New non-nuclear weight / thickness sensor for the measurement and automatic profile control of extruded film, sheet and coating

By Eric J. Reber, North American technical sales mgr., Mahlo America, Inc.

Abstract
Advances in infrared-light detection technology have contributed to the development of a new in-line NIR basis weight / thickness sensor that is 100% solid-state with improved temperature stability and >10x finer resolution than existing rotating-filter wheel devices. A new third-generation Automatic Profile Control System (APCS) takes advantage of this high-resolution measurement to flatten the extrudate or coating rapidly with significantly reduced scrap. Details of the solid-state sensor development will be presented, and the improvements to automatic profile control will be explained.

The extruded film, sheet and die coating industries always are looking for ways to improve product quality while reducing scrap, minimizing raw-material use and providing value-added documentation to their customers. An in-line Web Gauging System with Automatic Profile Control is one of the best tools to achieve these goals. Improving the quality of the measurement and being able to flatten the extruded or coated web much more quickly during startup and changeover is key to maximizing quality and cost reduction. This new development realizes these benefits in a truly groundbreaking, solid-state sensor design without the use of rotating-filter wheels or nuclear radiation. A fully intelligent auto-tuning Automatic Profile Control System (APCS) closes the loop on the quality and financial improvements.

Traditional near-infrared (NIR) absorption measurement

NIR Absorption Sensors can be used to measure polymer films and coatings. Most organic molecules have unique NIR absorption spectra. Band-pass filters selected to measure the absorbed light intensity at the absorption peak of the molecule of interest (PET or PE in the example of Figure 1) are used in conjunction with filters centered at reference wavelengths to obtain a measurement of the mass or thickness of the web component. The more light that is absorbed at that molecule's absorption wavelength, the more of those molecules are present in the web and, therefore, the greater the weight or thickness of the web or web component (i.e.: coating).

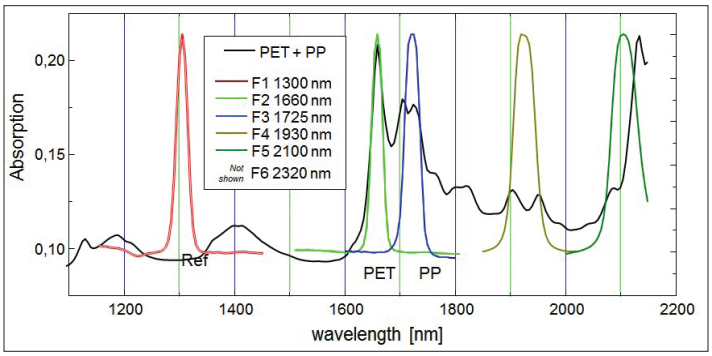

FIGURE 1. *Near Infrared (NIR) spectra of PET and PP polymers*

Existing NIR sensors use a halogen lamp, a Lead Sulfide (PbS) light detector and a spinning wheel containing three, four or six filters (see Figure 2). But, PbS detectors are quite temperature-sensitive, rotating motors are subject to failure and the time delay measuring the light through each filter in sequence can cause measurement errors with a moving web and scanning sensor.

New solid-state NIR absorption measurement

New detector: Advances in infrared-light detection technology have contributed to the development of a new in-line NIR basis weight / thickness sensor that is 100% solid-state with improved temperature stability and >10x finer resolution than existing rotating-filter wheel devices. Beginning with a new type of

