Acoustic drying of paper, films in commercial settings

By Jason Lye, Ph.D., chief technical officer, Heat Technologies Inc.

Abstract

Five years since publication of our technical paper, "How acoustically enhanced drying improves productivity, cuts energy consumption," [1] this article provides an update on the technology and how it is now being used in commercial settings. This firm's patented [2] acoustic drying system has helped converters, coaters and printers increase line speeds and dry at lower temperatures in a very small equipment footprint – at reduced energy consumption and lower carbon emissions.

Introduction

Acoustic drying technology is configured to the particular customer's exact requirements, which basically depend upon the amount of water that needs to be vaporized. Despite its significant impact on line speed and reductions in energy consumption, there is no magic to the system and the laws of physics still apply. If you need to evaporate 1 kg of water per min, then enough energy must be transferred into the water to satisfy the latent heat of vaporization. Acoustic drying systems are simply extremely fast and efficient at getting energy into the coating so it can act on the water without wasting heat.

This firm's turnkey, fully tuned acoustic dryer systems include a company-designed, high thermal-efficiency, inline heater, a carefully selected high-end blower, a patented acoustic-field generating dryer head and a control panel to integrate the components (see Figure 1). The systems are "tuned" carefully to generate an intense ultrasonic acoustic field at the air exit orifice. Each dryer system is custom-designed for specific requirements, including web width, speed increase desired, installation area, amount of water to be vaporized per unit of time and, if applicable, the composition of any solvents that may be present.

Adhesive drying on film and paper

Many repeat buyers of this firm's acoustic drying systems enable them to increase the productivity of existing coating and printing assets without significantly increasing asset footprint. Particular success has been achieved with drying challenging coatings, such as cold-seal and pressure-sensitive adhesives at high speed. Some examples include:

Water-based cold-seal on film

Goal: Increase line speed with minimal footprint; apply 45% solids water-based adhesive, 2-gsm dry laydown; using company-designed and installed acoustic dryer add-on booster. Results: 40-ft dryer length with 2.2-ft booster; line speed increased from 400 to 1,300 fpm; effectively tripled asset output. The booster was installed prior to the existing dryer to prevent surface coating skin formation. No intrusion into the customer's existing dryer was needed. A 5% increase in dryer length tripled the asset output.

