Refractory Systems | **Recent Lining Concepts for Thermal Treatment of Hazardours Wastes**

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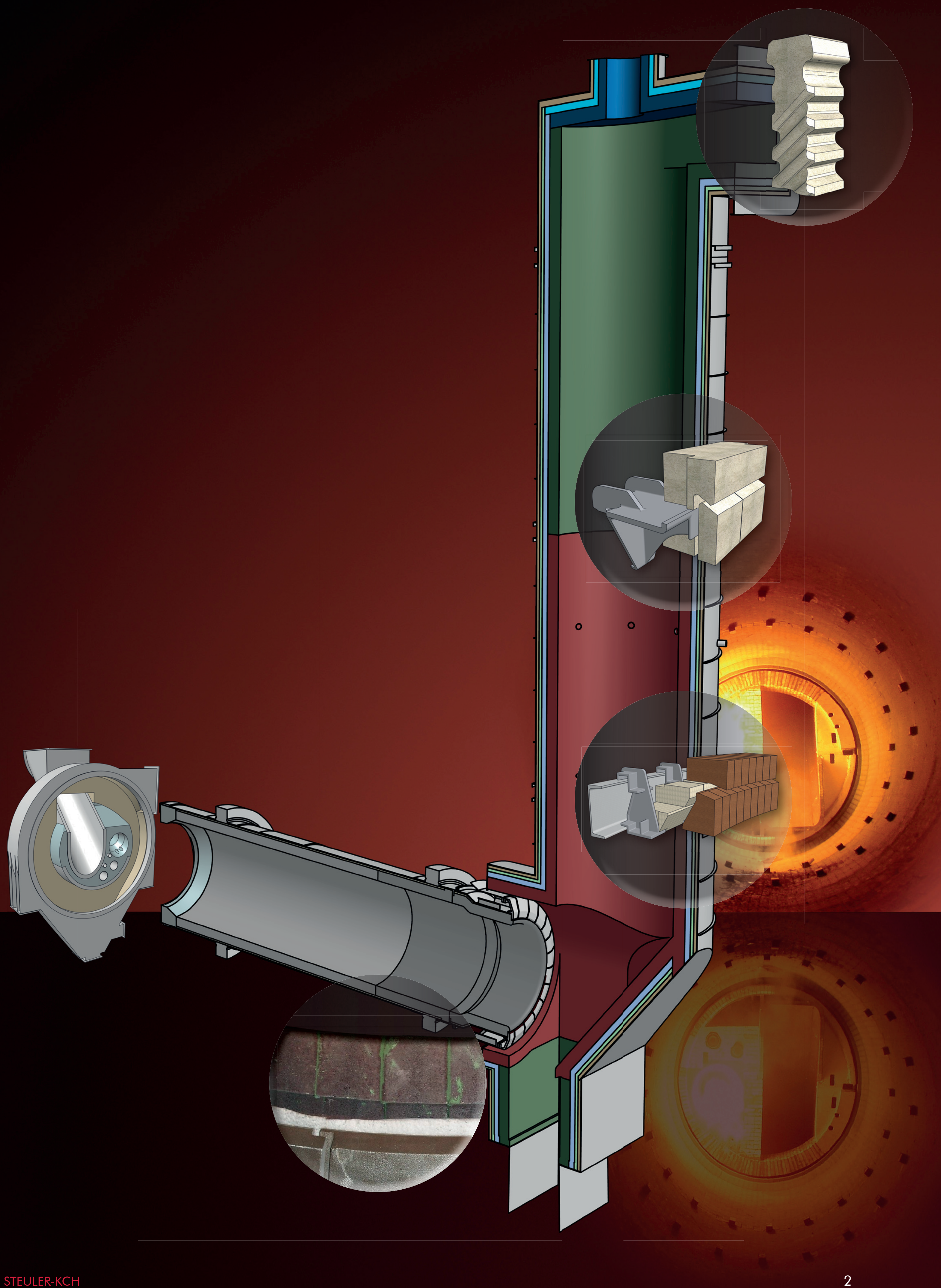

