METHODS FOR CLOSED LOOP COATING THICKNESS CONTROL

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INTRODUCTION

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.

INTRODUCTION

We will discuss how these systems can be applied to various coating methods including:

- kiss coating
- two roll (between the roll) coating
- offset gravure coating
- knife coating
- slot die coating
- spray coating
- reverse roll coating

MEASURING SYSTEMS

There are many methods currently available for online measurement of coating thickness/profile. These methods include:

- beta gauges
- gamma gauges
- IR systems
- X-ray systems
- ultrasonic systems
- laser systems

MEASURING SYSTEMS

Fixed Point Beta Sensors

Traversing IR Sensor

Traversing Laser Sensor

MEASURING SYSTEMS

These systems are typically used to measure one of two things:

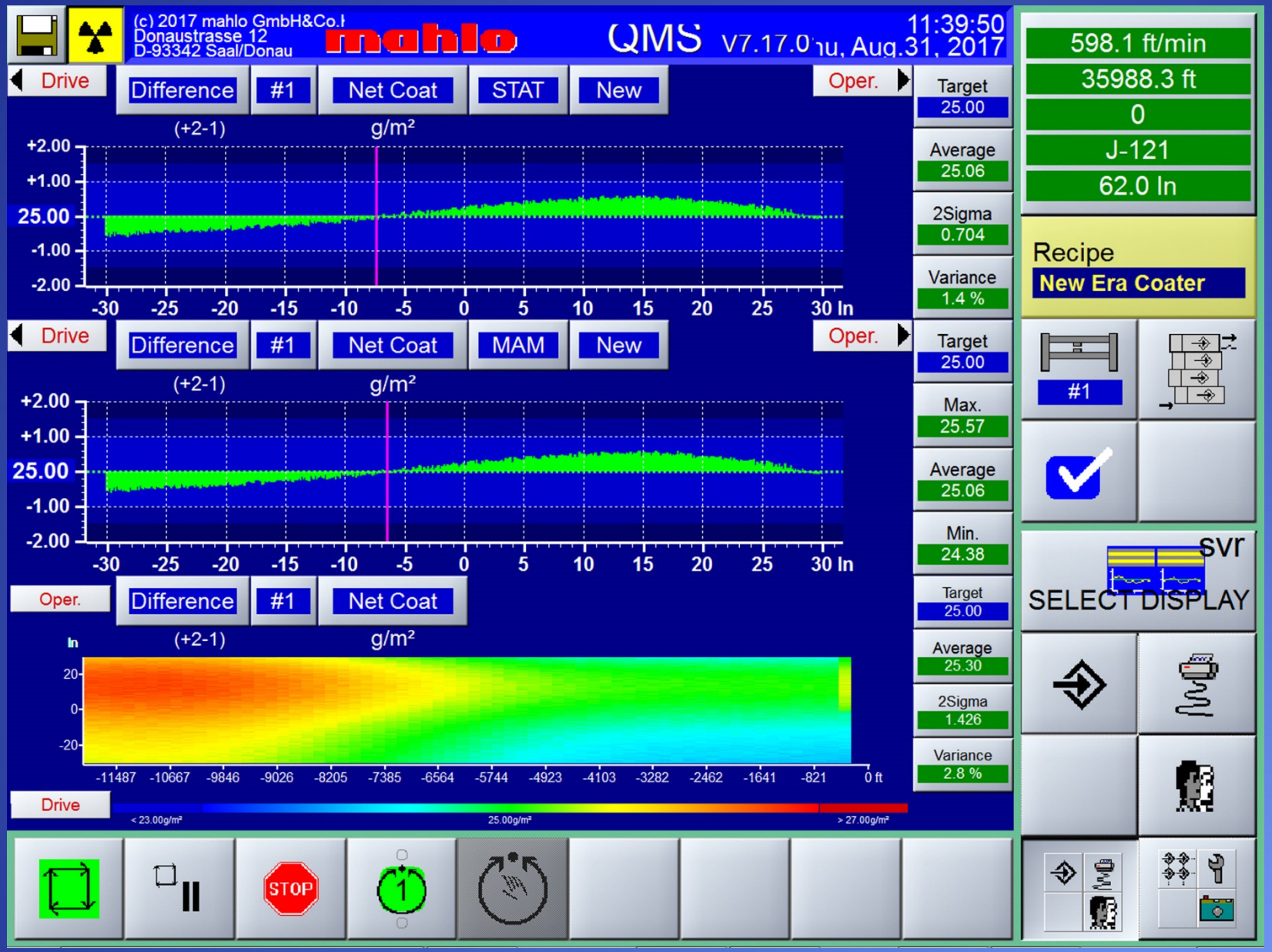
- the total amount of coating being applied to the web
  - by measuring the coating application at a fixed spot on the web (typically in the center)
  - by measuring the coating using a traversing sensor and then averaging the cross web results

