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Common Issues in High Speed Silicone Coating and What to do About Them

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Introduction

Silicone coating using a roll coater suffers from several process implementation issues, even at low speeds. As coating speed increases, the severity of these issues also increases. We will focus here on the following common silicone coating problems:

1. Functional defects (pinholes) caused by less than 100% silicone coverage.
2. Winding defects (telescoping, starring) caused by variations in coating uniformity in the cross-direction and machine-direction.
3. Machine and process upset caused by thin layer polymerization.
4. Personnel and machine exposure to harmful silicone dust caused by misting.

Recent initiatives in sustainability and on-going concerns for increased profitability are driving producers of silicone coated webs to increase their production speeds and increase raw material yields. We have found that the following key coating machine improvements can dramatically improve coating performance, sustainability, raw material yield and profitability:

1. Deflection compensated coating rollers provide thinner coating layers better uniformity.
2. Dust removal improves coating coverage, reducing coating defects.
3. Temperature control of coating rolls provides less risk of thin layer polymerization.
4. Limiting the number of film splits reduces the amount of misting at the source.
5. A mist collection system provides an ergonomically-designed method to capture mist before operators and machinery are exposed to it.

Overall Background

What is high speed?

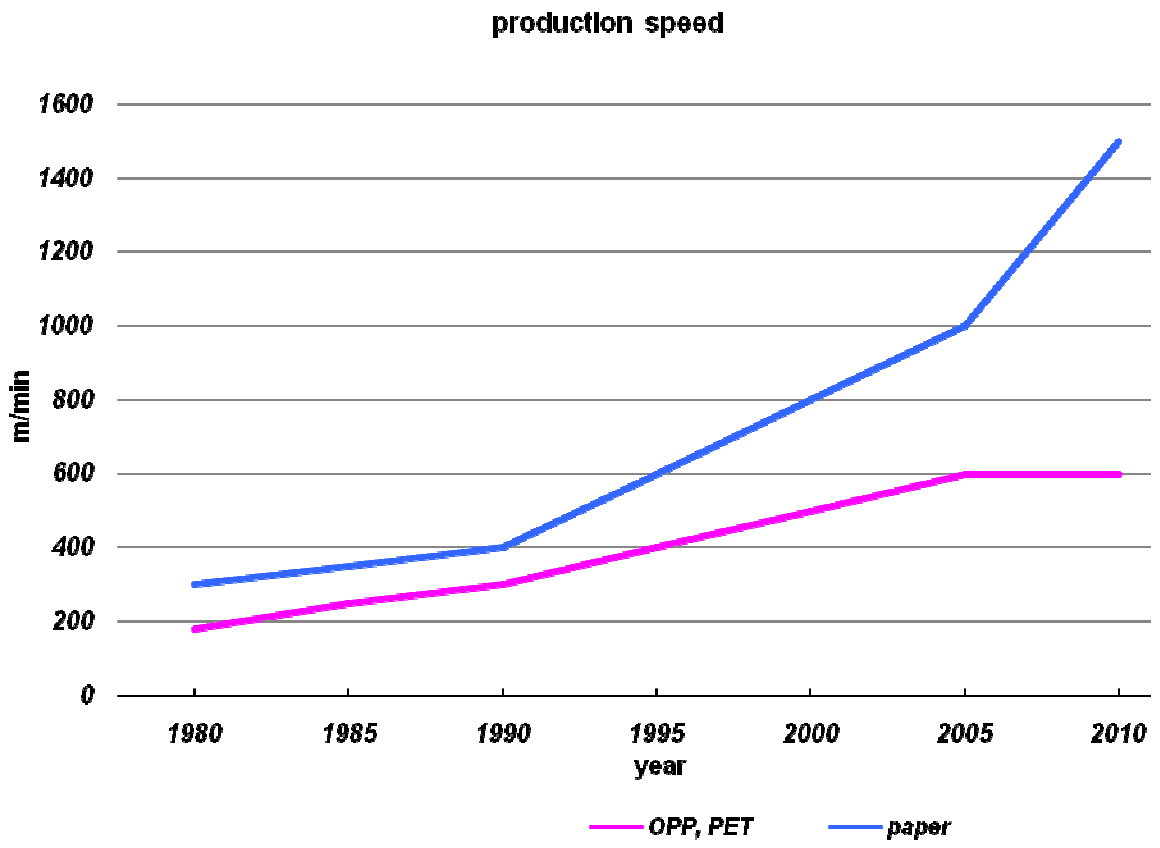
For the purposes of this paper, we will consider high speed to be line speeds above 600 m/min (2000 ft/min) to 1200 m/min (4000 ft/min).

