



Multivariate Analytics: The Secret to Better Batch Processes

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Creating Consistency in Batch Processes

The highly transient, dynamic nature of batch processing poses significant challenges to consistency. Many manufacturers struggle to keep up with demand due to variations in yield or throughput; others suffer losses when their products fail to meet customer or regulatory specifications.

The continuous manufacturing world has benefited from model-based control systems for decades, honing the ability to detect problems early and take corrective action to compensate. Holding processes within an optimal steady state has allowed manufacturers to maximize profit. Until recently, however, the ability to monitor and analyze the variables in a batch process to deliver the same types of insight and prescriptive action has been elusive. It has been difficult to effectively model the non-linearities and changing relationships inherent in the batch world. Organizations lacked a way to effectively organize and analyze the

vast amounts of data they have collected in order to make process improvements and correct the problems behind bad batches. In many cases, the adjustment itself can be readily implemented: sifting through data to accurately isolate the root cause of the problem is the true challenge.

Technology has at last evolved to accommodate the complexity of batch processing. These systems monitor multivariate data constantly to predict whether a batch will meet goals; if the system detects drift, it recommends corrective action such as adjusting reaction times or temperature to ensure the batch remains within specification. Multivariate analytics quickly deliver insights that can increase batch quality, yield and throughput. Some manufacturers have already realized 10 percent increases in production and 50 percent reduction in quality variability through the use of such tools.

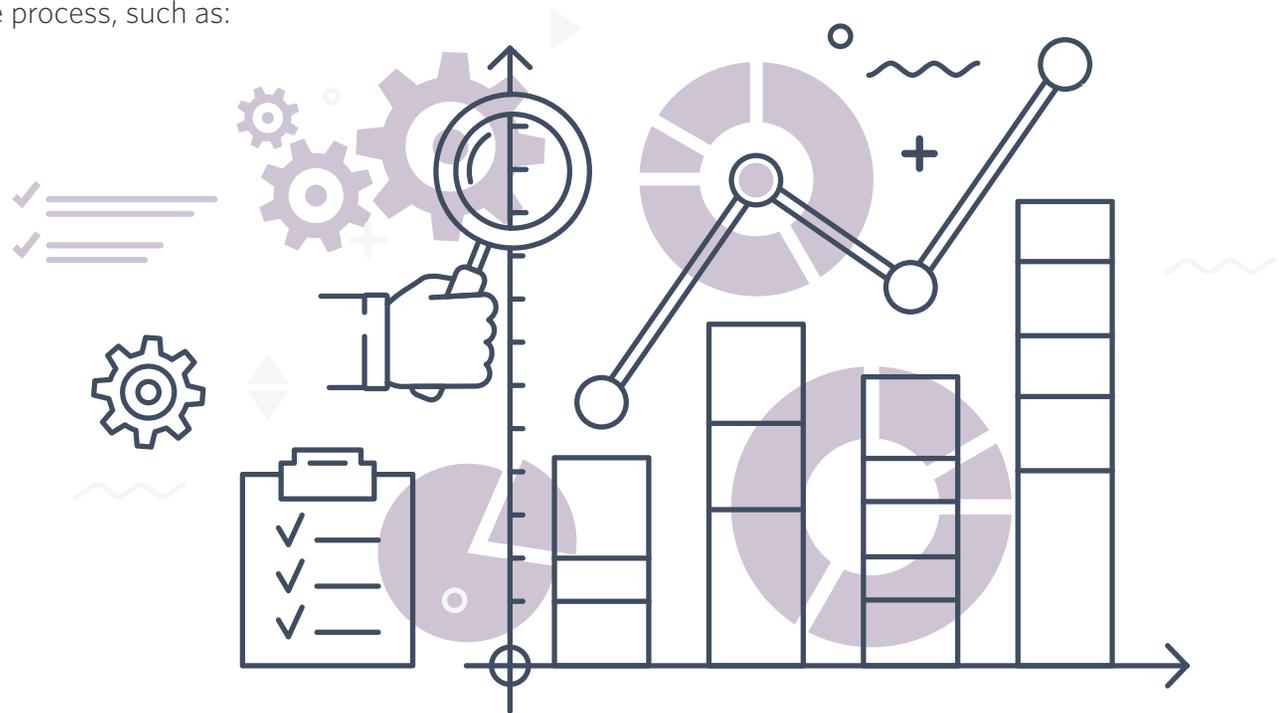
The tools that can support the process industry in sifting through the data are out there — but until recently have gained limited adoption. A recent PwC study found that the process industries, consumer goods, and industrial manufacturing sectors lag in digital innovation—they have been slow to adopt technologies that support better decision-making and efficiency enhancements. Conversely, they would benefit from the latest analytical technologies that empower organizations to make the best use of Big Data: “Machine intelligence can handle high volumes of disparate structured and unstructured data, managing and massaging it to produce analyses, assessments, and applications.”¹ The time is right for the process industries to take advantage of this technology, which is already delivering proven results. The good news is that initiatives such as Industry 4.0, IIoT and Smart Manufacturing demonstrate a growing recognition of the value of advanced analytics and a pursuit of technology that delivers insight to drive operational improvements.

