Operational Experiences with Refractories at Precalciner Cement Kilns

Dr.-Ing. Volker Hoenig – Head of Environment and Plant Technology Department, Verein Deutscher Zementwerke, Duesseldorf; Dipl-Ing. Peter Künne – Holcim Deutschland, Laegerdorf, Germany

Abstract

During the past 10 years the German cement industry has been facing several new or additional problems with the refractory lining of their cement kilns. For years it was not clear whether these damages observed were due to the new precalciner kiln technique or to the fact that these new kilns were fired by secondary fuels to a higher degree than the conventional preheater kiln before. Therefore VDZ has installed a working group, which collected the plants' experiences and gave recommendations for technical measures to prolong the lifetime of the refractory lining under the changed conditions.

1. Introduction

During the past 10 years the German cement industry has been facing several new or additional problems with the refractory lining of their cement kiln plants. At the same time there were at least two important developments which had a significant effect on the lifetime of refractories in the plants. One significant development was the change of the kiln structure. After the German re-unification several new kilns were installed, equipped with the precalciner technique. This technique was quite new for Germany because during a period of about 15 years very few kiln had been built because of economic reasons. The production capacity of precalciner kilns (with tertiary air duct) related to the total production capacity of the German cement industry has increased from 5% in 1990 to 26% in 2002. As the burning conditions in the sintering zone as well as the operational conditions in the precalcining zone of the kiln system are significantly different compared to conventional preheater kilns the requirements for the refractories are different.

The second important development was the increased use of secondary materials as raw materials or fuels for the clinker production. **Figure 1** shows that the substitution rate of fossil fuels by waste fuels increased from about 4% in 1987 up to nearly 35% in 2002. During this time the use of hard coal and lignite has been reduced correspondingly. Apart from this the use of petcoke, being also a primary fossil fuel, has increased up to a share of about 10%. In the year 2001 the consumption of the traditional waste fuels like tyres (237,000 t/a) and waste oil (128,000 t/a) were still significant. But the major rise in the use of secondary fuels were due to the increased utilisation of industrial waste fractions (more than 400,000 t/a), animal meal and animal fat (245,000 t/a) and fractions of domestic waste (102 t/a).

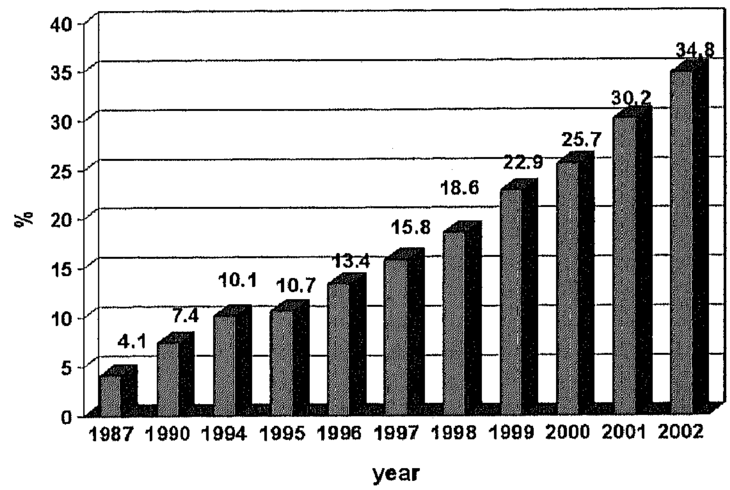

Fig. 1. Share of secondary fuels of the German cement industries' total fuel consumption (1987-2002)

2. Impact of secondary fuels on kiln operation

After the installation of new precalciner kilns the operators in some of these kiln plants made new and often bad experiences with their refractories linings. The important question was whether these experiences were due to the new kiln technique or to the fact that these new kilns were fired by secondary fuels to a higher degree than the conventional kilns before. Since the physical and technical properties of most secondary fuels are significantly different compared to coal dust, their increased use changes the firing conditions in the sintering zone as well as the availability of volatile compounds like chlorine, sulphur and alkalis in the kiln gas atmosphere. On the other hand waste tires are used in the kiln inlet firing and an increase of the substitution rate changes the temperature profile as well as the oxygen rich and oxygen lean zones in the kiln. If no bypass is installed industrial wastes, including plastics, as well as animal meal, which contain higher chlorine contents lead to higher chlorine loads in the burning material and in the gas atmosphere. Summarised, the utilisation of secondary fuels can have the following impacts on operational conditions which subsequently can have an impact on refractory lining:

- change of the temperature profile in the kiln, precalciner and preheater

- increased temperature changes due to the use of waste fuels with different calorific values and burning behaviour
- local temperature peaks
- increase of chlorine, alkali and sulphur content in the burning material and
- change of the gas atmosphere in kiln and/or calciner.

