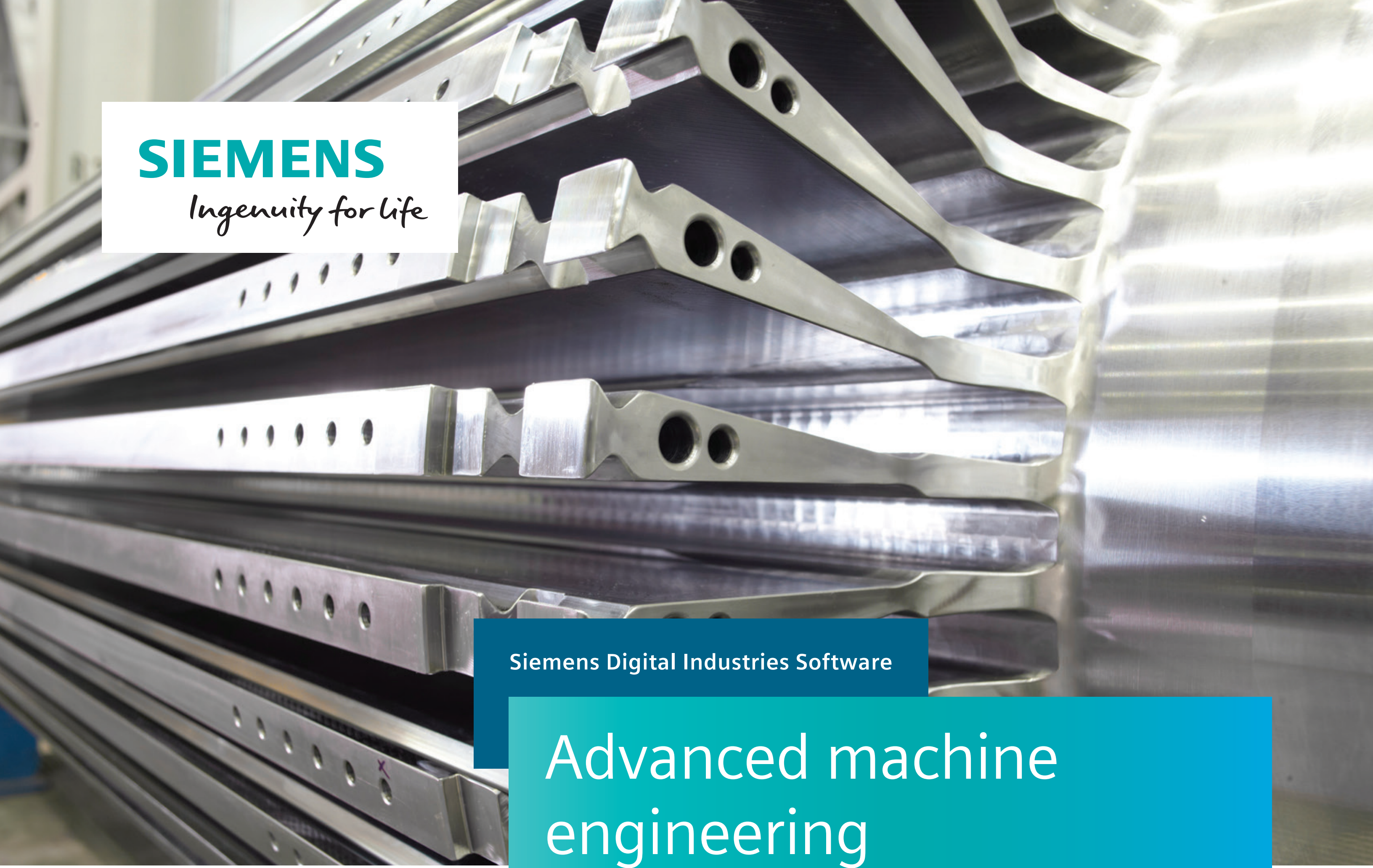

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Siemens Digital Industries Software

# Advanced machine engineering

## Technological innovations driving change


### Executive summary

Machine manufacturers are gaining a competitive advantage by implementing a digital thread approach to engineering which enables the rapid development of tomorrow's highly complex machines. Innovative technologies are rapidly advancing machine engineering processes, driving positive change in the industry, prompting companies of all sizes to meet the challenges and trends facing machinery manufacturers towards these evolutionary approaches, thus enabling machine manufacturers to take advantage of industry trends to drive the adoption of new technologies.


