Hall Monitors

After streamlining management of its QA measurement results, a sensor maker finds it also has quadrupled the data points it processes.

A Hall-effect sensor is a transducer that varies its voltage output in response to a magnetic field. The sensor detects either the amplitude or the direction of the field created by a magnet. In simplest form, the sensor operates as an analog transducer directly returning a voltage. Application-specific magnetic circuits include a pole piece that concentrates the field. Using groups of sensors, the relative position of the magnet and whatever it is attached to can be deduced.

Common in automotive applications, the Hall sensor is often combined with electronic circuitry enabling integration of the sensor in applications including clutch actuation control, gear shift control, gear selection indication, clutch/brake/accelerator pedal position, air circulation damper position, and camshaft and crankshaft position.

Hall sensors are manufactured in large volume. In the automotive sector alone, many tens of millions of units per year are required worldwide. Electricfil Corp., a Tier One automotive supplier, delivers electronic and electromagnetic systems to major carmakers globally. Electricfil's mission for these systems is to improve performance in three major vehicle functions: engine, drivetrain, and energy management. These applications all use Hall sensors, which is why Electricfil manufactures its own. As a result, the company has grown into one of the world's largest makers of these devices.

A Hall-effect position sensor delivers a signal proportional to the linear displacement and/or angular position of a magnet fixed to a moving part.

Founded in 1936, Electricfil is a private company with approximately 1300 employees and with facilities around the world. One plant, in Elkmont, AL, is devoted almost exclusively to the manufacture of Hall sensors. Much of the operation is automated—with processing lines dedicated to specific model sensors. According to Shaun Morris, quality technician at the plant, "In simplified terms, our Hall sensor manufacturing process involves separating PCB boards, soldering-in the Hall cells and terminals, positioning the resulting assembly in association with magnets, and then loading these elements inside canisters. All this is accomplished via automation. A conveyor then transfers the loaded canisters to an automated potting station where epoxy resin is dispensed into the canisters." Morris continues, "The canisters next travel to a curing oven. After a cure time of about a four-and-a-half hours, the canisters move to an overmold station where the canisters and terminals are overmolded to yield a monolithic end product." From start to finish, the processes takes about 24 hours.

The sensors manufactured in Electricfil's Alabama plant typically are used in applications that require the devices to interact with rotating parts. In general, this requires an overall part size tolerance of ± 1.0 mm. An oversize sensor may interfere

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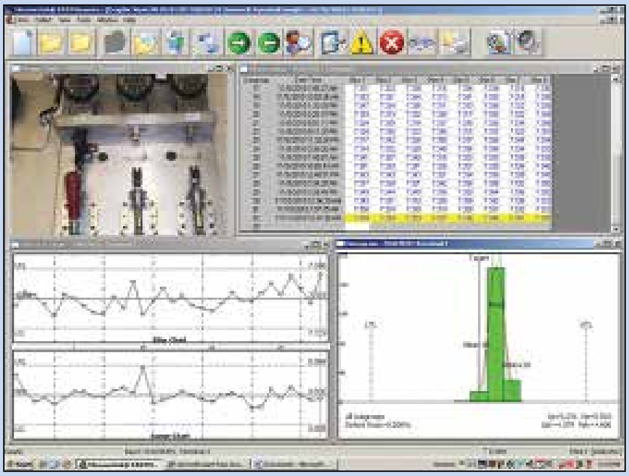
with rotating parts; if undersize, the sensor may be too far away to reliably "feel" the magnetic field. Most of the manufacturing processes involved call for dimensional tolerances ranging from ±0.25 to ±2.0 mm.

In addition to dimensional tolerances, tolerances are also established for "pull force" (measured in deca-Newtons) associated with destructive testing of the strength of soldered terminal joints, as well as tolerances for the weight (which translates to volume) of the potting material dispensed per each canister potted.

As a Tier One supplier meeting the most demanding requirements of automakers worldwide, Electricfil is a practitioner of global best practices. As such, the company considers process capability (C_{pk}) to be a key performance parameter. Accordingly, at its Alabama plant, Electricfil obtains QA measurement data from the full spectrum of manufacturing processes. Until recently, this entailed manual measurement data management. The effort was substantial. Morris explains, "As sensors move through production, units are batch-sampled at every critical point. Every point in the process has a corresponding measurement, some intended to help our customer, some to help us." Most dimensional measurements are taken with the aid of dedicated fixtures incorporating digital measuring tools—commonly digital calipers or digital indicators. The fixtures are set up so that the sample can simply be clamped in, and the tool zeroed out. Pushing a button yields the result.