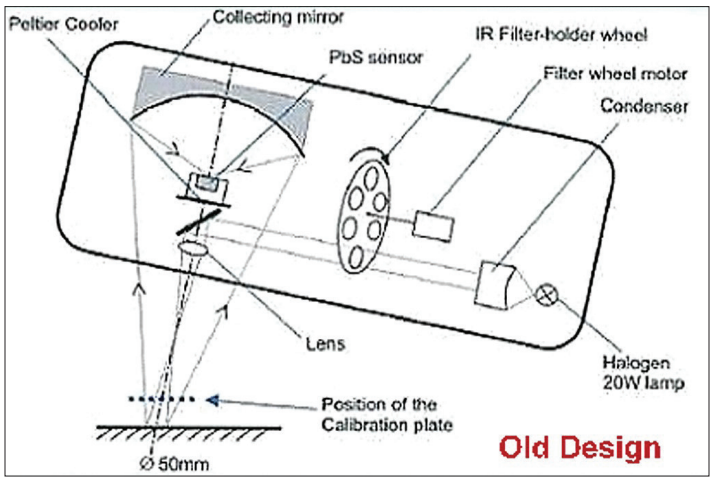

FIGURE 2. *Existing filter-wheel, Lead-Sulfide detector design*

infrared detector, this firm's new photodetector has a higher quantum efficiency, lower dark current and an ultrafast time response relative to the formerly used detector types. The much higher light sensitivity (~100x that of PbS detectors) means that the new detector exhibits a much larger signal change for a very small target-weight or thickness change, so the overall system gain is much lower, reducing temperature effects. In addition, a new standardization technique re-zeros the sensor when needed to eliminate any residual sources of drift that may result from dirt, aging, etc. The higher detector resolution expands both ends of the traditional filter-wheel sensor's measurement range to both lighter and heavier webs than previously available.

Solid-state array: A new ground-up design using the new photodetectors allows the elimination of failure-prone, motorized spinning-filter wheels. Six detectors, each with its own discrete narrow-band pass filter and a novel optical-fiber light pipe, provide true simultaneous same-spot measurements of all wavelengths very rapidly with no light modulation. This results in very fast, stable measurement with 100x higher resolution than that of older spinning-filter wheel devices. The use of an optical light pipe nearly parallel to the light source minimizes the effects of web flutter and can be configured with a small measurement spot for fine cross-direction (CD) resolution. The six-filter array design also facilitates the selection of custom filters for special applications. With no motors or other moving parts to accommodate, the solid-state sensor design is much simplified, easing access for the user to replace the lamp with the sensor remaining mounted on the scanner.

When used as part of an in-line scanning measurement system, the new solid-state NIR sensor (see Figures 3 and 4) is said to provide excellent CD resolution for accurate profile control and narrow defect detection. The new generation of NIR detectors also operates without special cooling requirements up to 60° C (140° F).

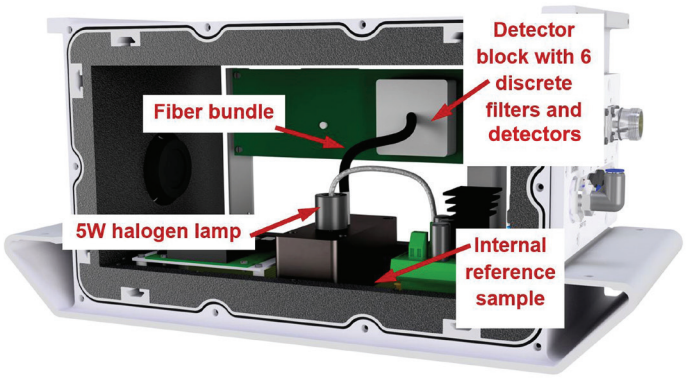

FIGURE 3. *Schematic description of new solid-state NIR sensor*

FIGURE 4. *Solid-state NIR sensor mounted on a traversing scanner measuring a moving web*

Applications: The new solid-state NIR sensor reportedly can measure both the moisture content and the basis weight / thickness of webs with high resolution, accuracy and excellent defect detection. The six-filter design allows for the simultaneous measurement of many of the above parameters. Its non-nuclear measurement technique is very selective and cost-effective as it can be configured in either single-sided reflection or dual-sided transmission modes (see Table 1).

Typical applications include the following:

- Single- and multilayer films
- Polymer sheet
- Aqueous and other organic coatings
- Nonwovens
- Moisture
- Paper and tissue
- Multiple measurements simultaneously

The small 6-mm (0.25-in.) measurement spot size and the fast scanning capability made possible by the low-noise new photodetectors make for an ideal component of an automatic die-measurement and control solution. A new third-generation Automatic Profile Control System (APCS) takes advantage of this high-resolution measurement to flatten the extrudate or coating rapidly with significantly reduced scrap.

New generation automatic die-control system

An APCS works in conjunction with an Automatic Die and will automatically adjust the die-lip gap to produce a flat coating, film or sheet. Fully integrated into the Web Gauging Control and Display Station, a new third-generation APCS takes full advantage of research into a given die lip's elastic modulus and thermal time constant to accelerate the achieving of a flat profile after a startup, grade change or upset.

