METHODS FOR CLOSED LOOP COATING THICKNESS CONTROL

By Bob Pasquale

OVERVIEW:

In this presentation we will address various methods that can be used to integrate a coater with a measurement system for automatic closed loop coating thickness and profile control. We will discuss how these systems can be applied to various coating methods including kiss, two roll (between the roll), offset gravure, knife, slot die, spray and reverse roll.

INTRODUCTION:

There are many methods currently available for online measurement of coating thickness/profile. These methods include the use of beta gauges, gamma gauges, IR, X-ray devices and ultrasonic sensors.

One of the main uses of these gauging systems is to measure the total amount of coating being applied to the web. This can be accomplished by either measuring the coating application at a fixed spot on the web (typically in the center) or by measuring the coating using a traversing sensor and then averaging the cross web results.

Another main use of gauging systems is to measure the coating profile across the web. This is accomplished by the use of a scanning sensor which traverses the web, measuring the coating laydown as it travels across the web to establish a profile of the coating.

A major benefit of gathering the coating thickness and profile information is to be able to use it control the coating applicator in order to obtain a targeted total laydown and profile. This closed loop control can be done in several ways, with the coating application method often dictating which way is most desirable.

In this paper we will review many of the methods that can be used to control the overall coating thickness/laydown as well as coating profile. We will focus on several different coating methods and how they can be automatically controlled to achieve the desired coating laydowns and profiles.

METHODS TO CONTROL COATING THICKNESS/LAYDOWN:

As indicated above, the gathered coating thickness information can be used to control the coating application method, automatically adjusting the coating system to reach a desired target application rate. For purposes of this presentation we are assuming that the type of coater being used has already been selected based on the respective coating process requirements.

The automatic adjustments can be implemented in one of several ways, with the type of coater dictating which adjustment method is applied. The adjustment systems can be broken down into several categories including:

- adjusting the speed of the coating application roll(s)
- adjusting the speed of the coating delivery pump
- adjusting the speed of the web processing line
- adjusting the coating gap
- adjusting a combination of the above

We will look at each of these methods, discussing how they are used to control the application rate, what types of coaters they are used with and how the thickness measurement system can be interfaced with them.

Adjusting the Speed of the Coating Application Roll(s)

There are several coating methods where the coating is applied to the web using an applicator roll. These methods can take one of two forms, either with all the coating being wiped onto the web by an applicator roll running in the opposite direction of the web or with the coating being split between the web and the applicator roll with the roll running in the same direction as the web. In both methods, adjusting the speed of the applicator roll directly affects the amount of coating that is applied to the web. Therefore, in these methods the information from the thickness measuring system is used to either speed up or slow down the coating roll in order to affect the coating transfer to the web.

Examples of these coating methods include kiss coating (Photo 1) and offset gravure coating (Photo 2).

Photo 1 – Kiss Coater

Photo 2 – Offset Gravure Coater

The ease with which today's drive and control systems can accurately control a motor's speed makes this method of adjusting the coating rate highly effective. Assuming that the applicator roll is already being driven by a typical state of the art variable speed drive with associated motor, motor speed feedback device and PLC, then the ability to control the motor's and therefore the applicator roll's speed on a finite basis is obtainable. Therefore, making small adjustments to the coating laydown rate can easily be implemented.

Assuming the drive and control system has the ability to communicate with the coating thickness measuring system, then the only modifications required to allow for the closed loop control of the application rate lie in changes to the control system's programming. No additional hardware is required.

Adjusting the Speed of the Coating Delivery Pump

Certain coating methods apply a pre-metered amount of coating to the web. In these methods the amount of coating is determined by the pre-metering device such as a coating delivery pump. In these cases the information from the thickness measuring system is used to speed up or slow down the pump to in order to affect the amount of coating delivered to the web.

Typical examples of this type of coater are slot die coaters (Photo 3) and spray coaters (Photo 4).

Photo 3 – Slot Die Coater

Photo 4 – Spray Coater

Similar to the discussions above for the previous described coating methods, assuming the pump is already being driven by a typical state of the art variable speed drive with associated motor, motor speed feedback device and PLC, then the ability to control the motor's and therefore the pump's speed on a finite basis is obtainable. Therefore, making small adjustments to the coating laydown rate can easily be implemented.

