Viscosity Sensing in Printing Applications

Measurement of Aqueous & Solvent-Based Inks Can Benefit From the Latest Advancements in Technology

By Justan Steichen

Maintaining the right viscosity for printing ink is essential to ensuring a high-quality printed product. Mixing the printing ink too thin may result in color inconsistencies, mottling and weak color print. On the other hand, mixing the printing ink too thick may result in adhesion issues, feathering, smearing or fill-in. Furthermore, printing product with excessively thick ink results in unnecessary costs and wasted ink.

IMPROVED VISCOSITY MEASUREMENT

- In-line viscosity measurements provide real-time feedback for improved viscosity control
- Quality and consistency of ink measurement is improved through intrinsically safe solid state sensor design
- No moving parts helps increase the ink delivery system's reliability, repeatability and robustness
- Due to the sensor's small size, ink delivery systems can be configured in ways that were not previously possible
- Viscosity measurement is achieved by correlating the sensor's BAW electrical parameters to the acoustic viscosity (AV) of the fluid
- Closed loop control of viscosity is reduced through the use of modern output interface options
- High-throughput flexographic printing is an ideal application example of the solid-state viscosity sensor

Techniques for determining ink viscosity vary considerably ranging from manual measurement instruments to microsensors with electrical output. The traditional manual viscosity measurement method uses a viscosity cup and a stopwatch to determine whether the ink is too thick or too thin.

Within the past couple decades, various viscosity instruments with an electrical output have been developed to replace the manual method and have allowed the measurement to become an integral part of the automated printing process.

More recent advancements in viscosity sensing have resulted in the development of in-line, compact microsensors with the added capability of algorithm adjustments to optimize the sensing technique. Additionally, printing press original equipment manufacturers (OEMs) can now design their own ink viscosity control systems for specific customer requirements and realize considerable cost savings.

This paper discusses the existing viscosity measurement techniques and reviews the latest advancements in acoustic wave viscosity sensor technology.

VISCOSITY MEASUREMENTS

In the printing industry ink viscosity measurement using a viscosity cup and a stopwatch is still considered to be the historical standard against which all other viscosity measurement techniques are referenced. There are numerous viscosity cups available, however, two viscosity cups, EZ Zahn #2 and Din 4, are the most commonly used.

Even today, some printers still make adjustments to viscosity with manual addition of solvent or base ink based on a viscosity cup reading. This approach has two major shortcomings:

it increases setup time and reduces throughput. In addition, the accuracy of manual viscosity cup measurements is very dependent on how conscientiously the operators start and stop the stopwatch and how much margin for error they allow. Since numerous types of cups exist, the resulting cup-second measurement is only meaningful for the specific cup used.

While electromechanical viscometers and automated viscosity controls have been available for over a decade, many OEM printing press suppliers have not incorporated them into their systems. In contrast, more sophisticated printing press companies use an automated approach in their press. As in other industries and other aspects of printing, automation improves throughput and quality.

MEASUREMENT INSTRUMENTS

Three electromechanical techniques are most commonly used for determining ink viscosity: the falling piston, the falling ball and the vibrating rod viscometers.

The falling piston viscometer is composed of a cylinder and piston assembly. The piston is raised drawing the ink to be measured into the cylinder through an inlet path. The piston is allowed to fall by gravity, expelling the ink sample out through the same inlet path. The time of fall in seconds is a measure of viscosity that can be correlated to other units of viscosity, such as cup seconds or centipoise.

Falling ball viscometers operate in a bypass line from the ink pumped to the printing press. Stopping the ink flow allows the ball to fall providing a timed measurement proportional to the terminal velocity and inversely proportional to the viscosity. The measurement is taken periodically and is not a continuous measurement. The separate fluid bypass is quasi-independent of the main loop to the printing press. It requires additional space to accommodate the separate flow path and associated instrumentation.

The third approach consists of a straight metal rod maintained in resonant vibration by a continuously applied power source. Installed in-line to the fluid flow, the sensor is between the ink pump and printing deck. The operating frequency is in the audible range (typically 300-500 Hz). High-pitched sounds and vibration in the press that is close to the resonant or harmonic frequency of the rod can affect the reading. Based on the mechanical operation of printing presses, it may not be uncommon to encounter these frequencies, but they can be suppressed with mechanical isolation to allow acceptable operation.

While falling piston, falling ball and vibrating rod viscometers have been successfully utilized in the industry, a new solid-state solution further simplifies the integration of the viscometer due to its small size, ease of use, and output interface options. Equally important, the sensor allows users to configure the viscoity control solution that is optimal for their application.