3. Observed refractories damages and damage mechanisms

3.1 Damages due to inadequate isolation

Most of the new precalciner kilns have been equipped with a 3-layer isolation, aiming at low outer kiln shell temperatures and at reducing heat losses. In addition to cold bridges, by which heat was conducted from the inner high temperature side to the steel shell, damages were caused like the total loss of cyclon ceiling or of huge parts of the brick wall in the riser duct. Volatile compounds, deriving from the kiln gas atmosphere (like K_2O, Na_2O, SO_3, Cl or H_2O), diffused as an eutectic melt or as a vapour through the open pore space of the brickwork or through the expansion joints up to the steel shell. The damage mechanism is well known: provided that the temperature is reduced below the acid due point (about 135 °C), the acidic compounds condense on the inner side of the steel shell. Hydrochloric or sulphuric acid can then lead to a strong corrosive attack on the metallic anchors. Together with mechanic stress, i.e. from cleaning activity or coating fall, this leads to the rip-off of the anchors. The part of the anchor which was covered by the refractory did often not show any damage.

3.2 Damages due to higher chlorine input

In kiln plants without chlorine bypass (kiln inlet gas bypass) the chlorine input should be limited to 0,25–0,3 kg Cl/t cl. At higher input rates the volatility of the alkalis and sulphates are increased to an extent that kiln operation can be spoiled significantly by coating formation and blockages of cyclones or meal pipes.

In many cement plants the chlorine input has been significantly increased by burning animal meal or plastic wastes. Most of the kilns, therefore, have been equipped with a chlorine bypass system. At those kilns, which had already a bypass system because of their raw material situation, the bypass rate could be increased.

A higher availability of chlorine in the kiln gas atmosphere leads to a higher volatility of the alkalis, mostly introduced into the process with the raw materials. If chlorine is not available the alkalis react with sulphur compounds to sulphates and are predominately bound into the cement clinker. As alkali chloride, on the other hand, they are vaporised in the sintering zone and increase the alkali cycle in the kiln plant.

These alkali vapours can diffuse through the refractory material and condense or react at certain temperatures in the refractory working lining or between the refractory and the isolating material. Since the salts being formed have a higher volume than the original compounds – due to the crystal growth – the refractory material is compressed by filling the pore structure with KCl, NaCl, K_2SO_4, $NaSO_4$ or $CaSO_4$. Under thermo-mechanical and/or mechanical stress this can lead to the destruction of the refractory by alkali spalling or bursting. **Figure 2** shows as an example the ceiling of a gas duct in a calciner swirling chamber, which has been completely destroyed by a combination of this mechanism and high temperature corrosion.

Fig. 2. Ceiling of a gas duct in a calciner swirling chamber, damaged by corrosion and mechanical stress

Alkali infiltration can also occur via the expansion joint. Under normal conditions – which means at moderate chlorine and alkali input, the lifetime of the expansion joint can be up to 10 years. At higher inputs, the alkalis "bypass" the refractory material through the expansion joint, infiltrate the isolation layers and crystallise in the cooler area near the kiln shell. There they can trigger a high temperature – corrosion of the steel shell. **Figure 3** shows an example of the corroded steel wall of a calciner. The corroded furrows on the steel wall fully match the structure of the expansion joints. Another damaging mechanism is, if the expansion joints are filled up with alkali salts, mixed with dust. Thus the expansion properties of the joints fail, causing severe damages to the refractory and the steel construction.

3.3 Damages due to higher temperatures or temperatures peaks

If new fuels with different or varying calorific values are used in the clinker burning process the operating staff has to adopt the kiln operation to these new materials. If this is not done very carefully, temperature peaks in the kiln inlet or the calciner firing can occur and the temperature limits of the refractory previously installed can be exceeded and its stability can be destroyed.

