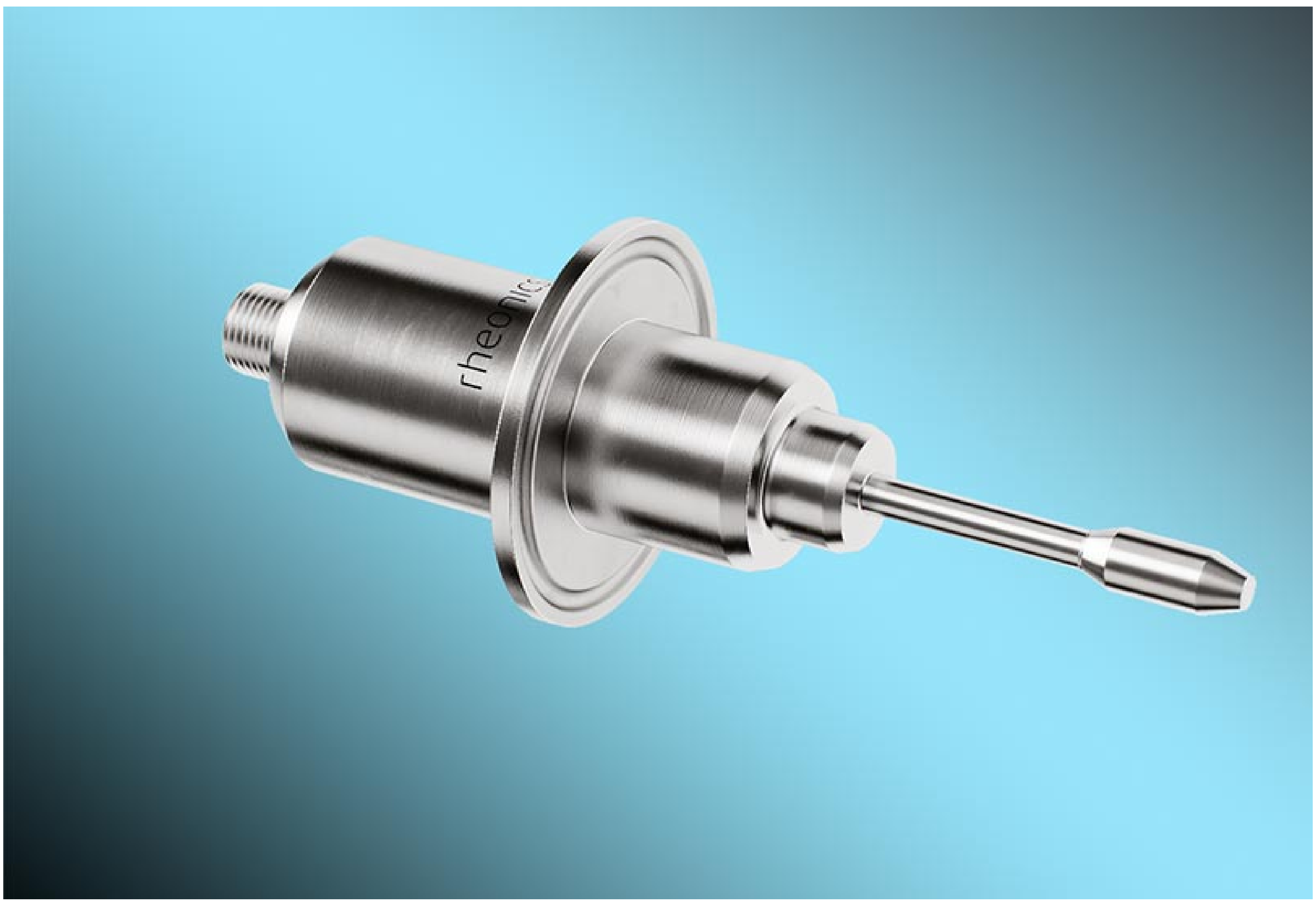
FOOD ENGINEERING

Tech Update: Sensors

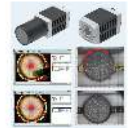
Using sensors to improve processes

Sensors today are ubiquitous and affordable with new devices on the horizon, so there’s no reason not to know what’s going on in your process



Rheonics’ SRV (DIN 11851) inline viscosity sensor has built-in temperature measurement, and can be inserted inline with equipment.

