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Microwave Rubber Heating Technology

Quality and Speed with Microwave Heating

Manufacturers wanting to produce new products, build new plants, or automate should consider microwave heating for their specialized heating applications.
Microwave heating is a quick and efficient method of heating materials that are difficult to heat by convection or infrared methods, so production rates increase and product quality improves.
The most widespread industrial use of microwave heating is for food processing, but it is effective for many other hard-to-heat products, including

- Rubber-gaskets, weather stripping
- Ceramics-catalytic converters,
- Chemicals and pharmaceuticals
- Investment casting waxes.

New applications are emerging and gaining in popularity as manufacturers discover the unique benefits of microwave heating.

Advantages

Because conventional heating methods require heat conduction from the material's surface inward, they are slow and inefficient for materials that conduct heat poorly.
The direct and efficient heating supplied by microwave energy offers several advantages for the production of these materials.

Quick heat penetration

Microwave energy penetrates into a homogeneous material, heating more uniformly than conduction methods.
Heat need not "soak" through the material thickness, so interiors heat rapidly.
Production rates increase, more than 100% for thick, heat sensitive, or highly insulating materials.

Selective heating

Since different materials absorb microwave energy at different rates, a product with many components can be heated selectively.
For example, pre packaged medicines can be sterilized without heating the packaging.

Amenable to automation

In addition to shortening normally slow heating processes, microwave heating is electronic, so it is easily integrated by manufacturers committed to automating their operation.

Improvement of product quality

Unlike conventional methods, microwave heating avoids degradation of product strength and surface properties caused by exposure to high temperatures.

Increased flexibility

Complex shapes heat more uniformly with microwave energy.
Also. microwave heating units feature instant on/off. so no equipment warm-up or cool down is necessary.

Combination with conventional methods

Microwave energy may be added before, after, or inside conventional heating or drying units to decrease processing times by as much as 75%.

High energy efficiency

As a measure of heat energy input to the material versus ac line power supplied to the unit, overall microwave energy efficiency is approximately *50%.*
Conventional fuel-fired heating processes are generally 10 to *30%* efficient.
So, although electricity is more expensive than gas or oil, the benefits of microwave heating can be realized without any increase in energy costs.

Space savings

Microwave heating equipment occupies 20 to*35%* of the floor space of conventional heating units.
The major drawback of microwave heating is company secrecy.
Companies using microwave heating tend to keep their processes confidential in attempts to edge out their competition.
Because their information is unavailable, the technical facets of the technology cannot be readily transferred to other applications.

Applications

Microwave heating's high speed, small space requirements, and electronic control make it attractive to manufacturers who are modernizing facilities and increasing automation.
It is firmly integrated into some industries that must heat materials more quickly and efficiently.

Rubber

Microwave heating saves energy during batch preheating of rubber before moulding into parts such as gaskets.
It has converted rubber vulcanization, required for strength and resiliency, from a batch process to a continuous one .
Heating by hot air, autoclaves, or salt baths is slow and difficult because rubber conducts heat poorly, but microwave energy rapidly heats the rubber within its bulk, up to five times faster than hot air heating.
Rubber is continuously extruded, microwave heated and vulcanized, and formed into products such as weather stripping and seals for expansion joints.

Sponge rubber

Pipe insulation and gaskets for automobile windows and doors are made from sponge rubber.
Sponge rubber is formed by adding a blowing agent that activates with heat, forming gas bubbles which are entrapped in the rubber.
A combination infrared/microwave heating process achieves an effect that conventional heating cannot.
Infrared heat first cures the surface to obtain a smooth "skin."
Microwave energy then cures the interior to a uniform porosity.

The Old Way

Rubber must be heat cured to obtain final strength and resiliency and to reduce stickiness.
Rubber conducts heat poorly, so any process that requires heat penetration, such as steam curing, is slow.
Synthetic rubber as compounded and extruded through a die.
The extrusion was sprayed with soapstone lubricant to control stickiness.
Workers then cut the extrusions into 10 foot lengths, loaded the lengths into pans, and stacked the pans on racks in small rail cars.
One loaded car was rolled into an autoclave 78 feet long and 5 feet high.
The autoclave doors were closed, and the steam was turned on.
The autoclave curing cycle averaged 30 minutes at 105 pounds per square inch and 307 ^{0}F.
After the lengths cooled for several hours, workersw ould cut them to customer specification, then pack and ship them.
The long steam curing cycle caused product quality problems.
The rubber often slumped and lost its shape before completely curing, and cut ends often distorted.
Both conditions contributed to the 5% scrap rate.
In addition, excess lubrication could cause product contamination.
The process had other drawbacks, too.
Scheduling labour and extrusion equipment to feed the autoclaves at a constant rate as tricky.
The 16 foot lengths were awkward for customer to handle: some customers spliced sections together, creating potential failure points: others cut the lengths further, wasting unusable ends.