In some cases the temperature profile in the calciner has been changed, aiming at a better combustion of the waste fuels ("hot spot") or a better reduction of NO_x by staged combustion

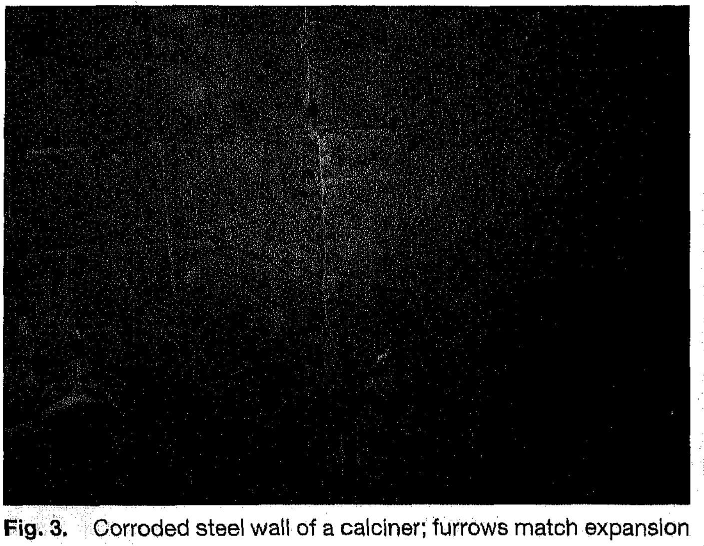

Fig. 3. Corroded steel wall of a calciner; furrows match expansion joints structure

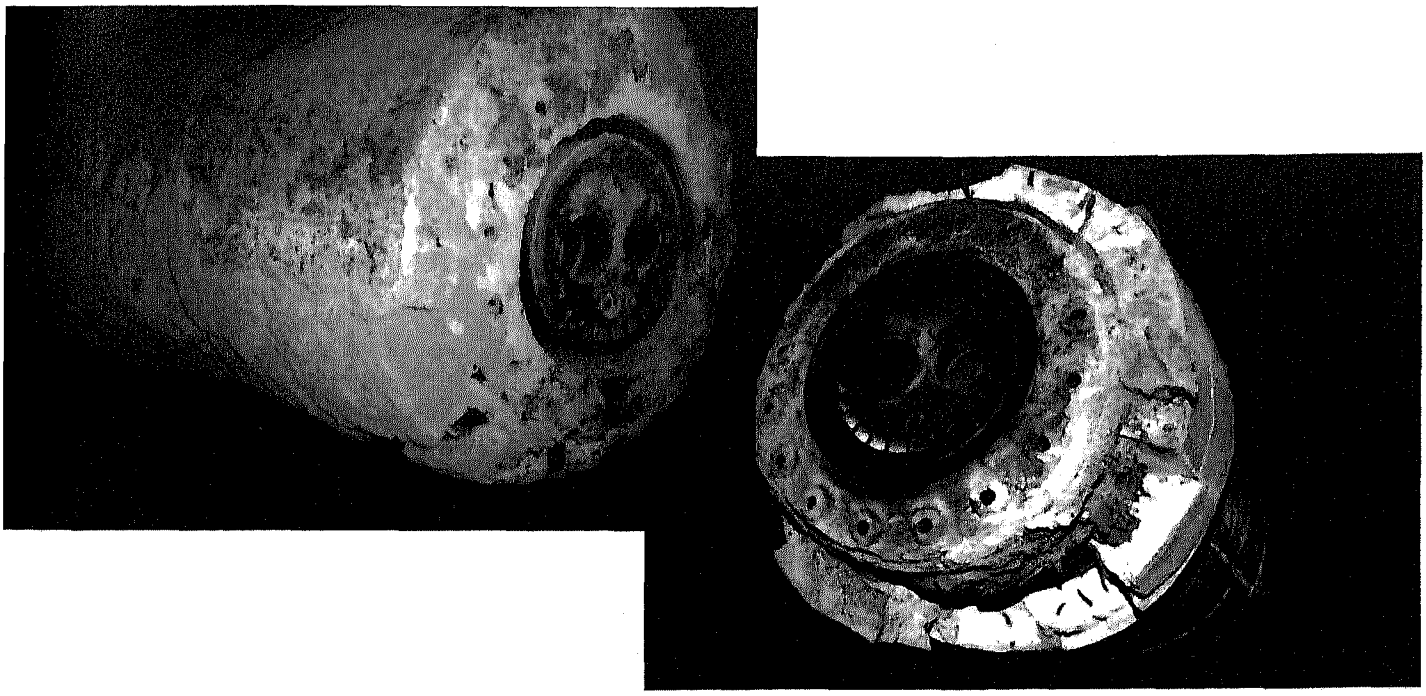

Fig. 4. Refractory lining of a cement kiln burner, damaged (right) and stabilised by a cast segment (left)

("meal staging"). Both measures can have very positive effects on the emissions of the kiln, provided that the refractory has been adopted to this operation mode. Otherwise they can damage the refractory seriously and lead to kiln stops.