As before, assuming the drive and control system has the ability to communicate with the coating thickness measuring system, then the only modifications required to allow for the closed loop control of the application rate lie in changes to the control system's programming. Once again no additional hardware is required.

Adjusting the Speed of the Web Processing Line

Unlike the above example, there are certain cases in which a pre-metered amount of coating is delivered to the web but it is not practical to change the rate at which the coating is being delivered to the process. This particularly applies to processes where the mixing or production of the coating is critical. In these cases instead of adjusting the delivery system the information from the thickness measuring system is used to speed up or slow down the web speed in order to affect the amount of coating delivered to it.

A typical example of this is extrusion coating.

Again, assuming the web line has state of the art variable speed drives with associated motors, motor speed feedback devices and PLCs, then the ability to accurately control the speed of the web on a finite basis is obtainable.

Once again, assuming the drive and control system has the ability to communicate with the coating thickness measuring system, then the only modifications required to allow for the closed loop control of the application rate lie in changes to the control system's programming. Once again no additional hardware is required.

Adjusting the Coating Gap

There are several coating methods that exist that rely on a gap to control/meter the amount of coating applied to the substrate. This gap can take several forms including between two precision rolls or a precision roll and another metering device such as a knife blade. In certain cases the gap between the two members is used to pre-meter the coating prior to it being introduced to the web while in other cases the coating is introduced to the web at the gap, resulting in the total thickness of the coating plus the web being metered. In these types of coaters, adjusting the gap between the rolls or roll and knife changes the amount of coating that is applied. Therefore, in a closed loop system the information from the thickness measuring system is used to open or close the gap in order to affect the amount of coating delivered to the web.

Examples of this type of coater are knife over roll (Photo 5) and between the roll coaters (Photo 6).

Photo 5 – Knife Coater

Photo 6 – Between the Roll Coater

It is typical in these types of coaters to have adjustable devices that allows the gap between the rolls or roll and blade to be varied. Often is the case that these devices are located on each side of the machine, typically between the bearing housings for the rolls or knife blade assembly. It is also typical that one of the rolls or the knife assembly is interconnected with cylinders that hold it against the adjusting devices. These adjusting devices can take one of several forms including a taper wedge or a screw system with adjustments between the rolls or roll and knife blade being achieved by moving the wedge in or out or turning the screw to extend or retract it.

The information from the coating thickness measuring system can be used for closed loop control of these gap adjustment devices. This is typically accomplished by interfacing positon controlled motors with the adjusting devices as well as using electronic readout hardware such as LVDTs, lasers or linear potentiometers to measure the gap. The information from the thickness measuring system is fed to the control system which in turn adjusts the positioning motors so the gap can be increased or decreased, with the electronic gap readout being used to either control or confirm the amount of movement (Photo 7).