Understanding What Impacts the Batch

Ensuring consistency with batch processes is no easy task. Sometimes processes require substantial changes. More often, though, manufacturers have the core recipe well established; they know the raw materials, relative amounts of those materials and suitable processing conditions to create the desired product. They may also have some understanding of how environmental conditions affect the batch process. But even with the right recipe and the right plan, inconsistencies creep into the process, such as:

- variations in raw material properties
- small changes in procedure
- changing environmental conditions

Prevailing conditions and operating choices influence the outcome of each batch. Small variations can steer a batch off course — but without understanding those exact variances, operators can't easily forecast the outcome or effectively compensate.





Making Sense of Mountains of Data

Analyzing raw materials, operating conditions and environmental influences to determine which variables, in what combinations, impact quality and production can seem daunting — collecting, organizing and processing all that data requires dedicated infrastructure and advanced analytics. Many organizations capture the correct data but fall short of extracting meaningful insights. They stand to benefit greatly from embracing advanced analytical tools that effectively extract insight from the data they have collected.

Half the battle is getting data stored and organized in a way that makes it easy to discover answers to the types of questions you want to ask about your batch process. Why does it behave well on some days and poorly on others? Data historians and production record managers (PRM) are an important part of the solution.

Historians collect process data from many systems and provide a data source for advanced analytics. However, as a recent *IIoT for Engineers* article pointed out, “process historian tools are not ideal for automating data analysis or search queries. They are ‘write’ optimized and not ‘read/analytics’ optimized.”² In support of this need, PRMs can assist in extracting and organizing the relevant data for analysis by allowing process engineers to quickly identify the batch start and end times as well as key transition points for the subset of batches matching specific search criteria. These criteria can include date range, product grade, quality assurance metrics, and so on. Once the PRM finds the matching batches it will slice out the associated historical data and package it in a way that is ready for analysis.

Even with sophisticated tools gathering and organizing key data, a challenging task remains: analysis to determine how best to adjust the batch process for each variable. With many data visualization and analysis techniques it may still be a daunting challenge for engineers and analysts to sift through all the data patterns to identify the root cause of a problem — and an appropriate solution — in a timeframe that ensures ongoing profitable production.

Finding the Cause Behind Five Years of Failures

A leading herbicide producer was suffering huge losses — more than half their batches were out of spec. The material couldn’t be reworked, resulting in high disposal costs as well as the costs associated with wasted production. Convinced the problem was related to the chemical composition of the raw materials, the company invested hundreds of thousands of dollars in an online spectrometer to measure every batch. Over five years, the plant amassed large volumes of data with no improvement in batch consistency.

