

Innovative Refractory Solutions Using a New Microporous Material for Kiln Cars in the Ceramic Industry

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ABSTRACT

An innovative kiln car lining for decoration firing of ceramic products has been developed and successfully tested. The lining is based on a new insulation castable using SLA-92, a microporous insulating material. Low thermal conductivity combined with the high thermal shock resistance and good workability of this new material accounts for the key advantages of the new kiln car design. Damages of the lining by thermal spalling can be reduced. Thereby less small particles are formed, which give off dust on the decoration of the ceramic product and cause downgrading of quality and low yield. The new technical solution has been tested for 6 months and shown advantages over the conventional kiln car lining. The paper describes the key properties of the new materials and the setup of the kiln car lining.

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1 Microporous Material SLA-92

The name SLA-92 of the newly developed insulating raw material stands for super lightweight aggregate of 92 mass-% Al_2O_3 . The other main component of this material is calcia (7–8 mass-% CaO), and the level of total impurities is very low, with SiO_2 and Fe_2O_3 contents max. 0.1 mass-%. The base mineral composition is calcium hexaluminate ($\text{CaO} \cdot 6\text{Al}_2\text{O}_3$ or CA_6). Among minerals in the calcium aluminate system, CA_6 exhibits the best thermal properties with

a melting point above 1850 °C. The bulk density of SLA-92 is around 0.75 g/cm³.

Fig. 1 shows the microstructure of SLA-92. Small CA_6 platelets are arranged like a house of cards with micropores between the crystals, which gives a homogeneous structure with a high internal porosity (typically 75 %). The pore size distribution of SLA-92 is shown in Fig. 2. It shows a narrow range of pore size between 1 and 5 μm with an average pore size of 3–4 μm . This structure accounts for the two key properties of SLA-92 described below, which make SLA-92 superior to conventional insulating raw materials.

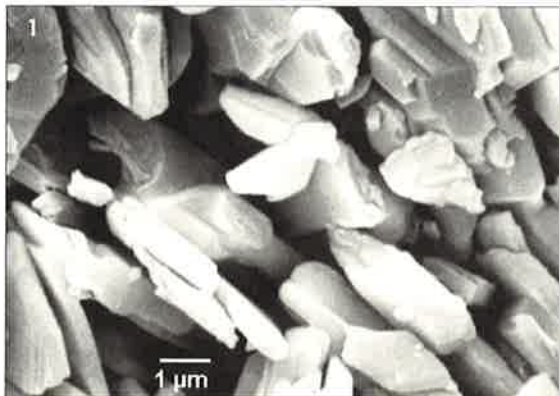


Fig. 1
Scanning electron
microscope picture
of SLA-92
(broken surface)

The microporosity hampers heat transport by radiation, which is the main transport mechanism at high temperatures, resulting in the low thermal conductivity of SLA-92 especially at temperatures exceeding 1000 °C. In general insulating materials are susceptible to spalling caused by thermal shock, because a temperature change creates a steep thermal gradient that causes high thermal stresses.

But thermal spalling occurs only if a crack developed by thermal stress propagates through the material. The microporous house-of-cards structure of SLA-92 hampers crack propagation and contributes to the high thermal shock resistance. This is an essential property of this new kiln car design.

The properties of SLA-92 including its long term stability at temperatures up to 1500 °C and its chemical resistance against alkalis or when in contact with silica-containing insulating refractories are discussed in detail by van Garsel, et al. [1, 2].

2 Microporous Refractory Castable

Intoval VL 1000 HT, a newly developed lightweight insulating castable, is based on the microporous raw material SLA-92. The castable is hydraulically bonded using high alumina cement. It is installed by casting under vibration, using 55–60 mass-% mixing water.

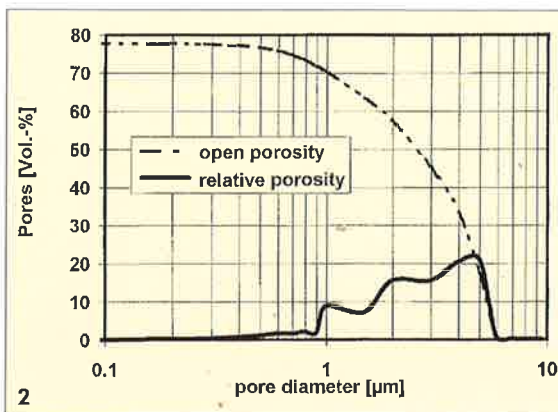


Fig. 2
Micropore size
distribution
of SLA-92
(Hg-intrusion
method)

Table 1
Data of microporous insulating castable INTOVAL VL 1000 HT

Prefiring	110 °C	1000 °C	1400 °C
Chemical analysis [weight %]			
Al ₂ O ₃		86	
CaO		10.5	
SiO ₂		3	
Fe ₂ O ₃		< 1	
Bulk density [g/cm ³]	1.17	1.05	1.04
Cold crushing strength [MPa]	7	8	10
Permanent linear change [%]	- 0.1	+ 0.1	± 0
Thermal conductivity* [W/mK]			
at 400 °C		0.37	
at 800 °C		0.34	
at 1000 °C		0.36	
at 1200 °C		0.39	

* measured by hot wire method (DIN EN 993-15)

Precast shapes of Intoval VL 1000 HT have been used to cover the kiln car plateau. After hardening in casting moulds, these precasts have been tempered at about 450 °C to remove the physically and chemically bonded water from the hydraulic bonding. Pre-firing at higher temperatures, is not necessary for most of the cases including the kiln car lining discussed in this paper.

