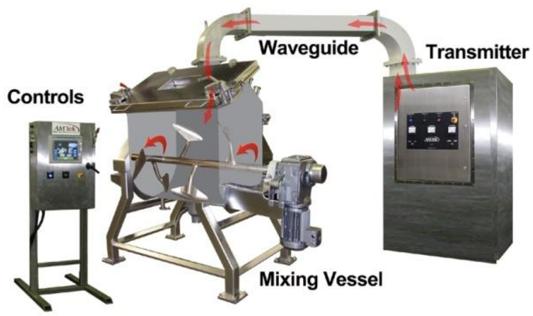


Comparing Microwave to Conventional Heating and Drying Systems

Chemical Product Processing

For Heating, Drying and Applications Involving Chemical Reactions

By Scott Jones, Marketing Manager, Marion Mixers

Features

Advantages

Economics

Drying systems, no matter how complex, all have the same core function: they remove moisture from a material. One of the most common methods for removing moisture is evaporation. Evaporation happens naturally on its own over time, but the process can be sped up with the application of heat to the material, either by direct or indirect measures. Direct heating methods expend energy to heat the target material itself. Indirect methods use energy to heat another object such as an oven or a boiler that acts as a reactor between the energy source and the material. Generally speaking, direct heating methods are faster, and cause more rapid drying.

Microwave Drying

Since the late 60s Microwave technology has promised to be the "next big thing" for industrial chemical processing for almost half a century. Processors recognize microwave's potential to limit their carbon footprint and cut operating costs by reducing energy. In the 1970s, many industries began to explore the use of the new microwave technology for industrial and chemical processing. *Industrial Microwave Heating*, a book by A.C. Metaxas and R.J. Meredith (originally published in 1988 and reprinted in 2008), lists numerous applications considered for heating by microwaves. In earlier days, the technology was relatively unknown, leading to safety fears. Large scale use was considered expensive when compared with conventional methods of heating. Since then, the technology has progressed to the point of being reasonably foolproof. For example, the FDA limits the amount of microwave energy that can leak from commercial ovens. This limit is far below the level known to harm people. Many safety features have been incorporated, and the overall cost today is very competitive.

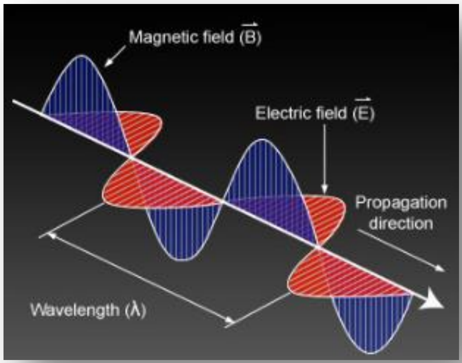
Microwave energy-alone or in combination with conventional energy sources makes it possible to control the drying process more precisely to obtain greater yields and better quality products in the shortest possible time. The mechanism for drying with microwave energy is quite different from that of conventional drying. In conventional drying, heat is transferred to the surface of the material by conduction, convection or radiation and into the interior of the material by thermal conduction. Moisture is initially flashed off from the surface and the remaining water diffuses to the surface. This is often a slow process in conventional drying and the diffusion rate is limited, requiring high external temperatures to generate the required temperature differences. The process time is limited by the rate of the heat flow into the body of the material from the surface as determined by its specific heat, thermal conductivity, density and viscosity.

Microwaves are not forms of heat but rather forms of energy that are manifested as heat through their interaction with materials. Microwaves initially excite the outer layers of molecules. The inner part of the material is warmed as heat travels from the outer layers inward. Most of the moisture is vaporized before leaving the material. If the material is very wet and the pressure inside rises rapidly the liquid will be removed from the material due to the difference in pressure. This creates a sort of pumping action forcing liquid to the surface, often as vapor. This results in very rapid drying without the need to overheat the atmosphere and perhaps cause case hardening or other surface overheating phenomena.

Microwave technology is an extremely efficient but under-recognized energy source for process drying. Applications where microwave processes prove beneficial include: dehydration, sterilization, pasteurization, tempering (thawing), blanching and cooking. In dehydration, the main purpose is to remove water. With pasteurization and sterilization microwave systems are designed to raise the product temperature to a certain level to destroy pathogens. Other applications include blanching where the product is heated then cooled rapidly or when maintained at an elevated temperature, as in cooking, tempering or sintering. Microwave drying—especially when combined with agitation is capable of reducing process time by over 50% in some cases and poses significantly less operator risk.

