Microwave heating – practical examples

by **Ivan Imenokhoyev, Peter Wübben**

Since approx. 50 years microwave heating has been available for industrial use. For showing the advantages of this technique, the theory of microwave heating will be explained and the practical application will be demonstrated with some selected examples. The recent article gives an overview of the possible kinds of industrial microwave heating and the advantages of it against conventional heating.

Microwave heating systems exist in many different industrial versions. Besides the classical chamber systems the heating with microwave is used in continuous drying and heating plants. Many years of experience in the microwave field and innovative ideas are the basis for the microwave units from Linn High Therm (LHT). The possible ways of applying this technology to drying and heating processes are as many as in conventional thermal process techniques. The treatment of materials by microwaves shows a number of promising advantages against conventional heating technologies, i.e. improved product quality, reduction of process time, saving of energy and energy cost by better efficiency, reduced environmental pollution, lower plant costs and higher production flexibility [1-5].

Microwave heating is a process in which electromagnetic energy with a frequency of 0.3 – 3 GHz penetrates a material and where the electromagnetic wave, or rather wavelengths in a range of 1 m to 1 mm, is converted into heat. For microwave applications mainly four ISM frequencies (Frequencies for Industrial, Scientific and Medical radiofrequency equipment) are available. The highest frequency possible is 28 or rather 30 GHz, for which an industrial and economic use is not yet visible.

The low frequency of 0.915 GHz requires some technical effort which is only justified for some special cases. The economically most relevant frequency is 2.45 ± 0.050 GHz which is used worldwide by household microwaves. From the point of view of microwave thermal process technology the SHF (super high frequency) band with a frequency of 5.8 GHz ± 0.075 MHz is useful for some industrial applications [5].

Before having a closer look at the principle of microwave technology, the conventional heating process is considered. In this heating method resistance or infrared heating elements, which are close to the material needed to be heated, are serving as the heat source. Via heat radiation and convection this energy is transferred to the outer surface of the material and has to migrate into the interior to effect a complete warm up. The thermal conductivity and specific heat capacity are the most important factors for this heating process [3].

Sensible materials due to circumstances may not allow high temperatures and if the material additionally has a low thermal conductivity a long process time is inevitable. This leads to a narrow window during production of certain products with conventional heating techniques. To bypass these confines the laws of physics have not to be rewritten but "high frequency technology respectively radar engineering" only has to attract more interest.

In case of microwave drying, the inverse temperature profile is advantageous, as a higher vapour pressure develops inside the material and drying is effected from the inside to the outside. In the colder outer layers, a part of the steam condenses and keeps the surface humid and permeable until there is no more steam from the inside and the surface consequently starts to dry, too. As water generally converts the most microwave energy due to its high loss factor, lower energy transformation (microwaves radiation without being weakened) is effected depending on the drying substance and drying rate of the inside although this energy can be used in other areas. This way, effective drying by removing all water nests is possible. Because of the different energy input of the materials to be dried, in principle different processes are possible although there is no essential difference above a humidity content of approx. 15 wt.-%. In this case, water determines the process. In the range from 5 – 15 wt.-%, the

Table 1: Overview of test for microwave treatment of leguminous plants

Technical Parameters / Description	Value	Comments
Test material	leguminous plants	Grain size 3-5 mm; filling height 35-60 mm
Start humidity of material	approx. 6.73 wt.-%	Measured with analysis balance Sartorius MA 40
End humidity of material	approx. 5.7 wt.- %	Measured with analysis balance Sartorius MA 40
Insects in material	Existing	In 5 plastic bags all 16 insects were after visual control estimated to be killed. On the next day 1 insect became alive. Totally appr. 6.25 % (1 insect) from 16 insects survived the microwave treatment and the rest 93.75 % (15 insects) were killed.
Ambient room temperature	27.3 °C	Measured value from resistance thermometer PT1000
Material inlet temperature	27.2 °C	Measured value from resistance thermometer PT1000
Material outlet temperature	see Fig. 2 & Fig. 3	Measured with PT1000 and IR-heat picture camera FLIR, USA
Microwave power	68 kW	85 Magnetrons a 800 W in operation
Hot air power	24 kW	2 electrically heated hot air zones
Temperature of hot air	95 °C	Pre-set value at temperature controller
Temperature of air on output	47 °C	Measured value of resistance thermometer PT1000
Total power	92 kW	68 kW of MW-power with 24 kW of hot air power
Belt speed	approx. 1.07 m/min	Measured value
Dwelling time	15.23 min	Calculated value
Cycle time	approx. 57.58 min	Measured value
Mass of material	2,100 kg	Measured value
Mass throughput	approx. 2,188 kg/h	Calculated value

drying substance itself can play a more and more important role. If the material itself can transform microwave energy into heat, the temperature of the material can increase although the temperature dependence of the dielectric constant determines the process. In case of certain chemicals, the chemically bonded water can be split off that way. Below 5 wt.-% humidity, microwave drying can become ineffective with decreasing humidity content. However, it is highly recommended to examine the material before for ensuring that the necessary temperatures can be reached [5].