Another temperature effect, based on a positive technical modification, is the increase of the secondary air temperature after a modernisation of the clinker cooler. Approximately 10–15 years ago the recuperation efficiency of clinker coolers was not higher than 60–70%, which lead to secondary (combustion) air temperatures of 700–800 °C. Meanwhile, most kilns have been equipped with a modern clinker cooler technology, by which an efficiency of up to 80% and a secondary air temperature of up to 1000 °C can be reached. As the kiln burner is encircled by the preheated secondary air, it has to be protected by refractory material. In the example shown in **figure 4**, the burner refractory had originally been fixed with anchors (right). After three months of operation it was nearly destroyed. To adapt the burner protection to the higher temperatures and to stabilise the refractory lining of the burner, it has been equipped with cast segments. The left photo shows the modified burner after six months of operation, still being free of any damage.

4 Technical measures to prolong refractory lifetime

A VDZ working group has gathered experiences made by the German cement plants and has described them in a leaflet for

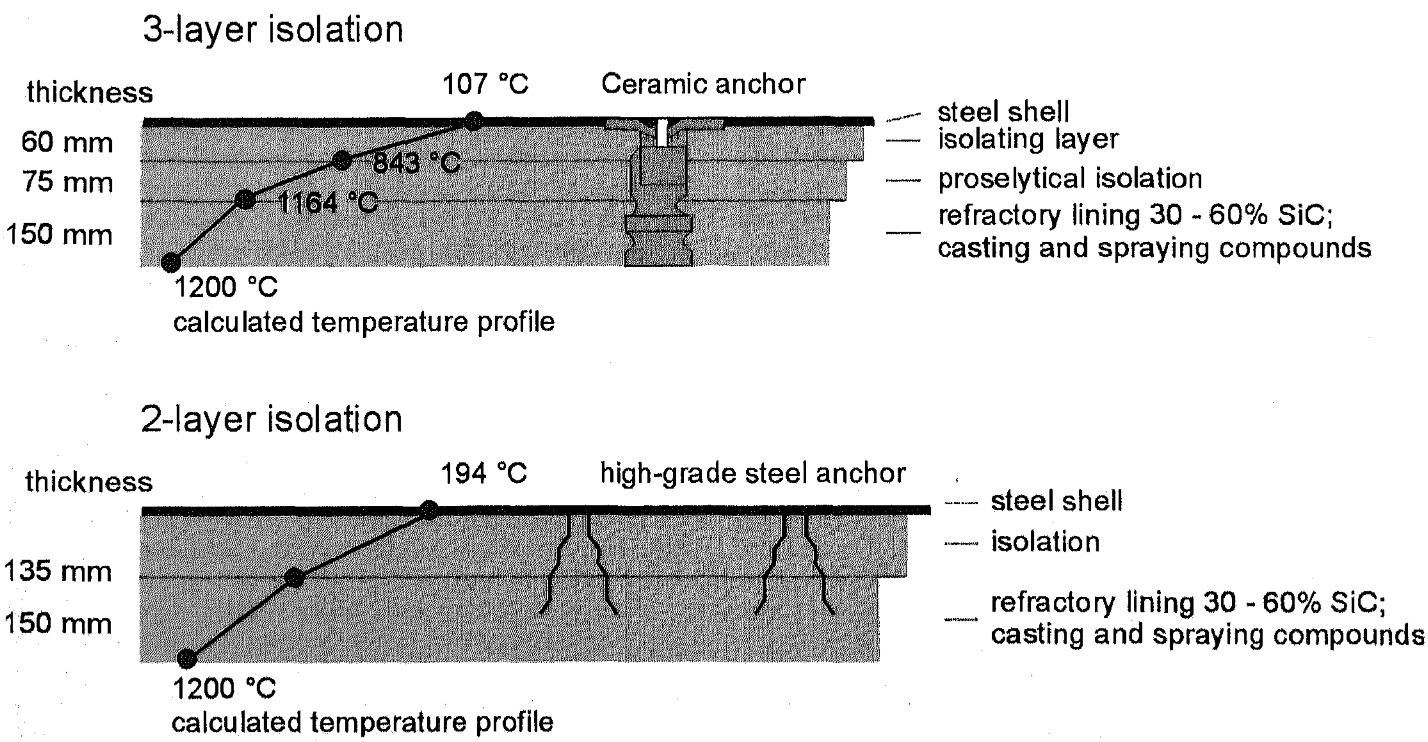

Fig. 5. Calculated temperature profile of a 2- versus a 3-layer isolation

the member companies. A number of technical measures has been recommended, aiming at a longer lifetime of the refractory in precalciner kilns.

