ARC WHITE PAPER

By ARC Advisory Group

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Siemens PLM Software's Advanced Machine Engineering Streamlines Machine Development

Overview

Industrial machine builders are confronted with business challenges that require new process changes in the design and deployment cycle. Process improvements that shorten the overall lifecycle of the engineering and design cycle will improve margins, while process changes that support the increasing demand for customization and specialized features will provide a competitive edge. This report provides insight into Siemens' PLM Software (Siemens PLM) Advanced Machine Engineering solution that enables machine builders to incorporate customization into the design process at a minimal cost.

Industrial Machinery Business Issues

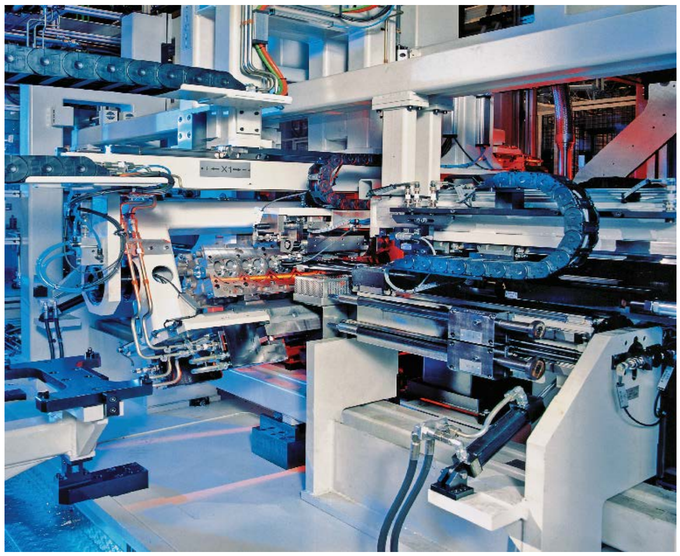
Machinery Market Becomes Increasingly Competitive

Manufacturers have altered their purchasing criteria -- formerly based solely on price -- to include price, productivity, and flexibility. This reflects the move toward basing capital expenditures on total cost of ownership. This is a wakeup call for machine builders to make investments in innovative machine designs that enable manufacturers to expand their manufacturing operations and improve efficiencies. Innovation in machine design is now highly valued. Innovation has been the driver behind many European machinery designs, as this region has a business culture that continues to invest in the next generation of machinery, even before the current generation is in full production. As a result, high-value machinery originating from Germany and Italy is commonly exported to U.S. and Asian markets.

However, machine builders based in emerging economies are beginning to meet the requirements of global manufacturers, while operating in a location in close proximity to plants. Consumer packaged goods producers, such as P&G, Kraft, Hershey, and Coca Cola, have traditionally relied upon machine builders in their developed domestic markets but now source machinery from builders in emerging economies, putting pressure on European machine builders. Therefore, emerging economies will represent the largest source of competition for production machinery over the next several decades.

Machine Customization is becoming the Norm

The standard machine is slowly becoming an anachronism; every machine requires customization to meet the specific needs of the manufacturer. Local regulatory requirements, wider operational ranges, short product lifecycles, and variations in the local labor pool are some of the drivers behind customization. For example, the skill set of the labor pool can lead to adding features and functions to make it easier to align work pieces or to simplify a changeover. Machine builders that are making the transition into custom design houses have leveraged modularity and reusability in all aspects of the engineering processes: automation software, mechanical systems, and electrical subsystems. The transition to modular electromechanical subsystems using distributed automation drives the cost out of customization. Subsystems are now self-contained mechanisms that rely on standard interfaces in software, mechanical design, and electrical layout.



