Dryer Technology for Flexible Packaging Laminations

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For more than a century, forced air, convection-style drying technology has been widely applied within the flexible packaging industry. Like any mature technology, this method of drying and curing has undergone relatively few dramatic changes over the past couple of decades. Nevertheless, high-efficiency, convection air dryers continue to be an effective and popular choice for a wide variety of coating and laminating processes. Therefore, the focus of this paper will be the application of existing drying methods and tools to process specific solutions, rather than new technology advancements. Topics to be covered include:

- Differences between roll support and flotation dryers
- Web and coating properties that influence dryer design
- Dryer selection
- Dryer features

Roll Support Dryers

A typical roll support dryer would generally support and transport the web on either a dead or live-shaft idler roll system. (See Figure 1.) The only available force for turning the rolls is the friction between web and the roller. By arching the roll path (usually with a wrap angle of 2-5° on each roller) the web can be kept in positive contact with the rolls. Typical roller spacing is between 10” and 24”. For sensitive webs, or to minimize marking or scratching of the bottom side of the substrate, rolls are often tendency driven or direct-driven at or near line speed. Idler rolls are usually fabricated from either steel or aluminum alloy material. The dryer operating temperature and other design factors such as web width, critical roll speed and deflection considerations, determine the materials of construction. For more sensitive applications with wider webs and higher speeds, low inertia, low deflection, carbon-fiber composite rolls will be used. However, they do have a temperature limitation of about 200° F. Regardless of roll design, the bearings should be external to the dryer box for ease of maintenance and the mounting pads adjustable for good roll alignment.

Slot nozzles are usually positioned opposite the coated side of the web. Typically they are located on 5 - 6” centers and about 1.5 – 3” from web. Slot widths are generally not less than about 0.1”. However, they can be 0.25” or wider for applications involving heavy solvent loading that need larger volumes of air for dilution purposes.

Arched roll support dryers have a long, successful track record of drying performance in the flexible packaging industry. And, they continue to be a very effective, low cost solution for a variety of coating and laminating applications. Their inherent design minimizes floor space as the web can enter and exit the bottom of the dryer, which is usually placed directly over the coater. In addition, they are many times better suited to handle webs that are neither flat nor straight.

Air Flotation Dryers

The concept of supporting a web between opposing impingement airstreams has been around for over a hundred years. (See Figure 2.) However, true non-contact air flotation dryers were only introduced in the late 1960’s. By definition, air flotation dryers transport and support the web on a cushion of air, in a sine wave pattern. This is accomplished by placing nozzles, or air bars, both above and below the web, in a staggered configuration. (See Figure 3.) Whereas a typical impingement nozzle found on roll support dryers is generally viewed as a heat...
transfer device only, an air flotation nozzle is used for both heat transfer and web support, with web stability usually being of overriding importance. The principle known as the “Coanda” effect is used to create the positive pressure air cushion. The relationship between nozzle velocity and line tension, along with nozzle geometry, determines the amplitude of the sine wave pattern (i.e. the distance between the web and the surface of the nozzles.) Though some traditional nozzle configurations have slightly higher heat transfer than flotation air bars, they do so at the expense of good web stability.

It is important to note that the air handling components and design thereof, can either positively or negatively impact web handling for either type of dryer. But this is especially true for flotation dryers as there are no rolls to guide the web. The biggest concern for drying is the uniformity of the air and temperature distribution in the CD (cross machine) and MD (machine direction). These are accomplished by good engineering practice for proper airflow and mixing of the heated air. The design of the exhaust and recirculation air stream components is of equal importance for good web handling, especially with lighter webs. (See Figure 4.)

Key Factors That Influence Dryer Design

In an effort to maximize profitability in an ever more competitive market, converters have been forced to address the challenges associated with running faster line speeds, thinner substrates and wider webs. Within the drying section of a typical coating/laminating machine, these challenges include both web handling and drying. Since paper is fairly easy to handle and dry, and foils are generally introduced after the dryer to avoid unnecessary web handling issues, we will focus this part of the discussion on films.

Below are some of the key problems associated with the drying of coatings used in the flexible packaging industry:

- Extensibility
- Baggy edges
- Camber
- Edge curl
- Skinning

Film Characteristics

Extensibility

No converter wants to introduce a nice, flat, uniform web to a dryer and pull out a wrinkled, necked-down string of taffy at the other end. So when dealing with extensible films such as polyethylene and polypropylene, we need to consider a couple of important issues.