Recent Lining Concepts for Thermal Treatment of Hazardours Wastes

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The amount of hazardous wastes has grown due to the evolution of economy over the last 50 to 60 years. Nearly every production process in the highly diversified industrial world is accompanied by the formation of by-products. Due to the question of sustainability different approaches have been made to minimize wastes or to recycle them into the process. That´s why waste stream residues are much more concentrated nowadays than they were in the past and due to the high diversification of the industries highly variable wastes streams may be yielded. An adequate management of hazardous waste treatment seems to be the incineration, also including a combustion process in which hazardous materials are converted to inert mineral residues and gases.
Regarding all these depicted factors challenges arise for the lining of the combustion chamber. In the following innovative lining concepts for the hazardous waste incineration site will be discussed.[1]

Introduction

Since the 1930s hazardous wastes have been successfully treated by incineration in rotary kilns. This type of aggregate has become a wide spread process incinerator as the combustion process runs stable for most simultaneously fed materials. The kiln can be fed with solid and drummed materials as well as hazardous liquids which can be injected into the burning chamber by nozzles. The preprocessing time of the feedstock tends to zero. A rotary kiln can be described as a cylindrical refractory-lined shell. During the incineration process most of the hazardous waste is destroyed by forming inert mineral residues and gases under a volume reduction to the same time. The incineration process is influenced by four parameters, these are: temperature, turbulence, residence time and oxygen concentration.2 Depending on the feedstock the rotary kiln is run in the range of 700-1315 °C while rotating around its own axis with 1.75-2.5 rpm.3 The longitudinal slope between the bearings of the kiln is usually between 3 and 4°. The inside of the kiln can be divided into four zones: inlet zone, burning zone, outlet zone and post-combustion chamber. Depending on the requirements that have to be fulfilled in each zone the lining material has to be adjusted.

Requirements for the lining concept of the rotary kiln

Solid and drummed materials are fed over a chute at the forefront of the kiln. In addition to this pumpable sludges and slurries can be injected into the kiln simultaneously, leading to an operating capacity of approximately 60000 t/a. Commonly applied rotary kilns in hazardous waste incineration have a diameter up to 5 m and a length between 6 m and 12 m (Fig. 1).[5]

The feedstock is cocurrently impinged with heat by means of a gas burner in the forefront of the kiln. The bed motion of the feedstock can be divided into the movement in axial and transverse direction. By supporting the motion in transverse direction with lifters the intensity of mixing, heat transfer, reaction rate and the progress of the charge in axial direction can be affected (Fig. 2). The residence time of the feedstock is determined by the movement in axial direction. [3]

During the furnace cycle the process parameters have to be adjusted in a way that organic compounds can be volatilized and combustion residues meet regulatory requirements.

Fig. 2: Inlet zone of the rotary kiln newly lined with andalusite bricks and lifters.

The rotary kiln drum can be divided into three zones: inlet zone, combustion zone and outlet zone. In each zone different requirements have to be fulfilled. As solid und drummed hazardous wastes are fed over a chute into the inlet zone the refractory lining material has to withstand the loading shock, the impact and abrasion. In case of a liquid or pasty feedstock a refractory lining material with a low open porosity and chemical resistance is required. Therefore inlet zones in hazardous waste incineration have been successfully lined with phosphate-bonded andalusite bricks and lifters. On the way to the combustion zone the feedstock is heated up to the designated operating temperature, while organic compounds are volatalized to form gases. The residue consists of highly reactive inorganic compounds which tend to form aggressive slags. In this zone high quality bricks based on fused corundum and a certain content of chromium oxide (Cr_2O_3) and zirconium oxide (ZrO_2) are applied, exhibiting highly corrosion and wear resistant properties. Depending on the concentration of soluble alkalies, earth alkali and iron containing compounds highly reactive slags may be formed which may interact with the refractory lining. In the worst case the refractory lining is infiltrated by the corrosive slag under the formation of new minerals leading to a degradation of the microstructure of the refractory lining. Nevertheless under these harsh operating conditions the bricks exhibit an acceptable lifetime. The combustion zone is followed by the outlet zone which is lined with the same quality of bricks. Depending on the conditions in the outlet zone the use of a brick quality with a lower content of chromium oxide may be possible due to the decreased reactivity of the slag and the lowered temperature. Compared with the combustion zone the slag in the outlet zone exhibits lower chemical corrosion properties.[5]

