Germany

Light-weight Kiln Cars for Refractory Kilns

When kiln car linings for high-temperature kilns are involved, most refractory producers primarily consider the aspects of cost and maintenance effort/lifespan. It is naturally very important that many of today's tunnel kilns which are in operation are already older models that use the same kiln car concepts that have been in existence for years now. The direct effect on the actual firing process is either not known or not considered.
Naturally many different systems are used.

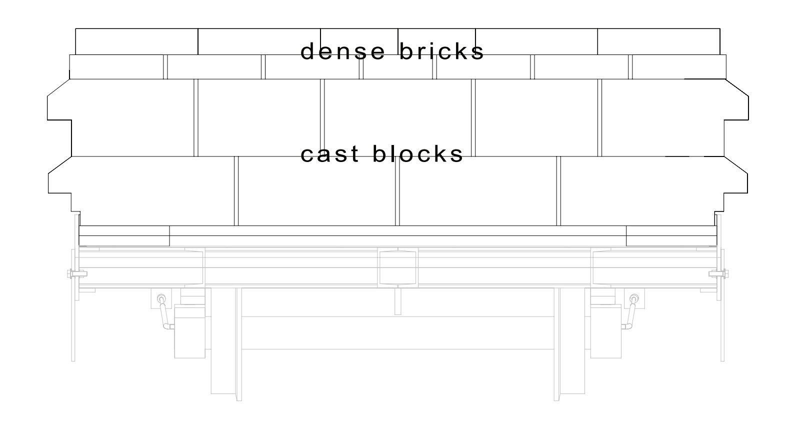

Fig. 1 Kiln car with typical heavy refractory lining

Introduction

In a great number of cases, the kiln car linings are made of large blocks of ramming mixture. These blocks are usually poured directly onto the car. The cost of these unformed masses is much lower than for preformed bricks.
And the great weight of the large individual blocks already ensures that the lining remains physically stable.
However, a great amount of work is required since everything has to be done manually. This is the reason that this system is very frequently to be found in countries with low wage costs although refractory producers of industrial countries also use such systems frequently which, in actual practice, means that one group of workers is permanently occupied with repairing/relining the cars. This represents a significant cost factor in addition to the relatively short lifespan of the large blocks which frequently split due to their size.
When this method is used, the top-most layer or the two top-most layers are usually made of standard, dry-pressed bricks which are normally laid without mortar and, as the wearing layer, can be quickly replaced. Such a layer also absorbs the high specific pressure of the product setting.
Cast or rammed mixtures are used for the layers underneath. These mixtures vary in quality depending on their location and the thermal stress whereas in the lower cold portion insulating mixtures can then also be used.
Usually these blocks are shaped so that a physical fixation is created between them and the individual parts cannot slip. Fig. 1 shows a schematic view of such a typical set-up.

Effects on the firing process

In the preheating zone of a normal refractory tunnel kiln, the product is heated by exhaust gases coming out of the firing zone in the direction of the kiln entrance. Burners are only required for higher temperatures. If the kiln channel is constructed correctly and there is a flow-optimized product setting, hot exhaust gases surround the product and this then ensures that the material to be fired is heated up in a more or less uniform manner based on the flow pattern.
However, the car lining can also only be heated convectively from above through the top-most layer which means that the upper layers of the kiln car lining heat up much more slowly than the product located above that. If a significant downward outflow of energy occurs due to the high heat conductivity of the lining layers located underneath, this causes distinct differences in the kiln between the temperatures in the product load above and below. Thus the temperature of the kiln car deck and the products directly above it have more than 200 °C difference in some cases. This can also almost never be corrected by optimization of the kiln settings.
The temperature deficit of the lower layers in the kiln car product load usually continues up to the main firing zone and the temperatures of the product load are not equal again until the soak time area.
This "running behind" of the temperatures in the bottom of the product load can only be attenuated by slowing down the firing speed although that reduces kiln performance and automatically increases specific power consumption.
This has the reverse effect on the cooling. Here the kiln car is usually much warmer