What coating methods were examined?

Multi-roll coaters were examined. Two different varieties of 5-roll coating and one version of 6-roll coating were compared.

Why is high speed roll coating important?

We have seen tremendous increase in interest in high speed coating, especially on paper substrates. See graph below.

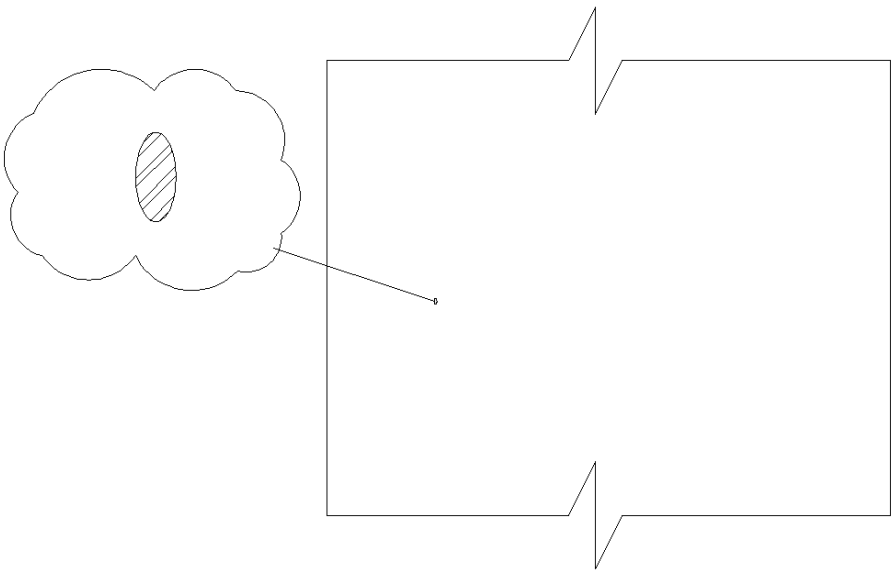


Coating Coverage and Uniformity

Pinhole defects occur when silicone coating coverage is not 100%. This can result from either too little coating applied, or from dust particles on the web or coating rolls.

Silicone coating seems to have a certain self-healing property, by which small coating drop-outs seen on the coating rollers don't appear as pinholes on the coated web. However, as coating layer thicknesses decrease, and line speeds increase, there is an increased tendency for drop-outs. Drop-outs represent a serious product failure as there is no release of the adhesive layer in the final laminated product.

