GSPC© - Graphic Statistical Process Control for Foundries

The October issue of *Foundry Management and Technology* has an excellent article on the benefits of SPC and process control software for foundries. What is SPC? Put simply, after each test on a process there is a question: should I make an adjustment to the process or not? Deming, an American statistician working the government of Japan, decided there needed to be a better way to make that decision and developed some simple equations to tell if a process was in control or needed adjustment.

The second idea is that of data mining – extracting information from historical data and trends – that allows process optimization. Often we find unexpected relationships, and can then make better informed decisions.

The field of SPC has grown from those simple ideas to today's software systems that help industry run based on those mathematics. I have put such systems into many foundries in the USA, Germany, and Australia, and they certainly improve the product and reduce cost when properly used. Our statistical package named Graphic Statistical Process Control or GSPC, and that is the topic of this month's eLetter.

The GSPC system consists of 3 parts: data collection, data sharing, and data mining. First, the types of data collection that a foundry might need:

Part one: getting the data

There are four different forms of data collection: manual, semi-automatic, fully automatic, and calculated. In manual data collection, we pick up tests and observations that are not able to be automated, or that are not cost effective to automate. The issues with manual tests: accuracy and prejudice. A muller operator making adjustments to his machine is constantly feeling the sand leaving the muller. On a 15 minute cycle he grabs a sample and runs a compatibility test. Is his data "good/believable"? It turns out that it is prejudiced. He only runs the compatibility test when he has the sand "feeling" good. Further, he is actually very astute at feeling the sand, and if it is too moist, he will strike off his tube with the scraper tilted to force more sand into the tube. Likewise, if it is dry, he tilts the scraper to lift some sand out of the tube. You have been had, and your data won't show anything other than that the operator is smarter than you are. Of course there are honest hardworking technicians unlike the muller operator I ran up against at one foundry. They need to think of themselves as the unbiased reporters of the process.

The next way to collect data is to take it from a machine or instrument automatically. An example would be the spectrometer. The operator makes a few burns, rejects bad burns as needed and then accepts the final average. This method is still subject to abuse. I saw a spectrometer operator burn a sample 8 times until one burn showed enough magnesium to be barely in range, then reported that single burn. That kept the foreman happy, and fortunately for him, I was not his supervisor. The foreman did respond by making an adjustment to the process, and the metallurgist had enough of a safety factor built in that no bad castings were shipped. But again, you might never know unless safeguards are built in.

The third way to collect data is to fully automate it. Molding machines, pouring machines, sand testing machines and many other systems have ways of reporting their data. This is often a large dump of data, and you will need graphic tools to make sense of it. Most humans don't do well with a long list of numbers. But due to our excellent image recognition wiring, we can quickly understand graphic representations and catch abnormalities. A sand muller recorder can easily generate 200+ samples a day: each sample with 10+ variables. Besides recording the automated data, it is sometimes good to annotate the data with the real world problems such as sensor malfunctions that might explain deviations.

The fourth way to collect data is to calculate well understood relationships between test values and record these values as well. For example, Professor Heine documented several relationships in sand testing, including available clay and muller efficiency. Total clay minus available clay indicates the clay not yet mulled in or in the form of clay balls. Muller efficiency can suggest when to adjust the plows in the muller or replace the bottom. Likewise in melting, the alloy factor is useful for pearlitic shops in reducing alloy costs. If the chrome and manganese are on the high side, you don't need as much copper to make your hardness/strength requirement. The alloy factor tells you where you are.

Manual Data Collection

Data collection is the process of getting the test values into the computer system in the most reliable means possible. Rather than have a person dedicated to data entry, we move that function down to the person actually doing the testing. The operator then can correct errors that are obvious to him, that an office person might not recognize. Sand moisture is never 39, but 3.9 is a valid value.