Requirements for the lining concept of the post combustion chamber

The rotary kiln drum is followed by the post combustion chamber. Inorganic residues like ash and slag are carried out of the rotary kiln drum, cooled and collected in a wet scrubber. Volatilized organic gases as well as flue gases of high velocity are carried into the post combustion chamber for their final combustion. Usually two gas burners incinerate residual hazardous components to non-hazardous gases at operating temperatures between 1000 °C and 1300 °C. Dust particles in the flue gas stream are filtered out before they are released to the ambient atmosphere.

Post combustion chambers are available in different versions. Elderly sites are rectangular in cross section while modern sites tend to be cylindrical. Usually the outer steel casing is about 8 m in diameter and up to 25 m tall. The buttress arch at the crossover to the combustion chamber represents an extraordinary constructional challenge as the lining material is exposed to high flue gas velocities, high incineration temperatures and chemical corrosive attack.[5]

Depending on the turbulent flow of the flue gases the choice of brick type varies. According to the chemical and mechanical stress the lining material has to withstand andalusite based bricks or fused corundum based bricks with designated contents of chromium- and zirconium oxide are applied. In addition to this another corrosive attack can be referred to liquid and gaseous wastes which are additionally fed in the lower part of the post combustion chamber.

Fig. 3: Installation of a buttress arch at the crossover to the post combustion chamber

Properties and application areas of the refractory laning material in the rotary kiln

Inlet zone
The lining of rotary kilns in hazardous waste incineration requires adjusted lining concepts according to the different stressed zones. Commonly chemically bonded andalusite or corundum based bricks and lifter bricks are applied in the inlet zone. Table 1 and Table 2 give an overview over the chemical and physical properties.

According to moderate temperature profiles in the inlet zone the formation of slags is not expected and an andalusite based brick with a relatively high content of silica can be accepted (Table 1). In addition to this both the andalusite based brick SA 605 P as well as the corundum based brick KE 85 P exhibit a sufficient cold crushing strength while low Young´s moduli are obtained simultaneously (Table 2). These properties are of high importance as the inlet zone is exposed to impact, loading shock and abrasion and an advanced wear of the microstructure.needs to be prevented.

Combustion and outlet zone
Highly reactive slags and gases are formed in the combustion zone and carried further on into the outlet zone. Especially in these zones high quality bricks are required. Table 3 and Table 4 give an overview over the choice of the possible lining materials.

The harsh operating conditions require enhanced chemical and infiltration resistances. These properties are achieved for bricks with a higher content of chromium oxide (Cr_2O_3) and a low content of silica (SiO_2). Simultaneously the Young´s modulus can be kept in low range by the addition of zirconium oxide (ZrO_2).

Even today it is still a suitable method to test the lining material in test fields during operation. These tests are indispensable for the continuous development of the refractory lining material as well as the choice of the best possible material by comparison.

Properties and application areas of the refractory laning material in the post combustion chamber

The lining of the buttress arch at the crossover to the combustion chamber can be described as challenging as the refractory lining in this section is exposed to high temperatures up to 1300 °C and abrasive flue gas jets. In this

section a purpose built brick is applied, combing the linear thermal expansion behavior of a andalusite brick with the wear resistant properties of a corundum based brick with certain quantities of chromium- and zirconium oxide. Table 5 and Table 6 give an overview of possible lining material in this section and their properties.

The buttress arch is lined with bricks, equipped with keys and slots (Fig. 3, Fig. 4) in order to protect the brickwork from shifting. The walls of the post combustion chamber are lined with andalusite based bricks or corundum based bricks with certain contents of chromium oxide according to wear.