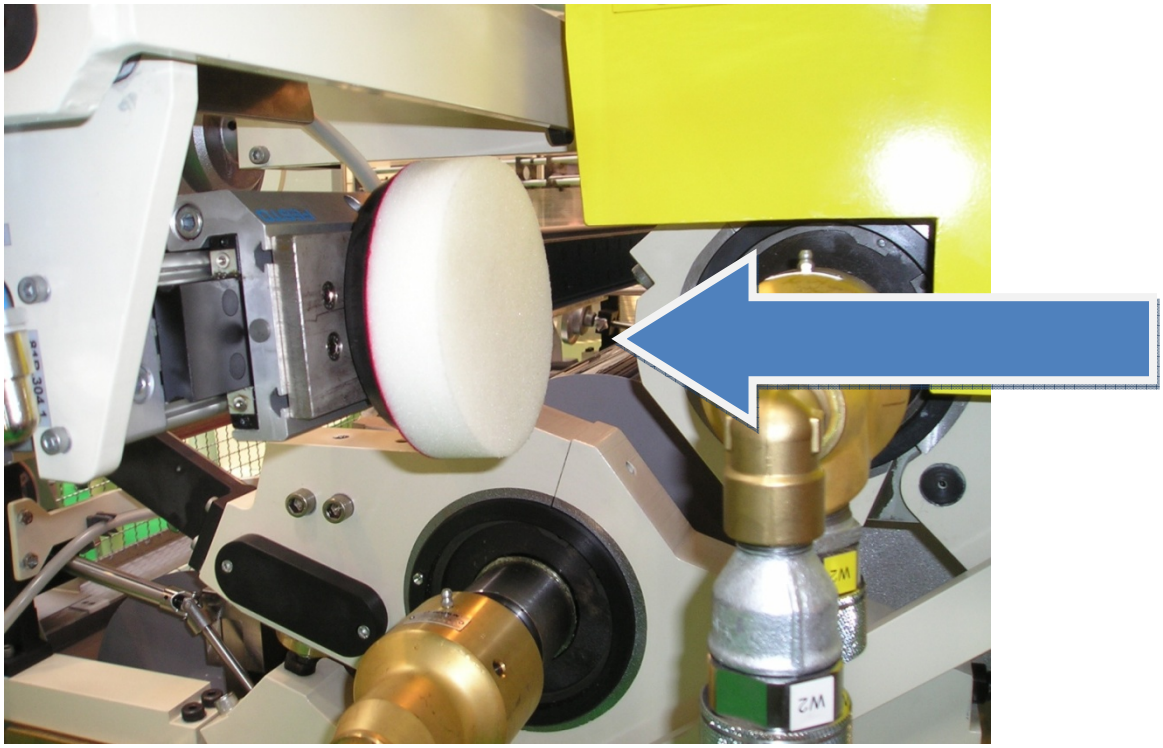
The picture below represents a coated web with a small area of coating drop-out. The hatched ellipse indicates where the paper substrate shows through since there is no silicone coating there.



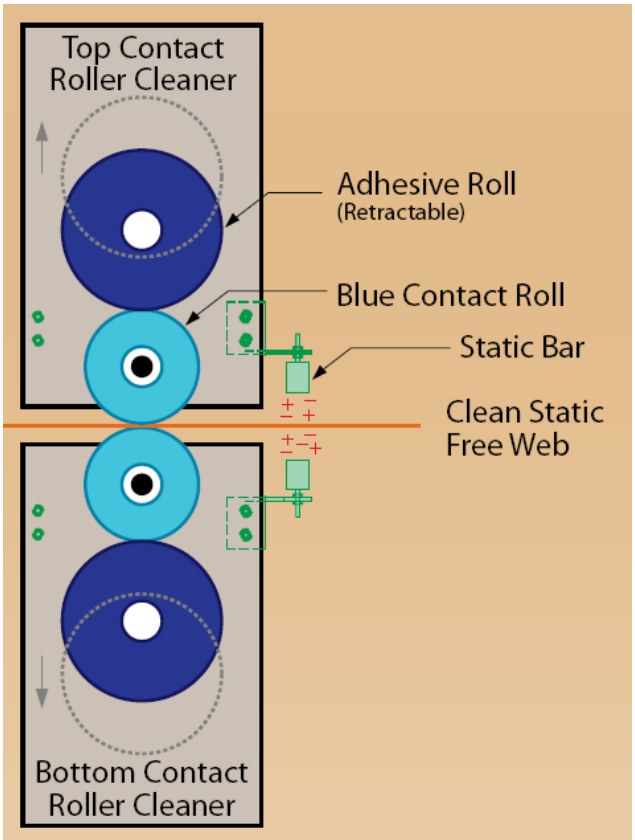
The easy fix is to increase the total amount of silicone put down to try to take advantage of the self-healing. However, this solution is not optimum since it results in lower raw material yields and higher costs.

