ALTAIR

GUIDE TO PROCESS MANUFACTURING

INTRODUCTION

Any industry that produces bulk quantities of goods such as pharmaceuticals, food, chemicals, or cosmetics, is seeking to produce these products consistently while reducing cost factors like waste and down time. Due to the nature of process manufacturing, multiple ingredients are combined to be mixed, coated, or sorted, so understanding the behavior of these processes is of paramount importance for manufacturers. Through the use of simulation modeling and Smart Manufacturing principles, manufacturers are now able to optimize these processes, leading to greater productivity and profitability.

In this guide, we explore the technologies and advances that smart manufacturing and industry 4.0 have to offer to the process manufacturing industry, as well as how simulation-based solutions can accelerate design, process efficiency, and production.

Process Manufacturing

Simulation, data analytics, and HPC is where intrepid companies gain an edge and stand out from the crowd. Deploying an effective strategy in these domains is key to a modernized and sustainable process manufacturing strategy.

USING SIMULATION IN PROCESS MANUFACTURING

Simulation is increasingly used by engineers and scientists during research, development, and through to process evaluation to improve product quality and time to market. The use of computer simulation in process manufacturing industries can help improve the understanding of processes and provide key insight into operations otherwise difficult or impossible to obtain through empirical data and physical testing. Simulation insights can offer increased process efficiency and help drive product and process innovation.

Array of Industries that Come Under the Umbrella of Process Manufacturing

Food and Beverages

- Edible Oil
- Dairy
- Meat & Poultry
- Packaged & Processed Foods
- Organic Food
- Confectionery
- Fresh Produce
- Beer
- Pet Food

Paints and Coatings

- Enamel
- Primer
- Putties
- Protective Coating
- Wood Finishes
- Powder Coating
- Wall Paints
- Automotive Paints

Chemicals

- Ink
- Paper and Packaging
- Pigments and Dyes
- Fuels and Lubricants
- Polyurethane
- Foundry
- Cement
- Plastics

Pharmaceuticals

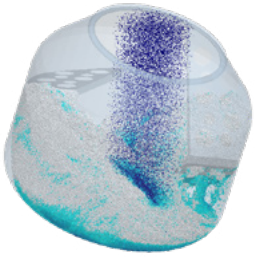
- Nutraceuticals
- Biotech
- API
- Herbals
- Injectionable
- Veterinary
- Medical Devices

Personal Care and Cosmetics

- Fragrance
- Skin
- Injectables
- Hair Cares

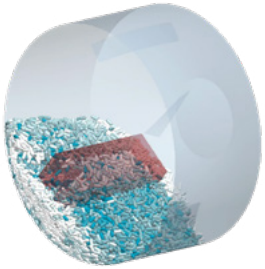
APPLICATIONS OF DISCRETE ELEMENT MODELING IN PROCESS MANUFACTURING

One simulation tool for process manufacturing is discrete element modeling (DEM). This is a particle-scale numerical method that enables engineers to model the behavior of granular materials such as tablets, powders, and aggregates. DEM is a valuable predictive tool for simulating and optimizing a range of processes including mixing, coating, die filling and spreading. It provides key information on processes otherwise difficult or sometimes impossible to obtain using experiments.

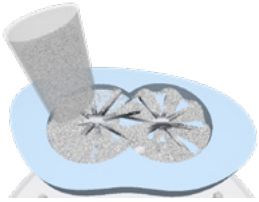


Mixing – DEM tools like Altair EDEM™ can simulate the mixing process of powders, tablets, aggregates, and other granular materials. This provides fundamental information such as the particle velocities and trajectories and allows for the prediction of mixing and segregation rates as well as the identification of dead zones.

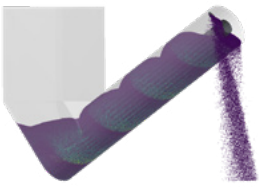
Many mixing processes involve fluids, making it necessary to couple DEM with computational fluid dynamics (CFD). This provides an accurate representation of the interaction between fluid and granular material.



