suprema KE 85 P
Chemical Analysis [mass-%]				
Al_2O_3	57	60	70	88
SiO_2	37	36	20	9
Fe_2O_3	0,9	0,9	0,8	0,3
Cr_2O_3	–	–	5	–
P_2O_5	2,7	1,4	1,5	1,4
Physical Properties				
Bulk density [g/cm³]	2,58	2,58	2,85	3,08
Apparent porosity [vol-%]	10	13	14	14
Cold crushing strength [MPa]	140	110	100	130
Young's modulus [MPa]	35 000	26 000	22 000	18 000
Linear thermal expansion coefficient [×10⁻⁴/K]	0,52	0,55	0,62	0,70

Standard material like chemically bonded andalusite bricks are sometimes not longer sufficient. A short lifetime like in the rotary drum is the result. Therefore in the case of appearance of liquid slag and high alkaline containing waste STEULER-KCH recommend a lining with chromium oxide containing Andalusite or andalusite-corundum bricks. In general this will lead to a significant enhanced lifetime of the lining.

One advantage of andalusite bricks is kept into the lining systems. And this is the reduced thermal expansion which will relate to a lower stress in the arch lining compared to a lining with corundum-based bricks like in the rotary drum (Fig. 4). State of the art materials for the lining of post-combustion chambers are listed in Tab. 2.

Additionally to the selection of a suitable material some design changes are possible. One common method is the construction of the arch dome out of bricks with a tongue and grove design. This ensures the stability of the construction and prevents from disintegration of bricks in the arch area. The workout of such a lining method is described and visualised on the figures below (Figs. 5 and 6).

Innovative material and/or design is necessary to improve the performance of the lining in the area of the support rings and the burner nozzles. The schematic drawing of a burner nozzle build out of a segmented brick design shows how an enhanced performance can be reached. The choice of material will lead to an optimised lifetime of the lining. Therefore andalusite, corundum or corundum with addition of chromium oxide may be used (Fig. 7).

Fig. 5 Arch area of the post-combustion chamber lined with tongue and grove brickwork during start of installation

Fig. 6 Arch area after installation of tongue and grove brickwork

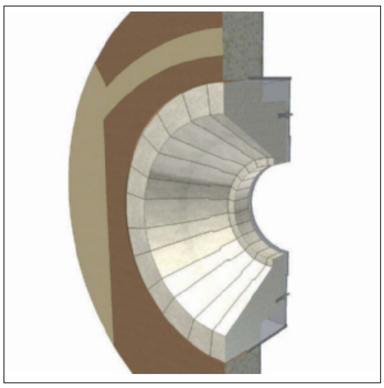

Fig. 7 Segmented brick design in burner area

Tab. 4 Properties of special types of lining material for the treatment of halogenated waste

	Suprema CZK 905 P	Suprema KE 99	Suprema KE 95 LW
Chemical Analysis [mass-%]			
Al_2O_3	87	99,5	93
SiO_2	2	0,2	5
Fe_2O_3	0,2	0,1	0,2
Cr_2O_3	5	–	–
P_2O_5	1,5	–	–
Physical Properties			
Bulk density [g/cm³]	3,41	3,35	1,50
Apparent porosity [vol-%]	12	15	52
Cold crushing strength [MPa]	150	120	15
Young´s modulus [MPa]	33 000	68 000	5000
Linear thermal expasion coefficient [x10⁻⁴/K]	0,85	0,85	0,70