Photo courtesy of: Rheonics

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Wayne Labs

Today, sensors are everywhere. There are proximity sensors, accelerometers, gyroscopes, magnetometers, biometric devices, IR and temperature sensors, humidity devices and even oximeters in your smartphone (though you may not want to depend on the accuracy of a smartphone-based oximeter)

Besides the basic four (flow, level, pressure and temperature) sensors used to provide a window into industrial processes, there's a myriad of other sensing devices that you find in everyday products—from toys to dishwashers and to automobiles. If your food or beverage operation isn't making widespread use of sensors to monitor your process, you can't expect to remain competitive for long—because as they say, "you can't control what you don't measure," and you can't expect actionable data from your process without them.

With some ingenious engineering and the right sensing devices there's no reason not to have control of your process. And if you don't have the engineering help on staff, assistance is as close as your system integrator. As Mark Leer, chief engineer at CHL Systems, puts it: "We are not a sensor manufacturer, but rather an integrator that uses sensors in our design/build projects." And, with the experience that integrators have from so many projects they do, they are often able to come up with novel solutions—like making one sensor do the job of several. "We were able to use a laser distance sensor to detect unfilled dough pockets and reject accordingly across numerous lanes of product before [entering] packaging machinery," says Leer.

Sensing and control for every exacting purpose

Sensor and controller makers have devices for exacting food/beverage applications. Brooks Instrument makes flow and pressure instrumentation and has, for example, mass flow controllers (MFCs) to take that data and keep processes on target. "The food and beverage manufacturing applications that our MFCs focus on include ice cream, cheese, butter, yogurt, cell-based meat and the fermentation of beer and wine," says Al Harvey, industrial flow specialist. Each application requires a measurable, continuous amount of air, carbon dioxide or other gasses to complete the recipes, he adds.

Endress+Hauser offers a comprehensive line of measurement instruments tailored for our industry, says Ola Wesstrom, senior industry manager, food and beverage. This includes simple sensors to advanced analyzers for hygienic process applications—as well as for the water, air, gas, electricity and steam utilities used in food processing plants.

Some people may not think of Festo as a sensor company, says Sebastian Balos, sales engineer – food and packaging. However, Festo offers a broad range of sensors including proximity sensors, flow sensors, optical sensors, and sophisticated machine vision systems. Festo's sensor line covers a broad range of applications from monitoring flows and pressures on process equipment to sensing the position of actuators and products in filling and packaging equipment, tracking product and package codes, and identifying product and package defects.

Rheonics develops, builds, and sells density and viscosity sensors and automated solutions that are used in a broad range of applications from food processing to petrochemicals, says Manpreet Dash, development engineer, Rheonics GmbH/applications engineering and markets development. "Our sensors are used in various stages of food processing like transport, mixing and coating involving both Newtonian and non-Newtonian fluids."

Rheonics' density and viscosity meters are widely used by global machine builders and manufacturers for monitoring batter mixing and coating, chocolate conching and wafer coating, creams, milk, yogurt, mayonnaise, sauce manufacturing, enteric coating for animal food products, monitoring alcohol and sugar content in wines and beverages, and for automating wastewater streams.

Thinking about challenging applications

Chances are that if you have a relatively recent dishwasher, it has a turbidity sensor—which can actually cut unnecessary rinses if the water is clear, saving you water and energy. Now apply the same principle in an industrial environment, and the savings can be real.

"One of the major costs of retorting is cooling water," says David Cohen, lead software engineer at Allpax, a ProMach brand. Plants are charged once to use the water and again to send it down the drain. "Our customers have been looking for a way to recapture direct contact cooling water without the need of expensive filtration systems," says Cohen. "We integrated turbidity meters into our water recovery systems. These meters are able to detect the cleanliness of the water, so we can discharge the dirty water at the beginning of the process and recapture the clean water in the middle and at the end of the process. This has resulted in a reduction of up to 50% of water usage saving plants a significant amount of money."

A challenging food application using conventional sensors is the process of making ice cream, says Brooks Instrument's Harvey. "Our MFCs inject measurable and repeatable amounts of air into the cream for it to reach a specific weight as well as a smooth and creamy look and texture. In conjunction with other devices, when cream is injected into cakes, our MFCs allow for consistency in the process so each cake has the same amount of cream."

When you've intentionally—or unintentionally—injected air into a product, measuring its mass flow has been problematic. Endress+Hauser's Wesstrom explains: "Due to entrained air in many food products such as milk, whipped products or viscous liquids, Coriolis mass flow technology has in the past struggled to provide accurate measurement. With a new approach, Endress+Hauser solved this problem using Multifrequency Technology in the Promass Q Coriolis meter, to a point that it is being used [for] determining gas void fraction in whipped products (over-run measurement)."

Why not simplify a process when you can? Festo's Balos explains: A customer recently sought Festo's help in designing a process solution for a unique application where water was used to move fruit gently along a "lazy river"-like loop. The flow of water needed to be monitored and controlled through piping on its way back to the beginning of the loop. There needed to be significant balancing of flow and pressure to keep the system flowing properly.