Mechanical, Electric, Hydraulic, and Pneumatic Components Machines Increase Complexity

Reducing the Cost of Design & Development

The most successful machine builders have focused on incorporating innovations in internal design processes to minimize project timelines. Reducing critical path items in a project, encouraging collaboration, and moving to concurrent design between electrical, mechanical and automation software groups has been the approach that holds the greatest promise to shorten project timelines. In conjunction, many builders have begun to realize the full potential of the engineering organization by employing knowledge repositories that facilitate reusability of prior developments. Machine designers are realizing there is a need to share and exchange new concepts throughout the development process. Due to the growing complexity of integration and the value of early design tradeoffs, machine builders need development methods that span across engineering domains.

High-tech and consumer electronics have long relied on development methods such as systems engineering and model-based design to integrate and validate throughout the development process. Industrial machine builders can apply these same development methods as they face the challenges of custom engineered solutions and standard products that use leading edge concepts.

Machinery Design Tools Addressing Industry Challenges

Rapid Prototyping Tools Lower Cost of Scenario Analysis

Design tradeoffs are both complex and innumerable when optimizing multiple elements of a mechatronic system. Successful balancing of design tradeoffs in a project, whether it is energy, cycle time, or range of operation, now demands more than just experience and domain expertise. Software tools for rapid prototyping of conceptual machine designs allows engineers to evaluate dominant design characteristics without physical prototypes.

Rapid prototyping tools cost-effectively evaluate critical design elements under multiple scenarios. Designers can evaluate multiple design scenarios to vet tradeoffs in implementations, prior to the fabrication of any physical prototype. Rapid prototyping systems rely on virtual machine models that incorporate mechanical assessments, actuator sizing, energy calculations, and dynamic testing. It is possible to evaluate alternative machine and subsystem geometries without the additional cost of physical prototypes, as mechanical interference and alternative component location are easily reconfigured in a virtual prototyping environment. However, this does not obviate the need for the final stage wherein a physical electro-mechanical prototype is essential for identifying performance characteristics that are not capable of being modeled in the virtual prototype.

Collaborative Development Environments

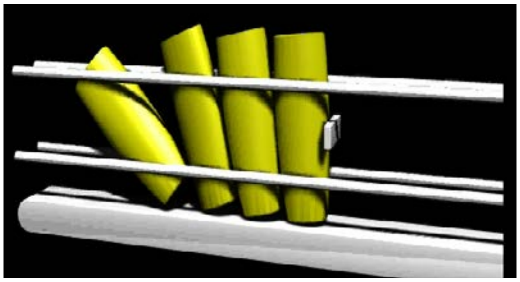
Machine builders need an organized, collaborative development platform that facilitates a functional, model-based design approach from the earliest stages in the development process. A single high-level functional model captures customer requirements and is shared among the engineering disciplines to validate system constraints and functions without transformation of models for each engineering discipline. The use of a common model is the ideal means to enforce collaboration earlier in the overall design process. Designers can validate machine geometry more effectively, leading to a highly efficient overall development process. A collaborative development platform that supports development tools for each engineering discipline, without requiring an import or export of design models, significantly lessens the potential for design errors. This reduces development time and subsequent project cost overruns.

Automation System Virtual Commissioning Tools

Mechatronic simulation and model based design tools have revolutionized the development of machine control solutions. However, virtual commissioning tools for the actual automation system (PLC, CNC, or motion controller) now enable the validation of the automation software logic, timing characteristics, and motion profiles well before the construction of the machine. Integrated development tools that emulate programmable logic controllers and motion controllers in a virtual environment provide another degree of validation of the entire system, before actual testing on the physical machine. Machine builders using virtual commissioning tools significantly mitigate the risks of oversight during the design process that commonly occur during the integration.

Concept Validation in a Virtual Environment

Three-dimensional simulation tools enable early validation of machine concepts. These simulation tools only provide value if they are true physics-based simulation solutions intended to analyze the physical interaction between machine components and product movement. This allows the systems design engineer to simulate and validate motion and force, general machine dynamics, kinematics, actuators, servos, as well as to detect collisions and interference with handling systems functions within the machine envelope.