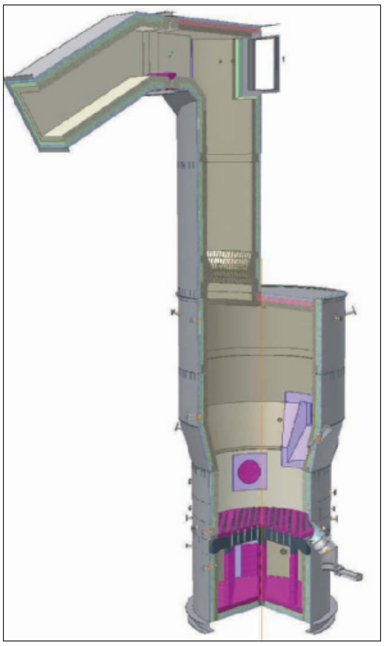

Fig. 8 Model of a fluidised bed incinerator

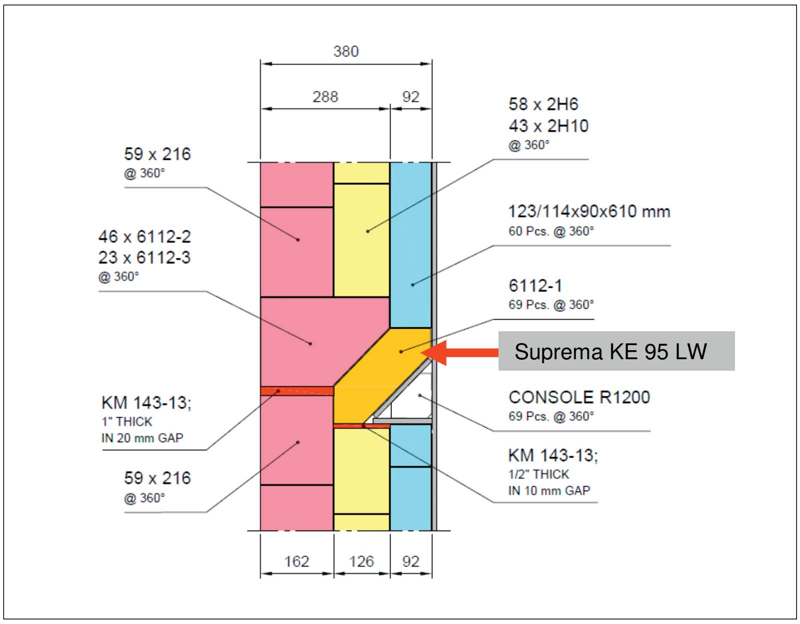

Fig. 9 Detail of the support ring area of a post-combustion chamber for halogenated waste

4 High alkaline contaminated waste

Regarding the treatment of high alkaline containing residuals like waste water, biomass or sewage sludge different types of incineration process are used. In the case of waste water treatment in the meantime so called thermal oxidisers are commonly used for the incineration. These non-rotating cylindrical combustion chambers were fed by lances in a conical part of the oxidiser.

During the resident time in the cylindrical part the reaction to disintegrate toxic components is fulfilled and in the outlet area the flue gas is quenched with water.

Another used treatment process is the fluidised bed incinerator as described on the model below. This system is often used for the disposal of wastes like sewage sludge or biomass (Fig. 8).

As refractory material basically alkaline resistant andalusite bricks are used. As standard material a chemically bonded brick is well established. For severe abrasive conditions a special high fired andalusite brick (Suprema SA 57 P) can be used.

In some incinerators also slag will occur. If this happens, an addition of chromium oxide to andalusite bricks will result in the best available performance of lining in the affected area. A short compilation of commonly used lining material is given in Tab. 3.

5 Incineration of halogenated waste

According to the mixed waste technology the incineration process can be done in rotary kilns with post-combustion chambers and also in non-rotating furnaces. The last type is commonly used for the incineration of halogenated carbon hydrates like e.g. CFC or FC containing residuals. The rotary drum is sometimes necessary for the incineration, when the feed of the kiln is a solid material like e.g. rocket booster fuels based on composite propellants containing e.g. perchlorate. The problem of incineration of halogenated waste is the attack of halogens to the refractory lining. Standard aluminium silicate material is attacked increasingly with the electronegativity of the halogens. That means that the attack is dramatically increased with every step of higher electronegativity from jodine to bromine to chlorine up to fluorine, which relate to the most severe conditions for the lining. Especially the silica content of every lining is attacked and therefore destroyed. To avoid this effect it is necessary to reduce the silica content of the refractory material down to zero if this is possible. In some cases the concentration of halogens is remarkable. This can be said, when the fluorine feed into the incineration chamber goes up to 150 kg/h with a concentration in the gas atmosphere of the kiln of app. 0,1 kg/Nm³. To withstand these conditions it is essential to use nearly silica-free, direct-bonded corundum bricks for the lining. The cold face lining can be done with hollow sphere corundum bricks. That ensures a low silica content of the complete lining (Fig. 9). If the incineration of solids is done in a rotary kiln the lining can be executed with low silica, chromium oxide containing corundum brick to enhance the resistance against eventually occurring slag. Tab. 4 shows the three major refractory materials designed for the use in a halogenated surrounding area. Fig. 10 shows the design of a CFC combustion chamber.