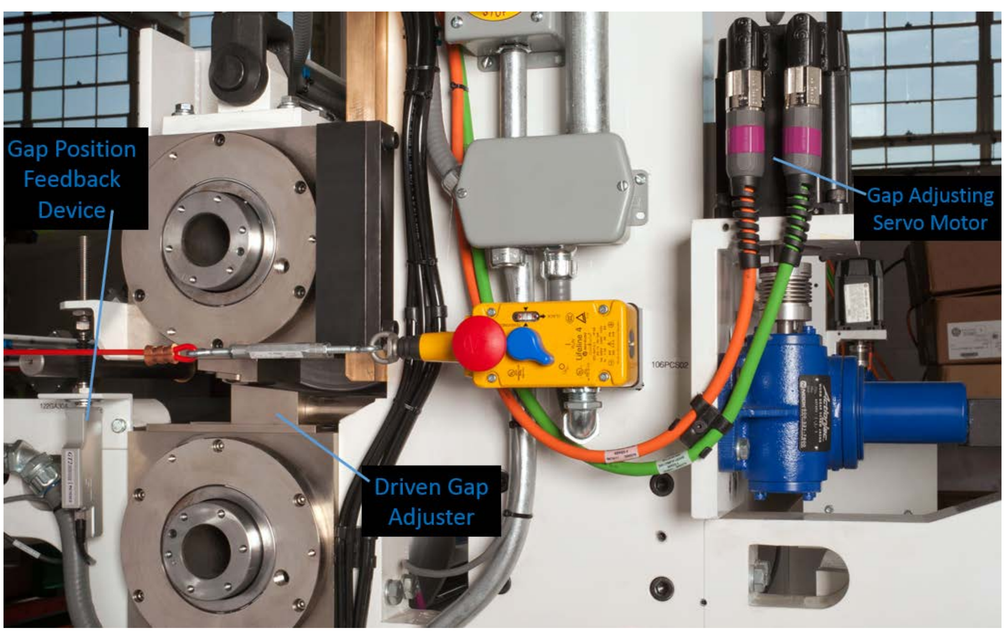

Photo 7 – Between the Roll Coater with Closed Loop Gap Control

Adjusting a Combination of the Above

In certain coating applications a combination of speed control as described in the first case and gap control as described above can be used to control the amount of coating being applied to the web.

A typical example of this is a reverse roll coater.

In this case adjusting the speed of the applicator roll can be used to implement minor changes in the coating laydown rate. However, for larger changes adjusting the speed of the applicator roll may not be effective, with the coating breaking down under these conditions. Therefore, for these larger changes the gap between the rolls needs to be adjusted.

Therefore, in applications such as these a combination of the previously described methods of control need to be instituted in order to successfully use the information from the thickness measuring device to control the coating application rate. It becomes important to have a properly programmed control system that is able to handle both minimal adjustments through the motor and drive associated with the applicator roll speed as well as larger scale changes through the gap adjusting devices (Photo 8).

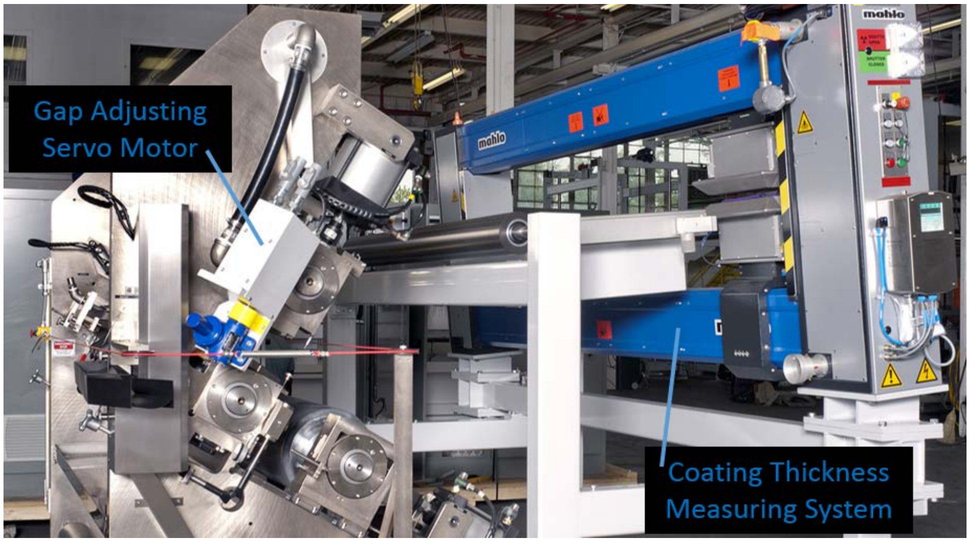

Photo 8 – Reverse Roll Coater with Closed Loop Speed and Gap Control

METHODS TO CONTROL COATING PROFILE:

Often it is the case that variations in the coating thickness are found across the web. For certain coating methods (as before we are assuming that the type of coater has already been selected based on the coating and application requirements) there are systems that can be applied to address these cross web profile variations. This can be accomplished automatically based on the information gathered by a measuring device.