First, these films are temperature sensitive. Depending on the film properties, they will begin to relax and/or lose stiffness at temperatures ranging from 140-180°F. Therefore, dryer temperatures must be fairly low, which means longer dryers or lower line speeds. Even though a particular product will run fine at higher temperatures and full line speed (due to evaporative cooling), issues may arise when the line slows down for various reasons and the dryer remains hotter than the web can handle. This will generally cause a web break and the undesirable line shutdown. Therefore, we need to be aware of the film temperature limits during the dryer sizing process.

Secondly, films lose tensile strength as their temperature is raised. This means tension must be kept relatively low to prevent elongation of the substrate when heated. At low tensions, web handling becomes a bigger concern. As alluded to above, problems can be caused by improper air handling design, particularly in flotation dryers. Even in roll support dryers, poor internal air handling design can create web steering issues or web flutter issues, which
result in product defects. It stands to reason that good air handling (both supply and exhaust) is especially critical when operating under low-tension conditions. Considering the importance of tension control when running extensible films, it is recommended that the dryer be a dedicated tension zone, independent of tension requirements in other sections of the machine.

Baggy Edges

When dealing with thin films that have baggy, or loose edges, special care must be taken (particularly in flotation dryers) to insure that edge flutter does not cause the web to come in contact with the nozzles. This condition can result in the coating "picking off" on the nozzles, which in turn can create coating defects and dryer cleaning issues. To some extent, this can be addressed by the proper selection of nozzle type and pitch, as well as with field adjustments to the nozzle spacing. However, due to the method of web support, there are limits to the amount of clearance that can be allowed before losing control of the wave pattern. For roll support dryers, baggy edges are less of a concern unless in the rare instance when the dryer is equipped with bottom-side impingement nozzles, in which case turbulence from edge flutter could potentially lead to defects.

Camber

Web camber is a fairly common manufacturing phenomenon for films produced on tenter-frame systems. (See Figure 5.) Since the web is not straight, it will tend to take its natural curvature over long, unsupported spans. This is less of a concern with short dryers but cannot be ignored as line speeds and dryer lengths increase. This in turn can present a scenario where the web shifts inside the dryer. It can reach a point where the web moves beyond the edge of the rollers and/or nozzles, resulting in coating or web handling related defects. As discussed above, pulling higher tension to mechanically straighten the web may not be possible. Frequently, the only solution is to make the idlers and/or nozzles wider to allow for the shift while maintaining roll contact and/or uniform air cushion contact within the dryer. Naturally, the amount of extra width required will depend upon the extent of the expected camber over the length of the dryer.

Coating Characteristics

Edge Curl

Thick coatings on thin films can present problems. As a coating dries, stresses are created that may cause the substrate to deform (e.g. edge curl on an adhesive coated film). Edge curl can also occur when there are uncoated edges of the web, since these areas do not realize the effects of evaporative cooling. Again, this can generally be addressed via tension control, but only if the dryer is an independently controlled tension zone. In addition, flotation dryers tend to limit edge curl since the web is forced into a sine wave that bends the web in both directions, making the curl more difficult to form. (See Figure 3.) This is the same principle that gives the inner layer of corrugated cardboard its strength. Sometimes the web must be passed over breaking rolls or an “s- wrap” roll section to prevent curl prior to rewinding.

Skinning

Though generally not an issue in flexible packaging, skinning may occur in unique situations. Heavier coatings with solvent-based formulations are usually the cause. This may make it necessary to incorporate a quiet zone or slow drying zone at the beginning of the dryer. This is to prevent skinning, which usually causes blisters or prevents drying to the desired residual level. Quiet zones are typically void of any substantial impingement (heat transfer) on the coated side, though there needs to be enough air movement to keep the solvent concentration at safe levels. Bottom-side heating in such zones is another tool to prevent skinning.

Figure 5: Web Camber
In flotation dryers, bottom side heating is accomplished through the use of air foils. These are designed such that they float a web from one side only. This allows the dryer manufacturer to design of the topside airflow for optimum drying. Air foils use a jet of air that flows along the face of the nozzle in the direction of the web, followed by a wing or air foil. (See Figure 6.) Some air foil designs achieve higher heat transfer by partially impinging on the web with a second jet of air. In either case, the air foil itself creates a negative pressure zone near the end of the wing that pulls the web down into the familiar sine wave pattern. Their primary use is in situations where the drying of a solvent based coating is intentionally minimized to prevent skinning.

**Dryer Selection**

**Coating**

Besides the obvious data like line speed and web width, the actual coating that is going to be applied has the most influence on dryer sizing. The dryer manufacturer needs to know the following:
- Coat weight (wet or dry)
- Solids content (%)
- Diluents (water or solvent)
- Cure requirements (time/temperature)

Coat weight is the mass of coating applied, per unit area of the web. It is imperative that the coat weight be clearly defined as a “wet coat weight” or a “dry coat weight.” The solids content is expressed in percent solids and the diluent will be either water or solvent. If it is solvent, many times it is a blend of several solvents. The amount of each is important as different solvents evaporate at different temperatures and rates. Though beyond the scope of this paper, the above information is also critical to sizing the oxidizer or solvent recovery system that is required to keep the converter in compliance.