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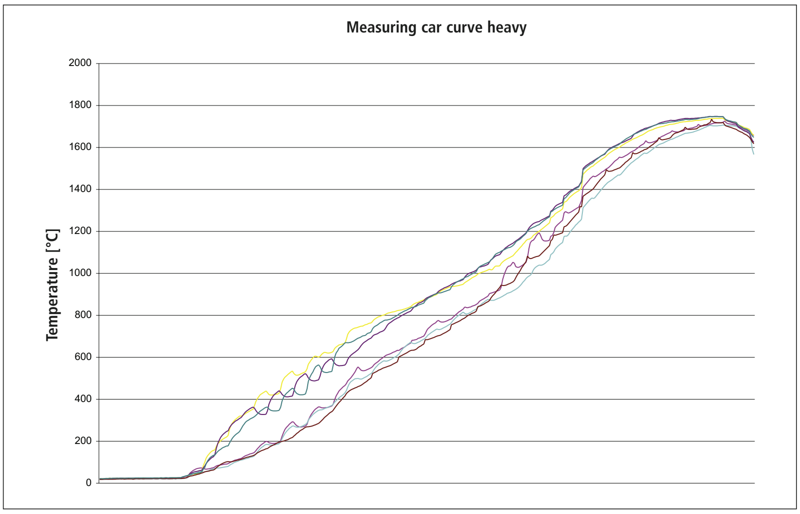

Fig. 2 Kiln car measuring curve with heavy car lining

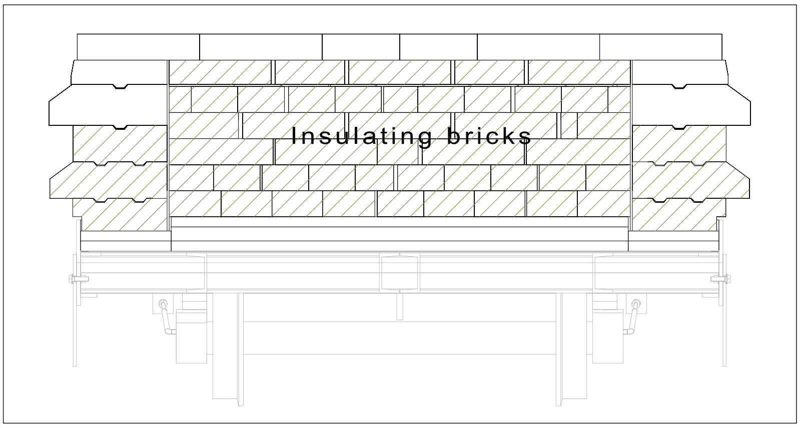

Fig. 3 Kiln with light lining out of insulating bricks

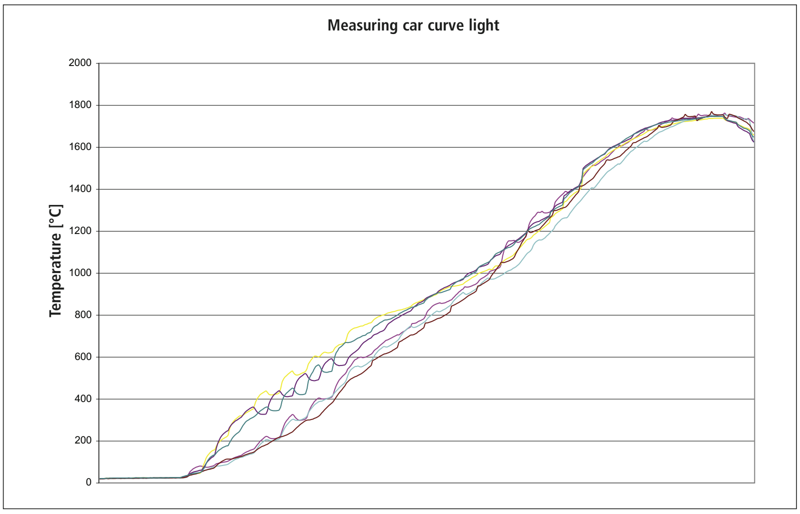

Fig. 4 Kiln car measuring curve with light car lining

than the product setting. Since the kiln car lining can only be cooled convectively from above via the top-most layer, the effectiveness of the cooling is limited and creates longer throughput times. Post heating after leaving the kiln is also typical for heavy linings. The already cooled down product is reheated again by the tremendously high temperatures of the heavy kiln car lining. This can slow down the unloading of the car significantly. With sensitive products this can also cause cracks in the product.

Although the layer of hollow blocks which is used occasionally under the product does somewhat improve the temperature compensation, it increases the mass to be heated and creates extra costs. Fig. 2 shows the great difference in temperature between the top and bottom product load in the preheating zone.

Light kiln car design

One solution to the described problem is to predominantly use insulating materials in the kiln car lining. This reduces the mass to be heated and prevents too much thermal energy from escaping. As a result, the top layers of the lining can warm up quicker and even the lower product layers reach the desired temperature faster. The differences between the top and bottom of the product setting are greatly reduced.