"The application team used a flow sensor along with a pressure sensor for monitoring," says Balos. These signals were sent to a Festo Motion Terminal (VTEM), which included a Festo PLC in one unit. The intelligent valve capability of the VTEM along with the sensors created a new and simple method for full analog control of valves in piping as opposed to the traditional use of on-and-off process valves. This setup eliminated the need for eight process valve sensors and reduced what would traditionally be eight side-by-side proportional pressure regulators down to fewer than four. "We achieved panel space savings along with an obvious cost savings due to a reduced number of components," says Balos.

Suppose you have a vessel sitting on a platform with load cells to monitor the weight of the vessel as an ingredient is added or "dosed" to the vessel, and you want to know when to stop adding the ingredient. Pretty simple—just shut off the valve when the ingredient reaches its tare weight in the vessel. Now, to add another ingredient, and you have to "zero" the weight to get a new tare weight, and do the same procedure again serially for each ingredient you add. Obviously, you can get accurate doses of ingredients, but it takes time.

John Parraga, process specialist with ECS Solutions, a certified member of the Control System Integrators Association (CSIA), thought there had to be a better way to meter the ingredients—not sequentially—but at the same time with the same instrumentation already in place. He came up with such a novel idea that he was awarded a U.S. patent, entitled, "Systems and Methods for Totalizing Parallel Feeds," (7,660,680). For more on this, see Parraga's patent description in more detail. Also, see the FE article, "How to use a single totalizer to dose concurrently multiple ingredients."

Beyond challenging applications

Today's applications are requiring sophisticated and more exotic sensors for both packaging and process related functions. For example, CHL's Leer describes the use of a 3D smart sensor to capture a candy tray profile on the fly to feed back location data to a vacuum pick robot at a rate of 20 trays per minute.

Many of Allpax's client processors use fragile containers (pouches, cups, bowls) to sell products to their customers. The containers require precise pressure control to ensure they do not rupture during the sterilization process, says Cohen. In the past, processors have had to send test containers to third-party test facilities to have the pressure profiles mapped. Any time a container or ingredient changed, they would have to send new packages to be tested and mapped. This can be an expensive and time-consuming process.

With the integration of a pressure profiler system, processors can now perform these tests and create their own pressure profile, saving time and money, says Cohen. The profiler sensor is attached to the container and placed in the retort. As the retort heats up, the container starts to deflect due to the added internal pressure. The pressure profiler system detects deflection and automatically increases the internal retort pressure accordingly to compensate and reduce deflection. Deflection measurement and retort pressure compensation continues throughout the sterilization process, creating the perfect pressure profile for the container.

In a yogurt cup filling application, a processor needed a smart IO-Link distance sensor that was capable of meeting an IP69K washdown rated environment, says Balos. Festo was able to meet these requirements with its SOOE light-barrier sensor family. IP69K requirements are a growing trend within the food industry, one reflected in the demand for Festo's IP69K rated valves. Taking traditional components out of stainless steel NEMA 4x type enclosures through resistance to harsh environments is also proving to be very cost effective with the positive side effect of being more efficient since the component or system is now closer to the application, which can improve machine performance.

Process applications more demanding

On the process side, challenging food and beverage applications using more sophisticated sensors include the production of cell-based meats and the fermentation of beer and wine, says Brooks Instrument's Harvey. For cell-based meats, MFCs deliver precise amounts of air, oxygen, nitrogen and carbon dioxide for closed loop control of the pH and dissolved oxygen in the bioreactor for the cells to grow. Specific volume and flow are critical to this process. If something adversely happens with the gas control, this can result in a ruined batch, wasted money and lost production.

In order to speed up the fermentation process of beer and wine, MFCs allow for a controlled and automated process to activate the yeast in order to make more recipes and maximize production. An oxygen sensor is used to provide feedback to the MFC to control the oxygen flow at peak level.

For its brewing process, Rahr Eagle Brewery wanted better control of its fermentation process. The brewery had been using variable area flowmeters to measure mechanically compressed air injection to increase oxygen content. However, the brewery wanted to use pure oxygen to activate the yeast—in which case precise sensing and control was needed. The brewery—with the help of William E. Young Company—installed a Brooks Instrument SLAMf mass flow controller with a NMA4X/IP66 enclosure to precisely control and automate pure oxygen levels.

Viscosity is a common quality control parameter mostly performed offline in a laboratory, with consequent delays and costs, says Endress+Hauser's Wesstrom. By using the Promass I Coriolis mass flowmeter with viscosity output, inline viscosity measurement can be performed, greatly reducing the production downtime associated with quality check steps, and in some cases enabling closed-loop control.