Dust Removal

Dust removal on the coating roll can be accomplished by an oscillating cleaning head as shown in the picture below. This provides the necessary cleaning while keeping operators' hands away from the running machinery.



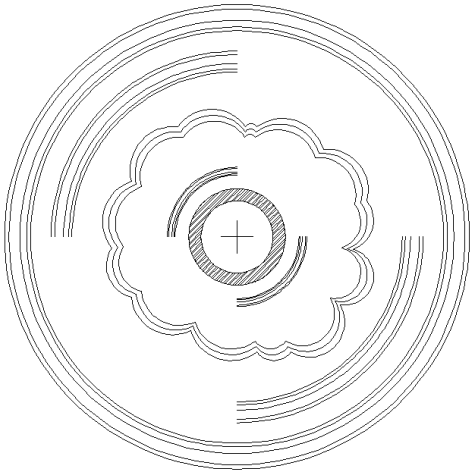
Dust can be removed from the web by installing a commercially available web cleaner like the one shown below.



Winding Defects

Winding defects such as dishing and starring occur when the profile of the web being wound is not flat. When the coating is thicker on one side of the web, it exerts a force on the winding layers, tending to push the web to the thinner side, and dishing results, as depicted below.

When the coating shows thickness variations in the machine direction, it interferes with tension control during winding, and may result in starring. In the diagram below, looking at the end of a wound roll, starring is shown as the poorly wound layers in the middle of the roll.



Coating Nip Uniformity

In a roll coater, the coating is applied to the web in a dynamic nip. There are not really definitive theoretical algorithms to predict fluid behavior under these conditions.

However, focusing on one aspect of coating uniformity, the uniformity of the gap between the coating rolls plays an important part.

In a typical roll coater, the nip gap is non-uniform due to uneven distribution of nip pressure, mostly caused by the fact that the nip loading force is applied just at the ends of the roll.

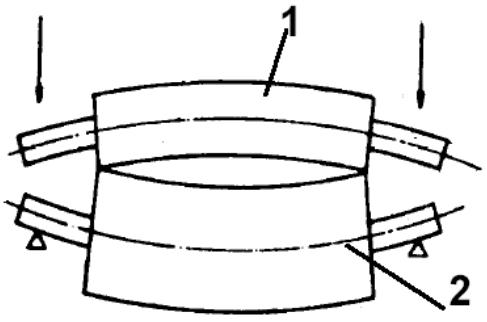


fig.1

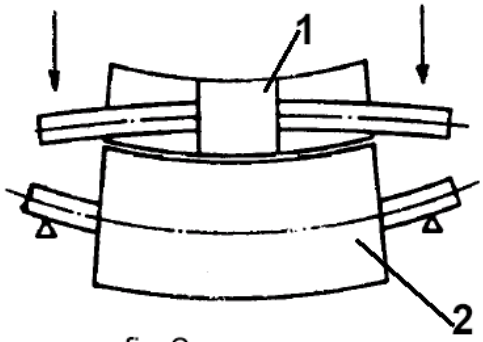


fig.2

In our recommended (patented) design, the nip roll has deflection compensation built-in. This results in the nip loading forces being applied more in the center of the roll, producing a very uniform nip gap and therefore more uniform coating coverage.

A comparison of coating coverage, low coat weight and uniformity achieved with this method compared to other methods is show in the following chart.

	5 Roll Coater with Deflection Compensation	5 Roll Coater without	6 Roll Coater without
Coat Weight Tolerance	±0.02 g/m2	±0.05 g/m2	±0.03 g/m2
Low Coat Weight Achievable	0.1 – 3.0 g/m2	0.5 – 3.0 g/m2	0.3- 2.0 g/m2

Thin layer polymerization

Thin layer polymerization in this paper refers to the curing of silicone coating on the coating rollers.

Most silicone formulations are reactive and thus have a finite pot life. Commonly, inhibitors are added to the formulations to extend the pot life. During normal process conditions, the inhibitors are evaporated from the coating layer during the first stages of drying, allowing polymerization to occur as desired further along the drying process.

However, the coating formulation is susceptible to early inhibitor evaporation on the coating rollers.