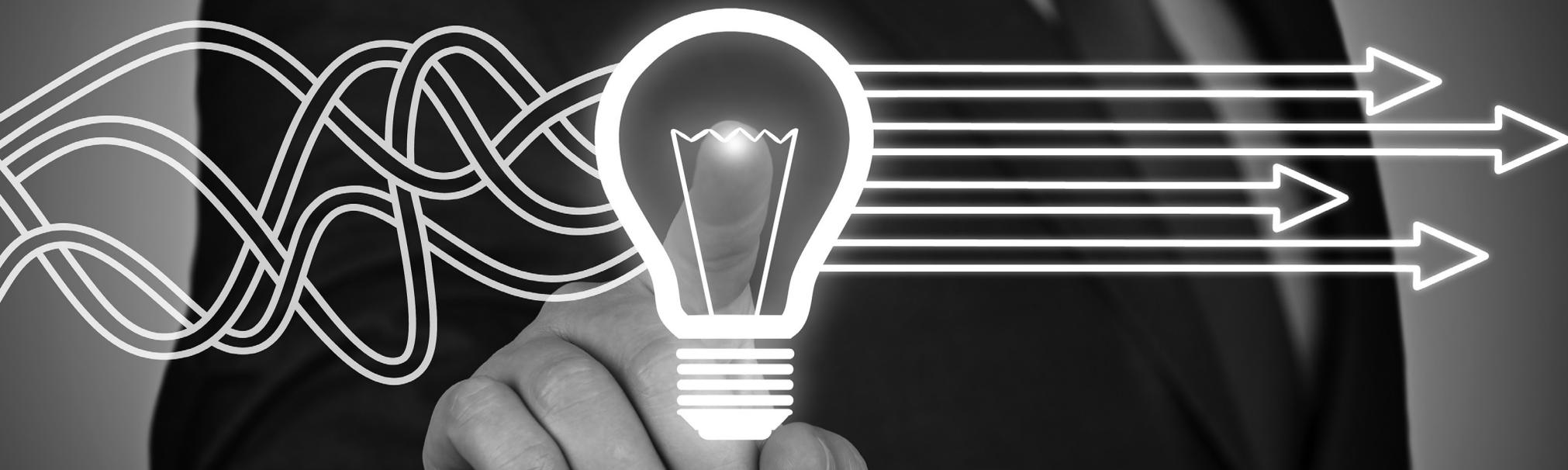
Batch multivariate analytics technology was able to identify the cause of the problem and recommend corrective action in a matter of weeks. Analysis revealed that poor quality batches occurred due to a variance in operating procedure rather than problems with raw materials. To start the batch, a reactor/dryer vessel is loaded with a granular material containing solvent. Then heat is applied through a jacket to evaporate the solvent and produce some chemical reactions. The batch multivariate analysis revealed that poor product quality was associated with batches where too much material was loaded into the reactor and/or heated up too slowly. When presented with this discovery, the plant personnel realized that under these conditions the material was staying at high temperature for protracted periods of time, enabling certain chemical reactions that produced unwanted byproducts. These byproducts rendered the product out of specification and unusable.

Once the analysis uncovered the cause of the problem, the fix was simple: load less material per batch and heat it fast to drive off solvent quickly and then cool the material down again early. This minimizes the

time spent at high temperature, limiting the opportunity for byproduct formation. This simple change in operating policy solved the production problem.

Extract Meaningful Insight from Batch Process Data

Using all the available data on raw material properties, environmental conditions, and variations in the execution of operating policy, multivariate analytics can assess whether or not a batch will meet yield targets, product quality and expected production throughput. If calculations reveal that the batch is deviating, the tool provides diagnostic information that helps operating personnel quickly triangulate into the root cause, enabling informed and timely corrective action. Corrective action can also be automated through calculation of in-flight adjustments to key recipe decisions such as amount and timing of an ingredient addition, increase or decrease in temperature, change in time