MEASURING SYSTEMS

These measuring systems are typically used to measure one of two things:

- the coating profile across the web
  - using a sensor that traverses the web, generating a cross web coating profile

MEASURING SYSTEMS



USE OF THE MEASURING SYSTEM'S INFORMATION

This gathered information can be interfaced with the coating applicator, allowing for the control of the:

- coating thickness
- coating profile

This closed loop control can be done in several ways, with the coating application method often dictating which way is most desirable.

USE OF THE MEASURING SYSTEM'S INFORMATION

- 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

There are several ways that the coating thickness information can be used to control the application method to reach a target coating thickness/laydown.

These methods can be broken down into the following categories:

- 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

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

- 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 type of coater being used dictates which of the previously outlined adjusting methods applies.

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

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:

- the applicator roll is running in the opposite direction of the web
  - all of the coating is transferred to the web
- the applicator roll is running in the same direction of the web
  - the coating is split between the web and the applicator roll

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Speed of the Coating Application Roll(s)

In these methods the information from the thickness measuring system is used to:

- speed up or slow down the coating roll in order to affect the coating transfer to the web

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Speed of the Coating Application Roll(s)

Examples of these coating methods include Kiss Coating and Offset Gravure Coating

Kiss Coater

Offset Gravure Coater

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Speed of the Coating Application Roll(s)

Comments on using the thickness gauge feedback for adjusting the speed of the coating application roll(s) to control the coating thickness/laydown:

- Assuming the applicator roll is driven by a state of the art drive/motor/speed feedback device, it is easy to accurately control the speed of the roll(s) and therefore the laydown rate.
- Assuming the drive and control system can communicate with the coating thickness measuring system (such as through a PLC), automatic closed loop control can be obtained through modifications to the control system's programming.
- No additional hardware is required.

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

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 methods the information from the thickness measuring system is used to:

- speed up or slow down the coating delivery pump in order to affect the coating delivered to the web

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Speed of the Coating Delivery Pump

Examples of these coating methods include Slot Die Coating and Spray Coating

Slot Die Coater

Spray Coater

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Speed of the Coating Delivery Pump

Comments on using the thickness gauge feedback for adjusting the speed of the coating delivery pump to control the coating thickness/laydown:

- Assuming the pump is driven by a state of the art drive/motor/speed feedback device, it is easy to accurately control the speed of the pump and therefore the laydown rate.
- Assuming the drive and control system can communicate with the coating thickness measuring system (such as through a PLC), automatic closed loop control can be obtained through modifications to the control system's programming.
- No additional hardware is required.

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Speed of the Web Processing Line

In certain cases a pre-metered amount of coating is delivered to the web, however 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 methods 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.

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Speed of the Web Processing Line

Comments on using the thickness gauge feedback for adjusting the speed of the web processing line to control the coating thickness/laydown:

- Assuming the web is driven by a state of the art drives/motors/speed feedback devices, it is easy to accurately control the speed of the web and therefore the laydown rate.
- Assuming the drive and control system can communicate with the coating thickness measuring system (such as through a PLC), automatic closed loop control can be obtained through modifications to the control system's programming.
- No additional hardware is required.