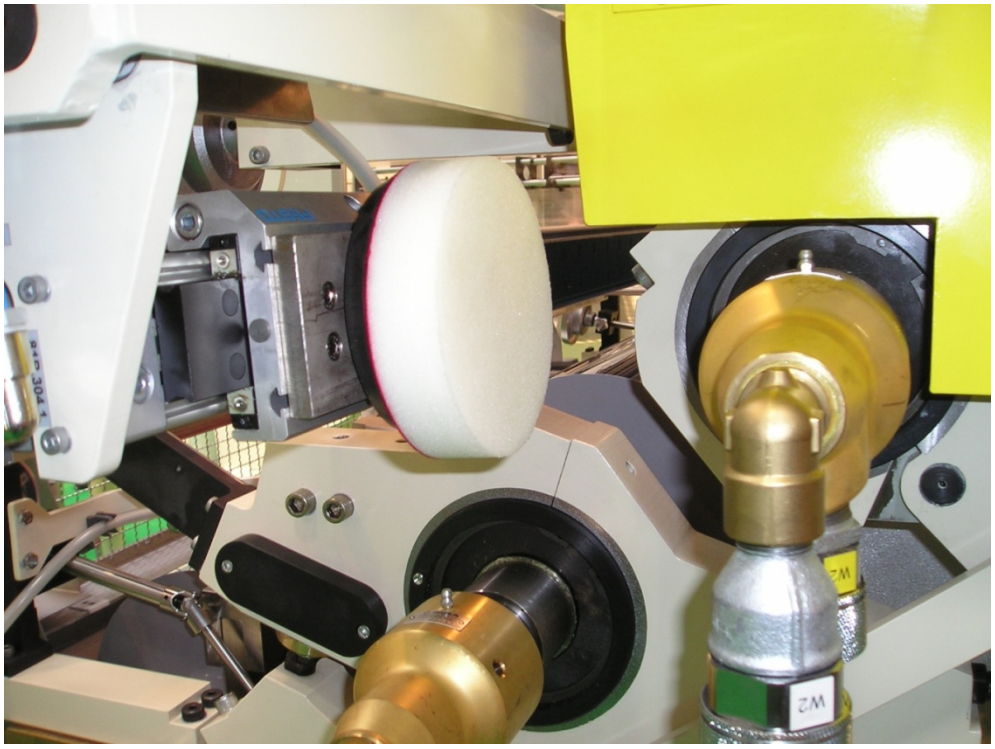
In the roll-coating process, each coating nip is an impression nip between a rubber and a steel roll. The footprint of the rubber roll represents a deformation of the rubber, continuously moving along the circumference of the rubber roll as it rotates. This deformation causes heat to build up in the rubber due to the friction in the molecules rubbing against each other.

Especially at high speeds, there is considerable heat generated – enough, in fact, to evaporate the inhibitors under the right conditions. Typically, at line stop, there is enough heat build-up, and too little silicone flow, so that the inhibitor evaporates off and the silicone undergoes polymerization, forming a layer on the coating roll that interferes with the coating process, and is very difficult to remove. In fact,

the best way to remove that layer would be to scrape it off mechanically. But, on a rubber roll this is difficult to do without damaging the rubber.

We recommend good temperature control of each of the coating rollers to keep them cool enough to eliminate the evaporation of the inhibitor at line speeds, and a quick cleaning of the rolls during a line stop event.

In the diagram below, you can see an example of the cleaning wiper that we saw earlier.



Misting Control

Silicone particles can become airborne in a roll coater due to the film splitting that occurs at each nip. Particles are literally torn out of the coating fluid and flung into the air.

