Viscosity Sensing in Printing Applications

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Measurement of aqueous & solvent-based inks can benefit from the latest advancements in viscosity sensor technology

Maintaining the right viscosity for printing ink is essential to ensuring 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 adhesion issues, feathering, smearing or fill-in. Furthermore, printing product with excessively thick ink results in unnecessary costs and wasted ink.

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, viscosity instruments with an electrical output based on the viscosity of the ink 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 has 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 white paper discusses the existing viscosity measurement techniques and reviews the latest advancements in acoustic wave viscosity sensor technology.

Background on Ink Viscosity Measurements

In the printing industry, ink viscosity measurements using a viscosity cup and a stopwatch is still considered to be the historical standard that all other viscosity measurement techniques are referenced against. There are numerous viscosity cups available, but fortunately, two viscosity cups, EZ Zahn#2 and Din 4, are the most commonly used. Even today, some printers still make adjustments with manual addition of solvent or base ink based on a viscosity cup reading. This approach has two major shortcomings. The manual technique increases set up time and reduces the throughput of the printing process. 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.

Viscosity Measurement Instruments

Three electromechanical techniques are most commonly used for determining ink viscosity. These include 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 so it is not a continuous measurement and the separate fluid path 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 control solution that is optimal for their application.

A Solid-State Viscosity Sensor for Modern Printing Presses

Vectron has developed a solid-state viscosity sensor based on bulk acoustic wave (BAW) technology. The BAW sensor 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 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.

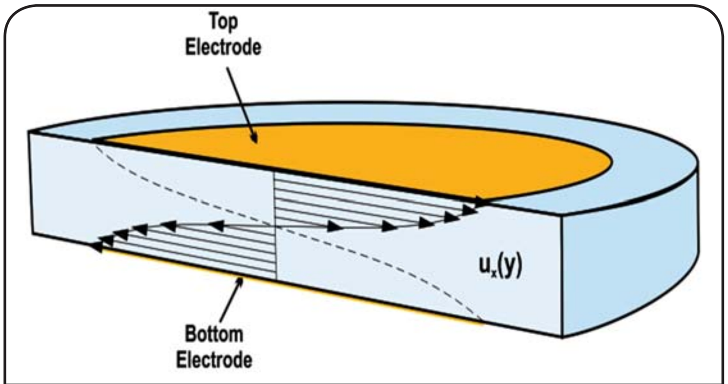


Figure 1: Increasing viscosity of a fluid placed on the top electrode results in an increase in the damping of the viscosity sensor and a decrease in the BAW oscillator's frequency.

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 control system designs without having to compromise their requirements based on available systems with bulkier viscometer sensing measurement methods.

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 an ATEX-certified viscosity sensor, an ATEX certified shunt-diode intrinsic safety barrier and a CANopen interface module.

VS-2511 Viscosity Sensor | **VB-2510 Shunt Diode Barrier** | **VC-2010 CANopen Converter**

Figure 2: The viscosity sensor, shunt-diode barrier and CANopen converter for solvent-based printing applications.

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 environment. The CANopen module allows easy access of the sensor temperature and viscosity data on a CAN bus using the CANopen protocol. Up to 16 sensor systems can be installed on the same CAN bus with unique node IDs selectable from the dip switches on the CANopen converter.

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

In addition to the CANopen interface module, the VisConnect™ analog/digital communication module converts output signals from the ViSmart viscosity sensor into industry standard formats and protocols including 4-20 mA and 0-4V analog as well as RS-232 digital outputs.

Vectron's ViSmart viscosity sensors 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 inches (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/cm^3. Also, since the operating frequency of the sensor is at 5MHz, Vectron's ViSmart viscosity sensor is insensitive to a broad range of frequencies, including those frequencies common in the printing industry; the sensor is specified to have no impact with operation up to ±20g from 5-2000 Hz. As a solid-state technique, the viscometer can be installed in virtually any mounting orientation as long as adequate ink flow exists in the process line.

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 and can provide significant differentiation, and enable system designers to add value and customize ink delivery to suite the specific needs of their customers.

An Example Application

High-throughput flexographic printing is an ideal application example of the solid-state viscosity sensor. Figure 3 shows the ViSmart viscosity system integrated into a flexographic printing press. Installed in-line with the ink delivery system, the sensor provides continuous measurements of the ink viscosity. The shunt-diode barrier and VisConnect CANopen converter are installed in a panel enclosure. The shunt diode barrier limits the energy available to the sensor, while the CANopen converter transmits the sensor temperature and viscosity data onto the CAN bus using the CANopen protocol. With its CANopen input from the viscosity sensor, a programmable logic controller (PLC) makes automatic adjustments to the ink viscosity by adding solvent.

