Basic Principle

Radio-frequency (RF) drying and heating uses RF waves to heat nonconductive materials (such as plastics and water) that contain polar molecules. RF energy is a rapidly alternating electromagnetic field. Polar molecules react to the field's rapidly changing polarity by moving around, creating heat in a manner similar to friction. Since many thermoplastics and thermosets have polar qualities, RF heating is an effective drying and heating technology for a large number of plastics applications.

However, not all polymers respond well to RF energy. The material must possess a certain level of electrical resistance and dielectric strength to withstand rapid heating from a strong electric field. The ability of a material to dissipate an electromagnetic charge is called "dielectric loss" and is measured by the dielectric loss constant. Polymers with a low dielectric loss constant (less than 0.1) do not react to the field sufficiently to heat quickly; polymers with a high dielectric loss constant (greater than 1) react so well that they tend to overheat. Simple aliphatic hydrocarbon polymers, such as polyethylene, polypropylene, and nonpolar polystyrene, exhibit a low dielectric loss, thus are not good candidates for RF heating. On the other hand, polymers such as polyurethane, polyvinyl chloride (PVC), and nylons exhibit strong dielectric losses and are readily heated by RF fields.

System Description

Some common applications of RF heating include sealing layers of plastic to form laminates, preheating preforms, preheating filler, facilitating the curing of thermoset molds, and drying pelletized resin. Plastic sealing relies on the speed and controllability of RF to produce a uniform bond between plastic surfaces. Since sheets have a uniform geometric profile, the field created by RF energy is consistent and can be adjusted to an intensity sufficient to fuse the sheets together as they pass through the heater at comparatively high speed (up to 12 feet per minute in some cases). This high-speed sealing promotes a level of productivity that far surpasses any other heating method. Also, RF sealing is versatile enough to bond different types of polymers and metals to plastics.

RF heating is also used to preheat preforms prior to thermoforming and compression molding. Preforms are plastic shapes that roughly fit a mold and are heated, liquefied, and pressed during thermoforming or compression molding. Preheating these preforms quickens the mold processing time by making the preform more pliable and lessening the amount of heat that must be transferred to them while in the mold. Thick preforms are difficult to effectively preheat with surface heating methods. The penetrating characteristics of RF energy provide advantages over convective and infrared heating techniques, which primarily heat the surface of the plastics. Since plastic is typically a poor thermal conductor, heat is not rapidly transferred internally. RF energy, however, penetrates the plastics and thoroughly warms the preforms to provide a pliability that improves the molding process.

Similarly, RF heating can preheat the filler used in many plastics applications and facilitate the curing of high-quality thermoset molds. Preheating filler—an additive that expands the volume of a resin—lessens the viscosity of the mixture, thereby improving its strength and flexibility. Preheating also reduces wear and tear on machinery and improves the energy efficiency of the plastic product manufacturing process because it requires less power to press the thermoset material into the mold. The penetrating qualities of RF are also advantageous for thermoset mold curing. Because plastics are poor conductors of heat, thermosets tend to overheat on the outside before the inner regions reach a high enough temperature for curing. RF heating penetrates and warms plastics evenly, reducing the potential for overheating.

RF energy can also be used to dry pelletized resin. Many resins absorb moisture and must be dried prior to being fed into production equipment. Since water is exceptionally polar, it responds favorably to RF energy; consequently, high moisture levels in pelletized resin create high dielectric loss characteristics that promote rapid heating. As the moisture in the resin heats up, it evaporates. A physical principle of dielectric circuits (including capacitors) dictates that low dielectric losses create low electrical impedances on the power supply. As the dielectric loss characteristics of a resin decrease, (which occurs as the resin dries), less energy is pulled from the RF field. This effect creates a self-limiting drying process: relatively wet resin consumes a large amount of energy from the RF field; however, this energy draw decreases as the resin dries. This principle also applies to resins with a variable moisture profile. When exposed to RF energy, the wetter areas of a resin feedstock absorb more energy than the drier areas; this promotes uniform drying and minimizes the risk of overheating. Recognizing that many resins coagulate at high temperatures (200–250°F), precise control of the drying process is critical to avoid feed problems.

A typical RF heating unit consists of a power supply, oscillator, and a set of electrodes. The power supply provides the high voltages needed for the oscillator to generate high-frequency energy (2–100 MHz). The electrode system receives the high-frequency energy and converts the power to RF waves. Because the same frequencies are used for radio communication, RF heaters must be shielded to avoid radio interference.

Advantages

- Rapid, uniform, heating/drying: Heat is generated uniformly throughout the material; unlike with a convective process, no time is needed for the heat to flow into the material from the surface. The resulting decrease in drying time can allow a plant to increase productivity and even upgrade

Radio-Frequency Heating and Drying System Characteristics

Dimensions	Length: 15–40' Height: 5–10' Width: 5–10'
Power Rating	1–1000 kW
Energy Consumption	52,000 kWh annually*
Key Inputs	
Power	Electricity
Other	Oscillator tube replacement
Key Outputs	
Solid Waste	None
Air Emissions	None
Water Effluent	None
Cost	
Capital	$1000–$2,500,000
Operating and Maintenance	$200–$10,000

* Assuming a 50-kW unit used 4 h/d, 5 d/wk, 52 wk/yr.

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