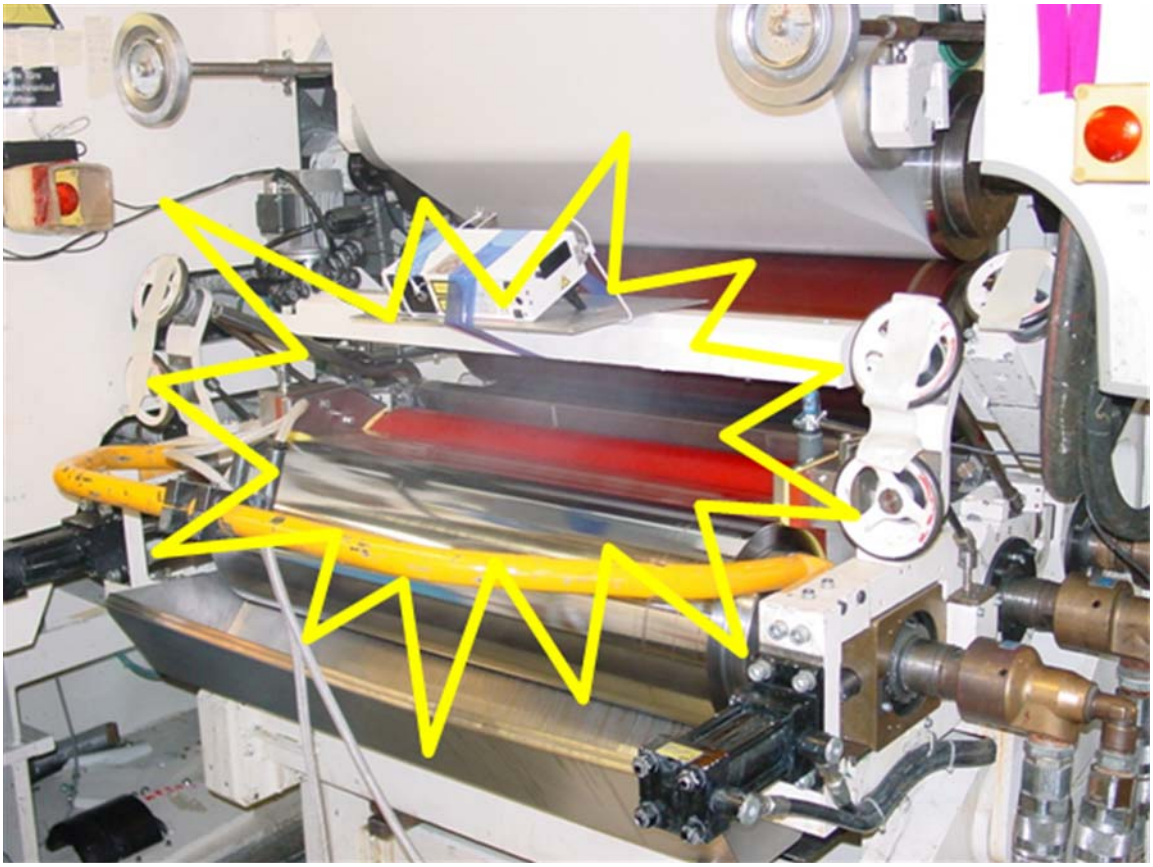
Silicone particles present a health hazard to people who might breathe them into their lungs. They also have a deleterious effect on nearby machinery. These particles are small, lightweight and very slippery. It is common for the floor around the coater to become very slippery with the risk of operator falling.

Silicone is difficult to clean from floors and machinery surfaces.

A common problem is that these particles are drawn in to fan-cooled motors, damaging the motor rotors. At a minimum, the clean-up of machinery surfaces near the coater is a maintenance headache and increases overhead costs.

Also, when silicone mist enters the dryer and becomes heated, it can form a very fine silicone-dioxide powder, requiring clean-up inside the dryer and ductwork.

At low coating speeds, below 300 m/min, misting is generally not present. As speeds pass 300 m/min, though, misting appears and it seems to increase exponentially with speed.



We recommend three methods to reduce the impact of misting.

1. Buy a silicone formulation with an anti-misting additive.
2. Keep the number of film splits as low as possible.
3. Capture silicone mist at the source before it contaminates breathable air and infiltrates machinery.
4. Design the dryer to be easy to clean.

Anti-misting additive

These work well, though not perfectly, and add to the raw material cost.