From Spectrometers

One of the most important kinds of data comes from the foundry spectrometer. We have three ways of collecting it: from the results transmission when the operator presses the send button or from a special program we have to collect the burns and compare against the process limits. This program also allows automated math calculations and manual input, the semiautomatic folding in of combustion carbons/sulfurs/nitrogen, and thermal analysis data. The third method is used for some of the older spectrometers where we take actual control of the spectrometers and run it in the place of an OEM computer. Currently this mode is only available for the older Baird Spectrometer models. The other models have been installed on ARL, Spectro, OBLF and a number of other brands. Additional functionality for high alloy shops is an add-in that calculates what would be needed to correct the charge from alloys on hand.

From LECO™

The newer models of LECO include a serial port for transmitting the results. We bring that serial cable into a USB port on the spectrometer data capture computer, and hold the LECO results for the spectrometer operator to fold in to his chemistry.

From MeltLab™

The MeltLab can file directly to GSPC. It can also send a duplicate of its analysis to the Spectrometer program to allow the operator to fold these results into his chemistry.

From Hartley™ Sand Controllers

The Hartley spits out a good number of test values every few minutes. We bring the results in to a computer through a USB port (one for each Hartley), and automatically file each set of tests. The data is of course immediately shared across the plant.

From molding machines and pouring machines

These machines often have a printing function, can file to a network, or can be adapted to allow their results to be queried. At one company we not only captured the data but also reported up time, down time, molds made, time to next pattern change (based on the number of molds ordered) and helped control the bond and new sand additions based on the sand to metal ratio and the core sand per mold.

From the sand lab

Specialized calculations help calculate system efficiencies, muller efficiencies, active bond, grain fineness number, fines and many other sand related values. The operator enters in the raw data and the computer performs the calculations, files the data and shares the results across the network.

From brinell stations

The operator keys in the part number and then either enters in the diameters or, if your machine is automated, the machine transmits the diameter to the computer. The computer calculates the sample size based on AQL level, calculates the brinell number from the diameter, stores it with the batch, and finally saves the data for the lot.

From Image analyzers

Nodularity, nodule count, carbides and other tests can be captured from these instruments. Most systems are not yet friendly with other software, but we are working on a data capture with a Paxit system from LECO. I will let you know how that works out.

From Melting Operations

Here we generally capture charges, additions, weights, temperatures, temperature times and tap times. With the Charge correction module mentioned under the spectrometer, there are additional features, such as standard operating instructions, conformations and messaging between MeltDeck and the Spectrometer lab that can be saved and filed.

Part two: sharing the data in real time with SPC information

These tools are meant to be as hands-free as possible. The tests you choose to display when configuring the program display tell the operators what you consider most important. The knowledge that the superintendent is seeing this information displayed in his office, and will quickly come out on the floor if the process gets out of control, is a strong incentive to the worker to pay attention to his job.

Process Windows

This application allows 1 to 16 windows of data and graphs to be continuously displayed and updated on an individual's desktop or on a display monitor in the foundry. Each station can customize the display based on the purpose of that station or the person's responsibility within the organization. Refresh time is generally set from 15 seconds to 60 seconds. Tests can be color coded if not in control, and labeled high or low. Each window can be dedicated to a different process such as sand, furnace 1, furnace 2, pouring line 3, etc. The program automatically knows what grade of metal is in the furnace and what the specific ranges are for that metal. This view is especially helpful for the operator of a given process.

Data Screen

This function shows the last 20 samples from a selected process. It generally needs only a single mouse click or two to display. This is a reference screen that is useful for controlling trends, and seeing when recent changes to the process started. This is generally helpful for the department foreman. On starting his shift, he can see a quick review of how the process ran on the previous shift.

Melting Deck

This is a combination of data in and data out. The operator needs to be able to see lab chemistry, thermal analysis results, temperatures taken, and possibly additions required to correct the furnace or standard ladle additions for the current part. In addition, he may need to input his own observations or decisions, or just acknowledge that he did what was recommended.

Other computer systems

We have implemented data sharing with the B&L foundry system, as well as providing data export to corporate computers through real time ASCII file exchange.