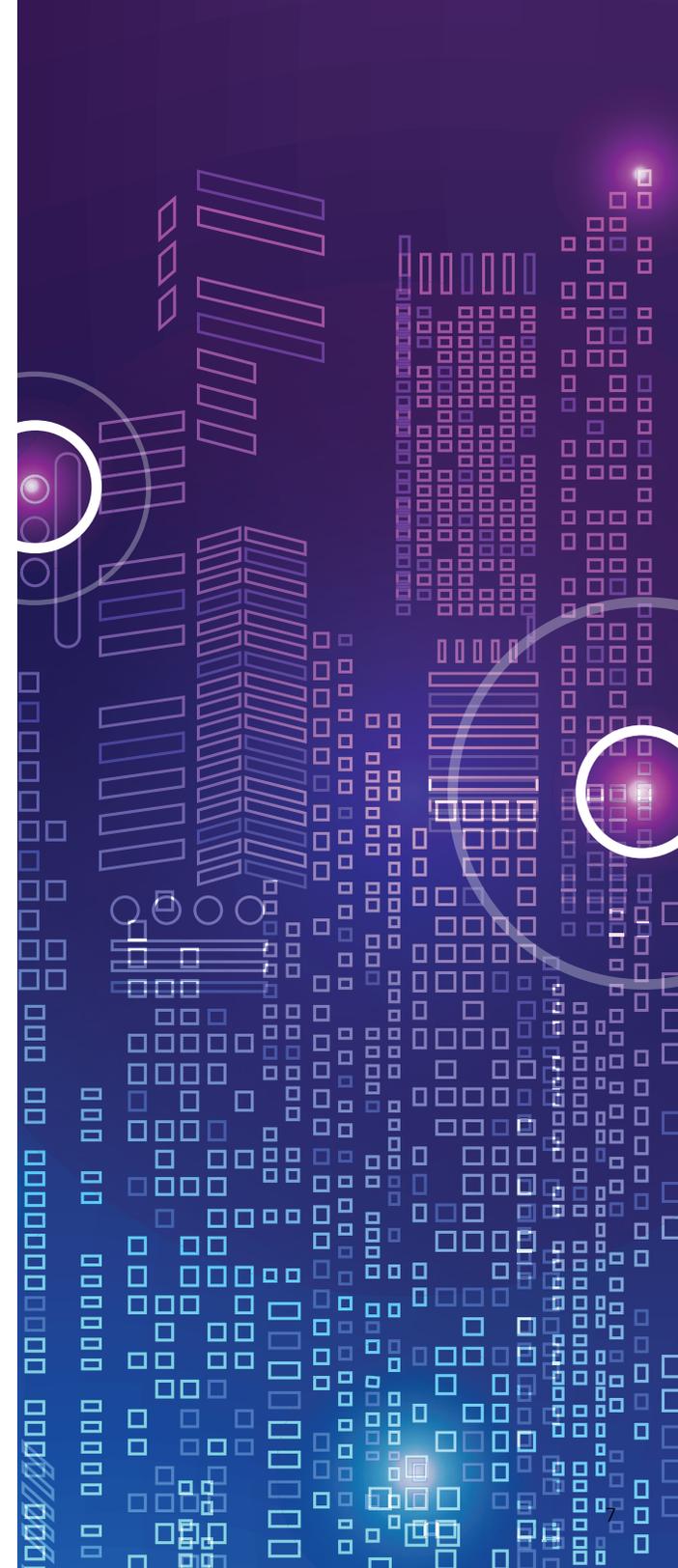
allowed for current batch execution step and so on. These timely, even automated, interventions steer batch outcomes consistently to higher yield, quality and throughput.

Multivariate analytics tools quickly make sense of the information collected in disparate systems, connecting the dots to identify patterns and prescribe process corrections. An *Efficient Plant* article titled “Disrupting the Future” calls out that “the emergence of smart-data discovery capabilities, machine learning, and the automation of the entire analytics workflow is enabling organizations to handle vast amounts of information.”³ Batch processing is ripe for this type of analysis.

Examining batch-specific workflows, multivariate data analysis can uncover all of the key patterns among variables, how these patterns change through the duration or progression of the batch and ultimately how those changes affect batch outcomes. Optimal process adjustments at key points through batch evolution are the difference between a batch that stays on course and one that drifts off spec. Trying to find and optimize these adjustments in reams of industrial data can be challenging. Multivariate analysis allows process engineers to find the real signals and separate them from the noise, examining the model findings in an intuitive way. The latest tools allow engineers to interact with the data quickly to draw immediately meaningful conclusions.