Summarised, the most important measures are:

a) Adaptation of the chlorine balance
- Limitation of chlorine and alkali input. If no bypass is installed the chlorine and alkali input should be limited by reducing the maximum content in the secondary fuels and raw materials. The limit itself is plant specific and has to be investigated individually.
- Installation of a chlorine bypass
  If the chlorine and alkali input cannot be reduced (i.e. because of economic reasons) a chlorine bypass should be installed instead to limit the cycles of alkali chlorides in the kiln system.

b) Adaptation of the kiln operation
- Avoid "hot spot" operation
- Limitation of meal staging for NO_x reduction
- Limitation of the pre-calcining rate (i.e. < 95%) to avoid temperature peaks
- Avoid lack of O_2 in the kiln inlet to limit the sulphur cycles in the plant

c) Adaptation of the refractory materials
- Reduce 3-layer isolation to 2-layers
- **Figure 5** gives an example of the calculated temperature profile in a 3-layer and a 2-layer isolation. In this case the kiln shell temperature has been about 100 °C with a 3-layer isolation which was lower than the acid due point of 135 °C. By reducing the number of layers to 2 the temperature was increased to 190 °C and corrosion by acids could be limited significantly.
- Use of alkali resistant monolithic material with at least 30% SiC in the calciner, riser duct, kiln inlet and burner
- Use of alkali resistant bricks in the rotary kiln
- Use of a combination of steel and ceramic anchors in the calciner, kiln inlet and riser duct
- Use of cast segments without anchors for kiln burners

5 Summary

From the damages observed in the precalciner plants of the German cement industry, it can be deduced that neither the new technique nor the increased use of waste fuels were the only reason for these damages. Today the experiences show that if the kiln operation as well as the refractory material are adapted to the new operational conditions the refractory consumption can reach the same level as prior to the change.

A VDZ working group has put together the experiences of the plants' operating staff and has described these in a leaflet for the member companies. (F 008)

Wear Resistant Lining Concepts in Cement Kilns using Alternative Fuels

Dipl.-Ing. Holger Wirsing, Leiter Entwicklung Geformte Produkte; Dipl.-Ing. Kai Beimdiek, Leiter Entwicklung Ungeformte Produkte; Dr. Hans-Jürgen Klischat, Leiter Forschung und Entwicklung/Qualitätswesen – Refratechnik Cement GmbH, Göttingen, Germany

Abstract

Past lining concepts in cement kilns and the influence of the increasing use of alternative fuels on the refractory materials of both kiln sides are reviewed. Products on the basis of high alumina raw materials which have been optimised by the addition of SiC concerning the increasing alkali loads is treated in this article. The influence of the constructive design of refractory linings is shown.

Use of secondary raw materials

Like in other branches of industry where refractories are used, the lining of a cement kiln has been optimised considering technical and economical aspects, based on decades of experience.

Up to now, thermochemically highly resistant basic bricks are installed in the burning areas (transition zone, sintering zone of cement rotary kilns) to reduce corrosion by clinker melts and other thermochemical factors. The extended areas before and behind the high-temperature zone are lined with fireclay as well as high alumina bricks and refractory concretes respectively, depending on the predominating temperatures. These refractories offer a good price-performance-ratio and guarantee a safe kiln operation.

Heat exchangers and pre-calciners are lined with bricks and concretes with an Al_2O_3-content of approx. 30%–60%, depending on the temperatures and mechanical loads. Depending on the kiln type, the design and operational mode of the kiln bricks with 25%–50% Al_2O_3 proved successful in the inlet area of rotary kilns. Corresponding to the rise in temperature towards the kiln outlet, the Al_2O_3-content increases up to approx. 60%–70% (up to the transition to the basic lining).

As high alumina products are not sufficiently resistant to clinker melt attacks, they are used exclusively in kiln areas where the liquid phase content contained in the kiln feed is reduced due to the formation of clinker phases. Therefore, high alumina products containing approx. 70%–85% Al_2O_3 are used only in the kiln outlet and cooler inlet area exposed to high thermal and hot abrasive loads by clinker material. In the cooler area where the temperature of the clinker decreases, once again, high alumina bricks and concretes with lower Al_2O_3-contents are used.

In case of normal burning conditions (with gas/carbon/oil as fuels) the lining concept described above offers a safe and cost-optimising kiln operation.