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Coating Gap

There are several coating methods 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
- between a precision roll and another metering device such as a knife blade

This gap can be used to control the amount of coating in several ways including:

- pre-metering the coating prior to it being introduced to the web
- introducing the coating to the web at the gap, resulting in the total thickness of coating plus web

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Coating Gap

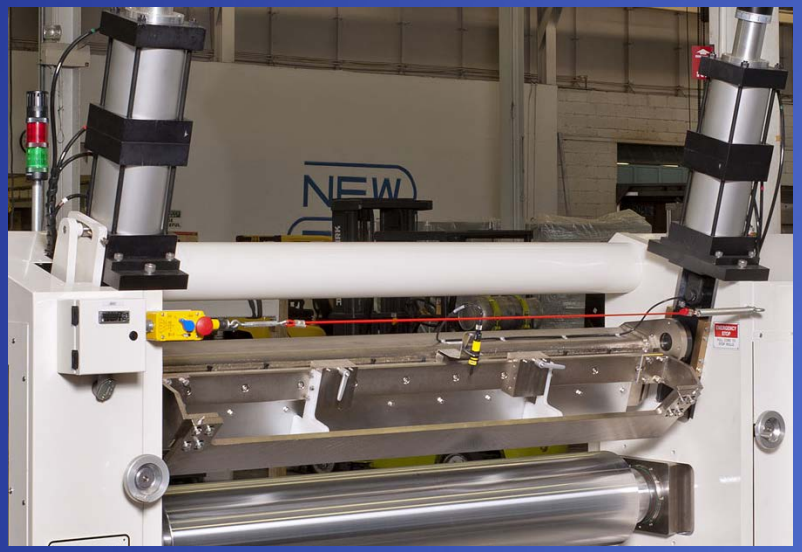
In these methods the information from the thickness measuring system is used to:

- open or close the gap between the rolls or roll and metering device in order to affect the amount of coating introduced to the web

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Coating Gap

Examples of these coating methods include Knife Over Roll Coating and Between the Roll Coating