Fig. 1: Microwave belt drier MDBT 70+24/1040/210/16300, (installed Microwave power 70 kW, hot air power 24 kW, throughput approx. 2,000 – 3,000 kg/h)

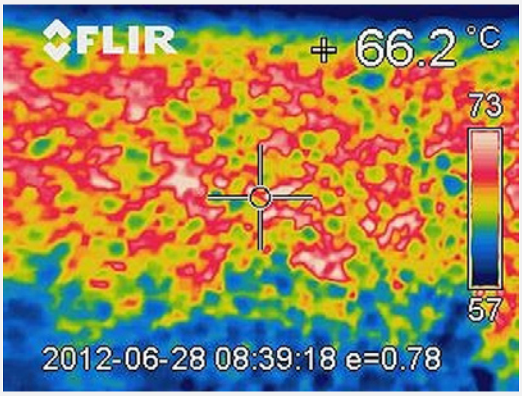

Fig. 2: Surface temperature distribution at a long time test measured with thermal IR camera

At the beginning of the 90's, the company Linn High Therm started their activities in the area of microwave heating in cooperation with Riedhammer. In order to meet the demand for industrial dryers, a modularly designed microwave continuous belt dryer was developed.

Due to the easy and flexible concept of modular design, it was possible to manufacture a cost-effective microwave continuous belt dryer (MDBT) which can be used for various applications. It is a universal device which can be adapted to various applications e.g. for drying wood, ceramics, chemicals, food, building materials, for hardening of fibre reinforced composite materials (GFC/CFC) and more. Furthermore the microwave heating principle can be used for defrosting, calcining, hardening, tempering and acceleration of chemical reactions.

Some practical examples of microwave treatment are listed below which describe the functional principle and illustrate the effectiveness of industrial microwave plants in detail.

MICROWAVE TREATMENT OF LEGUMINOUS PLANTS

Table 1 gives an overview about the microwave treatment of leguminous plants i.e. beans, peas. The microwave treatment (**Fig. 1**) is used for the reduction of germs, killing of insects without the danger of damaging the product, influencing taste or optical appearance while increasing durability.

The effectiveness of microwave treatment and the resulting product temperature can be seen on thermal IR figures. **Fig. 2** shows a typical temperature distribution of a long time test. A continuous temperature measurement during microwave treatment in the product is possible via PT1000 resistance elements or a fibre optical measurement system. **Fig. 3** shows the measurement results from a temperature measurement with PT1000 resistance elements.

MICROWAVE TREATMENT OF SALT

As test equipment the microwave belt drier MDBT 9/2,45–1,6/5,8+3/640/1650 was used (**Fig. 4**). The belt speed of approx. 0.3 m/min was kept constant during the microwave treatment of salt. The humidity of a small sample of approx. 10 – 13 g was measured by a humidity balance analysis at test start and end.

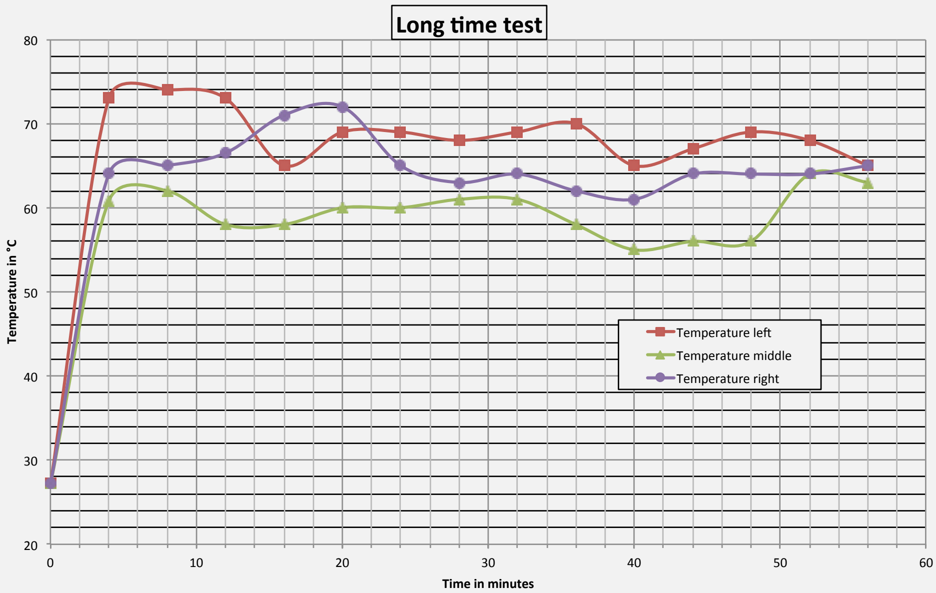

Fig. 3: Temperature vs. time in material during long time test, measured with PT1000