Coating – Coating uniformity is critical for processes such as tablet coating and certain food coatings. With EDEM, it is possible to obtain key parameters such as the residence time of the tablets under the coating spray, intra-tablet coating variability, and tablet velocities pattern. In fact, many of these are difficult or even impossible to get by physical experimentation. EDEM can also be used to investigate how the shape of a tablet, the drum speed, and the fill level are influencing the coating process.



Die Filling – Die filling is a common process in many industries including pharmaceuticals and powder metallurgy. A consistent and uniform process is very important as it influences the quality of the final product or component. EDEM can be used to assess the effect of various key parameters, understand micro-macro dynamics of particles inside the feed frame, and visualize segregation inside the feed frame and during die filling.



Conveying – Screw conveyors are frequently used in a range of industries to transport granular materials. With EDEM, companies can analyze the flow rate of different materials in the conveyor and get information on the forces and wear on equipment. EDEM can be used to predict any risk of blockages, assess the mixing and compression of the material, and obtain information on system capacity and power requirements.

ADDITIONAL SIMULATION SOFTWARE IN THE PROCESS MANUFACTURER'S TOOLBOX

System Modeling

Within process manufacturing, machines are an integral part of the production process, performing a range of increasingly complex functions and tasks. The combination of mechanical structures and mechanisms with sensors, actuators, and computing power has changed product performance expectations. Understanding how these systems operate is highly important.

New process manufacturing systems require full-system simulation to drive the mechanical, electrical, and control requirements necessary to deliver outstanding customer experiences. Altair math and system design products include concept studies, control design, multi-domain system performance optimization, controller implementation, and testing.

Altair Activate® provides an open integration platform for modeling, simulating, and optimizing multi-disciplinary systems-of-systems using inherent 1D block diagrams. Users have the option to include subsystem models either from Altair's 3D tools, such as Altair MotionSolve™ and Altair Flux™, or from 3rd-party tools. Models can also be imported from Simulink®.

Structural Simulation

Simulation-driven design deployed early in development is proven to significantly reduce expensive prototype-builds and physical testing. Altair Inspire™ easily generates dynamic motion simulations of complex mechanisms, automatically identifying contacts, joints, springs, and dampers. Forces obtained from a motion analysis are automatically applied as inputs to a structural analysis or optimization and can be used to determine initial requirements for motors and actuators.

Computational Fluid Dynamics (CFD)

The range of CFD applications encountered in process manufacturing varies tremendously depending on the industry. The solutions often involve single and multi-phase flows, incompressible and compressible flows, and isothermal and non-isothermal problems. Multiphysics are common, involving complex interactions between fluids and moving parts. For example, in food processing applications, you may want to look at convective heat transfer with hot/cold air during the coating process. Altair AcuSolve™ provides powerful fluid flow analysis capabilities which can be coupled with EDEM to execute multiphysics simulation.

Multi-body Dynamics Simulation

By considering realistic motion-induced loads and environmental effects, engineers and designers can be confident that their products, when made and operated, will perform reliably, meet durability requirements, and not vibrate excessively or fail from fatigue.

As a tool for simulating ever-smarter products as systems-of-systems, MotionSolve facilitates multi-disciplinary collaboration across product development teams. For example, it enables the combined simulation of subsystems for mechanical plants together with those for electrical/electronic subsystems (e.g., controllers).

Machine Building Tools

Today's machine builders are creating products that are increasingly intelligent to differentiate them in a crowded marketplace and to meet the production demands of their clients. This shift is facilitated by highly accurate machine simulation technologies which can allow companies to test concepts, tune productivity limits, take advantage of predictive maintenance capabilities, and more.