Speaking of viscosity, one of Rheonics' Swiss customers needed to create the "perfect" chocolate wafer bars, however, the bottleneck was the consistency of the chocolate and cream layer, which needed to be applied in the exact thickness to ensure the correct final thickness of the wafer and to give the perfect crunch to their customers, says Dash.

A Rheonics inline viscometer SRV was installed by the chocolatier on its production lines to monitor the chocolate and cream mixture to ensure the viscosity of the mixture was controlled within tight limits to allow consistency of coating. The chocolate-cream-nuts mixture was a complex fluid with air entrapped and the customers had not found any instrument that was able to give reliable and repeatable measurements before using the SRV.

Sensors in the future

"We believe that vision systems and sensors will become less expensive, easier to use, and will likely be used in more applications than they are now," says Festo's Balos. Sensing in the form of vision, X-ray, and metal detection will provide the ability to capture huge amounts of data, which will allow processors to manipulate it in ways that lead to fewer recalls and safer food products. This is the type of database information so necessary for successful track and trace implementation, adds Balos. Regarding food safety, Balos suggests that the rapid sensing of harmful food pathogens is something we'll see in the near future.

"We will see developments in optical technologies for color, turbidity and so on—but the most significant advancement will be the adaptation of Raman Spectroscopy for inline or at-line measurement of proteins, fats, sugar types, and other parameters," says Wesstrom. Other newer technologies include surface acoustics for concentration measurement and microwave for moisture in solids.

“Because of advancements in production techniques and adoption of mass-produced sensors (think, for example, radar used in automotive for automatic cruise control), we will see an influx of simpler sensors for less critical applications, supporting digital transformation strategies,” adds Wesstrom. It should be kept in mind that many of these simple sensors are not and won’t be suitable for very dynamic applications with foaming, steam, agitation etc., so there will be a mix of simple and more advanced measurement instruments in the future.

Viscosity is a property that is affected at the molecular level and has tremendous amount of information about the process but has been hard to quantify reliably with existing instruments, says Dash. Viscosity provides insights on the properties that matter the most in case of food products—texture and consistency. These properties influence taste, aroma, flavor and the mouth-feel and make-or-break product reception for consumers.

A major constraint to adoption of viscometers in food industry has been two-fold: first a lack of robust, inline, repeatable viscometers, and second, the lack of integrated plant control systems capable of making good use of viscosity information in the overall control strategy. There was always a perception that although food rheology is important, it is a difficult subject to monitor reliably.

Software’s future role in sensors

No question about it—software plays an important role in today’s sensing systems, and its application will be in different ways. “I think we will see a mix; some instruments will still require sophisticated software to work, while for some it will be sufficient to get the raw signal,” says Wesstrom. As an example of providing just a raw signal, Endress+Hauser is now offering a “transmitter” which is part of the cable from the sensor. “We have started with pH, conductivity, and a few other liquid analysis products—but the CM82 transmitter can be adopted for other measurement parameters as a way to reduce instrument cost,” says Wesstrom.

Cloud-based services for asset health monitoring and traceable performance verification are rapidly being adopted by the food industry, which has a greater need for performance and safety records, says Wesstrom. An example of this is Endress+Hauser’s Heartbeat Technology, which combines diagnostic, verification and monitoring functions for process optimizations.

Software is already playing a role for more advanced diagnostic features for predictive maintenance, and maintenance engineers can use software to perform system checks, says Harvey. For example, Brooks Instrument’s onboard advanced diagnostics on its “smart” devices help with predictive maintenance and troubleshooting. One diagnostic ensures proper continuous flow to a bioreactor. A restricted flow alarm is delivered to the operator if the inlet pressure is limited to the MFC. Another diagnostic is the backflow alarm that notifies the operator when bioprocess liquid or gas accidently flows backwards to the MFC. A secondary feature is the Brooks BEST software that allows the customer to troubleshoot and calibrate the MFC in the field. “Another secondary feature is our web portal that allows the customer to view MFC settings, control the device, and troubleshoot in the field,” says Harvey.

Software is going to play a key role in the future of sensors and the endless possibilities it will offer plant engineers in terms of acquiring and analyzing process data, detecting events that need intervention, optimizing their processes and gathering insights about the factory processes, which have both short- and long-term implications, says Rheonics’ Dash.

There is a range of applications in the food industry, and it is important to understand that each application in unique in terms of the process goals, norms and regulations, product changeovers and plant engineers’ experience, common factory floor practices and knowhow, says Dash.