The data of Intoval VL 1000 HT are given in Table 1. The bulk density, which depends on the pre-firing temperature, is between 1.17 and 1.04 g/cm³. The cold crushing strength is between 7 and 10 MPa, and over the entire pre-firing temperature range, it exceeds the strength (1–3 MPa [3]) of typical insulating fired bricks of ASTM class 23–30. The high thermal shock resistance of refractories based on SLA-92 was proved in a previous investigation [1], and it is also a key property of precasts based on Intoval VL 1000 HT.

The thermal conductivity is between 0.34 and 0.39 W/m·K, which is comparable to that of the insulating bricks of ASTM classes 26, 28, and 30 previously used for kiln cars. In contrast to conventional insulating refractories and even to fibrous materials, refractories based on SLA-92 do not show a steep rise in thermal conductivity at temperatures exceeding 1200 °C [1]. This is due to the microporous structure, which hampers heat transport by radiation.

The new microporous refractories based on SLA-92 are of special interest as fibre replacement material, since ceramic fibers were classified as a category 2 carcinogen by the European Union in December 1997 [4].

3 Innovative Kiln Car Design

Conventional plateau linings of kiln cars are built of different layers of insulating bricks or ceramic fiber materials, which are covered by a refractory plate. Both types of linings create problems during use because of dusting over the decoration of ceramic products to be fired. The low mechanical strength and the low thermal shock resistance of insulating bricks result in the development of small dust



Fig. 3
Innovative kiln car lining with microporous Intoval VL 1000 HT precasts (white) and refractory plate on top. The bottom layer is made of molar bricks

particles, which are blown by the burners in the kiln and deposit on the decoration. Ceramic fibers tend to devitrify as result of the crystallization of mullite and cristobalite during an extended lifetime. When devitrified, fibers become much more brittle and generate small dust particles. Fibrous materials, therefore, have to be covered by refractory plates, but due to the thermal stress during the rapid cooling of ceramic products and the kiln car plateau these plates tend to crack because of thermal shock.

The new kiln car structure combines precasts of Intoval VL 1000 HT, which are used instead of insulating bricks or ceramic fiber materials, and a refractory plate placed on the precast top. The precasts are optimized in respect to their surface geometry to avoid high thermal stresses in the refractory plate during heating and cooling. A patent has been filed for this new precast design.

The format of the precast is adjustable to individual requirements either by adjusting the size of the casting mould or by cutting the precast at the construction site. The precast should be as thin as possible to reduce energy loss owing to the heat stored in the kiln car lining. A precast thickness between 30–80 mm is recommended, the exact thickness depending on the kiln type and the products to be fired. Fig. 3 shows the lining of a kiln car plateau using Intoval VL 1000 HT precasts and a refractory plate on top.

4 First Industrial Application Results

The new kiln car lining has been tested in chinaware decoration firing. The firing cycle was 90 min cold-to-cold with a maximum temperature of 1260 °C, and each kiln car performed 40 cycles per week. The new lining design has been tested for 6 months, namely for about 1000 firing cycles. Recent results show good thermal properties, and no damage by thermal shock after 6 months usage, either of the precasts or of the refractory plates. A reduction in discard and downgrading that result from decoration damages by dusting can be expected, if the rest of the kiln cars are also lined with the new system.

Fig. 4 shows the new design in comparison to the old system that uses insulating firebricks in the top layer of the plateau lining. Whereas the insulating bricks require a little repair with Blakite (chemically-bonded refractory mortar), microporous precasts show no damage. The refractory plate placed on top of the precasts has high mechanical strength and high abrasion resistance, which prevent dust generation during the placement and removal of the kiln feed.

The tests with the new system are continuing to find out the achievable lining life, which is expected to be superior to the conventional system. In general the lining life of kiln car linings with the conventional system is between 12–24 months, de-



Fig. 4
Kiln car with
decoration firing
kiln feed: left side
new system, right
side old system
(repairs with
mortar at the
edges of the
insulating bricks)

pending on the quality requirements of the chinaware decoration and the specific plant conditions.

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5 Outlook

Discontinuous kilns used in the ceramic industry benefit from a lowest possible bulk density of the refractory lining, because it reduces energy loss through to the stored heat. Therefore trials are in progress further to reduce the bulk density of the castable used for fabricating the precast, and new precast constructions are being developed to reduce their weight.

Based on the experience with the new microporous insulating castable and its combination with a refractory plate, further applications of this system in the ceramic industry are considered, e.g., glost firing of chinaware or firing of advanced ceramics.