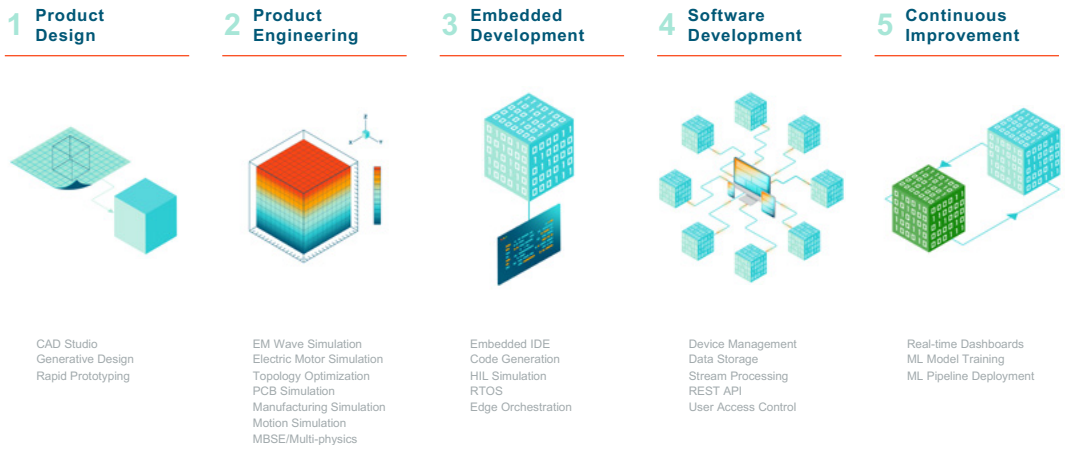
Quality in the development process. With simulations solutions from Altair, product quality is increased through more accurate and predictive virtual models, enabling the identification of cause-effect relationships and load determination in the simulation model. Synergies are also created through closer cooperation with the help of straightforward linkage of mechatronic sub-models to a machine simulation of the overall system.

Technical Risk Reduction. Through a consistent understanding of the overall system thanks to easy-to-use connections between the models of mechanical design, drive development, and control technology, users can achieve higher cycle rates without sacrificing quality or reliability, reducing technical risks in contracts with 3D simulation and system-of-systems considerations.

Closer to Reality. By create more accurate 3D simulations of machine elements for load determination for drive and control, it is possible to optimize their interaction to enhance machine operation and minimize downtime. Vibration problems can be represented and eliminated comprehensively, drives can be designed process-dependent, control concepts can be laid out, and control parameters can be optimized.

Build Improved Next Generation Equipment. Design and engineer better versions of equipment using performance data and the real life environmental and loading conditions of the current equipment in operation.

Smart Product Development. Building intelligent machines requires an integrated approach, accounting for communication to and from the equipment for analysis and control, as well as structural, EMI/EMC, cooling, and edge connectivity aspects of the development. A combination of concept design, engineering, embedded based control systems, data acquisition and control looping, and data analytics are therefore all necessary to complete the intelligence loop.