New predictive algorithms are used for a novel automatic-tuning feature which reduces setup time and takes the guesswork out of the determination of control coefficients. Advanced modeling tools for extrudate neck-in fully characterize any web distortion for fast and accurate control all the way to the edges of the web. And, an integrated diebolt-failure detection utility continuously monitors each heater and immediately reports a fault condition in the die. This firm's APCS units are fully modular and come pre-wired to the mating connector of the autodie power cable to make them truly plug-and-play.

Fast Start Mode: When Fast Start is selected, the PID tuning, neighboring diebolt compensation and control damping are set to much more aggressive values (User Selectable), and the diebolt heaters are overdriven for a short duration with control action performed after the very first scan (see Figure 5). When the product is flat to within a recipe-dependent standard deviation or footage, the control reverts to normal control mode. The result is a flat, in-spec sheet in the shortest possible time and in the shortest length of material.

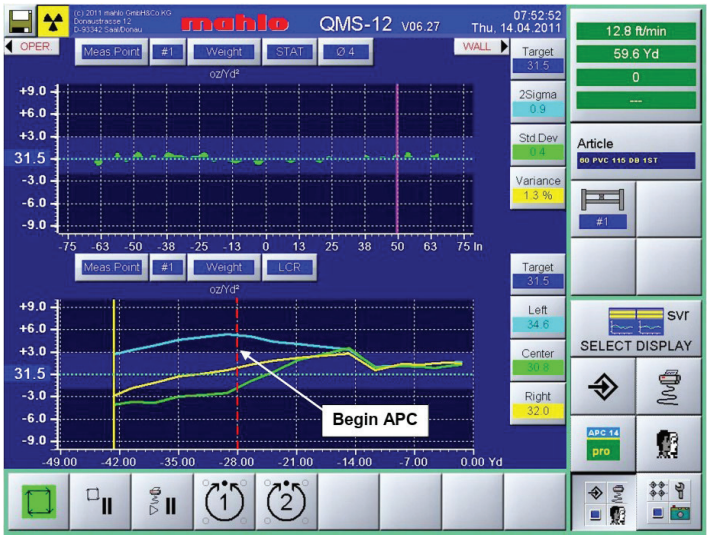

FIGURE 5. *Startup time / length to saleable flatness within four minutes*

TABLE 1. *Specifications of solid-state NIR Reflection (IMF-R) and Transmission (IMF-T) sensors*

Specification		Value		Unit
Parameter		Basis Weight & Moisture		
Type		IMF-R	IMF-T	
Measuring principle		Reflection of infrared light	Transmission of infrared light	
Measuring range Basis weight [1]	Paper	~ 10 - 30	~ 10 - 200	g/m²
	Polymer	~ 10 - 60	~ 10 - 500	
Measuring range Moisture [1]		~ 0.2 - 15	~ 0.2 - 15	% H_2O
		~ 0.2 - 10	~ 0.2 - 30	g/m²
Measuring range Coating [1]		0.2 - 200	-	g/m²
Repeatability [1]		Better than 1%		
Measuring gap		10 / 15 / 30	10 / 15 / 30 / 60	mm
Temperature range without cooling		10 - 50		°C

1) Measuring range and measuring accuracy depending on the material (analysis of material samples necessary)

Automatic Tuning: The new APC System includes an auto-tune feature, which sends varying amounts of power to subtly increase and decrease the web thickness on different parts of the web. It also determines the heating and cooling response times of the die for the particular polymer.

These time constants are used to calculate the APCS PID-tuning coefficients, which then are stored in recipe (see Figure 6). This tool is designed for ease of use by the line operator or process engineer.

Predictive Neck-In: The amount and shape of neck-in and edge bead is dependent on a large number of parameters – polymer, melt temperature, extruder and haul-off speeds, roll distance, die design attributes, etc. The APCS incorporates preprogrammed neck-in algorithms to provide correct non-linear necked-in diebolt mapping and precise control out to the edges (see Figure 7).

Automatic Diebolt Heater Check: The standard Automatic Diebolt Heater Check measures for heater continuity upon startup and automatically at user-selectable intervals. Not only does it detect and alarm in the case of a heater failure, it also identifies the specific bolt that has failed and then compensates for the failed diebolt using the neighboring diebolt heaters until the defective heater is replaced. Special color coding graphically displays the failed diebolts on the APCS power profile.