Solvent-based (toluene) heavy adhesive on film

Goal: Replace a 50-year-old oven dryer; apply 40% solids

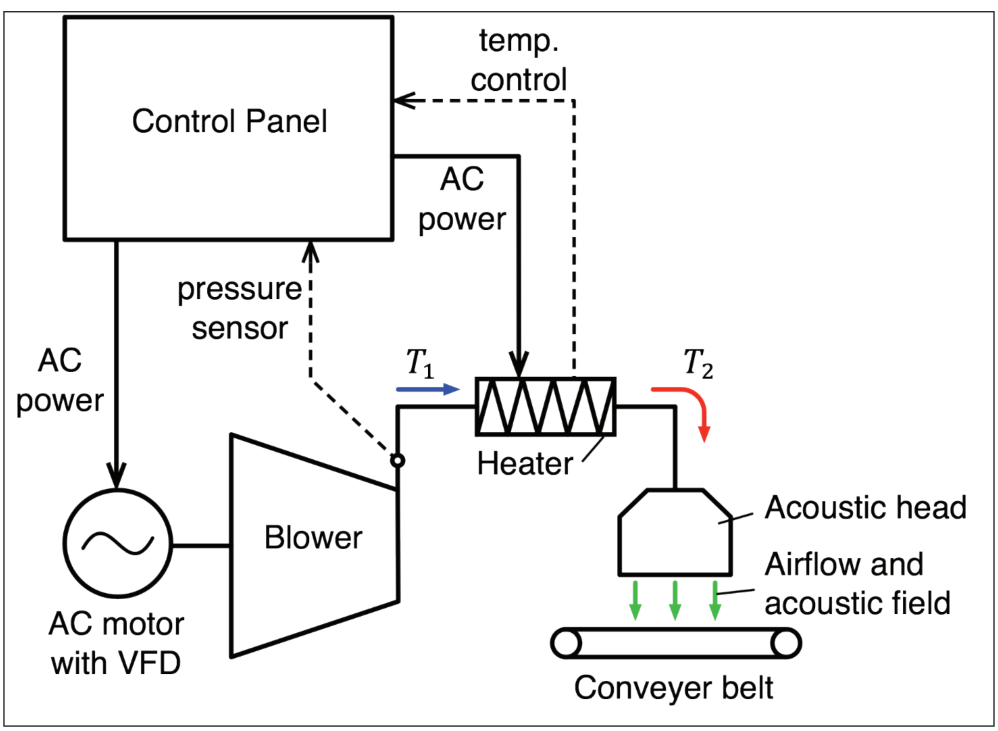

FIGURE 1. *Acoustic drying system main components*

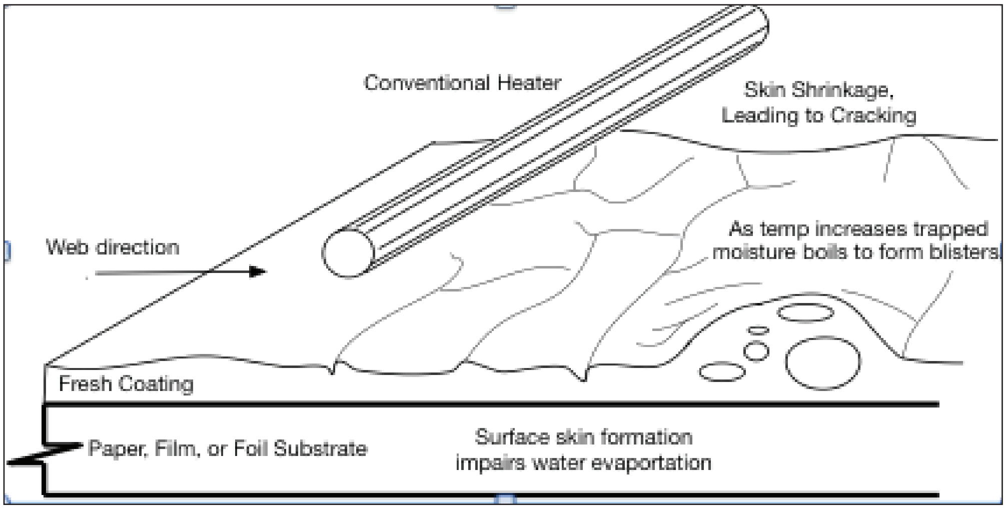

FIGURE 2. *Thick coating skinning under radiant heat, leading to slower drying and ultimately blistering and cracking*

solvent-based adhesive, 25-gsm dry coatweight; using company-designed and installed acoustic dryer. Results: 56-ft dryer length with 4-ft booster; 87% reduction in power consumption.

Water-based adhesive coating
Goal: Increase line speed; apply 50% solids water-based adhesive; 25-gsm dry coatweight; using company-designed and installed booster system prior to, and without any modification of, the existing dryer. Results: 75-ft dryer length with 1.5-ft booster; line speed increased from 170 to 250 fpm (47% faster with limited space).

Pressure-sensitive adhesive (water-based)
Goal: Increase line speed to press maximum with limited space; apply 35% solids water-based p-s adhesive; 5.2-gsm dry laydown; using company-designed and installed booster system prior to, and without any modification of, the existing dryer. Results: 19-ft dryer length with 18-in. booster; line speed increased from 800 to 1,000 fpm (20% faster with spare capacity).

Water-based adhesive on paper
Goal: Replace infrared (IR) dryer to save power, increase line speed; apply 40% solids water-based adhesive, 3.25-gsm dry laydown; using company-designed and installed acoustic drying system only. Results: Installed power reduced from 650 kW to 120 kW (81% decrease); 50-ft dryer length reduced to only 8 ft (84% shorter); line speed increased from 500 to 650 fpm (30% faster); elimination of IR dryer also improved the finished properties of the food-packaging material. In addition, the customer noted the material was so much whiter when dried acoustically vs. infrared.

Solvent-based (hexane/ethyl acetate) adhesive on latex-reinforced paper
Goal: Increase line speed; apply 40% solids solvent-based adhesive, 35-gsm laydown; using acoustic dryer as replacement for IR dryer. Results: 65.6-ft dryer length cut to only 2.95 ft (96% decrease); line speed boosted from 65.6 to 131 fpm (100% increase).