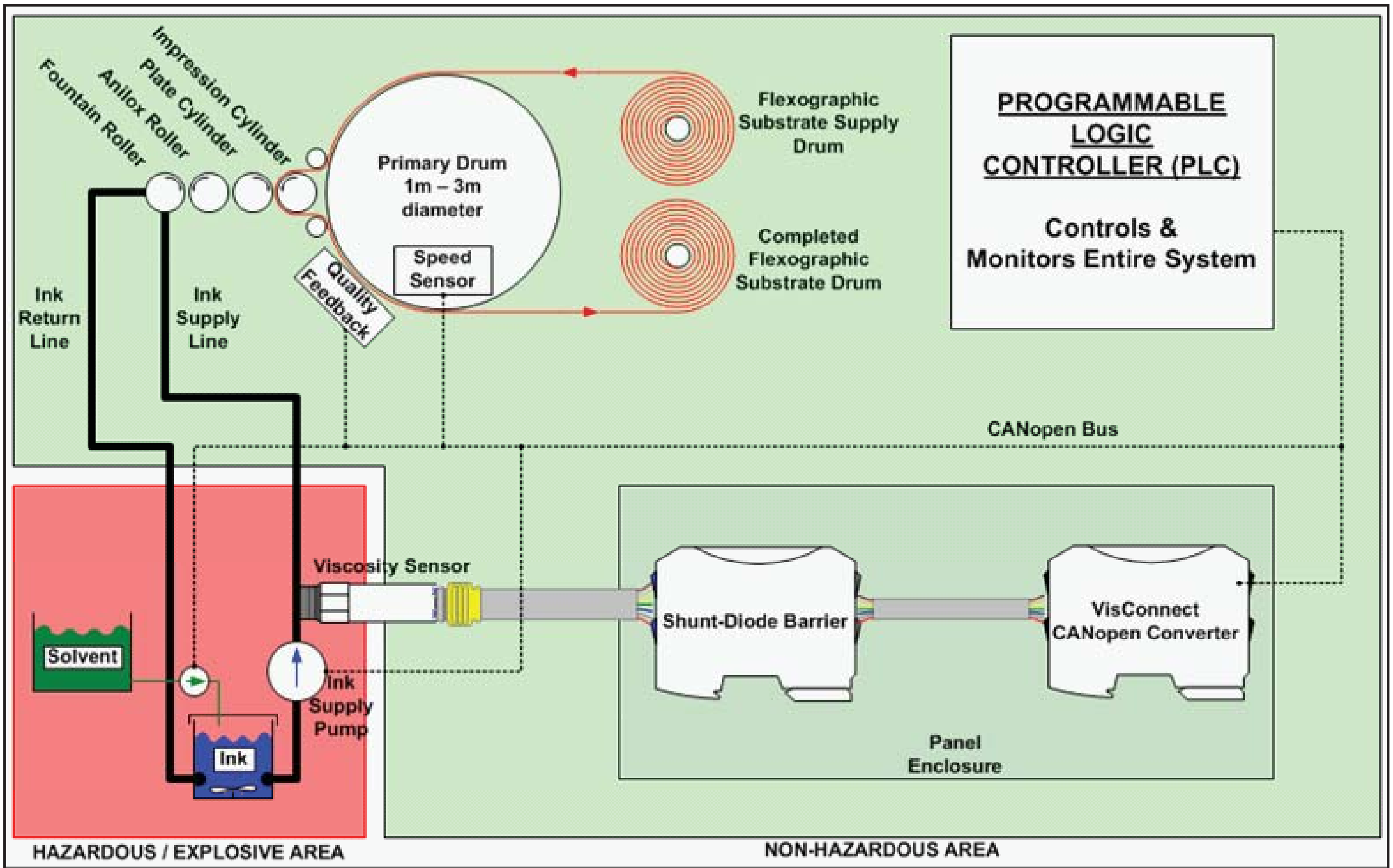
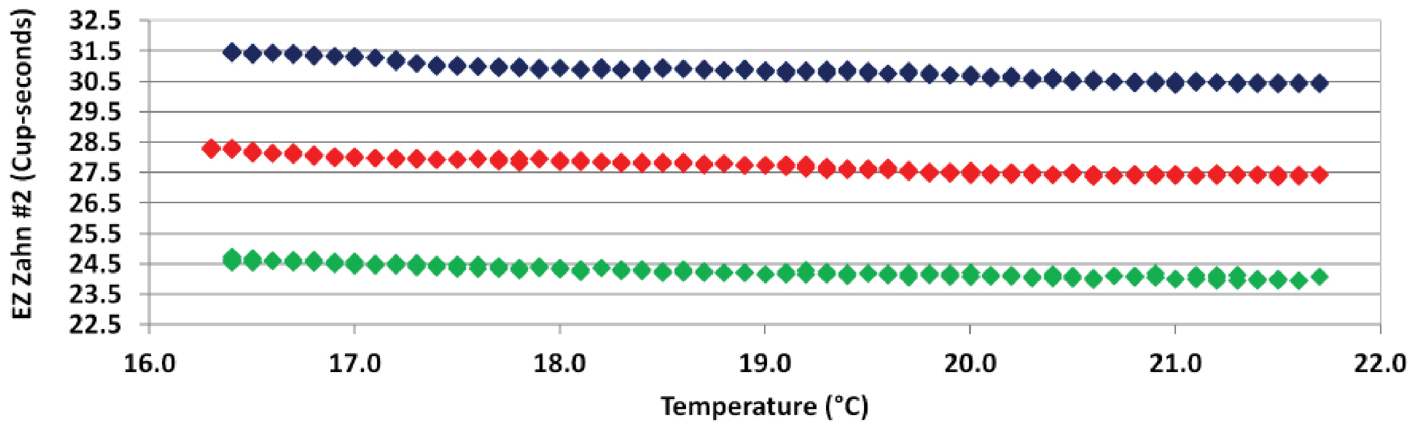