DIGITAL TWIN AND SIMULATION SOFTWARE

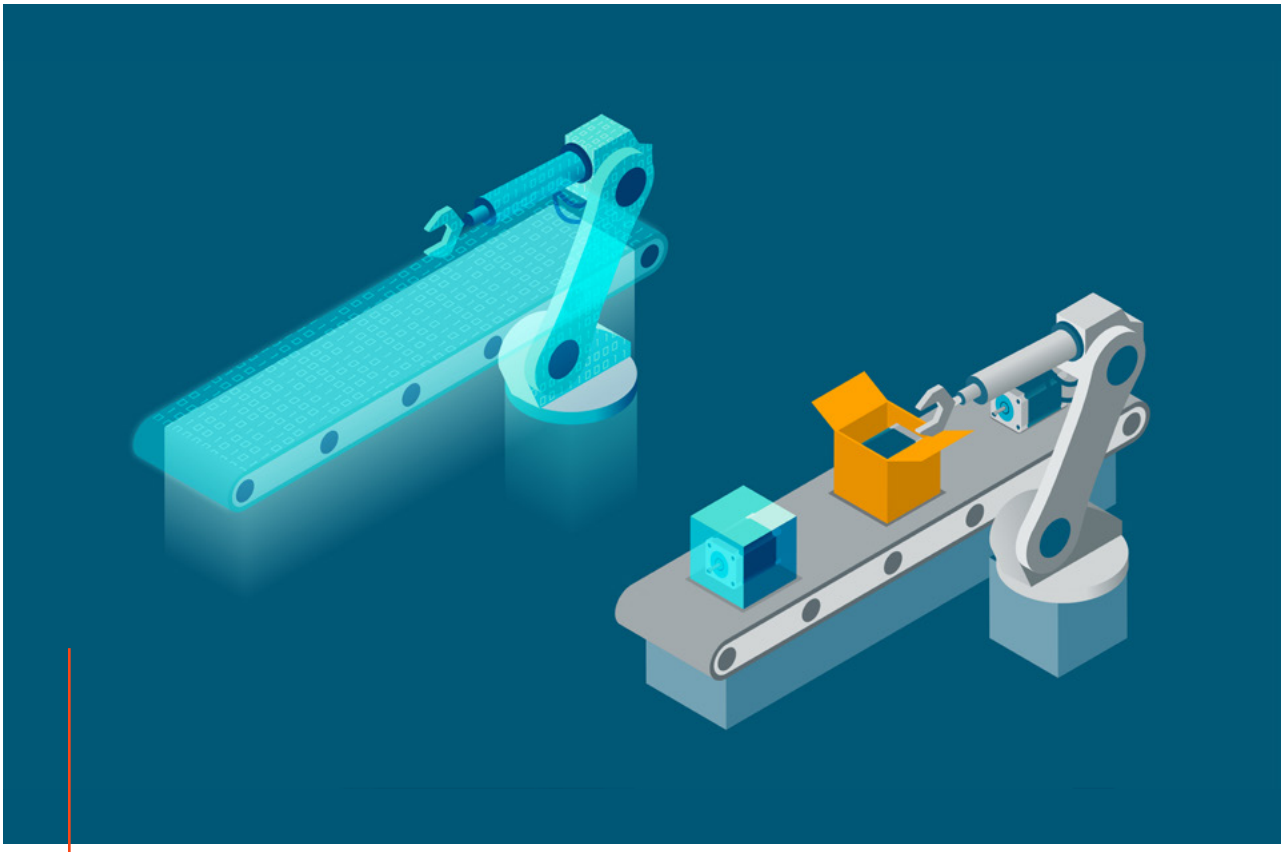
Digital twins help organizations optimize product performance, gain visibility into the in-service life of a product, know when and where to perform predictive maintenance, and understand how to extend a product's remaining useful life (RUL). This can be an incredibly useful tool in process manufacturing, especially considering the demanding methods such as continuous manufacturing or the potential cost savings of implementing such a tool.

Within process manufacturing, numerical modeling software such as EDEM can be incorporated into the digital twin model to simulate processes such as mixing and coating. Data collected from existing processes can be sampled and compared to the optimal parameters in a simulated model to identify possible failures and issues, becoming an integral part of the decision-making process when considering how to improve or accelerate existing methods.

The same principle could be applied to CFD and finite element analysis (FEA) simulations: collecting data from 'real-world' processes and comparing it to simulated representations that require CFD or FEA to be fully understood.

A combination of physics-driven and data-driven digital twins provide an equipment manufacturer, as well as the operations manager, a greater insight and control over the process, enabling fine tuning of equipment and process parameters, ensures timely intervention for maintenance, and has an indirect impact on production and inventory costs. This, therefore, helps the equipment designers engineer a better next version of the product.

Visit Webpage - Learn more about Altair's digital twin platform.



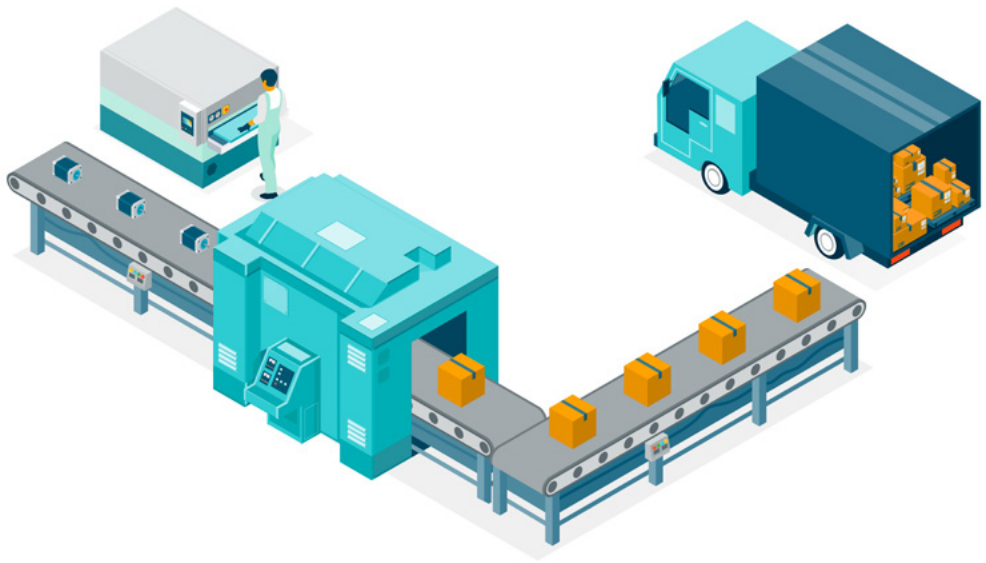
“Applying digital twin technology drives system understanding for better design, higher operational efficiency and reduced implementation risks.”