Mechanism of Microwave Heating

Microwave energy does not heat the room; only the desired material with no harmful greenhouse gas emissions from the heat source. The energy is mainly absorbed by a wet material placed in the cavity. Microwaves are electromagnetic waves having a wavelength (peak to peak distance) varying from 1 millimeter to 1 meter.



Frequency of microwaves lies between 0.3 GHz and 3 GHz. 1GHz = 1,000 MHz. A domestic microwave operates at 2450 MHz (a wavelength of 12.24 cm.) Industrial/commercial microwave systems typically operate at 900 MHz (a wavelength of 32.68 cm). This range allows more efficient penetration of the microwave through the material.

In the past there was some reluctance towards using microwave energy as a heat source in industrial processing because of the inability to heat product material with uniform energy distribution. But times have changed with new technologies, designs and processes. Take for example the jacketed microwave mixer featured below with a paddle-style agitation system. It provides gentle agitation that stirs the material for superior, uniform heat distribution. This allows the microwave to apply all the heat directly into the load. The jacketed trough can be used to cool the product maintained in the same vessel as shown in the application below.

Microwave mixer designed to dry
a proprietary chemical compound

Non-uniform heat distribution results in underexposed and overexposed material in the same batch. Marion Mixers custom designs and manufactures microwave mixers that feature horizontal trough reactors with paddle-style agitators, transmitter system and controls. This design increases the drying effectiveness significantly. A paddle-style agitator keeps the material in constant motion as it is being heated. This allows the maximum surface area to be exposed to the microwave's energy at any given time. This not only speeds up heating and evaporation, but also increases product quality by virtually eliminating uneven heating and product scorching.

Energy Savings

The offsets to the current cost of electricity include: increased speed of drying, the direct coupling of energy into the material and possible lower drying temperatures. Heating the volume of a material at substantially the same rate is possible. This is known as volumetric heating. Processors that use steam, gas or electric heating systems are aware of the high costs of running these systems. Consider these energy-saving benefits of microwave heating verses conventional heating.

- Slash energy consumption by up to 50% or more
- Reduce man-hours and downtime involved in cleaning
- Minimize additional equipment such as heated jackets, boiling pans and heating & cooling vessels
- Smaller equipment footprint
- Eliminate warm up and cool down time
- Microwave energy does not heat the room only the material

Energy is transferred through the material electro-magnetically, not as a thermal heat flux. Therefore, the rate of heating is not limited and the uniformity of heat distribution is greatly improved. Another common misconception is that microwave heating is always more expensive than heating by conventional techniques. This of course will depend on regional energy costs and utility rates but in many cases microwaves can be used at least 50% more efficiently than conventional systems, resulting in major cost savings.

Also imperfect heating causes product rejections, wasted energy and extended process times. Consequently, the quality of conventionally heated materials is variable and frequently inferior to the desired results. With microwave systems, materials heat rapidly and evenly on surfaces that aren't sticky or hot.

Advantages of Microwave Drying

Speed

Microwave drying works *fast*. This is because instead of applying energy only to the outside of the product, microwaves work directly to dry material *from the inside out*. Most conventional heating and drying methods approach material from the surface, applying heat only to the outside edges. This technique removes surface moisture very quickly, but it is highly inefficient when it comes to removing liquid trapped *inside* the material. If external temperatures are kept high enough, as in an oven, the material's inner moisture will diffuse to the surface and evaporate, but this is a passive and lengthy process. Drying technology expert Arun S. Mujumdar, professor of mechanical engineering at the National University of Singapore, Singapore and author of the *Handbook of Industrial Drying, 3rd edition* recently estimates that a full two thirds of the process time of conventional drying systems may be spent in removing that last one third of internally stored water (Mujumdar 295). The inability to quickly dry the inside of a material is one of the greatest inefficiencies of indirect heating systems.

By contrast, this is where microwave systems excel. When a wet material is exposed to dielectric microwave energy its interior pressure shoots up pumping moisture out to the surface. Often this moisture is forced out in the form of a vapor, such as steam. It can dry most materials in less of the time required by conventional methods.

Microwaves also require no heat-up or cool-down time, meaning less waiting and more efficient use of time. The equipment's compatibility with CIP (clean in place) and COP (clean out of place) systems also offers a substantial reduction in downtime due to maintenance.

Product Quality

The superior control offered by microwave systems also contributes to higher quality by making product temperature much easier to regulate. Many applications have very specific parameters for heating: perhaps a material becomes explosive at a given temperature, or loses an important attribute if heated beyond a certain point. While steam and fuel are both difficult to control, microwave equipment and control panels allow for very minute temperature regulation, assuring accuracy within one degree of the desired temperature. When combined with agitation, this precision, batch after batch, reduces product fouling to keep yields high.

