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Innovative applications for microwave heating – Melting and controlled solidification of metals, drying and heating of refractory materials

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Innovative applications for microwave heating – Melting and controlled solidification of metals, drying and heating of refractory materials

Malte Möller, Horst Linn

The history of industrial microwave heating is more than 40 years long and in the last 10 years it has grown into an established technology for a number of applications. Nevertheless there is still a huge potential for microwave technology in many other applications. Some of the new and ongoing developments are presented in this article.

Especially the ever increasing importance of energy efficiency and production speed work in favour of microwave heating. This is due to the fact that microwave heating is a volumetric heating technology that heats the complete volume of a material at the same time, compared to conventional heating technologies that heat only the surface of a material. Therefore the speed of microwave heating does not depend on the heat conductivity of the material but only on the heating power (for the effective heating speed, dielectric properties and process play of course an important role too). For many heating processes, especially drying processes, the total process time can therefore be greatly reduced when applying microwave heating.

At the same time the heating efficiency of microwave heating is increased as only the product is heated in a microwave unit. The atmosphere and drying chamber are not heated directly by the microwave but only by heat loss from the hot product. Therefore a higher portion of the heating energy is used for heating the product itself instead of heating the atmosphere and drying chamber, resulting in reduced energy requirements for the heating process.

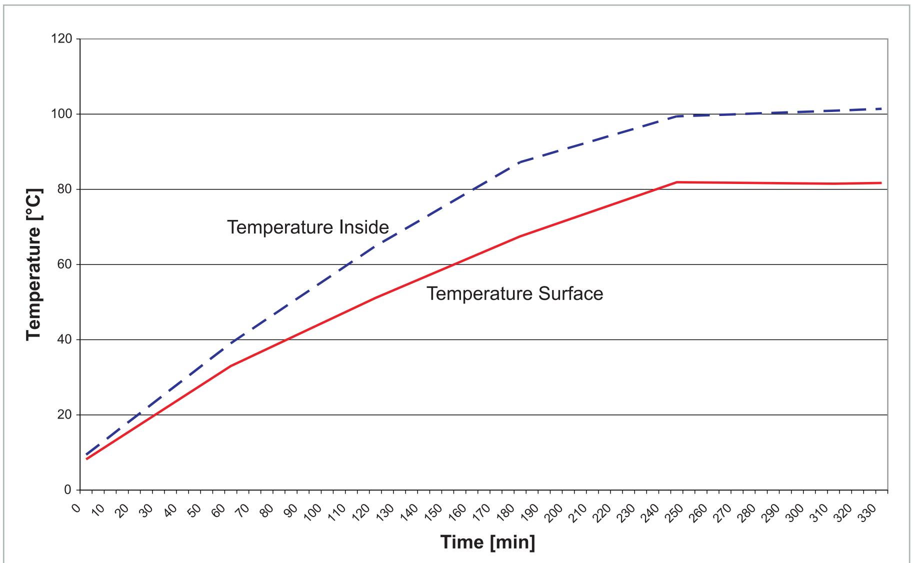

Fig. 1: Microwave heating curve of a single 55 kg refractory brick

Melting and controlled solidification of metals

Although microwaves cannot directly heat metals it is nevertheless possible to heat or even melt metals with microwaves by using a susceptor material. This susceptor material, usually SiC, is heated by the microwaves and in turn heats the metal. This can be done by either using a crucible made out of susceptor material or by using a microwave transparent crucible and placing the susceptor material around the crucible.

This offers a simple and efficient method to heat and melt small metal quantities. Also different atmosphere options are possible, including vacuum and protective gas.

Due to the selective heating of the microwaves that heat only those materials that show good coupling capabilities, it is possible to selectively heat some parts of a product by placing susceptor materials in those areas that shall be heated. The areas without susceptor material stay relatively cold as the microwave heating is there much lower.

This effect gives the possibility to affect the temperature distribution of the melt or solid during casting or solidification. To selectively cool areas in the casting mould is already common technology, but it has been difficult to selectively heat areas in the mould. With microwave heating of susceptor materials that were placed in the casting mould the selective heating will be made much easier.