The way the user inside the plant interacts with the sensor data is going to rely heavily on how best the software and the deployed data processing algorithms are suited to take care of the needs of that application. Therefore, software bundled with the sensors needs to provide for the monitoring of the calculated process variables from the measured variables according to the specific application/industry. This is supported by smart sensors, like from Rheonics, which use a combination of edge and cloud technologies to enable deep process knowhow not possible from traditional sensors.

Intuitive software ensures an easier learning curve for plant managers, operators, and engineers to interact smoothly with the software and reap the full benefits of Industry 4.0 and automation technologies, adds Dash.

AI will help simplify software

“Software will continue to simplify,” says Festo’s Balos. AI and machine learning will grow rapidly and make it easier for processors to set up equipment for sophisticated tasks. And furthermore, AI and machine learning rely on big data acquired by sensors. In the fruit industry, for example, there is a need to inspect for bruising on soft fruit. Bruises can be all shapes and colors. AI will have the ability to learn (based on vision sensor data) what to look for. AI systems will teach themselves the patterns to find damaged product. And, it all begins with sensors and the acquisition of sensor data.

But what about wanting a certain mix of “imperfections” to create a “hand-made” look, I asked Balos. For example, you wouldn’t want chocolate chip cookies to have consistently chips showing at the center, and 12-, 3-, 6-, and 9-o’clock positions, right?

“Vision and AI will certainly allow manufacturers to have this option if they want it,” says Balos. “It will allow for the variant window of pass and fail to expand, learn and adapt its way out of cookie-cutter patterns. It might sound like this technology is a bit out there within the food manufacturing world, but the reality is that this technology is more common than one might think.

“Think of your smart phone and Face ID,” adds Balos. “Each time you look at your smart phone, a pass or fail is performed to allow you to have access. Changes to your hair style and color, facial hair, makeup, sunglasses on or off etc. were never initially preprogrammed variants; they were learned and adapted to by sensors and AI technology on your phone. No matter what I look like, I am still the only one that can access my phone. Taking this and applying it to the food manufacturing is certainly doable. Perhaps the only thing missing at the moment is just some implementation creativity.”

Because of their ubiquity in just about any application you can imagine—consumer, medical or industrial—sensors cost less than they did previously; in general, they’ve become smaller, and wireless functionality provides some use cases not previously available. With AI software and built-in asset checking, today’s sensors are becoming much easier for process plants to install and use; and operators and management are able to get critical data from their processes, letting them get a leg-up on the competition. The question isn’t, “Can you afford to install sensors,” but rather is, “Can you afford not to use them and the actionable data they can provide?”

The wireless option: Extending sensors’ range

Wireless sensors have been around for some time, but should you deploy them for critical applications? “A wireless option depends on the application,” says Brooks Instrument’s Harvey. In food labs or other applications with research and development, wireless will most likely be the way of the future. If the wireless signal fails, the lab won’t lose tens of thousands of dollars in a batch due to the small volumes used in the testing environment. However, in plant production environments, hardwiring is a must for the PLC to effectively communicate with the MFC in real time for more reliability.

“As advancements such as 5G come online, communication to sensors and equipment will become increasingly wireless,” says Balos. “Powering components wirelessly in a plant, however, will remain an issue to be solved.”

Power scavenging technologies (vibration, light, etc.) are already in use, and with rapidly improving battery technology, along with faster and more reliable wireless networks, so many measurements are moving in this direction, says Wesstrom. Wireless is today mostly used for slow processes and as a tool for remote configuration and troubleshooting. Going forward, we will see increased adoption for asset health monitoring as an enabler for predictive maintenance and process optimization.

Depending on the application, deriving power from vibration, heat, flow or solar may be feasible options, says Dash. The biggest bottleneck so far in wider usage of energy harvesting technologies is the low power output of harvesters and high-power requirement of sensors. Advanced low-power sensors being created today are deriving knowhow from pacemakers and hearing aids to reduce their power budget, which makes self-powering a medium-term possibility.

One key advantage of wireless and self-powered sensors is the significant reducing in installation cost of sensors, says Dash. Today, 70-80% of the project budget for sensors goes towards installation so taking the wires out could reduce this dramatically and be the game changer that industry needs to adopt pervasive sensing.

For more information:

Allpax, a ProMach brand, www.allpax.com

Brooks Instrument, www.brooksinstrument.com

CHL Systems, www.chlsystems.com

ECS Solutions, https://ecssolutions.com/

Endress+Hauser USA, https://www.us.endress.com/en/industry-expertise/food-beverage-productivity-quality-cost

Festo, www.festo.com/us

Rheonics GmbH/Applications Engineering and Markets Development, www.rheonics.com

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