Advanced machine engineering is a term Siemens introduced several years ago focused on ensuring greater certainty in the development of next-generation machines.  It also reduces ramp-up time to production through virtual design and commissioning, resulting in better upfront validation, shorter commissioning times and more immediate productivity.

# Abstract

It is an intimidating mission to design, validate and manage modern-day manufacturing and assembly machines to achieve first-class quality while optimizing cost. Advanced machine engineering marries the development of the digital twin with the collaboration of the many disciplines to develop the machine into a complete solution suite. These are complex multidisciplinary designs – combining mechanical, electrical and fluids – requiring a single source of truth in design to address the back-and-forth process that exist between engineering silos.

In addition, because nearly all machines require automation code, advanced machine engineering enables virtual machine simulation, testing out the PLC code in a virtual world with a digital machine, before testing it on a physical machine. This addresses the need to validate what the machine will do before installation on the factory floor, only to discover errors. Therefore, anything that was tested physically in the past can now be simulated virtually.

This white paper outlines the trends, technologies and processes in place that are driving and progressing advanced machine engineering.

# Industrial machine industry – trends

Industry mega trends are affecting customers operating machines within their respective industry audience. Technology advancements are driving industrial machinery companies to realize Industry 4.0, with some staggering implications.  Consider the following trends that are re-shaping the engineering, manufacturing and service operations for most machinery suppliers:

- **Consumer driven customization** - Machines automate processes to help companies' lower costs and expedite delivery of their goods to the end user. Hence trends in the broader consumer market ultimately end up defining what machinery customers need. A typical consumer product's development cycle is compressing – lot sizes are smaller, and product life spans are shorter. So, machinery customers need machines that are more flexible and adaptable to an ever-changing product mix, often with customized features or functions that require machine builders to innovate more quickly.
- **Smart machines** - Machinery component suppliers have completely embraced IoT enabled devices. Thus, machinery manufacturers are on a steep learning curve in knowing how to take advantage of available information. The number of I/O (input/output device-driven) channels and different communication protocols (wired networks, and wireless 5G) provides an order of magnitude increase in information flow compared to recent years. Therefore, automation code developers are forced to choose which channels to use, while building more intelligent machines.
- **Hyper automation** - Discrete programming is enabling machine users to gain insights from all the IoT information. The hyper-automation trend requires vast amounts of data and cloud-based analytics to accelerate learning about machine behavior and performance to automate machine functions.  Also, hyper automation is enabled by the emergence of low-code tools that help machine users mine data analytics for many business processes – manufacturing optimization, engineering reliability and cost reductions.

- **Global, highly innovative competition** has always existed but now the challenge comes from more flexible, agile start-up companies that begin from the basis of machine learning and are not encumbered by existing business processes or legacy customer engagements.  Some offer production-as-a-service and other innovative software-enabled service monitoring tools and machine optimizations – even on competitor's machines.

# Advanced machine design – customization and simulation

Therefore, these trends are driving consumer-driven customization, thus resulting in immense changes in machinery. People expect to get what they want when they want it.  This equates to a shorter lifespan for these products. Manufacturers need to ramp up very quickly to rapidly produce sophisticated products while supporting more variants. Advanced machine design is being impacted by this dynamic towards customization and escalating the pace of change. Consequently, machines need to be more adaptable in reacting to changing consumer trends.

Performing simulation earlier in the design is enabling the generative design movement in CAD. Instead of designing first and then simulating afterwards to uncover problems with the design, the generative design uses forces, kinematics and the constraints in the design to assist in shaping it. Also, this is useful even when not using additive manufacturing technologies.

Simultaneously, there is an increase in collaborative multi-discipline design, with much electrification in advanced machinery that it is difficult and challenging to simulate in the machine without a way to validate the PLC and automation code that governs the machine.

The technology and tools are now in place to significantly drive change and exponentially increase efficiency, giving a true competitive advantage to machine builders, helping them to deliver machines into the market faster.