Thomas Van Hlabeke – MX3D, Project Lead, MX3D,
https://www.youtube.com/watch?v=IKiAGzS_MCk

CONTINUOUS MANUFACTURING – GOING BATCH-LESS

Continuous manufacturing is a term used to describe the constant production and processing of a material or mixture of materials. While industries such as chemical manufacturing have adopted this method of production, pharmaceutical manufacturers have yet to employ this industry wide. Due to globalized and volatile markets, reduction of time to market is as essential as safe, resource-efficient, and flexible production, driving more process manufacturers to investigate this production method.

Given the segmented nature of batch processing, producing products in this way takes more time, leading to less output and less profit. There are of course advantages to batch processing such as less workforce requirements and less costly equipment, however, given that the pharmaceutical industry loses about $50 billion a year because of the general inefficiencies of batch processing, continuous manufacturing can be a potential solution to that problem.



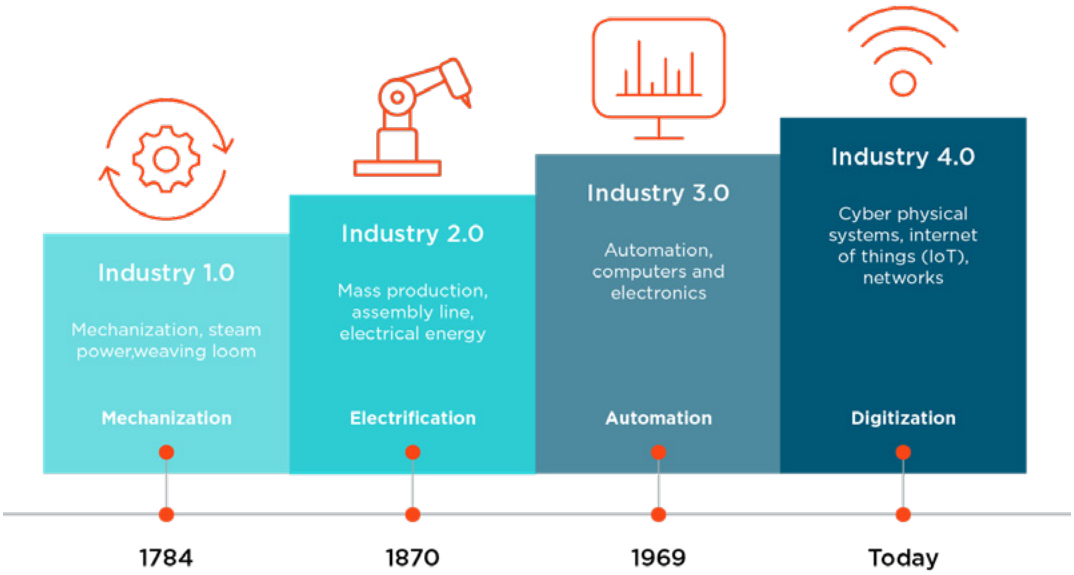
With continuous manufacturing in mind, the emphasis to get it right the first time is a driving force of the movement, and so the reliance on accurate simulation models and smart manufacturing technologies is higher. An ‘always on’ approach leads to advantages such as a higher product yield and increased profits, but ensuring the system in place will function correctly over long stretches of time requires a thorough knowledge of the demands that system will face.