These automatic adjustments can be implemented in one of several ways, with the type of coater dictating which adjustment method is applied. Two examples of these adjustment systems are:

- adjusting the profile using local adjusting bolts
- adjusting the profile by using bending

We will look at both of these methods, discussing how they are used to control the profile, what types of coaters they are used with and how the thickness measurement system can be interfaced with them.

Adjusting the Profile Using Local Adjusting Bolts

When using an adjustable lip die the profile of the coating can be changed through the use of the provided adjusting bolts. These bolts, which are located across the width of the die, are adjusted to locally modify the gap between the die lips, thereby affecting the coating distribution and hence the coating profile.

It is fairly typical to use the coating profile information from a thickness measuring device to automatically adjust the bolts. This can be performed in several different ways including using motors to screw the bolts in and out, using pneumatics or hydraulics to adjust bolts, and heating the bolts.

In all of these applications, the additional hardware indicated in the above paragraph is required in order to automatically actuate the movement of the bolts. In addition, programming is required to allow for the interfacing of the profile reading system with the actuating hardware.

The above technology can also be used with knife coaters. In this case the knife coating blade, which is typically mounted on a holder, can be locally profiled using jacking screws that can push or pull the blade to change the gap between the blade and the roll and therefore, change the coating profile. As with the die coater, additional hardware and programming is required to allow for the interfacing of the thickness measuring system with the coater to allow for closed loop controls.

Adjusting the Profile Using Bending

In many coating applications separating forces can result in an uneven cross web coating profile. These separating forces, which are typically generated by the coating as it is being metered to its application thickness, result in the bending/bowing of the coating rolls and/or knife assembly. Assuming a uniform design of the coating rolls or knife assembly, the maximum bend (or deflection) occurs in the center of it and can be calculated using the following formula:

$$d = \frac{5wL^4}{384EI}$$

Where:

d = the maximum deflection

w = the force exerted on the roll or knife by the coating

L = the length of the roll or knife over which the force is exerted

E = the roll or knife material’s modulus of elasticity

I = the moment of inertia of the roll or knife

The difficulty with using the above formula to calculate the deflection of the rolls or knife is determining the force (w) that is exerted by the coating. There are many variables that affect this force including the physical/chemical properties of the coating, the coating thickness that is being applied and coating application speed.

This bending/bowing results in an uneven coating profile, with a thicker coating being applied in the middle than on the edges.

Certain coater designs allow for the use of a system that applies an external force to the rolls or knife so that the deflection resulting from the coating’s separating force is minimized. This external bending force can be applied to the middle or ends of a knife blade assembly or coating rolls using several different methods including taper wedges, motors and screws, or cylinders.

The coater designs that allow for this type of system to be incorporated include reverse roll coaters, between the roll coaters (Photo 9) and knife coaters (Photo 10).

Photo 9 – Between the Roll Coater with Automatic Roll Bending

Picture 10 – Knife Coater with Automatic Blade Bending

As indicated above, the separating forces and therefore the resulting deflection of the rolls or knife blade are affected by several process related factors. Therefore, the forces required for the external bending also varies with the process conditions. The use of the data from a thickness measuring system allows for the closed loop control of the bending equipment, so that the proper force can be applied to minimize the deflection, allowing for the greatest coating uniformity across the web.

Assuming the above described bending hardware such as motorized screws, driven taper wedges or position controlled cylinders already exists to allow for bending of the rolls or blade, then no additional hardware is required to allow for the closed loop control using the thickness measuring system. The only additional requirement is the programming to allow for the interfacing of the closed loop control.

CONCLUSIONS

There are many different methods available that allow for the closed loop control of the coating application rate based on the feedback from a thickness measurement system, with the method used typically dictated by the type of coater that is applying the coating. Additionally, depending on the coating method being used, there are systems that are available that allow for the control of the cross web coating profile based on the feedback from the measurement system.

BIOGRAPHY:

Bob Pasquale is one of the founders and principals of New Era Converting Machinery, where he serves as President. He holds a degree in Mechanical Engineering from Stevens Institute of Technology and has worked in the web converting industry since 1985. He is the holder of several patents in the industry. Bob can be reached at bob.pasquale@neweraconverting.com.