A prime example of virtual commissioning effectively operating is Tronrud Engineering, who develop, manufacture, and supply innovative machines and equipment. A digital twin of the new machine allows the designers, engineers, and programmers to work simultaneously and continuously interact and share their knowledge. They positively impacted the bottom line by reducing and compressing their commissioning and engineering time.

*"By working on the design, mechanical components, and programming simultaneously, we can drastically reduce the time to market. In another project, this approach allowed us to save about 20 percent or two months,"* says Erik Hjertaas, General Manager Packaging Technology at Tronrud Engineering.

Also, in response to the results of the parallel execution of development steps in an interdisciplinary team, Tor Morten Stadum, PLM Manager at Tronrud Engineering, states, *"We shortened the design phase by about ten percent and commissioning by 20 to 25 percent."*

These advanced machine engineering capabilities enable a truly comprehensive digital twin with multi-disciplinary design, virtual machine simulation and commissioning and a multi-disciplinary bill of materials. Let's discuss these differentiators in further detail.

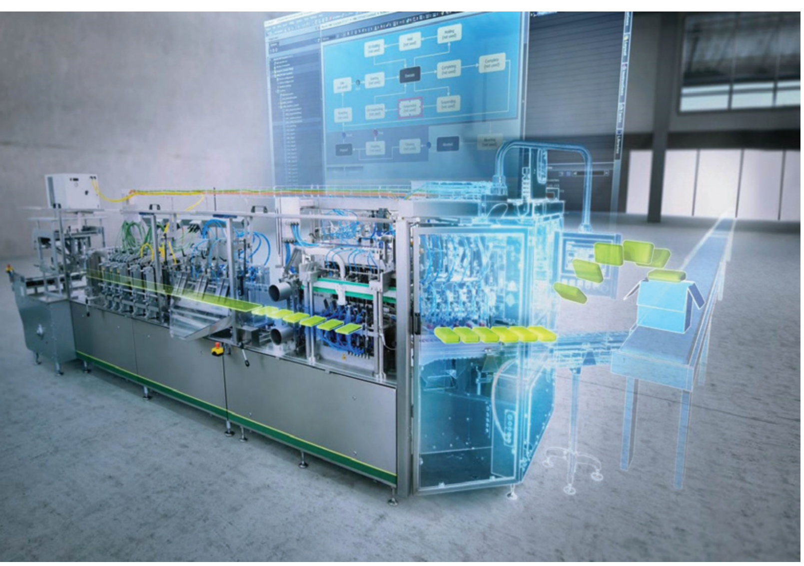
# Key differentiators – multi-disciplinary design, virtual commissioning and multi-configuration management

The following solution differentiators are separating VC and multi-configuration BOM management:

- **Multi-disciplinary design** - Machine manufacturers are leveraging a multi-disciplinary design to make their manufacturing more efficient. Multi-disciplinary design is defined as assessing the complexities of building a machine, including engineering the design and manufacturing. Traditionally, most machine manufacturers focused on CAD and manufacturing parts within tolerance for everything to function mechanically, and the mechanical arrangement and assembly related to the machine. The machine was primarily a mechanical piece of equipment, like yesterday's automobile or airplane. Therefore, the mechanical design was in one area with the electrical design, while the schematics and software development were in their separate silos.

  However, the industrial machinery paradigm is changing. For example, the electrical motors and rotary equipment to move camshaft gears are driven by software and PLC codes, thus accelerating *performance-based programs* in recent years. The software is adaptable to conditions on the floor and the machine reacting to real-time sensor readings. Even something as simple as a cylinder extending and retracting can be based on a pressure differential and flow regulation that were unavailable to small and medium-sized businesses a few years ago due to prohibitive cost. As a result, more mechanical capabilities and features are being replaced by software. It's a game-changer for every machine designer.

  Multi-disciplinary design is a blending of capabilities and skill sets in a more collaborative environment. This scenario pays dividends in quality output of the machine design – everything works together and has its place. It is more of an art form than bolted on electrical, sensors and cable-runs. It is an integrated solution. Therefore, it is creating harmony in the multi-disciplinary design that did not exist when disciplines were in silos, thus transitioning into advances in simulation.



- **Virtual machine simulation and commissioning** – A second differentiator provided by advanced machine engineering is virtual machine simulation and commissioning. This refers to how a machine proves or validates the software code in the virtual world before physically operating on the factory floor.

