Inline NIR measurement and process control

Why Measure?

Measurement and analysis is an essential requirement for quality control in process industries. The aim is to always ensure product quality and consistency and the nearer to real-time identification of a problem and quick adjustment the better. Achieve consistency and customer loyalty will be guaranteed, helping to maintain and even increase sales revenue as the product and manufacturer's reputation grows.

On-line process measurement also provides a way of reducing waste or having to rework part manufactured batches. It prevents stopping and restarting the production line thereby conserving energy, reducing plant wear and operator cost.

Combining higher product quality with lower operating costs is the magic formula to improving profitability and rapid return on investment.

NIR technology provides a powerful non-contact instrument that can be used effectively on-line to analyse:

- Moisture
- Fats and Oils
- Protein
- Ash
- Starch
- Colour and Spec count
- Particle size
- Sugar
- Fibre
- Granulation

The most sophisticated of the online systems will have a high resolution NIR Spectrometer and colour camera within a single unit.

If this is the case it should also have the sensor and software capacity to measure and analyse both the NIR measurements and the camera data at the same time thereby achieving seamless processing without the need to stop production for separate laboratory analysis.

The key considerations for installing measurement technology are:

- Appropriate measurement parameters for the product and process
- Suitability of the technology for an industrial processing environment
- Precision and accuracy of the measurement technology to control the process
- Interface with existing process control and ERP systems
- Ease of comparison with/calibration to the reference method
- That it offers full documentation and traceability
- A fast return on investment

Ideally the laboratory will have the same instrument as the online version. This can be used to accurately define and optimise mixing ratios or conduct small scale experiments for future full scale production requirements.

Continuous measurement v random laboratory sampling

The choice between using a continuous, on-line approach or a laboratory sampling method can be dependent on a number of factors, such as costs, suitability of measurement location, or if a sample homogenisation is required to create a representative method.

Continuous, on-line measurements bring the possibility of increased efficiency through improved process control. Compared to laboratory sampling methods it can reduce the amount of waste or reworked product, operator time and plant energy.

On-line measurements are set to target levels and then given a critical high and low limit. Online analysers measure continuously many times a second and should the processing material get close to an out-of-spec reading they will signal to the automated control system for correction. This means there is no waste since there is no ‘out of spec’ product. Taking online measurement in real-time has another key benefit; it is in permanent operation and therefore is not dependent on random human intervention, which could lead to sampling errors. The system does not require specialist laboratory expertise for everyday monitoring.

On-line measurement is not without its challenges, the technology needs to be capable and the system has to be of high enough quality to meet the requirement.

Since the product is moving, the measurement technology must be fast enough to measure the product as it flows through processing and must be of sufficient speed and resolution in order to provide real-time measurements.

There must also be confidence that the measurements made are accurate, repeatable, reliable, not prone to drift and are not influenced by the ambient conditions that surround the processing plant. This might include lighting, temperature fluctuation, cleaning regimes and humidity variation.

Laboratory checking during processing uses historical sample data and measurements from small samples. It is time consuming and requires a skilled or semi skilled technician to be in attendance. Should measurements go beyond critical levels, production would need to be stopped and it would require manual adjustment to the automation system before restarting. Any correction would be likely to cause product waste and downtime.

Both on-line and laboratory systems are calibrated to the primary reference method. These calibrations might come from the laboratory itself or from an external calibration resource.

NIR measurement technology

All materials are joined together at the molecular level by bonds between the different atoms that make up the material. In certain food, constituents (such as moisture, fat or protein) these bonds can absorb energy if they are exposed to particular wavelengths of infrared radiation (light). When a substance is exposed to NIR light it absorbs an amount which is proportional to the amount of the constituent present, and reflects the rest.

In practise, on-line NIR measurements are made using an NIR sensor, instrument and camera positioned within the production line while laboratory measurements feature a similar sensor and instrument positioned above a revolving bowl containing the sample. For both techniques, the instrument contains a light source and generates the specific NIR wavelengths by using rotating optical filters to transform the light into sequential pulses of light at the desired wavelengths. This is focused onto the product being measured. By capturing the amount of light reflected back from the product and comparing it to the intensity of the original beam, the amount of the constituent present can be calculated.

NIR measurement is a powerful technique because the measured constituents offer the application technician a choice of different wavelengths which can be selected according to the required measurements.

NIR is a 'Secondary' method which must be calibrated to a customer-approved 'Primary' source calculation.

Accuracy and Reliability

This is a crucial part of adopting NIR technology for process control. Although there are numerous NIR instruments available on the market, not all are capable of delivering the performance necessary for effective system control. The following are key criteria which should be met if the system is to be capable of controlling the process for a satisfactory return on investment.

- Can the instrument continue to measure uninfluenced by changes in ambient conditions?
  (Lighting fluctuations, humidity changes, temperature variations)

- Can the system operate without sensitivity to any product variations?
  (Particle size, variations in sample height, seasonal or within-batch changes)

- What is the measurement performance?
  (accuracy, reproducibility, robustness of algorithms, absence of drift)

A combination of processing power, application engineering and the optics used in the instrumentation determine the performance levels above. Although all NIR instruments work on similar principles, it is essential that the overall optical system used within the system is capable of producing a measurement accuracy and reproducibility that will allow it to be used to control a process.

Accuracy will depend on reference methods but typically the system should achieve the levels set by the laboratory.

Production Integration

For on-line applications, the communication platform used by the system is important in terms of easy integration into the processing environment. Ideally both digital and analogue connectivity should be available to provide flexible integration into production networks and management information systems. With more and more environments making use of fieldbus industrial network protocols, fieldbus compatibility is extremely important. The emergence of Ethernet as a well accepted industrial protocol means that NIR systems should support a variety of protocols, such as Ethernet IP, PROFINET, Modbus/TCP, Profibus and DeviceNet. Ethernet connectivity enables enormous flexibility in system structures and reduces cabling and hardware required to create an optimally functioning configuration.

At the very simplest level, manual control of the process would be possible based on the measurements from the system and visible on the screen of the operator work station. For closed loop control, analogue outputs can provide signals for control and digital outputs can be used for communication with a PLC, DCS, SCADA or a PC.

Ethernet compatibility also opens up many possibilities for remote diagnostic routines, downloading of raw data for further processing and installation of updated software.

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