Knife Over Roll Coater

Between the Roll Coater

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

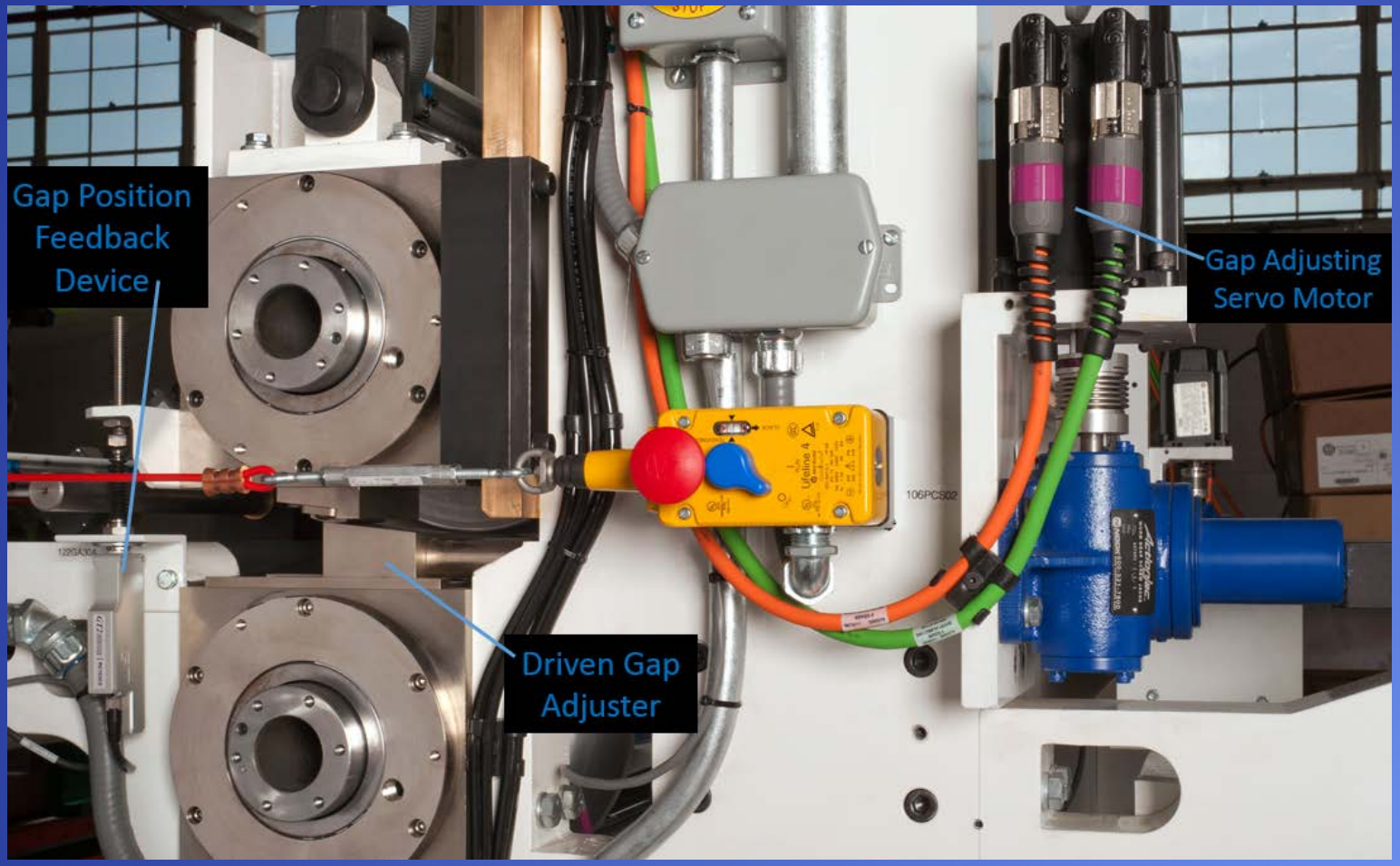
Adjusting the Coating Gap

Comments on using the thickness gauge feedback for adjusting the coating gap to control the coating thickness/laydown:

- Typically adjusting devices such as screws or wedges are located on each side of the machine to adjust the gap between the rolls or roll and metering device.
- Hardware can be added to allow for the automatic positioning of the adjusting devices. Examples of this positioning hardware are:
  - servo motors
  - hydraulic cylinders
- Also required is the addition of hardware such as LVDTs or lasers to allow for reading of the gap.
- Through programming the coating thickness measuring system's information is interfaced with the positioning hardware to automatically adjust the gap and therefore the amount of coating applied.

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting the Coating Gap



Between the Roll Coater with Closed Loop Gap Control

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting a Combination of Roll Speed and Gap

In certain coating applications a combination of applicator roll speed control and gap control can be used to affect the amount of coating being applied to the web.

An example of this is a Reverse Roll Coater.

In these methods the information from the thickness measuring system is used to:

- speed up or slow down the applicator roll to implement minor changes in the coating laydown rate
- open or close the gap between the metering and applicator roll to implement major changes in the coating laydown rate