Drying cold-seal adhesive at low temperatures

In part because of the higher coatweight, drying cold-seal adhesive has been troublesome ever since its introduction into food packaging in the 1960s. While very popular with consumer food companies, in many cases, printing, converting and packaging companies have had to reduce coating-line or printing-press speeds to ensure full drying of cold-seal coatings, thereby reducing their productivity when using this alternative to heat seals.

Drying heavy coats of materials, such as cold-seal and pressure-sensitive adhesives, while maintaining coating quality can be tricky – especially on plastic films. When a thick layer of coating is subjected to high temperature or radiant heat, the top layer often dries faster, forming a “skin” (see Figure 2). Once a skin is formed, water or solvent evaporation is thus hindered. This is because the diffusion coefficient of water or solvents through liquids is much higher than the diffusion coefficient of water or solvent through a solid skin. Instead of leaving the coating as a vapor, trapped underlying liquids may vaporize within the film layer and form bubbles or blisters underneath the skin. Alternatively, as the skin continues to dry, it also may shrink, forming cracks in the surface. Blistering and cracking are two serious coating defects faced by industries wishing to dry thick film coatings.

However, with these difficulties in mind, this firm demonstrated a commercial cold-seal dryer last fall (see Figure 3). The acoustic, three-slot, 26-in.-wide dryer is mounted over a conveyor belt so customers can perform trials and test their materials. The acoustic chest – the part of the dryer that creates the acoustic field – is only 8½ in. long in the machine direction, yet a similar system replaced a hot-air drying oven 8 ft long while increasing line speed by 100%. The setup also reduced that customer’s drying temperature enabling them to print on shrink-wrap film – and saving energy as well.

During the demonstrations, Loctite® Liofol® CS-861US1, a water-based, natural-rubber, latex food-grade, cold-seal adhesive manufactured by Henkel Corp. (Cary, NC) was coated and dried onto PET film. Mayer-rod drawdowns were prepared by hand to give approximately 2.5-gsm dry coatweight on the PET film. The

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coated sheets were taped to a metal plate and dropped onto the conveyor belt running at 250 fpm. The acoustic dryer dried the coating in one pass.

Thermal imaging showed that, even though the coating was completely dry, the temperature of the film and plate had not increased dramatically, demonstrating the efficiency of the system in terms of using energy to vaporize water vs. using thermal energy to heat the substrate (see Figure 4). Almost all of the thermal energy was consumed evaporating the water from the coating. The coated film dried at a cooler temperature because heat alone is not required to dry it.

Drying inks on paper or film

Tempering of paper prior to high-quality printing

Goal: Print onto film for a flexible, paper-packaging material; consistently reduce paper moisture content down to 3% from a typical 5-7%; using acoustic drying system at unwind rather than inverted "U" dryer at first printer color station. Results: ~16-ft dryer length reduced to 1.3 ft long (92% decrease); line speed increased from 500 to 1,000 fpm (100% increase); consistent achieved a 3% paper-moisture level.

Drying gravure-printing inks

Goal: Increase speed of gravure-printing press by 25%; print 30% solids, water-based gravure inks at 6-gsm coverage via a 1.8-meter-wide gravure press; using company-designed and installed booster system. Results: 50-ft dryer length plus 1.5-ft booster (3% increase); line speed increased from 300 to 450 fpm (50% faster).

Replace solvent inks with water-based inks while drying at the same line speed

Transitioning from solvent-based inks to water-based can be challenging. While less expensive per lb, water-based inks are far more difficult to dry due to higher specific heat capacity and a latent heat of vaporization – an order of magnitude higher than most commonly used solvents. A 4-ft-long acoustic dryer (booster) was added to a 40-ft-long oven; no intrusion into main oven was needed. Results: Dryer length increased ~10%; line speed increased from 110 to 450 fpm – roughly 400% faster.

Residual solvent removal from printed inks

Residual solvents in printed media can be problematic, especially in paint-sensitive products such as tobacco. Certain regulated products also have minimal requirements for residual packaging solvent. Removing the last traces of solvent is tough, usually requiring long residence times in ovens or, in some cases, storage in a warehouse. Working with several customers facing this problem, we found that exposure of the dried ink to six acoustic slots (~0.60 to 1.0 meters long) at 30 mpm reduced residual solvents from 45 down to 20 ppm – a 55% reduction.