Some coatings may also require a certain amount of thermal curing to achieve their intended functional properties. Since thermal curing is a time/temperature-based phenomenon, the dryer may need to be extended to account for this demand. Accurate information regarding the amount of time the coating needs to be subjected to the cure temperature is of major importance as it translates directly to dryer length, given a desired speed.

**Drying Rate**

Once the above information is known, computer models are used to size the dryer. For new or unusual coatings, lab trials may also be required. The type of coating will have a significant influence on the overall dryer length as various coatings can be dried at substantially different rates. (See Figure 7.) In general, primers and varnishes can be dried much quicker than adhesives. To some extent this is due to the relative coat weights of the different coatings, but also influenced by the properties of the coatings. By nature, evaporating the diluent from an adhesive coating will be more difficult than primers or varnishes. However, if all coatings are to be run through the same dryer, the worst-case situation needs to be used for sizing of the dryer.

In general, nozzle type, the distance between the web and the nozzle, nozzle velocity and nozzle temperature determine the heat transfer rate of convection air dryers. The cost of making the nozzle position adjustable is usually cost prohibitive. However, varying the nozzle velocity is easily accomplished with dampers or variable frequency drives. Likewise, the temperature is regulated with a burner actuator for gas-fired systems or a control valve for steam and thermal oil systems. Both velocity and temperature control are incorporated in most of today’s dryers.
Dryer Length/Configuration

Dryer length is directly related to line speed: as speeds increase, so will the dryer length. Though most of the coatings used in flexible packaging are fairly easy to dry, today’s higher line speeds (in excess of 1500 FPM) warrant longer dryers. Because of height and access issues, the maximum effective length of an inverted “U-shaped” dryer, as shown in Figures 1 and 2, is about 20-25 feet. Should the required dryer length be more than that, serious consideration needs to be given to a “flat” horizontal idler roll dryer or a horizontal floater dryer. Another option is to look at multiple zones to shorten the effective dryer length. Unfortunately, this can increase the cost substantially. But since longer dryers can cause issues with the machine layout, it may be a reasonable alternative.

Dryer Features

Heat Sources

All convection air dryers require a source of heat energy. One of the most notable advancements in this area is not so much technology-based as it is an industry wide focus on energy conservation and cost reduction through the use of existing heat recovery technologies. Though direct gas-fired systems are still the most common, there is a trend toward steam and thermal oil heated systems and even a limited use of air-to-air heat exchangers. (See Figure 8.) This is especially true when there is energy available from an oxidizer or some other source. As energy costs continue to rise, there will be even more interest in maximizing energy recovery.

Retraction

Regardless if the dryer is roll support or flotation, inverted U-shape (see Figures 1 and 2) or flat, (see Figure 4) access is required for threading, cleaning and maintenance. Many older dryers relied mainly on doors for entry into the dryer. Many newer dryers provide better access by incorporating some sort of split box that is mechanically opened. This could be of a pivoting design referred to as “clamshell” or it could be a parallel or planar style as illustrated in Figure 8. Actuation could be by pneumatic cylinders or mechanical screwjacks. In most cases, the improved access easily justifies the incremental cost.

Control Systems

As with other industries, many of the latest advancements in convection drying technology have taken place in the area of control systems, in particular, in the field of solid-state electronics. Whereas older drying systems utilized a basic relay logic based control scheme with single function temperature controllers and manually adjusted damper systems, this is not the case today. Most modern machines are equipped with a variety of sophisticated PLC and/or PC based systems that are capable of controlling virtually every dryer function. Some of these capabilities include

- Automated dampers and fan drives
- Closed-loop process control
- Data logging of process parameters
- Recipe control for different products
- Trouble shooting via modem
Service and maintenance diagnostics

Cleanliness

In markets where cleanliness of the end product is critical, the dyers need to be designed accordingly. Generally this would include some degree of HEPA (High Efficiency Particulate Air) filtration of the air that imparts on the web as well as Stainless Steel internals. In addition, to minimize the collection of dirt and to make cleaning easier the following features should be considered:

- Continuous seam welded construction
- Ground smooth internal welds
- Removable nozzles
- Non-fibrous gaskets
- Plasma coating or nickel plating
- Minimized use of fasteners

All of these will increase the cost significantly but may be necessary to qualify products in certain markets.