Part three: Data mining

Data mining is going through thousands and tens of thousands of tests to find patterns and cause and effect (correlations). While daily reports may be generated from the stored information easily enough, it is the sharp mind of someone who understands the processes well that can use data mining to extract the hidden data on processes, and use it well.

A vendor offered a less expensive MgFeSi alloy for making ductile iron to a foundry once. The plant metallurgist agreed to a trial and ordered a 3000 pound box of the material. He further left word for his 1st shift metallurgist to see that the material was used at the 6 AM start of shift. The plant metallurgist arrived at 7:30 and sat down to mine the data from about 30 treatment ladles that had run since 6 AM. He had chemistries, percent magnesium in the alloy, LECO sulfurs, and ladle weights as well as a calculated recovery rate equation already built into his system. The math on cost versus recovery, he had to do himself. The salesman strolled in at 8 AM thinking he would be there all day for the trial only to learn that his product had already been disqualified and pulled from the process. The process required more of his “cheap” product to maintain magnesium levels due to poor recovery, and it was not only not cost effective, but generated more slag. No use running all shift when the facts were so quickly clear.

One shift had significantly better magnesium recovery than the other two shifts by about $25,000 per year. The corrective action was just to pay the better alloy tech two hours of overtime. He came in an hour early and stayed an hour late to train his two counterparts on his “better” way of adding alloys. Later checking showed the savings had spread to all shifts, and the company made itself $75,000/year.

A pouring line showed a sudden $500 jump in pouring scrap that was not reflected on the other pouring line or on the other shifts. When the information was shown to the pouring foremen, he acknowledged that he needed to spend more time with his new pourer, and in the following days the problem went away.

Crush scrap was ever increasing on one part on one molding line (cope and drag) and on all shifts to over 2%. Since it was all shifts and only one line, but on a part that was high in the cope, a people problem and a pattern problem could be ruled out – it seemed to be a machine problem. A meeting with the maintenance superintendent with graphs and data in hand led to some high speed video on the cope closer. With proof, the funds were made available and the cope closer was rebuilt and stiffened, reducing the crush back to 0.2%.

Data mining requires both a sharp person and the tools to make sure investigations are quick and mathematically sound, and not just one person's guess or opinion. The Graphic Analysis application allows this to happen. This is a tool for the superintendent or manager who understands the process and can ask the right questions. It is not for some young graduate who thinks he has found something when the sand moisture and the clay level correlate.

You start by picking a process or a group of related processes, and then putting conditions such as a date range, a part number, or a certain test value range to be searched for. Conditional tests include: in the range, not in the range, less than, greater than, equal to, not equal to, and Boolean operators such as "*and"* and "*or*". So you might ask for all the heats where the silicon was out of range on the high side, or just all the heats that were "out of range for silicon or manganese, or chrome, or copper on second shift between 1 August and 1 November 2010". If you have other kinds of analysis tools, you can go to the data page and copy the data set found by the search and then paste it into Microsoft Excel or some other program.

The data is structured to be a table of rows of test samples, and columns of test results. You set your system up to hold as many samples as you want. The limit is 2 billion samples, but practically speaking 100,000 to 200,000 samples should be plenty. The small model system stores up to 60 test variables per test sample and a larger system that stores up to 120 variables per sample per data base. Upper limit on the total number of data bases is currently 600, but no foundry goes much above 10 or 20 databases. Part numbers are limited to 6,000, but most foundries stop somewhere around 1,000. The date recall system is limited to 3 years in the small system, and 10 years in the large system. You can and should always archive the databases into yearly files. These databases are considerably larger than Excel can handle.

The system is currently running in a diverse group of foundries with different needs: Victaulic, Quality Castings, Bremen, Neenah, GM Defiance, Neunkirchen (formerly Intermet), Dalton-Warsaw, and Northern Iron, to name a few. In each case, the extent of data collection and the sophistication were customized to the foundry's needs and wants. The system takes a few months to install and customize, but has been up and running since the mid–80s at Victaulic, with the others following later. If you think your foundry might be ready for an excellent tool for process control, let us know.