SOLID-STATE SENSOR

A solid-state viscosity sensor, based on bulk acoustic wave (BAW) technology, uses a piezoelectric sensing element excited by a high-frequency oscillator and operates in the thickness shear mode (TSM) of vibration. In this mode, shear displacement occurs on the crystal faces in the plane of the crystal plate.

As shown in **Figure 1**, the displacement profile occurs throughout the thickness of the plate and is a maximum at the surfaces. Because the displacement motion is parallel to the plate, the TSM continues to operate in fluids making it ideal for fluid sensing.

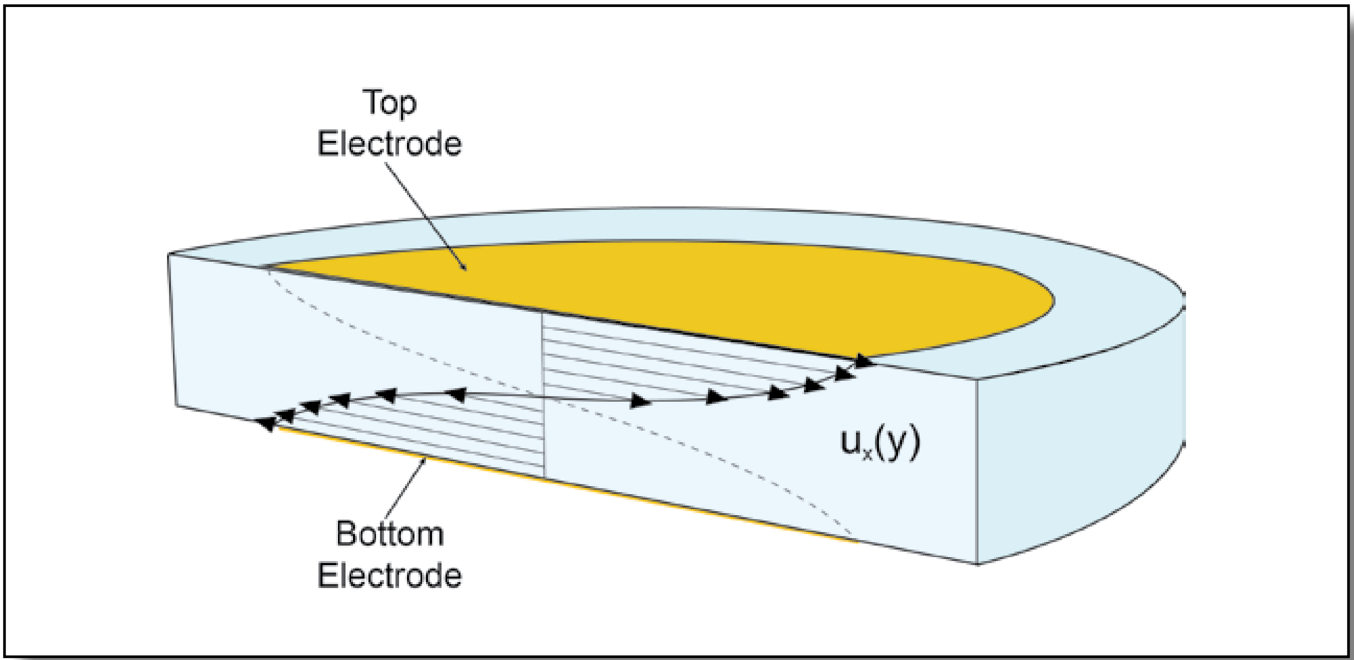

Figure 1: Increasing viscosity of a fluid placed on the top electrode results in an increase in the damping of the viscosity sensor and a decrease in the BAW's oscillator's frequency.

When a TSM BAW device is placed in a liquid, a layer of fluid couples to the cyclical shear displacement of the vibrating surface. Increases in viscosity increase the damping of the TSM BAW. Also, the loading of the device reduces the BAW sensor's frequency. The viscosity measurement is achieved by correlating the measured BAW electrical parameters to the acoustic viscosity (AV) of the fluid.

The general relationship between acoustic viscosity and kinematic viscosity (in centiStokes (cSt)) is: AV = kinematic viscosity x density^2 (in cSt x (g/cm^3)^2).

The solid-state sensor is a fraction of the size of previous viscometers, has no moving parts, is insensitive to vibration, and provides an alternate design approach for users. Offered strictly as a sensor, Vectron's ViSmart sensor solution allows system integrators and OEMs to implement viscosity control system designs without having to compromise their requirements.

The sensing solution readily measures aqueous or solvent based printing inks. As shown in **Figure 2**, the ViSmart viscosity sensor system consists of two to three components depending on the application requirements. For solvent-based printing inks and other hazardous applications, the viscosity measurement solution consists of a hazardous location certified viscosity sensor, a hazardous location certified shunt-diode barrier and a DIN rail mount converter.