This has already been tried often in the past but specific properties of the insulating bricks used in the design have set certain limits.

This is the reason why the predominant use of insulating bricks for a lining is still relatively rare even today.

One problem involved with this is the high physical load of the top layers caused by the product, which can be up to 2 t/m^2. As well known, insulating bricks consist almost exclusively of material containing high alumina which tends to deform under great physical loads and high temperatures which then reduces the lifespan drastically. In the past, this problem often caused designs with light weight materials to fail. However, during the last 10 to 15 years, the selection and quality of available insulating bricks has improved significantly (e.g., several manufacturers offer insulating bricks of a certain temperature class with different degrees of density and strength). The significantly improved process control in modern tunnel kilns allows faster firing times than in the past so that the transient thermal stress of the bottom layers is reduced.

Even in a light-weight kiln car setting, at least the top layer of the kiln car lining must be made of dense bricks which offer sufficient resistance to pressure. In addition, a chemically resistant top layer is indispensable for basic products, for example.

The design of a physically and thermally stable, light-weight kiln car lining for higher firing temperatures >1600 °C requires a great deal of constructive experience since mortar can only be used to a very limited degree due to the changes in size caused by the continuously changing temperatures. Particularly with insulating bricks, the mortar joint is frequently more stable than the brick itself since bricks crack easier and this weakens the kiln car construction over time.

Kiln car superstructures made of shaped bricks are available on the market, which physically interlock with each other (e.g., the so-called knobbed blocks) so that mortar is no longer needed. However, these systems are usually very expensive since so many different formats are needed and that makes production time-consuming.

An alternative is a setup which only uses shaped bricks around the outer edge. This ring provides the entire setting with sufficient stability so that normal bricks can be used for the inner portion of the lining.

Fig. 3 shows the schematic setup of such a kiln car lining.

Such a light-weight lining offers considerable advantages for the firing process. Only one layer of dense bricks has to be heated. The temperature in the lower insulating layers drops quickly and the amount of energy needed is considerable less than with a heavy setting.

An even greater effect on the firing process is the already described fact that the kiln car heats up faster and the temperature compensation related to this in the product setting during heat-up is much better.

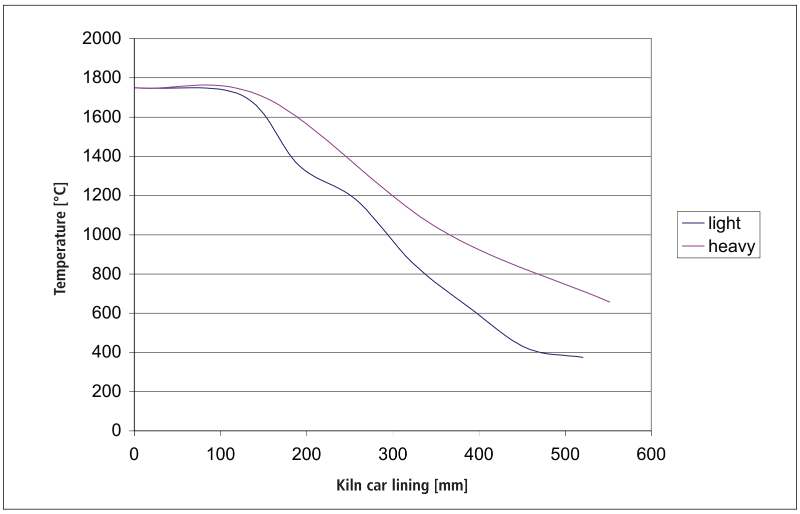

Fig. 5 **Temperature curve inside the kiln car brickwork at 1750 °C kiln temperature after 30 h firing time**

Cooling can also be designed much more effectively which accelerates the entire firing process.

In Fig. 4 one can see that the differences in temperature between the top and bottom are considerably smaller than those shown in Fig. 2. This measurement was carried out in the same kiln with the same temperature curve.

The temperature curve inside the kiln car brickwork shows, that the heavy car lining consumes considerably more energy than a light-weight car lining. This causes a higher vertical heat flow into the car. Fig. 5 shows the transient temperature curves in heavy and light kiln cars after having reached the temperature of 1750 °C after 30 h.

It is certainly sensible to give more attention to the kiln car of an existing kiln system particularly regarding acceleration of the firing process.

Summary

The use of light-weight kiln cars has a significant positive effect on the energy consumption of refractory kilns and should be considered in all cases.

Results from recent kilns equipped with light-weight cars show high energy savings when compared to traditional massive kiln cars.