Fig. 4: Microwave belt drier MDBT 9/2,45–1,6/5,8+3/640/1650

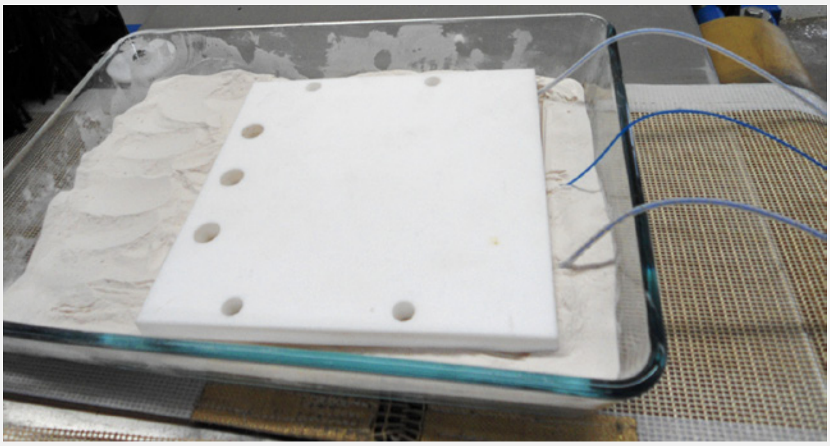

Fig. 5: Placement of fibre optical sensors

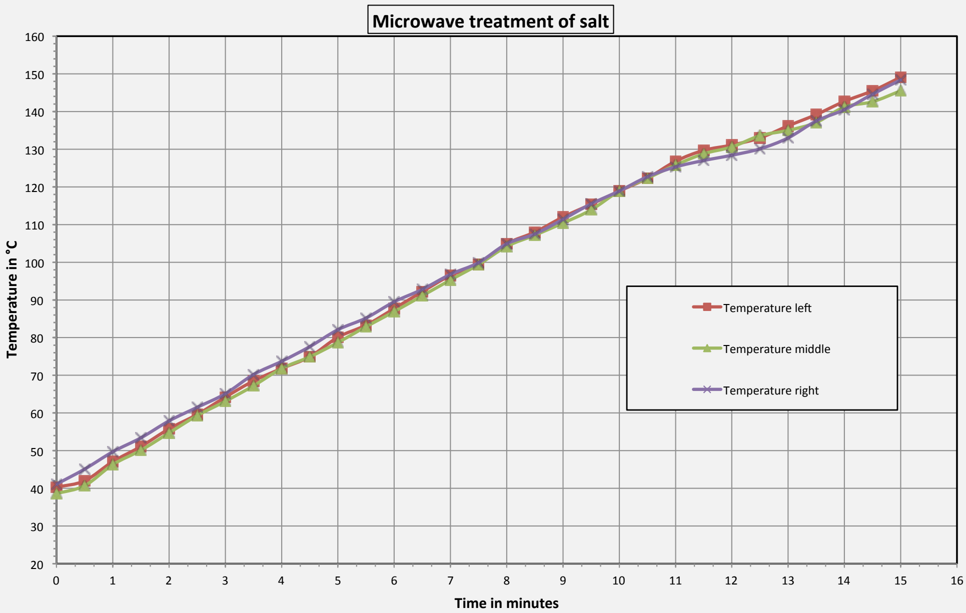

Fig. 6: Temperature course in salt measured with fibre optical sensors

The total microwave power was approximately 10.6 kW. The temperature of the bulk material was measured by a fibre optical temperature measurement system. Three fibre optical sensors were placed in the material according to **Fig. 5**. The measured results are shown in **Fig. 6**. Additionally the surface temperature was controlled by pictures from a thermal IR camera.

For the technical process it is important to reach a high degree of efficiency and a homogenous electromagnetic field. This is realized by nine 900 W standard magnetrons which do not only have a long lifetime but also significantly lower maintenance and repair costs. All materials which are in contact with the product are made of stainless steel, Teflon or silicone. During design phase, it was also put emphasis on the fact that all components can be cleaned, maintained and changed easily.

CONCLUSION

This article gives an overview of innovative microwave heating plants for applications in different industrial fields. They have been developed for laboratory and productions by Linn High Therm based on many years' experience and are used successfully worldwide. In specific examples it is shown how the effectiveness of microwave heating can be controlled.

LITERATURE

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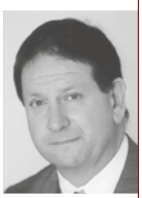
AUTHORS

Dr. **Ivan Imenokhoyev**
Linn High Therm GmbH
Eschenfelden, Germany
Tel.: +49 (0) 9665 / 9140-48
imenokhoyev@linn.de



Dr. **Peter Wübben**
Linn High Therm GmbH
Eschenfelden, Germany
Tel.: +49 (0) 9665 / 9140-62
wuebben@linn.de