Continuous monitoring and fine tuning of the process and equipment in operation is therefore critical to ensure minimal system breakdowns and consistent product quality.

SMART MANUFACTURING AND INDUSTRY 4.0

Industry 4.0 has become synonymous with the future of manufacturing, and many process manufacturing leaders are at the forefront of this movement. But what is Industry 4.0 and why is it relevant?

Industry 4.0 refers to the fourth industrial revolution in manufacturing. Ever since the first industrial revolution and the use of steam-powered machinery to aid the manufacturing processes, industrial advancements have been on a slow but steady rise, taking advantage of the technology of that time. With intelligent technology now so ubiquitous around the globe, Industry 4.0 and the components involved with this shift forward lead to smarter, more efficient manufacturing processes.



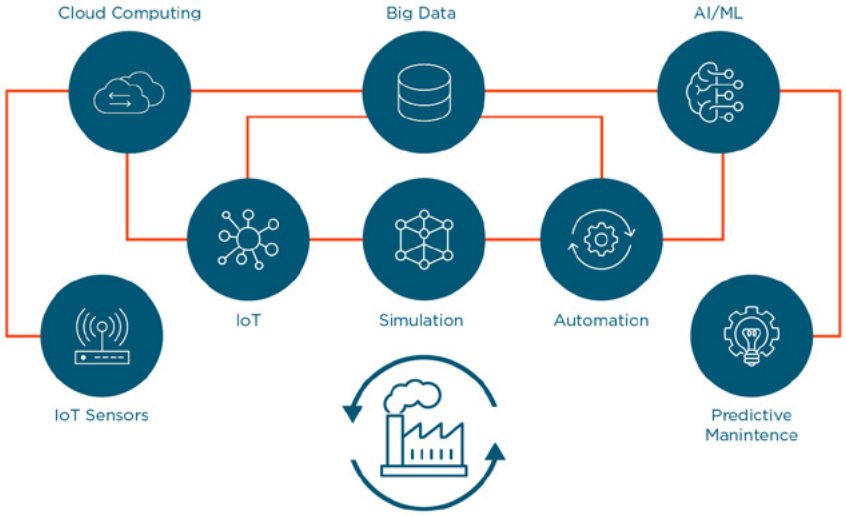
While the use of smarter, more powerful technologies allows Industry 4.0 to become a reality, the computational power needed to run detailed simulations and process large sets of data is higher than ever before. In the data center and in the cloud, Altair's industry-leading HPC tools let you orchestrate, visualize, optimize, and analyze your most demanding workloads.

Important for the success of implementing Industry 4.0 is the availability of data related to the right parameters in or near real-time to analyze and react to the situation. Connectivity is at the core of data extraction and control, increasing in complexity when the number of equipment and devices increase and are spread across geographies. Altair's IoT Application allows you to undertake device management, edge orchestration, data storage, data streaming, dashboard visualizations, as well as custom application builds to get the most out of your Industry 4.0 initiatives.

"By 2023, the smart manufacturing market will grow to approximately 480 billion U.S. dollars."

NordCloud, "Industry 4.0 7 Steps To Implement Smart Manufacturing", https://www2.nordcloud.com/ai-in-mfi

Equally necessary is to have solutions and platforms that use an open architecture to allow easy integration with existing or legacy systems and technologies, protecting investment and reducing upgrade cost. A modular approach ensures that investment is specific to what is required rather than a complete system over-haul. Altair's open platform philosophy is at the helm of ensuring all this and more, extending to Altair's IoT applications for smart manufacturing as much as the other areas of product design and engineering.



Smart Factory - Continuous Intelligence

LEVERAGING DATA IN PROCESS MANUFACTURING

Implementing this new way of working is not without its challenges. An important consideration is how to leverage the massive amounts of data produced by both simulation and in-service process monitoring. Here are three ways in which manufacturers can leverage data analytics for process manufacturing.

1. Preventative vs. Predictive Maintenance – The effects of downtime (whether scheduled or not) has an obvious impact on process manufacturing and when it comes to the maintenance of equipment, a preventative approach is usually taken. Based on experience and historical performance, companies schedule service on a regular basis because of wear and tear that leads to downtime if unattended.