Summary

Whether your dryer will be a roll support or flotation design and the extent of features to be included will depend upon the unique requirements of the application. One thing is for sure. A “one-size-fits-all” philosophy simply won’t work. Rather, today’s converter must take extra care to fully and accurately communicate the range of properties of the products they are seeking to produce and the dryer features they feel are necessary. A flotation dryer is usually the best choice and can almost always be custom designed to run a wide variety of products. However, in most instances, more attention is paid to operating the extruder and less to operating the coater/dryer. Therefore, roll support dryers may be preferred as they are generally less operator intensive, even though they are less efficient and require more scheduled maintenance. In any case, the better the dryer manufacturer understands the customer’s needs, the better they can customize the complete dryer design to meet those needs.
For the flexible packaging industry, forced air convection drying is more about…

- the application of existing drying methods and tools to process specific solutions

than it is…

- new technology advancements

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**Introduction**

- Roll Support vs. Flotation
- Web and Coating Problems
- Dryer Selection
- Dryer Features
Evolution of Convection Drying

- Natural convection
- Hot air convection ovens
- Forced air convection
- Web support methods
  - Drag bars
  - Idler rolls
  - Sine Wave Flotation

Roll Support Dryer

Nozzles

Roll Support Dryer Features

- Idler rolls
  - Live shaft or Dead shaft
  - 10’ – 24’ centers
  - 2 - 5° wrap angle
  - External bearings

- Impingement slots
  - 0.1” – 0.25” slot width
  - 1½ – 3” from the web
  - Coated side only
Idler Roll Options

- Driven
  - Tendency drive
  - Direct drive
- Lightweight
  - Low inertia
  - Carbon-fiber composite
- External bearings
  - Temperature
  - Ease of maintenance

Flotation Dryer

Air Bars

Flotation Dryer Features

- Nozzles (air bars)
  - Opposing pressure pad nozzles
  - Non-contact
  - 10 – 20” centers
  - ¼ - ½” from the web
- Idler rolls
  - Change of web direction only
Definitions

- Supply
- Nozzle Velocity
- Return
- Exhaust
- Recirculation
- Make-up Air
- Heat source

Common Drying Challenges

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Extensible Webs

Problems
- Temperature limits (140° - 180° F)
- Loss of tensile strength
- Web handling (low tension)

Solutions
- Longer dryers
- Reduce tension
- Uniform supply and exhaust air distribution
- Dryer must be discreet tension zone
Good Air Handling Design

Cross-machine exhaust duct

Adequate Exhaust Area

Tapered supply ducts

Camber

Problem  Solutions

- Web shift  ➢ Higher tension (if possible)
-  ➢ Wider rolls and nozzles

Baggy Edges

Problem  Solutions

- Edge flutter  ➢ Adjust sine wave
-  ➢ Adjust air velocity
-  ➢ Arched roll support?
**Edge Curl**

**Problem**
- Drying stresses

**Solutions**
- Higher tension
- Flotation

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**Tension/Velocity Relationship**

- Normal Sine Wave
  - Good Web Handling

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**Tension/Velocity Relationship**

- “Flat” Sine Wave
  - High Tension
  - Low Velocity
  - Poor Web Handling
Tension/Velocity Relationship

- “Large” Sine Wave
  - Low Tension
  - High Velocity
  - Poor Web Handling

Skinning

**Problem**
- Skinning of coating

**Solutions**
- Lower the evaporation rate
- Airfoils in flotation dryers

Single-Side Flotation

- Non-contact
- Reduced Heat Transfer
**Scratching**

**Problems**
- Rollers not turning
- Contact with nozzles

**Solutions**
- Flotation
- Tension/Velocity

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**Dryer Sizing**

- Coating
  - Coat Weight (wet or dry)
  - % solids
  - Water or solvent
  - Cure
- Computer modeling
- Lab Trials

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**Drying Rate**

 ![Drying Rate Graph]

- Evap. Rate vs. Dryer Position
- Primer and Adhesive curves
Heat Sources
- Gas fired
- Steam
- Thermal Oil
- Electric
- Air-to-air HX

Retraction
- Clamshell
- Planar
- Pneumatic
- Screwjacks

Basic Control System
- Relay logic
- Discrete temperature controllers
- Manual dampers
- Fixed speed fans
- Pressure gages
### Advanced Control System

- PLC based
- Pressure transmitters
- RTD temperature elements
- Automated dampers
- Variable Speed Fans
- Graphic Operator Screens
- Web temperature control
- LEL Control
- Data logging
- Modem connection

### Cleanliness

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### Summary

- Accurate process information
  - Dryer Type
  - Dryer Length
  - Configuration
  - Desired features
Summary

- Accurate process information
  - Dryer Type
  - Dryer Length
  - Configuration
  - Desired features

Thank You

Presented by
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Please remember to turn in your evaluation sheet...