FIGURE 3. *Acoustic three-slot commercial dryer used for pilot trials*

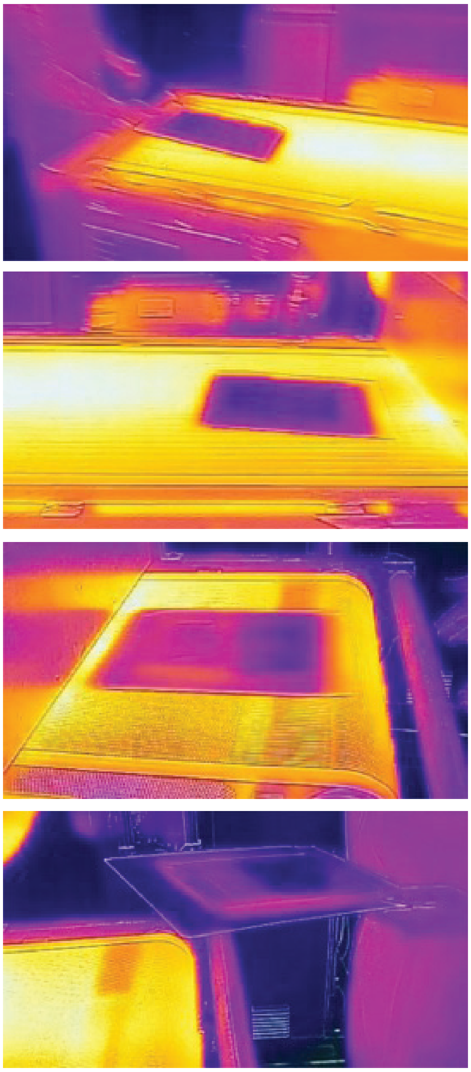

FIGURE 4. *Four thermal images demonstrate acoustic drying of cold-seal adhesive at low temperature. From top to bottom: 1) Coated sample placed on moving conveyor belt at 250 fpm; 2) Sample transported under the acoustic dryer; 3) Sample (still cool) emerging from under the dryer; 4) Inspecting dried coating. Note that based upon the color, the temperature of the dry cold-seal coating is still around or slightly below body temperature.*

Competitive drying systems

There are four main technologies that compete with acoustic drying in various situations. For instance, if the ink used is black or otherwise very dark in color and the substrate is not sensitive to heat, then infrared drying may be the way to go. It will be less expensive than acoustic drying and just as efficient for black inks. If the ink or coating is not black or at least very darkly colored, then most of the energy is wasted trying to IR dry it. For adhesives and colorless coatings, pilot-line tests demonstrate that this firm's acoustic drying is at least five times more efficient than IR in these situations, and does not damage the substrate.

Ultraviolet (UV) curing is another method against which acoustic drying does not really compete because the principles of operation are so different. However, collaboration is possible to employ acoustics to dry waterborne, UV-curable coatings that then can be cured using LED or mercury lamps.

Compressed air drying works well – however, the energy required to run the air compressors is significantly greater, and the maintenance cycle is much shorter than for acoustic drying. Compressed-air systems require daily bleeding of condensation and frequent desiccator-cartridge replacement.

Microwave drying is a comparable technology in terms of capital-equipment cost. However, the expensive microwave emitter has a limited lifespan, leaving acoustic drying as a much better long-term investment in most cases. Some customers also have complained that microwave drying can be difficult to control in terms of overheating the substrate and sometimes may produce uneven heating. ■

Jason Lye, chief technical officer of Heat Technologies, Inc. (Atlanta, GA), holds a Ph.D. in Fiber and Polymer Science from North Carolina State University and a Bachelor of Science in Color Chemistry from the University of Leeds (UK). He has more than 15 years of business development experience. Lye's industrial career includes dir.-External Business Development-Technology Assets for Newell Rubbermaid, Inc., and senior licensing mgr. for Kimberly-Clark Worldwide, Inc. He also held several R&D positions in digital imaging and textile chemistry with Kimberly-Clark, Imperial Chemical Industries, Ltd., and Courtaulds Plc. Lye can be reached at 678-358-4569, email: jlye@heattechnologiesinc.com, www.heattechnologiesinc.com.

References

1. *Converting Quarterly* 2011 Quarter 3, page 63.
2. US Patent 8,167,519 and other patents pending.