Acquiring QA measurements was not a problem. Managing the resulting data, however, was. Manual data management involved plotting results on a paper control chart. Some

Navigating the MeasurLink Screen



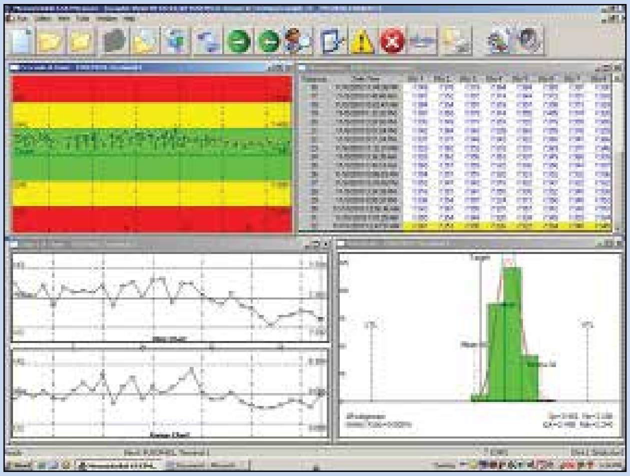
MeasurLink screen shows from top left to bottom right: Image of fixture, observations for run, X-Bar & R (sample over range), and histogram. The view setup shows a visual queue (image), the individual measurements (observation), how the sample is compared to history (X-Bar & R), and the history of the process (histogram).

Image Chart: Showing an image helps an operator/inspector see which specific measurement or part they are measuring and can act as a visual instruction. Visual information on the screen can help operators act consistently.

Observation Chart: This type of chart shows current and past measurements for each subgroup or sample (row) and the individual measurement of each observation within the subgroup (column). The first column over the observation is a time data stamp.

X-Bar and R: "X-Bar" (mean) chart tells when a change has occurred in central tendency of the sample and the "R" (range) chart shows the variation that has occurred within the sample. This type of chart is useful to see that the sample (subgroup) is within an expected average and the range of those measurements is not excessive.

Histogram: Histograms are not charts, but show the frequency distribution. Histograms are useful information, as they show the past and can show the inspector what has been happening.



The screen immediately above shows from top left to bottom right: pre-control chart, observations for run, X-bar & R (sample over range), and histogram.

Pre-Control Chart: The pre-control chart is also called a stop light chart, it shows the operator when individual measurements are good (green), when they are pushing the tolerance (yellow–warning area), and out of tolerance (red). This type of chart is easy for the operator to understand, but does not tell the operator/inspector whether a trend is occurring. Pre-control charts are a type of run chart, but not a control chart.

All other charts are the same as in the first screen.

of the information was then input to Microsoft Excel files for manipulation. Morris explains, "As production increased and the demand for QA measurement data grew, the record-keeping and analysis function had become a full-time job, a bottleneck. There had to be a better way." Morris tells what happened next, "We knew that the Mitutoyo digital measuring tools used in most inspection setups had digital outputs—we thought there should be a way of using that signal to facilitate a more efficient way of managing the acquired data. It turns out that Mitutoyo actually has software that does exactly that; it is called MeasurLink."

MeasurLink is a cross-platform software program for continuous collection, monitoring, evaluation, archiving, and transfer of QA measurement data. It supports all digital Mitutoyo measuring instruments while interface to third-party equipment is available. It also accommodates manual entry of attribute information.

Implementing MeasurLink in Morris' plant means that now QA stations have their inspection gage/fixtures connected to PCs running MeasurLink. Morris says that earlier installations had gages cable-connected to PCs, but that the latest installations utilize wireless connection for more flexible deployment.

Auto-loading QA measurement data into MeasurLink provides Electricfil with a capability that, according to Morris, is analogous to "Googling" information. He says, "Measurements are captured by the system and are available in real time. You acquire the variables from calipers and gages. You also get attributes—like Go/No Go results from terminal pull-force tests or Pass/Fail results from resin weight tests and so on. But it is possible to see much more. We can correlate specific machines, workcells, and times with production. We can parse the information by operator, station, raw material lot, job, and order numbers—all the traceability data. And we can filter data to generate any kind of histogram, view process control charts, and get the complete story on any bad measurements: Are they common to a machine? An operator? Do they correlate to tool wear or an alignment issue? These are the kinds of questions that MeasurLink answers. MeasurLink can also actively monitor parameters in real time, for example sending e-mail alerts should a process fall out of tolerance."

Electricfil QA work station for measuring Hall sensor dimensions. Station employs fixtures with integrated digital gages connected to a Mitutoyo MeasurLink measurement data management system.

Much of the operation is automated, with processing lines dedicated to specific model sensors.

And while software-based QA management has increased the data points routinely processed in the plant from around 30 to over 140, the total labor time devoted to the activity is now less than half what it had been. Morris reports, "Where manually performed QA record keeping and report generation had been a full-time job (a tedious, not very popular one), the task now is considered pleasant while much of the operator's time has been freed for other duties." ▽