Along with the above feature set, the new generation APCS includes independent PID control of diebolt heating and cooling, neighboring die bolt compensation, die bolt heater profile autosave, profile target shaping and automatic tuning, and is compatible with all autodies.

Conclusion

The new solid-state NIR sensor will replace both older filter-wheel IR sensors and nuclear gauges for a more accurate and cost-effective, in-line-measurement solution for polymer films and sheet, coatings and moisture. Where fully automated profile control is of interest, the small spot size and fast measurement capability of the new sensor is coupled with a third-generation APCS that is focused on a single goal: control the CD profile to the flattest possible in the shortest amount of time and material. ■

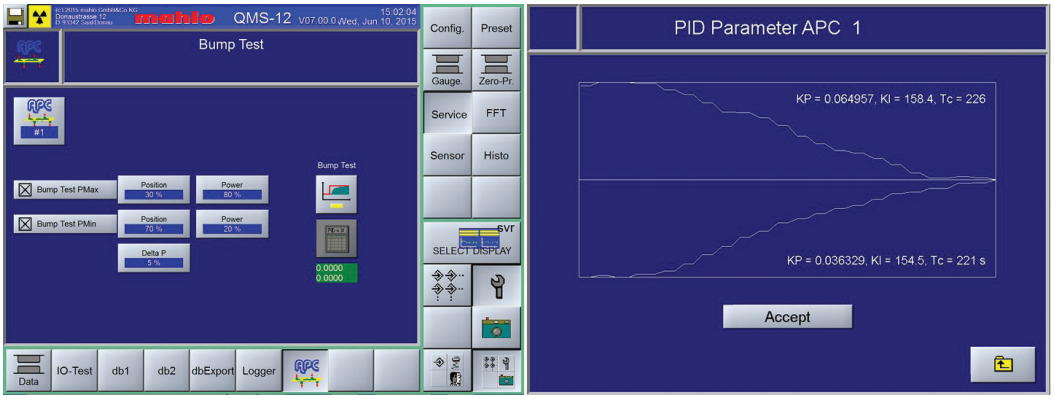

FIGURE 6. *Calculated PID-tuning coefficients stored in recipe*

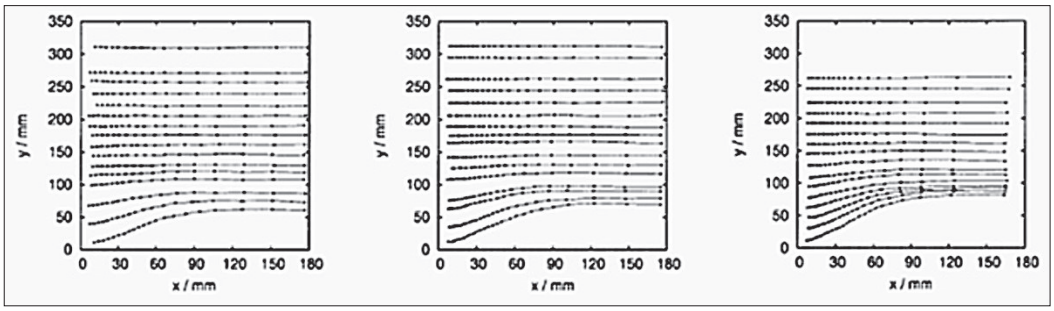

FIGURE 7. *Various web edge conditions due to non-linear neck-in*

Eric J. Reber, North American technical sales mgr.-Mahlo America, Inc. (Spartanburg, SC), holds advanced degrees in Physics and Mathematics from Marquette University (Milwaukee, WI). His web-gauging sensor development work began with Barber- Colman's purchase of Indev Gauging. He set up a sensor design center for web gauging for Eurotherm International (now Thermo-Fisher Gauging) in Newberry, England, and headed up sensor development for NDC Systems (Irwindale, CA) where he was responsible for the development of NDC's original beta transmission sensor and laser caliper sensor and O-frame scanner. Reber has numerous publications throughout his 35 years in the web-gauging industry and holds multiple sensor patents. He can be reached at 864-576-6288, fax: 864-576-0009, email: eric.reber@mahloamerica.com, www.mahloamerica.com.