Figure 3 shows how easily the ViSmart viscosity sensor system components can be incorporated within a flexographic printing press. The sensor easily integrates in-line with the fluid to be measured, while the shunt-diode barrier ensures excessive energy does not get supplied to the sensor in the hazardous classified area. The DIN rail mount converter allows continuous and easy access to the sensor temperature and viscosity data on a CAN or RS-485 physical layer utlizing a variety of protocols.

For aqueous inks and other non-hazardous applications, the shunt-diode barrier is not required and the sensor can be directly connected to the DIN rail mount converter.

The sensor's small size and other capabilities can have a significant impact in printing equipment design. For example, the sensor can be used in ink management delivery systems, including modular type designs that can be quite small or complex. In many cases, the sensor integrates so well into the equipment that the sensor may become virtually invisible and unnoticeable by the end user. Buried in the design and so compact that it is becomes hard to see, the limited space for the sensor precludes the use of other available viscometers. In the highly competitive printing press arena, the sensor allows flexibility in design, provides significant differentiation, and enables system designers to add value and customize ink delivery to suit the specific needs of their customers.

VS-2511 ViSmart® Viscosity Sensor.

VC-20xx VisConnect® Converter Series.

VB-2510 Shunt-Diode Barrier.

Figure 2: The ViSmart® viscosity sensor, shunt-diode barrier and VisConnect® converters for solvent-based printing applications.

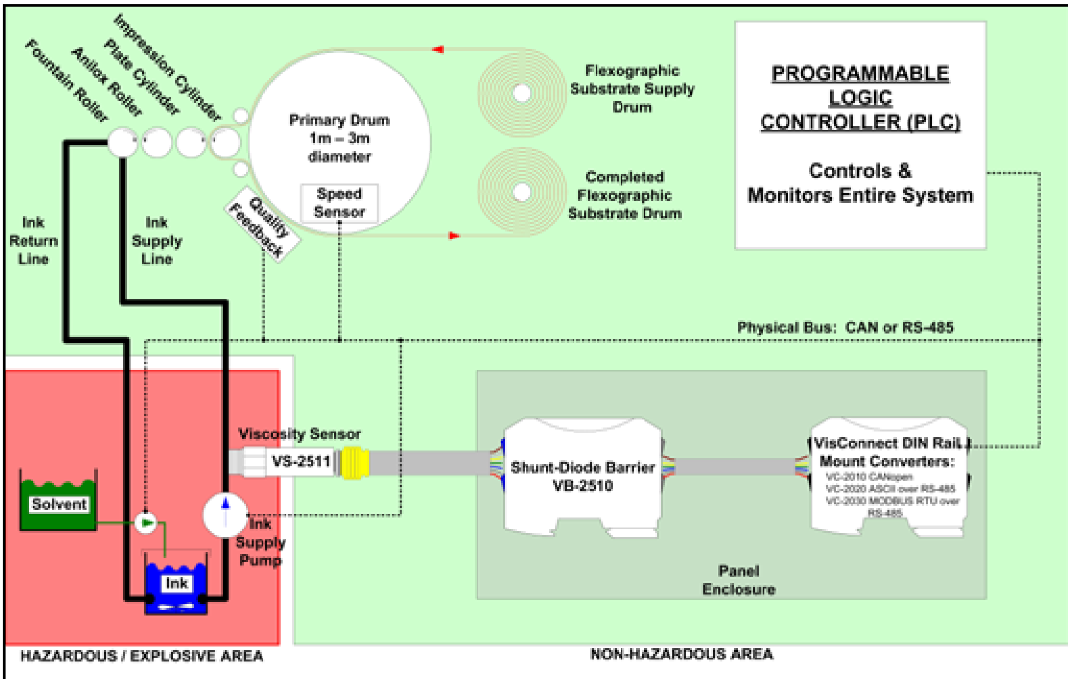

Figure 3: The above figure shows how easily viscosity sensor system components can be incorporated within a flexographic printing press. The sensor easily integrates in-line with the fluid to be measured, while the shunt-diode barrier ensures excessive energy does not get supplied to the sensor in the hazardous classified area. The DIN rail mount converter allows continuous and easy access to the sensor temperature and viscosity data on a CAN or RS-485 physical layer utlizing a variety of protocols.

SENSOR OUTPUT TO VISCOSITY-CUPS

Printers have decades of knowledge based on the use of viscosity cups and often the optimal ink viscosities are known in units of cup-seconds for a particular type of viscosity cup.