Fig. 3: Installation of a buttress arch at the crossover to the post combustion chamber

Conclusion

Rotary kiln sites have become state of the art regarding hazardous waste treatment. The development of corundum based bricks with certain concentrations of chromium- and zirconium oxide have improved the durability of the lining material significantly. The tailored brick CAK 710 P applied in the crossover to the buttress arch represents a new generation of lining material combining moderate linear thermal expansion properties with a good wear resistance. With regard to recent developments concerning the different refractory lining materials the durability has continuously been improved.

References

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3. *A.A. Boateng, "Rotary kilns – Transport phenomena and transport processes", Elsevier, chapter 1 1-14 (2008)*

4. *Schematic drawing according to J.J. Santoleri, J. Reynolds, L. Theodore, "Introduction to hazardous waste incineration", Wiley-Interscience, 2. Edition, chapter 7 326 (2000)*

5. *J. Sperber, R. Burgard, F.-J. Duennes, „Innovative lining concepts for hazardous waste incineration", Refractories Worldforum, 4 [2] 85-89 (2012)*

Table 1: Chemical composition of typical bricks applied in the inlet zone, Manufacturer: STEULER-KCH.

	Suprema SA 605 P	Suprema KE 85 P
Al_2O_3	60	88
SiO_2	36	9
Fe_2O_3	0.9	0.3
Cr_2O_3	-	-
P_2O_5	1.4	1.4

Table 2: Physical properties of typical bricks applied in the inlet zone, Manufacturer: STEULER-KCH

	Suprema SA 605 P	Suprema KE 85 P
Bulk density in g/cm³	2.58	3.08
Apparent porosity in Vol.-%	13	14
Cold crushing strength in MPa	110	130
Young´s modulus in MPa	28,000	18,000
Linear thermal expansion (35-1000 °C) in %	0.55	0.70

Table 3: Chemical composition of chromium oxide containing bricks used in the combustion and outlet zone, Manufacturer: STEULER-KCH

	Suprema CZK 825 P	Suprema CZK 855 P	Suprema CZK 905 P	Suprema CZK 810 P	Suprema CZK 815 P
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

Table 4: Physical properties of chromium oxide containing bricks used in the combustion and outlet zone, Manufacturer: STEULER-KCH

	Suprema CZK 825 P	Suprema CZK 855 P	Suprema CZK 905 P	Suprema CZK 810 P	Suprema CZK 815 P
Bulk density in g/cm³	3.14	3.35	3.41	3.43	3.48
Apparent porosity in Vol.-%	14	12	12	12	12
Cold crushing strength in MPa	140	140	150	150	150
Young´s modulus in MPa	41,000	46,000	33,000	31,000	25,000
Linear thermal expansion (35-1000 °C) in %	0.75	0.80	0.85	0.85	0.85

Table 5: Chemical composition of typical bricks applied in the post combustion chamber, Manufacturer: STEULER-KCH

	Suprema SA 605 P	Suprema CA 705 P	Suprema CAK 710 P
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

Table 6: Physical properties of typical bricks applied in the post combustion chamber, Manufacturer: STEULER-KCH

	Suprema SA 605 P	Suprema CA 705 P	Suprema CAK 710 P
Bulk density in g/cm³	2.58	2.85	3.00
Apparent porosity in Vol.-%	13	14	14
Cold crushing strength in MPa	110	100	100
Young´s modulus in MPa	28,000	22,000	20,000
Linear thermal expansion (35-1000°C) in %	0.55	0.62	0.65

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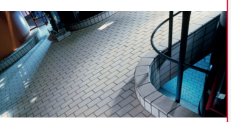

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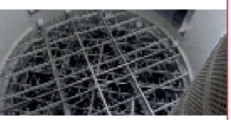

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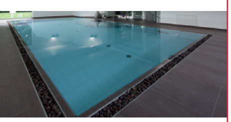

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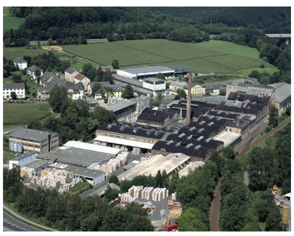

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