6 Conclusions

Regarding the incineration process it is indispensable to have a high communication level between customer and supplier to improve the performance and lifetime of the incineration plant.

The generation of low silica, chromium oxide containing corundum bricks for the lining of rotary kilns will lead to a significant improvement of the plant performance. With a state of the art material for the post-combustion chamber like the Suprema CAK 710 P it is possible to extend the lifetime of the lining also in the very critical parts of the chamber. The utilisation of low silica containing lining material is essential in the field of incineration of halogenated waste. Therefore STEULER-KCH offers also special hollow sphere corundum bricks like the Suprema KE 95 LW with high strength e.g. for the back lining of post-combustion chambers or for the hot face lining to protect support rings.

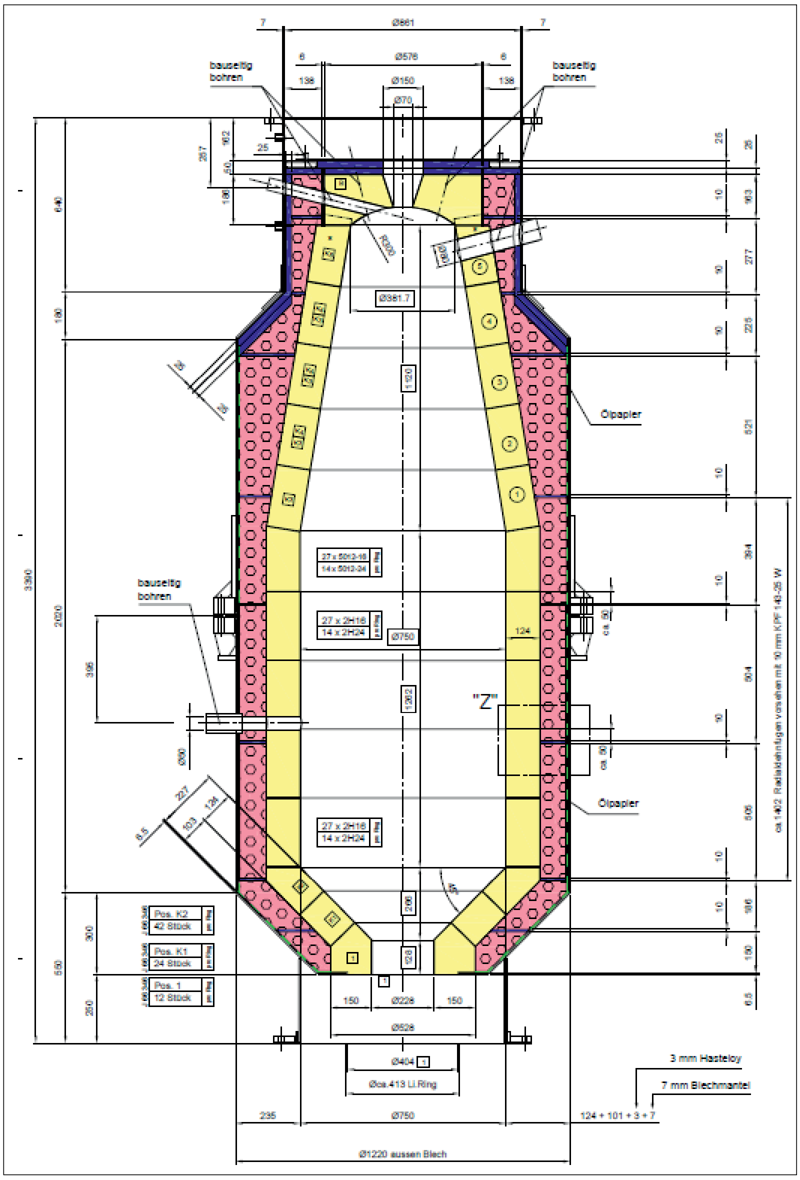

Fig. 10 Drawing of a CFC combustion chamber