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

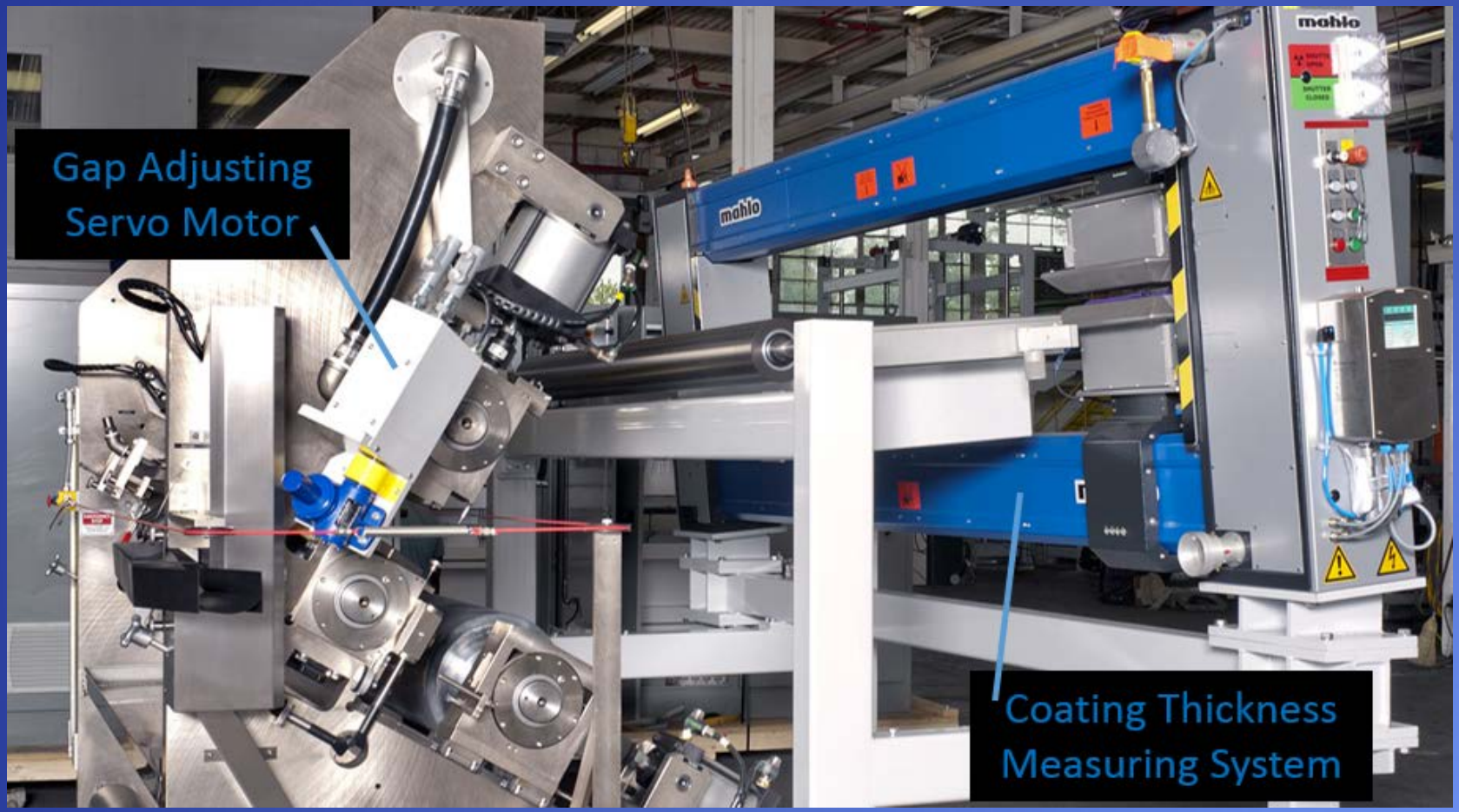
Adjusting a Combination of Roll Speed and Gap

Comments on using the thickness gauge feedback for adjusting a combination of roll speed and gap to control the coating thickness/laydown:

- In applications such as these a combination of the previously described methods of control need to be instituted for proper automatic closed loop control.
- 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
  - larger scale changes through the gap adjusting devices

METHODS TO CONTROL COATING THICKNESS/LAYDOWN

Adjusting a Combination of Roll Speed and Gap



Reverse Roll Coater with Closed Loop Speed & 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 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.
- We are again assuming that the type of coater has already been selected based on the process requirements.