Applications

A few variables go into determining the potential effectiveness of microwave for a given application. The material's mass, specific heat, dielectric properties, heat loss mechanism, geometry, and coupling efficiency all make their way into the equation. It's worth remembering, too, that microwave technology can work exceptionally well as a partner process; that is, it can be a highly effective supplement to a conventional process. A hybrid system utilizing a traditional convection oven and microwave can capitalize on the efficiencies of both technologies. Three hybrid combinations are the most common:

1. Preheating: Microwave energy is applied first thing to bring all moisture content to the surface of the material. The material then is sent to a conventional drier or oven, which flashes the moisture off.

2. Booster Drying: Microwave energy is added when all surface moisture has been removed and the drying rate of conventional systems begins to taper off—about two-thirds of the way through the process. The microwave is used to bring remaining moisture to the surface and remove it.

3. Finish Drying: Microwave energy is applied at the very last stage of the drying process, as the material leaves the conventional oven. In finish drying, the microwave takes over just as the conventional system's efficiency plummets and its own efficiency is greatest.

Finish drying is the most popular of the hybrid styles. A primary benefit it can offer is sanitization of the material: if the appropriate temperatures are used, the product in its final stage will be pasteurized as well as dry.

Microwave Safety and Myths

Using patented applicator designs such as chokes, microwave vendors are able to reduce electromagnetic leakage from system entry and exit points to virtually non-detectable levels in microwave mixer heating vessels. Chokes are used around doors, windows and seams to prevent microwave leakage. This poses no threat of electromagnetic energy to the health and safety of equipment operators if all precautions are followed. As a further precaution, control systems are supplied with safety interlocks and leakage detectors that shut down power instantaneously in the event of equipment malfunction.

Myths such as microwaves can cause damage to pacemakers are no longer valid. Modern pacemakers are shielded from stray electro-magnetic forces and have a backup mode that takes over if a really strong electro-magnetic field disrupts the main circuit's programming.

Another myth has to do with arching and the noticeable sparks that are visible when a metal object is placed inside an operating microwave device. In fact, microwaves can be applied to products in metal vessels as long as the mass of product and the intensity of microwaves are matched. Arching takes place when too much energy is applied to a given mass of product in the vessel.

Application Testing

For the past two years Marion Mixers and AMTek Microwave, two of the industry leaders in the use of Microwave technology for chemical and food process drying have been conducting product application tests at their respective state-of-the-art test labs to determine the benefits of using microwave compared to conventional drying methods. The materials they have tested are extensive and they welcome the opportunity for further product testing. Following are the features, benefits and economies of using microwave technology.

Feature	Benefit	Economic Value
Decreased Process Time	Decreased energy usage on basis of btu per batch processed	Energy savings due to shorter batch times
	Ability to pulse the power for precise control	Reduced production costs
More Compact	Requires a smaller equipment space or footprint	Reduced fixed cost savings
	Can be remotely located in a dry, safe area	More usable plant floor space for increased production
Safety	Chokes, mesh screens, and safety interlocks for complete operator safety	Prevent employee injuries and liability claims
	Safer than steam and hot oil heating	Prevents injury & worker discomfort
Easy Cleanup & Maintenance	CIP and COP capable	Less teardown/better turnaround
	Less chemical and water usage	Higher profit margins
	More production time available	More product/more profit
	Less mess	Improved working conditions
Higher Power Densities	More efficient energy usage	Increased production speeds
	Selective heating - "product not plant"	Decreased production costs
	Heat not expended to heating air, walls of the oven, conveyor and other parts	Since energy source is not hot there is a plant cooling savings: HVAC Savings
Precision Energy Control	Can be turned on and off instantly	Eliminates the need for warm up and cool down
	Product heating occurs from top down	Reduces product fouling
More Uniform Temperature Profiles	Energy is selectively absorbed by areas of greater moisture	Minimizes overprocessing; no scorching, overheating or case hardening
	Enhanced product performance	Improved yields
No-Contact Drying Technology	Reduces production run times	Reduces both cleaning times and chemical costs
	Lack of high temperature heating surfaces	Reduces material finish marring
No Greenhouse Gas Emissions From Heating Source	May Eliminate the need for environmental permits	Cost savings
	Improves working conditions	Employee retention
3A Sanitary Compliant	Product safety Workers Comp Savings	Reduce product recalls and liability expense
	USDA accepted designs 3A-Sanitary Certifed designs	Sanitary & hygienic standards compliant if needed
Increased Plant Throughput	Less handling, floor traffic, fork trucks, pallets, transfer points and congestion	Better employee ergonomics, safety and product damage
	Less floor space requirements, contamination, product damage	More productivity