The New Way: The 60-Second Cure

Pawling's need to produce continuous rubber strips with a minimum of handling mandated a continuous extruding and curing process. It investigated salt bath and hot air curing, but both had the same heat penetration problems as steam curing.
Was convinced that only a combination of microwaves and hot air could provide the fast cure a continuous process needs.
Microwaves rapidly generate heat within the rubber itself; hot air maintains the temperature, efficiently completing the cure.
The new rubber curing line is only 115 feet long.
The extruder occupies 15 feet, the microwave section 40 feet, and the hot air section 60 feet.
Synthetic rubber is compounded and extruded by the same methods as before, although most formulations have been modified to more efficiently absorb microwaves.
A temperature-resistant belt transports the extrusion from the die directly into the microwave/hot air curing unit at 70 to 100 feet per minute.
Extrusion and curing requires approximately 1 minute, depending on line speed.
Upon exiting the hot air section, the cured rubber plunges into a water bath.
According to customer demands, it is then either machine sliced or coiled into continuous lengths of up to 1000 feet, packed, and shipped.

The Results: Gains in Quality, Productivity, and Safety

A more desirable product.
Now, supplies rubber to customer-specified lengths and tight tolerances.
For instance, items like high-pressure gaskets are less likely to fail if they have not been spliced.
The microwave/hot air process cures unusual shapes within a minute, before they have time to slump and distort.

Increased flexibility.
Microwaves cure diverse shapes at uniform rate, so manufactures a greater variety of products.

Elimination of steps.
Lubrication and manual handling of the product are virtually eliminated.
Workers no longer cu rubber and load and unload pans and autoclaves.

Reduced labour costs.
Less labour is required to handle the product.
Labour costs have decreased from 14% to 9,5% of total unit product cost.

Material savings.
Raw materials for the new formulations are slightly more expensive.
But the fast cure cycle eliminated scrap from slumped or distorted product, resulting in material savings of 5%.

Less floor space.
The straight 115foot production line requires 20% to 35% of the space occupied by a conventional line.

Energy savings.
The microwave units have a working efficiency of about 50% versus 10% for steam produced by an oil-fired boiler, more than offsetting the higher cost of electricity.

Safer work environment.

The hazards associated with steam curing have been eliminated.
Injuries, mainly due to workers cutting their hands during slicing operations, have decreased.

Technical Considerations

For each potential application a careful evaluation should be made to determine if microwave heating is the
best alternative.
The following considerations will guide your process evaluation:

Material characteristics

Every material's ability to heat under exposure to microwave energy is determined by a property called the loss
factor.
Materials with loss factors between 0.01 and 1 generally heat adequately at microwave frequencies.
But these values should be viewed as guidelines only, since the loss factor is dependent on temperature, frequency, and moisture content.
For example, some ceramics do not heat under microwave frequencies at room temperature but wiII heat effectively at 500 ^{0}C.
The ability of other materials, such as polymer resins and ceramics, to absorb microwave energy can be
improved by formulating in dielectric therms.
The material's sensitivity to rapid heating must also be considered.
The rate at which the material can be heated without damage limits the speed that microwave energy can be applied.
For example, drying ceramic moulds too quickly causes cracks and bubbles, and the mould cannot be reused.
Materials that must be heated slowly to maintain their integrity might fare best with a combination microwave/
conventional heating system: the microwave energy is applied only for the portion of the process for which it is best suited.

Penetration depth

Microwave energy may penetrate to 50 cm for materials with a low loss factor but only a few centimetres for high-loss materials such as water.

Frequencies

The FCC-assigned microwave frequencies for use by industry are 915 and 2450 MHz.

Most applications use 2450 MHz because the microwave units are smaller and easier to work with and generator development is more advanced.
But915 MHz is more economical for applications requiring more than 60 kW of power.

Deeper penetration into the material can also be achieved with 915 MHz.

Power

A material's heating rate is governed by the amount of microwave power input to it. Power level requirements are calculated based on the properties of the material being heated for a particular throughput and the Initial and final temperatures.
The power level and estimate of its efficiency are then confirmed with equipment tests.
Material temperatures are adjusted by precise control of the power level and belt speed.

Once the technical feasibility of microwave heating for your application has been determined, several economic
factors must be considered:

Capital costs

Microwave heating equipment typically costs $2000 to $5000 per kilowatt of installed power.
Included in this price are the microwave power supply, oven, conveyor, process controls, and temperature sensors if needed.

Operating costs

Energy costs for microwave heating are comparable to those of conventional heating methods but may be offset by savings in other areas of production, such as increased production speeds or reduction in inventory.
Maintenance and labour costs are also roughly equivalent to those of conventional methods.
Magnetrons have an average lifetime of 5000 to6000 hours.
Replacement costs for a 2450-MHz magnetron range from approximately $150 for a 1 -kW tube to $3000 for a 6-kW tube.
A 60-kW, 915-MHz tube costs approximately $6000 to replace.
Applications of microwave heating prove successful when at least some of the following parameters contribute to
favorable process economics:

- **A batch process can be converted to a continuous one.**
- **The finished product has high value.**
- **The microwave equipment functions only for the process steps for which it is best suited.**
- **Current plant space is minimal.**

In Conclusion

Microwave heating technology is currently underutilized.
Microwave heating is a faster, more efficient heating method for no conducting materials In many operations, but the most sensible applications may be new lines and plants and modernization efforts.

Its adaptability to increased automation and electronic control helps it to easily integrate into high-speed operations.
Combination microwave/conventional heating systems will become increasingly important in the next 10 years.
These systems are economical for energy- and time-consuming processes.
The technology and equipment are commercially available.
Specialty applications such as ceramic firing will develop more slowly as research work continues.
Microwave heating for large-scale chemical processes will grow, but most applications will remain confidential.