Increase Productivity, Quality and Profit

Optimizing batch processes with multivariate analytics offers tremendous value. Whether producing fewer, high value batches or many lower value batches, software that quickly diagnoses deviating batches to enable informed and timely intervention pays for itself many times over. The industries that benefit from this technology include specialty chemicals, pharmaceuticals, batch polymers, bioprocessing and food.





One **food manufacturer** used a batch APC system to control batch fryers and realized a 50 percent reduction in quality variability. In addition to helping them further advance their premium supplier status, the technology also delivered a double-digit boost in throughput — adding more than enough on-specification capacity to offset the cost of the technology for their growing brand.

A **large chemical company** wanted to control particle diameter in an emulsion polymer. Around 10 percent of the batches produced fell outside the specification limits. Analysis showed parts-per-million impurities in the raw materials affected the number of nucleated particles during the nucleation phase, which in turn affected the rate at which the particles grew during the growth phase. However, the plant had always run each batch for exactly the same duration. This resulted in the average

particle diameter varying from batch to batch in response to the number of nucleated particles and associated particle growth rate. A batch multivariate model was able to infer the rate of particle growth and then recommend an adjustment to the batch duration so that the particles grew to the target diameter: slower growth requires longer batches and vice versa. As a result, the batch-to-batch variability in particle diameter decreased by 50 percent, resulting in zero off-spec batches.



Streamline the Collection, Organization and Analysis of Batch Data

Increasingly, organizations are buying into the value of advanced data analytics. In the C-suite there's talk of Industry 4.0, IIoT and Smart Manufacturing, spurring enterprise-wide initiatives to make better use of data and apply advanced analytics.

As the first step, manufacturers should focus on automatically capturing all relevant batch data and making it immediately available for analysis. Plant historians, LIMS systems and PRMs ensure plants can reliably collect, organize and retrieve relevant data. Multivariate batch analytics can then efficiently mine the large volumes of data to extract actionable insights on how to improve the process. Combining a robust, scalable and highly usable data infrastructure with modern multivariate batch analytics can enable manufacturers to achieve a step change in their ability to learn about and improve their batch processes. The prize is an industry-leading market position gained through premium product quality and high production efficiency.

A natural response for some is that using more advanced mathematical methods is complicated. However, trying to look at complex data without advanced tools can be frustrating, slow and unfruitful. Manual analysis and basic data analytics can't quickly hone in on the most relevant information buried in the data — people can be blinded or overwhelmed by the sheer volume of information. Without the power of multivariate batch analysis, subtle data patterns with big impact on outcomes can be hard to identify; the needle remains buried in the haystack.

Data analytical tools have evolved, no longer requiring users to have special skills. Intuitive user interfaces make it easy for process engineers, control engineers and data analysts to perform complex analysis quickly. Users can become proficient with just a few days of training.





Optimize Batch Processes with Multivariate Analytics

Multivariate batch analytics empower manufacturers to optimize their batch processes and drive greater profit. With the insight these tools provide, process and control engineers can move beyond a reactive response to production problems — learning from the data, they can adjust processes to increase throughput, improve yield and enhance quality on an ongoing basis.

In the future plants will be able to automatically control batch production, allowing advanced process control systems to make in-flight adjustments to the batch execution to ensure desired outcomes. Tapping into the power of multivariate analytics for batch processing can reduce waste, increase high quality production and inform new product development. Such tools offer a competitive advantage that manufacturers who want to stay ahead of their industry cannot ignore.

Aspen Technology offers a comprehensive suite of tools to effectively collect, organize and analyze batch process data, empowering a step change in your organization's ability to take hold of the promises of Industry 4.0.

¹"Global Operations Study 2018: Digital Champions." PwC. 2018.

²"Use process analytics efficiently." Bert Baeck. *IIoT for Engineers*, September 2018.

³"Disrupting the Future." Gary L. Parr. *Efficient Plant*. March 2018.

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