  The behavior of the machines is being driven by software, which is why simulating the code running on a virtual twin of the machine generates substantial dividends in time and resources. With virtual commissioning, the PLC software validates in a managed environment with a full modular product development strategy. Now machine builders have the simulation upfront and link the software to the modules. This set up is a groundbreaking achievement for companies to be competitive in this space.

Moreover, virtual simulation provides a physical safety aspect because if the machine collides in the virtual world, it is substantially safer and less costly to fix than on a physical machine. Virtual commissioning drives the behavior of the motors, integrating that into the kinematics. This is powerful because a mechanism on a machine might move faster than expected, leading to an actual impact load greater than what was anticipated. Replicating the kinematics in virtual commissioning uncovers potential hazards leading to a swift resolution.

Furthermore, by embracing virtual commissioning and visualization, machine builders bring customers into a virtual reality wall to interact with the machine in its digital form. From a financial perspective, this pays huge dividends because no one purchases a machine sight unseen. Also, they will not purchase it merely on a claim of virtually simulation via running software code. Therefore, a customer needs to substantiate that a machine works before it is shipped to their plant.

Many software integrations and safety factors are necessary to run a machine, and this becomes a stressful and monumental task to perform physically with the customer in attendance. Therefore, the virtual world is ideal for turning a machine on and carrying out commissioning. There is less pressure for both the machine builder and its customers. It brings together the engineering upfront in the design, with the collaboration of various disciplines for testing the machine code.

- **Bill of materials** - A third differentiator of advanced machine engineering is the multi-disciplinary bill of materials (BOM) for machine builders as they create more sophisticated, smart machines.  It gives manufacturers greater flexibility to respond to customer demands for customization.

  Every machine, and every order, that a machine builder receives is often a new project. Consequently, machine builders need a way to track the diverse options, and variants, for integrating requirements along with project and change management, while managing the entire BOM throughout the product life. This means from the original engineering design, through manufacturing and then managing that machine bill of materials throughout its service life.

  A level of planning capability is required for every engineering discipline, providing a more agile approach. Also, there is a need for traceability of customer requirements, engineering requirements and activity that is performed by the design engineer, electrical engineer and controls engineer for executing the project. This includes the journey from a high-level customer requirements specification document through the BOM structure and attaching it to the actual task that is necessary for the deliverable. This process provides a level of capability for ensuring and reducing the risk in meeting customer requirements, leading into the topic of the sophisticated software solutions that are implemented into every machine.

# Industrial machinery – advancing software solutions for smarter machine

Advanced software is a necessity for machine manufacturers facing competitive globalization, shrinking margins, rapidly expanding customization, environmental and government regulations, as well as Industry 4.0 and other smart factory initiatives.

In the face of these significant challenges, machines must be smarter. If a company is unable to address the complexity that comes with adding software to their machines or developing an advanced machine from customer requirements to compete aggressively on a global basis, their days of profitable growth are limited. Essentially, the core requirement is becoming machine design innovative in the operation and development process.

The difference between a company being good and great comes down to the quality and innovation in their automation code. Great code provides intuitive user interfaces, promotes ease of use and takes advantage of new hardware capabilities and software algorithms to help machines move faster, more safely and with less wear and physical stress on components.

However, writing great code is not enough, as the lines of code in machines today have an increased magnitude of complexity. Therefore, it is critical to test that code in the virtual world and run it through all the use cases before loading it on the physical machine. Companies are under pressure to deliver more customized machines faster, with added complexity. It's no longer possible to rely on, and safely physically validate, the machine.

Every machine is released to the customer with a set of binaries that represent the compiled machine operation and UI code. With conventional practices, programmers scramble to get last-minute changes to the code locked in before the machine ships. In this chaotic environment, it is imperative to retain a locked version of the final code to use for several purposes – service, catastrophic backup, lessons learned for future machines and upgrades to previous machines in the field.

Having a code repository is not enough. Each software variant must be traceable and retrievable to the serial number machine as part of the machine bill of material. Through the machine life, future upgrades in both hardware and software need a traceable system record, representing the living digital twin of the machine.