METHODS TO CONTROL COATING PROFILE

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

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Local Adjusting Bolts

Certain coating methods allow for the coating profile to be adjusted using bolts located across the width of the coater. An example of this is an adjustable lip die coater, where:

- bolts are adjusted to locally modify the gap between the die lips

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Local Adjusting Bolts

Certain coating methods allow for the coating profile to be adjusted using bolts located across the width of the coater. An example of this is an adjustable lip die coater, where:

- bolts are adjusted to locally modify the gap between the die lips
- adjusting the gap between the lips affects the amount of coating that passed between them and gets applied to the web

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Local Adjusting Bolts

Certain coating methods allow for the coating profile to be adjusted using bolts located across the width of the coater. Another example of this is a knife over roll coater, where:

- jacking bolts are located across the width of the coating blade, allowing for the blade to be adjusted locally

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Local Adjusting Bolts

Certain coating methods allow for the coating profile to be adjusted using bolts located across the width of the coater. Another example of this is a knife over roll coater, where:

- jacking bolts are located across the width of the coating blade, allowing for the blade to be adjusted locally
- adjusting the blade locally changes the gap between the blade and the roll, thereby affecting the amount of coating that passes beneath the blade and gets applied to the web

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Local Adjusting Bolts

It is 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
- heating the bolts

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Local Adjusting Bolts

- In these applications additional hardware as discussed in the previous slide is required to allow for the automatic adjustment of the bolts.
- In addition, programming is required to allow for the interfacing of the profile feedback system with the actuating hardware to achieve closed loop control.

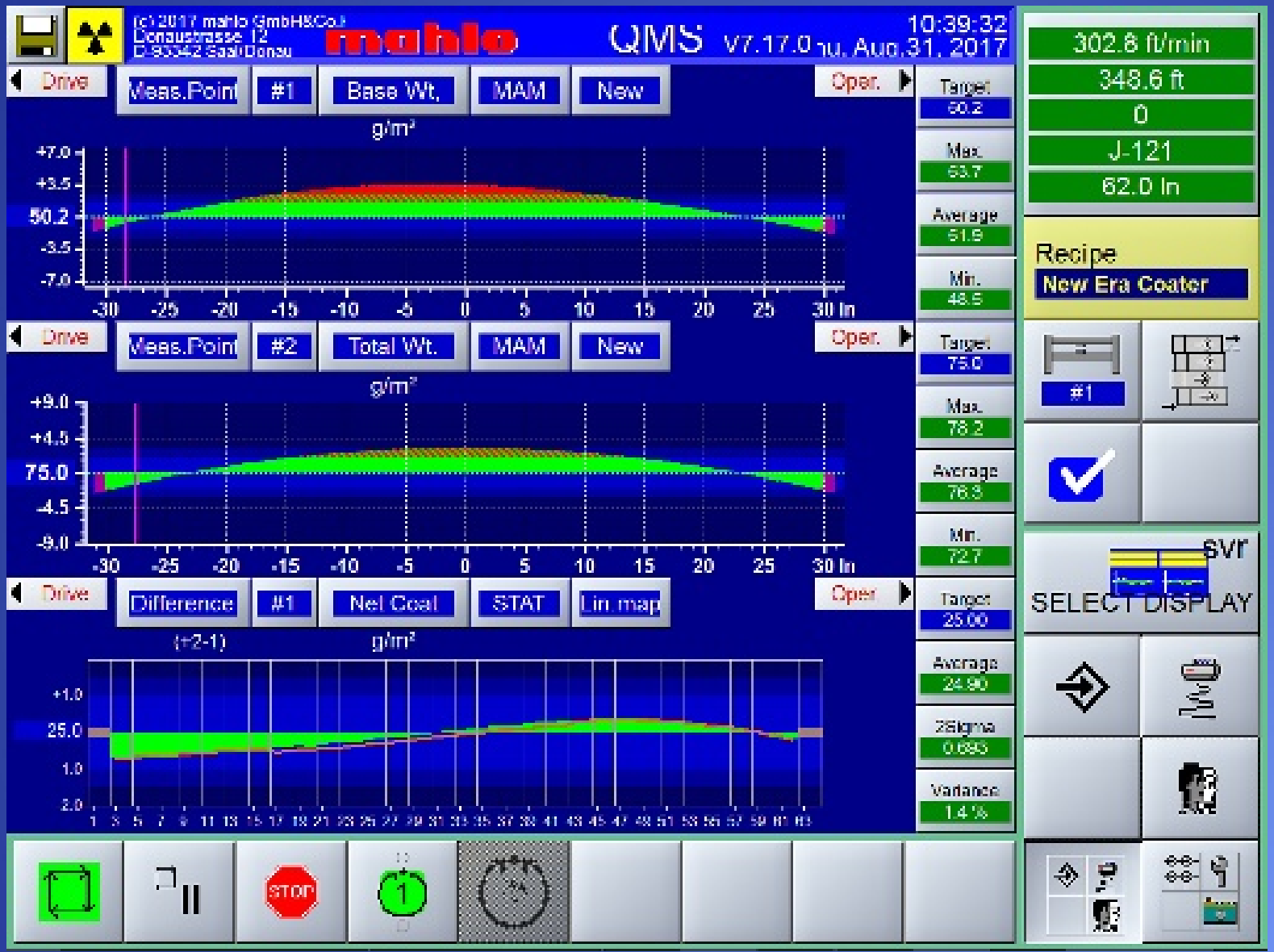
METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending

- In many coating applications separating forces can result in an uneven cross web coating profile.
- These separating forces are typically generated by the coating as it is being metered to its application thickness.
- These separating forces 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 bending (or deflection) occurs in the center of the roll or blade.
- This bending/bowing results in a thicker coating being applied in the middle than on the edges.

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending



METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending

The maximum bending or deflection can be calculated using the following formula:

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

Where:

d = maximum deflection
w = force exerted on the roll or knife by the coating
L = length of the roll/knife over which the force is exerted
E = roll or knife material's modulus of elasticity
I = moment of inertia of the roll or knife

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending

The difficulty with using this formula to calculate the deflection 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
- coating application speed

As any of these conditions change so to does the force on the rolls and/or blade.

This changing force results in a changing deflection and therefore a changing coating profile.

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending

Fortunately certain coater designs allow for the use of a system that applies an external force to the rolls and/or coating metering device (knife) so that the deflection from the separating force can be minimized.

This external bending force can be applied to:

- the middle of the roll(s) or metering device
- the ends of the roll(s) or metering device

Several different methods can be used to apply this force, including:

- taper wedges
- screws
- cylinders

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending

Coater designs that allow for this type of system to be incorporated include:

- Reverse Roll Coaters

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending

Coater designs that allow for this type of system to be incorporated include:

- Between the Roll Coaters

Between the Roll Coater with Automatic Roll Bending

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending

Coater designs that allow for this type of system to be incorporated include:

- Knife Coaters

Knife Coater with Automatic Blade Bending

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending

By using the data from a thickness measuring system:

- the amount of bending force can be automatically adjusted to minimize the deflection, allowing for greater coating uniformity across the web
- as the operating conditions change, causing the separating force and deflection to change, the system can automatically adjust the bending force to minimize the cross web coating variation

METHODS TO CONTROL COATING PROFILE

Adjusting the Profile Using Bending

Comments on using the thickness gauge feedback for adjusting the coating profile using bending:

- The previously discussed additional hardware is required to allow for bending of the roll(s) or knife blade
- Programming is required to interface the gauge's data with the bending hardware to allow for automatic closed loop control of the coating profile.

CONCLUSION

- 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.
- The method used is typically dictated by the type of coater.
- 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.

Acknowledgment

We thank Mahlo America Inc. for use of pictures of their hardware in this presentation.