With a smart manufacturing approach, companies can rely on data streamed from equipment to build an accurate digital twin model, helping them to predict when maintenance is required to keep that machine running, leading to a more efficient maintenance process and an increase in uptime with minimum costs. For example, the use of vibration sensors provides an alert when motors, bearings, or other equipment begin to falter and require maintenance

2. Quality Costs – A high-profile warranty cost is not just something that can damage a company's profits and margins; the company's reputation is also at risk. Currently the approach to addressing and reducing warranty claims is to conduct a root cause analysis after the event – an inefficient process than does not solve the problem.

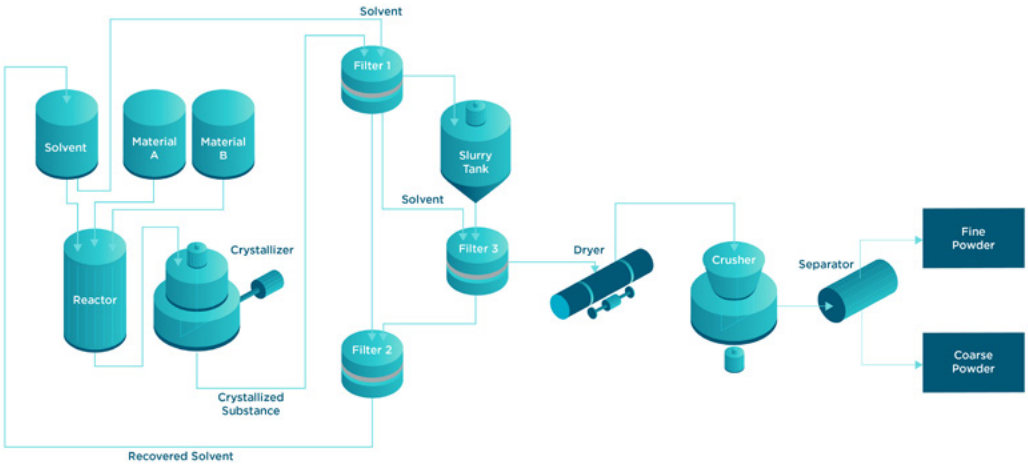
In an ideal world, process manufacturers would know where and when their products fail and prevent these from completing the cycle and reaching the customer. Companies who implement a smart manufacturing approach focus on using data to continually compare product quality in real time. This preventative measure allows process manufacturers to stop quality problems from happening in the first place, maintaining the company's reputation, and ensuring its products remain of high quality.

3. Improved Efficiency – Identifying and removing bottlenecks is one of the key ways in which data produced from smart factory technologies can be leveraged to provide a more efficient manufacturing process. Traditional approach involves manually analyzing different systems and processes to uncover inefficiencies, often difficult to identify at all. By tracking the data produced in real time thanks to smart manufacturing technologies, inefficiencies and bottlenecks usually unnoticed are identified. Key proponents of this are the use of artificial intelligence and machine learning algorithms that can review large amounts of data in real time to discover anomalies and correlate them to detrimental events.