# Industrial machinery – digital twin

The digital twin holistically is a representation of the physical machine – its performance and recipe for manufacturing it. It corresponds to everything that constitutes the machine: mechanical, electrical, hydraulic, fluid, pneumatics, design domains, performance, simulation and automation code. Moreover, the digital twin encompasses the manufacturing and service life, basically having a digital version of the as-maintained, as-serviced machine from the point of origination through to end-of-life, when it gets recycled.

There is a blurring of lines between mechanical, electrical and software, so there cannot be a digital twin of the machine without representing all the domains. Also, a comprehensive digital twin is imperative because every function a machine performs depends on an integration of mechanical, electric, pneumatics, and software domains. Therefore, these domains must be included in the digital twin to assist in creating and maintaining the most comprehensive digital twin.

As machines become more complex and machine builders create more variants that requires a digital twin of each machine built, there needs to be traceability of the machine's serial number at the point it is released through manufacturing and into service life.

Advanced machine engineering innovations, like digital twin, impact all areas of manufacturing to affect the operations of a plant positively.

# A case study - Eisenmann

Another notable model of advanced machine engineering in action is Eisenmann, a leading global provider of industrial solutions and services for surface finishing, material flow automation, thermal process technology and environmental engineering plans and builds made-to-measure manufacturing, assembly and distribution plants that are highly flexible, energy- and resource-efficient and have been deployed by enterprises throughout the world for more than 60 years. Advanced machine engineering with simulation innovations evoke notable feedback from Eisenmann:

- *"The simulation model we create with Plant Simulation is often part of the deliverable to our customers. Many of them also use Plant Simulation themselves, so they know how to run the simulation and change the needed parameters. This is a big benefit for them because they get a virtual model of the physical line,"* says Dr. Heiner Träuble, Simulation Expert Automotive Paint Systems Eisenmann.
- *"We are very pleased with the discrete event simulation capabilities we have developed in Eisenmann throughout the years, especially our use of Plant Simulation,"* says Sebastiano Sardo, Senior Vice President, Eisenmann Conveyor Systems.

Using the Xcelerator portfolio, a suite of services from Siemens Digital Industries Software Solutions, helps manufacturers create the most comprehensive digital twin and integrate simulation within machine design to be flexible, capable and adaptable.

# Conclusion

The market is ripe for proficient experts uniquely positioned with capabilities for providing customers with the solutions by serving the product improvement process. The next generation of software is advancing beyond current versions. The methods for engineering are transitioning and becoming exponentially more proficient than a decade ago. The technology and tools are driving change to significantly increase efficiency to create true competitive advantages for machine builders and suppliers by expediting the delivery of machines into the market via advanced machine engineering.

Advanced machine engineering solutions are emerging today that address the challenges and trends that are driving the machinery industry today.  These include multi-discipline design, virtual machine simulation and commissioning and multi-disciplinary BOM and configuration management.

Multi-disciplinary design enables collaboration between the various disciplines, including mechanical, electrical, software and fluids, all within a single design environment, thus the need to build an accurate digital twin that supports these disciplines. Furthermore, virtual machine simulation and commissioning is enabled by a tightly integrating the simulation solution supporting parallel product development. Finally, there are now advanced capabilities for managing the entire BOM for all the options and variants required to advance machine builder support throughout its product life, from the original engineering design through manufacturing, and into service life.

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## About Siemens Digital Industries Software

Siemens Digital Industries Software is driving transformation to enable a digital enterprise where engineering, manufacturing and electronics design meet tomorrow. Our solutions help companies of all sizes create and leverage digital twins that provide organizations with new insights, opportunities and levels of automation to drive innovation. For more information on Siemens Digital Industries Software products and services, visit siemens.com/software or follow us on LinkedIn, Twitter, Facebook and Instagram. Siemens Digital Industries Software – Where today meets tomorrow.

## About the author

**Bill Davis** is the Solution Director of Industrial Machinery and Heavy Equipment Industry for Siemens Digital Industries Software. His experience and insights have been acquired from a career spanning 30 years in engineering and operations management with machinery and heavy equipment companies. Bill holds a master's degree in Business Administration from Marquette University, with a concentration in Operations Management and Strategic Marketing, as well as a Bachelor of Science degree in Mechanical Engineering from Milwaukee School of Engineering.

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