Figure 3: Mounted in-line with the ink supply line, the solid-state viscosity sensor provides continuous viscosity measurement of ink to allow real time control of ink viscosity.

Printers have decades of printing 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 is a Din 4 or EZ Zahn #2 viscosity cup, Vectron's 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 of the viscometer 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.



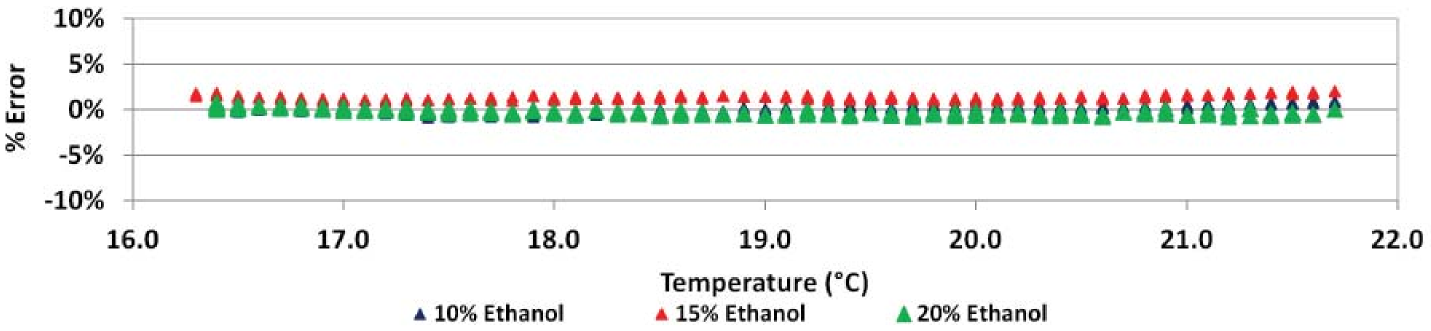


Figure 3: Calibrated sensor measurements vs. temperature for varied (10 to 20%) concentrations of ethanol mixed into Flint CF white ink translated into EZ Zahn #2 cup-seconds and the associated error.

Contact Vectron to find out how to take advantage of this measurement capability.

Summary/Conclusions

Viscosity is a critical printing industry parameter that impacts quality and cost. Vectron's ViSmart viscosity sensor enables real-time measurement of ink viscosity, and because of 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.

To get started, you simply need to contact Vectron to help you determine the exact requirements for your specific application.

About The Author

Ray Haskell has over 16 years of experience developing sensors and precision frequency control components. He is currently the Engineering and Product Marketing Director for fluid sensor products at Vectron International. He has developed numerous sensor and precision frequency control technologies that have led to new and innovative products. More recently his focus has been on the development of bulk acoustic wave viscosity sensors for printing ink and lubricant applications and the practical implementation of this technology through the use of novel in-situ calibration algorithms. Prior to joining Vectron, Ray was a Senior R&D Engineer at Sensor Research and Development Corp. where he developed acoustic wave based liquid and gas sensors and also developed high temperature semi-conducting metal oxide sensing transducers. Ray holds a M.S. in Electrical Engineering from the University of Maine (Orono) where he worked in the area of acoustic wave and solid state sensors. Ray has eleven patents and fifteen publications in the sensor and frequency control areas.