Fig. 2: Microwave chamber dryer 21 m^3 / 30 kW

Drying of refractory bricks

For many shaped refractory products a drying process is required before the sintering as even low percentages of water may damage the product in the sintering kiln. Due to the large sizes of most refractory products and low heat conductivity of most refractory materials, the drying process is usually very time consuming, resulting in drying times of some weeks. Typical for most of these drying processes is that the initial water content is quite low (often less than 5%), compared to many processes in the ceramic industry where water contents of more than 10% are common. So the process challenge for refractories is more a heat transfer problem than a mass transfer problem as for ceramic drying.

In **Fig. 1** the microwave heating curve of a single 55 kg refractory brick is shown. The initial water content was about 6%. After 5½ hours at 1.6 kW microwave power, the moisture content was reduced to less than 1%. The effect that the surface temperature is significantly lower than the core temperature is typical for microwave heating as the surface is cooled by heat transfer to the atmosphere.

For practical purposes the drying time of a single brick is much less important than the drying time of a whole batch of bricks. The idea is to dry the bricks directly on the kiln car with the same stacking as for the firing kiln, so that no additional handling is required. Either a separate microwave drying chamber is used or the microwave drier is installed directly in front of the firing kiln.

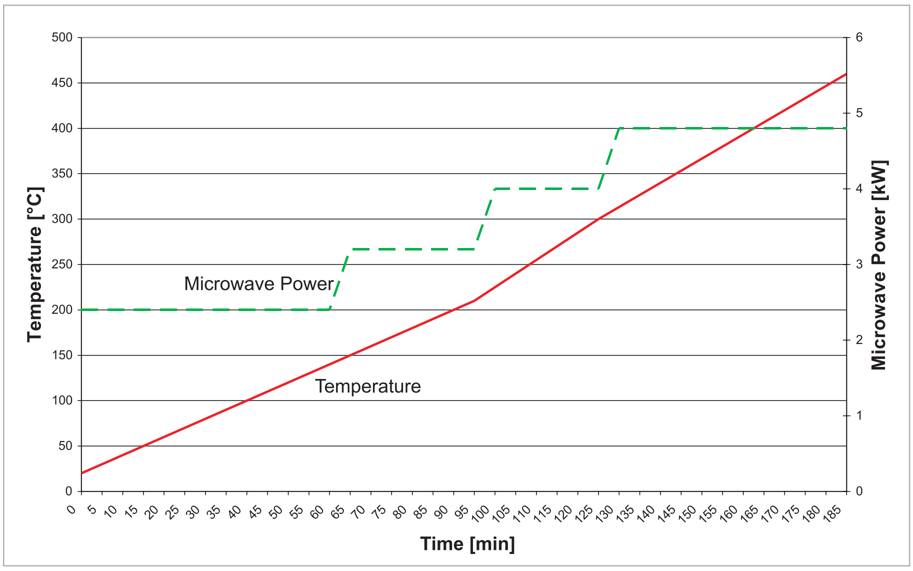

Fig. 3: Microwave heating curve of a purge plug

To use the available kiln space as effectively as possible, the stacking of the bricks on the kiln car is quite dense, which of course affects the drying time. For a complete kiln car with a load of about 3500 kg of refractory bricks, the microwave drying time is expected to be about 1-2 days. This compares very favourably to the several weeks of the conventional drying process.

In **Fig. 2** an industrial microwave chamber drier is shown that can be used for this purpose. The unit has a microwave power of 30 kW and a chamber size of 21 m^3.

Heating of gas purging plugs

Purge plugs, as used for liquid steel treatment, are made of refractory castables and must undergo a thermal treatment during production. During this heating process, the remaining free water is evaporated and some organic materials are burnt off that give the defined porosity required for the purge plug to perform its function. For the complete removal of the organic material, a temperature of at least 400 °C must be achieved in the whole volume of the product. Due to the low heat conductivity of the refractory castable, the conventional process requires about 80 hours.

As shown in **Fig. 3**, with microwave heating the product can reach 450 °C in only 3 hours. So the whole production process can be significantly shortened.

Some drawback of the microwave process is, that the steel cover of the purge plug has to be removed for the microwave heating as it would shield the product from the microwaves, effectively preventing the heating. ■

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