Film Splits

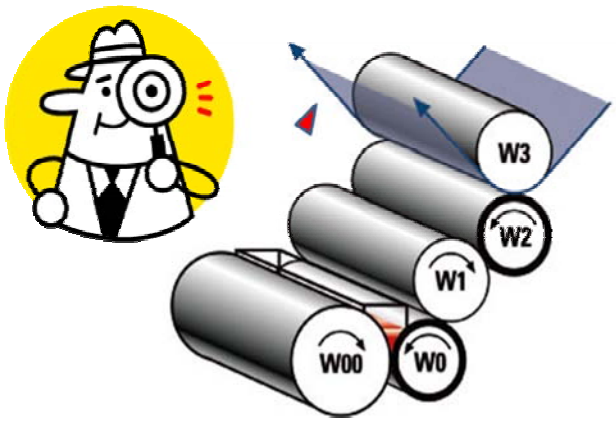
There is a built-in trade-off related to reducing the number of film splits. These splits are necessary to produce the thin coating layer that we are trying to achieve to minimize raw material costs.

We have studied multi-roll coaters and recommend a five-roll coater instead of a six-roll coater for the application of silicone.

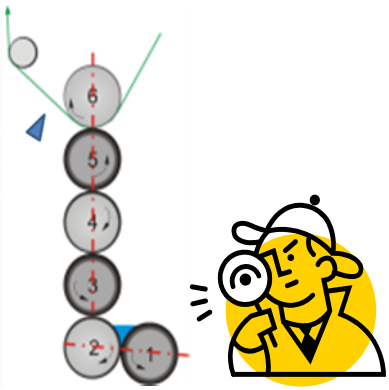
Advantages of Five Roll Coater

Compared to the six-roll coater, the five-roll coater has the following advantages:

1. One less roll, therefore one less nip, therefore one less film split, therefore less misting.
2. Lower initial investment due to one less roll and one less drive.
3. Lower energy cost due to one less drive.
4. Lower maintenance cost.
5. More ergonomic geometry because the web with the applied coating is visible from the tending side of the coater where the coating pond is.



Good view of coating applied



Poor view of coating applied

Although we have not quantified silicone misting in either method, the observation is that less misting occurs in the five roll coater than in coaters with more rolls.

Mist collection

It is common for older coating machines to lack an ergonomic mist collection system. Retrofits of mist collection systems to older machines are possible, but are often done in a way that interferes with the ergonomic operation of the machine.

Our system, seen in this picture, is effective at capturing mist without getting in the operator's way. During production, the system is engaged to the coating process. It can be retracted when necessary for operator convenience or maintenance during non-production periods.

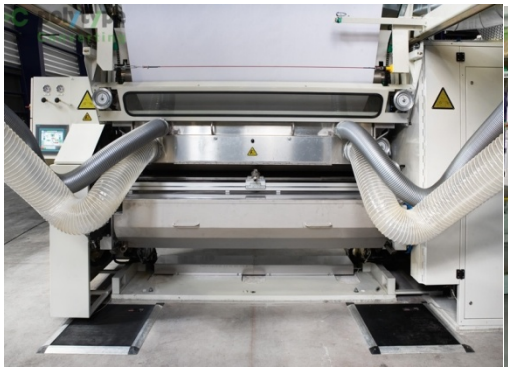


Figure 1: Active Position

Figure 2: Retracted Position

Important design details are to have an air knife to scrape off the boundary layer of mist at the point where the coated web exits the collection hood.

Conclusions

- ✓ High speed silicone coating requires special machine features for success
- ✓ Deflection compensation rollers improve coat weight uniformity, especially at low coat weights
- ✓ Temperature control of coating rollers and mechanical wipe reduce effects of thin layer polymerization
- ✓ Fewer nips produce less misting
- ✓ Misting not eliminated can be captured

Further Work

1) Today's results are qualitative, not quantitative
2) More research needed to measure effectiveness of methods used

Other coating methods, such as curtain coating, offer ways to avoid or reduce the problems described above, but that is the subject for another paper!