IS YOUR DRYER OPTIMIZED TO GET YOUR DESIRED PRODUCT?
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Introduction:
Drying pressure sensitive adhesive is a complex phenomenon which has been studied extensively and in increasing depth in recent years.\textsuperscript{1,2} However, translating this increasing understanding to pragmatic information usable by the practitioners of commercial drying has been limited. While advances in the theory and design of dryers and instrumentation can result in improved processing economics, most coating companies have not acted on them, usually due to reluctance to invest more money in an existing, apparently satisfactory process. It is the purpose of this paper to select a single aspect of this improved understanding which, with minimal equipment costs, can improve coater operating economics.

There are three major components to the cost of operating a coating/drying system:
1. The costs of running the system. This includes fixed costs such as capitalization of equipment, labor, and overhead; and variable costs such as the cost of process heating.
2. Process scrap: The cost of materials that go into the coating process but do not result in product. All coating processes generate process scrap, particularly in the setup stage.
3. Product scrap: Material that ran through the process that should have resulted in product but were found on inspection or (worse) further down the value-added chain to fail to conform to a critical characteristic. While these can be manifold, common to most PSA coating processes are in incorrect coat weight, high retained volatiles or incorrect release performance. Since such occurrences involve more than the coating operation their impact can be far beyond, including loss of customer confidence and business.

Reducing fixed costs of a coating operation by increased throughput-speed is of course a worthwhile goal. However, for much of the coating market actual running time operating costs are overshadowed by change over time and start up scrap. This can get particularly expensive when dealing with specialized or value added materials. Wasting a few thousand feet of EDP materials might be an acceptable start up cost; wasting as much foil or hologram embossed polyester and 90# polykraft liner is probably not. Process control techniques that can reduce such loss should therefore be of interest to such coaters. The proposal of this paper is that an understanding of coating temperature profiles can allow reductions in such expensive and unnecessary scrap.

The discussion below presumes an air impingement dryer operating at constant temperature and air velocity. This is unrealistically simple but the underlying principles are the same for multiple zone and varied process conditions.
The web temperature profile in an impingement dryer fall into four regions which are dictated by the changing mechanisms of drying (or more accurately by the limiting factor).

1. **Initial heat up**: The sensible heat needed to warm the web from ambient to the initial zone temperature. Given the limited heat capacity of typical roll materials, this is typically of short duration.

2. **Constant temperature/Evaporative drying**: The effect of evaporative cooling on the web temperature. Web temperature might begin to ramp up slowly early in this region but will be well below zone temperature. This is the most rapid drying region.

3. **Increasing temperature**: Evaporative cooling effects are dropping off as diffusion through the drying mass of coating becomes the rate limiting factor.

4. **Plateau temperature**: Diffusion drying, potentially to fully dried. “Fully dried” is more a market concept than a physical reality; for most uses >1% solvent or 2-3% water is fully dried.

Varying market needs gives rise to a wide range of operating parameters. A stock label line may have a very short constant temperature region (due to high solids, low applied coat weight and aggressive drying). Likewise the plateau region might be minimized for highest through put speed, since drying out the last few percent of moisture might not be economically feasible or necessary. In a different market world an engineered tape could have a lengthy constant temperature region for the opposite reasons (low solids, heavy applied coat weight, carefully controlled drying) and a greatly extended plateau region for ultra-low volatiles or a high degree of thermal cure.

**TEMPERATURE PROFILING:**
The state and degree of retained volatiles of a coating in a drying process can be monitored by the web temperature through the dryer using infrared sensors. Given:

- a dryer operating at steady state
- a coating with constant solids and volatile composition

A sensor in the constant temperature region will see about the same temperature from the end of initial warm up until the beginning of the diffusion limited range. Likewise a sensor in the final plateau region is approximately at zone temperature from the end of the increasing temperature region until exiting the dryer. Thus a temperature in these regions does not define a reproducible process point.
A sensor in the increasing temperature region however, has the potential to be a unique process point, both for coating temperature and solids. If data has been collected for these conditions in previous coating runs, a change in temperature at a given location within the increasing temperature range can therefore indicate a change in process condition. Two advantages of using this information are apparent.

Change over can be done more quickly, likely with less set up scrap.

As an example take a waterborne coating line changing adhesives (and coat weight), film and release liner. There is a “recipe” of process conditions but the final product needs to be verified for adhesive coat weight and retained moisture content. The traditional approach would be to run a sample amount, stop, and verify coat weight and moisture content by lab methods. However, from previously recorded temperature profiles, it is expected that the temperature at the sensor should be 170°F. If this temperature is now achieved at the sensor it can be taken that the correct operating parameters are also achieved. Moisture content and coat weight can be preliminarily verified by a single known temperature. Moisture content and coat weight can be lab verified offline*, without interrupting production or generating unnecessary scrap.

Critical parameters can be monitored real time.

Continuing from the example above: An unintentional change in adhesive coating results in an increase in coat weight. The transition from constant temperature to increasing temperature is delayed, the increasing temperature region is more gradual. The coating temperature under the sensor is now 135°F.

* In-line coat weight and moisture content systems are of course available but we’ll leave them to somebody else’s paper.
Thus a web temperature sensor positioned in this region can be an in-line warning of a process shift. Other aspects of how improved process reliability are potentially as varied as the market areas served by the coating industry.

SUMMARY:
Using infrared sensors to establish known coating temperature profiles in conjunction with product recipes can improve process reliability, reduce set up scrap, and improve product performance. Such sensors are inexpensive and easily integrated into existing coater systems. As noted above, more fundamental improvements in dryer system efficiency are available. In this climate of rapidly increasing material and energy costs, all coaters are encouraged to review their systems for potential improvements.

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