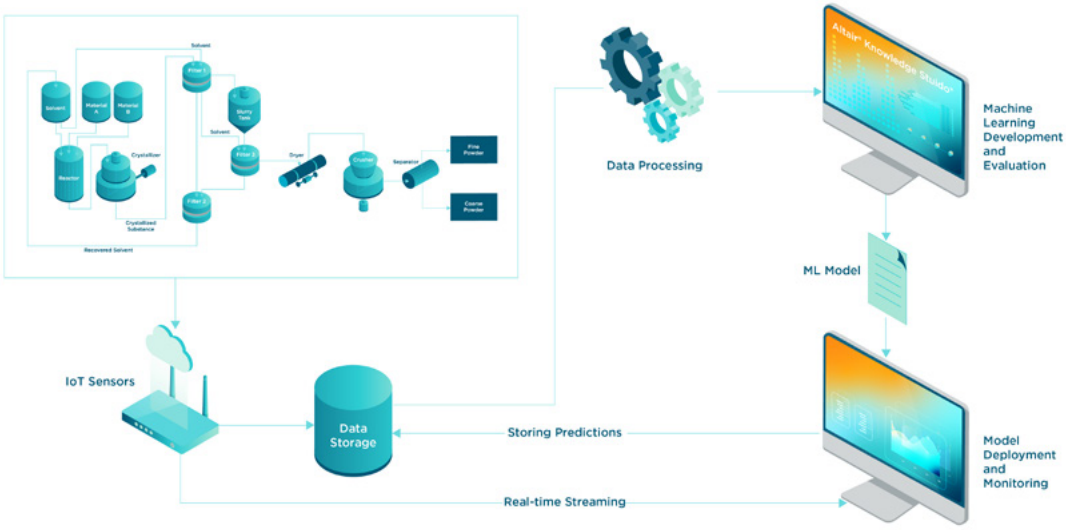
HOW SMART MANUFACTURING CAN BE USED IN A PHARMACEUTICAL PROCESS

The pharmaceutical industry is a heavily regulated, competitive market and pharmaceutical companies face the challenge of reducing time to market while consistently maintaining high quality products.

In this example of an organic synthesis process using two materials and a solvent, only fine powder can be used for the production of tablets. Coarse power is either thrown away or collected for a second round of crushing and separation. As a result, a machine learning (ML) model is needed to predict the likelihood that the current batch will need extended crushing time to yield an acceptable level of fine/coarse particle size of 90%. Batches with less than 90% fine/coarse output need to be flagged in advance for extending the crushing cycle.



In the example below, data collected using Altair's IoT application during the synthesis process is aggregated from the different runs using a python script embedded in Altair Knowledge Studio™ and used to create and validate the ML model. The ML model script is used by Altair Panopticon™ to produce scores representing the predictions of the batch status immediately after the drying cycle is complete, allowing the user to monitor the development of the entire process with the use of a dashboard. The solution can be further extended to automatically fine-tune or control the physical process to meet the production goals.



IMPLEMENTING A SMART MANUFACTURING PROCESS

While smart manufacturing provides many solutions in the world of process manufacturing and the relevant industries, implementing these changes require several considerations. Here are five steps to implementing smart manufacturing and the technologies that comprise it.

1. Connect – Connecting machines, peripherals, and other data sources to a common network is the basis to use data to automate value creation. This enables the communication between machines, otherwise known as machine-to-machine communication (M2M). Feko can be used to design antennas, providing efficient analysis of a broad range of electromagnetic issues. Learn more here.

2. Collection – After achieving connectivity comes the collection and storage of production data. This collected data is crucial and acts as the foundation for the next steps in the process. Knowledge Studio can be used to process this data and prepare it for analysis.

3. Visualize – While a smart factory relies on data, generating value from it is essential. Allowing the user to filter, sort, and add meaning to data, visualization helps uncover first insights such as most common errors, total production quality, and maintenance information. Panopticon offers comprehensive streaming processing and visualization of real-time operations, enabling users to make insightful, fully-informed decisions.

4. Analyze – It's possible to emulate how an expert would use data to generate insight using specialist software. For example, incorporating predictive maintenance based on this data allows maintenance tasks to be scheduled according to machine conditions derived from data. Using physics simulation and system modeling tools such as EDEM, engineers can understand the physics of a process, leading to more optimally designed equipment, efficient systems and higher product quality.

5. Automate – As a last step, the system is enabled to perform autonomous decisions and actions, supporting the entire organization's decision making.

Altair's IoT Application also spans across all the steps above providing real time connectivity, storage, processing, analysis, and, visualization of data – as well as extend a feedback look for automated control through autonomous decision making both on the cloud and at the edge.

WORKING WITH ALTAIR

Through the use of simulation, process manufacturing industries can learn more about their varied applications allowing them to design better equipment, optimize manufacturing processes, and build more efficient factories. Altair's data analytics and processing solutions equip process manufacturers with the tools they need to move towards Industry 4.0 and smart manufacturing.

Altair is a global technology company that provides software and cloud solutions in the areas of product development, high performance computing (HPC) and data analytics. Altair enables organizations across broad industry segments to compete more effectively in a connected world while creating a more sustainable future.

To learn more, please visit www.altair.com