To simplify ink correlation procedures, Vectron has established calibration techniques that the end user can use to translate the sensor's output into any unit of measurement they require. Whether it's a Din 4, EZ Zahn #2 or any other viscosity cup, simple calibration techniques allow the printer to translate sensor measurements directly into units of cup-seconds for their viscosity cup of choice.

The top of **Figure 4** shows the raw sensor AV measurement translated into units of cup-seconds for an EZ Zahn #2 viscosity cup. The bottom graph in Figure 4 demonstrates the minimal error in the translated value of cup-seconds viscosity.

WRAP-UP

The use of Vectron's ViSmart Solid State Viscosity Sensors, Shunt-Diode Barriers, and VisConnect DIN Rail Mount Converters enable real-time measurement of ink viscosity. Due to the sensor's small size, ink delivery systems can be configured in ways that were not previously possible. As a result, a more compact and more versatile ink management delivery system can be designed by either system integrators or directly by the printing press OEMs themselves with excellent system performance.

Vectron's ViSmart viscosity sensors reflect technologies discussed in this piece. They are offered in two series: VS-2000 and VS-2500, depending on the application requirements. For OEM printing applications, the VS-2500 series is the recommended solution and has an M12 x 1 circular connector. The VS-2500 is Φ1.00 x L 4.23-in. (Φ25.40 x L 107.42 mm) and is substantially smaller than the falling piston, falling ball and vibrating rod viscometer solutions. The viscosity range is 1 to 400 AV (~1.7 to 510 cSt) for Cannon S60 calibration fluid with a density of 0.886 g/cm3. For more information, please visit www.sengenuity.com. ■

About the Author: *Based in Hudson, NH, Justan Steichen has worked for Vectron International for 5 years and is the product marketing manager and applications engineer for fluid sensors. He has well over a decade of electrical circuit design, system design, and product test experience across a varitey of industries including cellular communications, aerospace, and industrial electronics. He holds a BSEE from Univeristy of Colorado, Colorado Springs.*

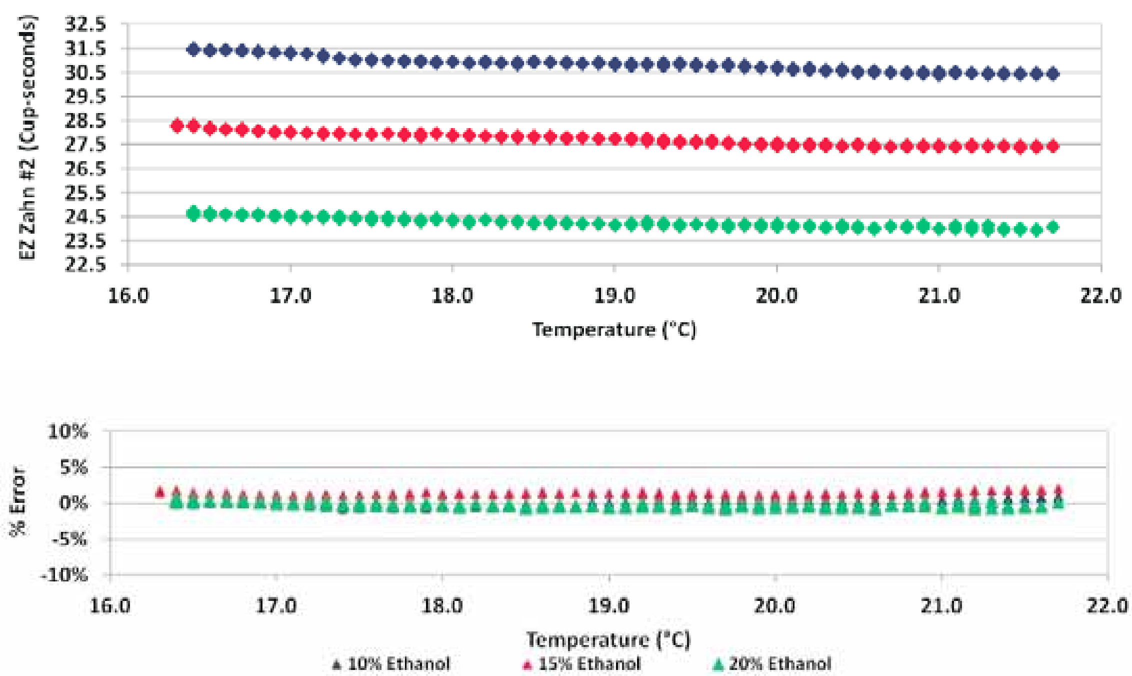

Figure 4: Calibrated sensor measurement vs. temperature for varied (10 percent to 20 percent) concentration of ethanol mixed into Flint CF white ink translated into EZ Zahn #2 cup-seconds and the associated error.