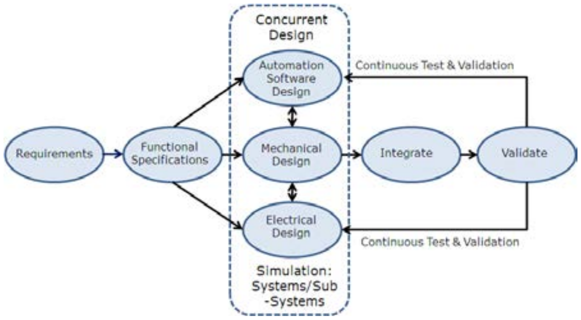


Physics-Based Simulation

The aim of system-level simulation is not to conduct detailed analysis and validation of the specific characteristics (vibration, thermal, frequency response, or stress) of individual components, but to simulate the overall machine system and the behavior of the interaction between the various engineering design disciplines. This type of simulation enables system designers to model and validate component-to-component interactions in conjunction with the overall system behavior. It also allows designers to more accurately specify components like motors, servo drives, hydraulic servos, and other actuators more accurately, based on a virtually simulated machine model.

Concurrent Design Produces Improved Machines

An interdisciplinary development platform enables engineering teams to concurrently develop mechanical, electrical and automation software component designs, long before any physical prototyping or testing is possible. In an early systems-level simulation environment, the various engineering disciplines can work together with a single model to develop and refine requirements for the individual sub-systems. Once validated, tools relevant to each discipline can be used to address the detailed design. The traditional sequence of development in machine design begins with the mechanical design, followed by the electrical design. Concurrent design environments enable software development to reference a common systems engineering requirements model. Without a single model, functional errors found in the late stage physical prototype cause costly development delays. Model-based design addresses these issues confronting the machine builder. The use of functional modeling for conceptual design, the ability to virtually model, simulate, and validate the machine, and improved reuse methods will give machinery builders that adopt these tools a definite edge in the market.



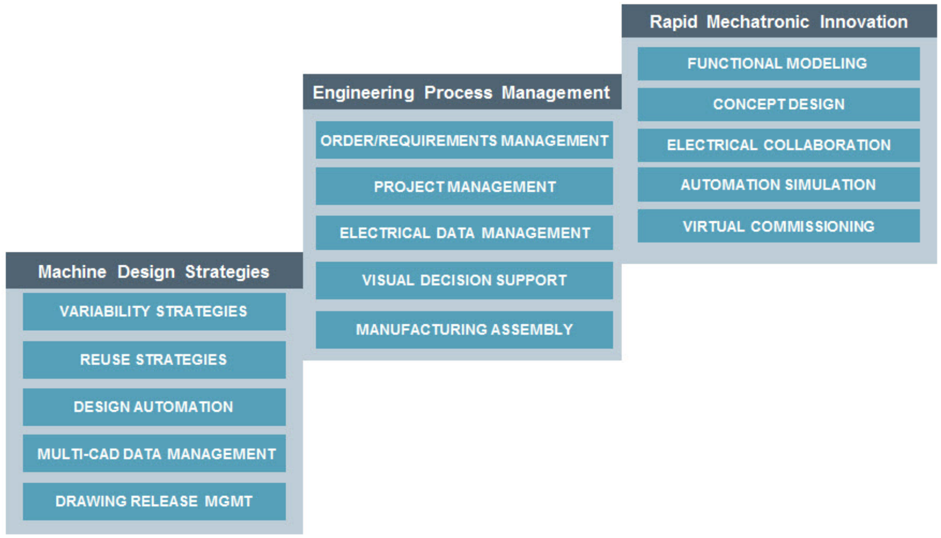
Concurrent Design Reduces Design Time of Machines

Siemens PLM "Advanced Machine Engineering" Solution

Siemens' PLM Advanced Machine Engineering (AME) environment will have a significant impact in streamlining machine design. AME relies upon using a common virtual machine model throughout the entire specification, design, and commissioning cycle that provides:

- Early concept evaluation of customer requirements
- Concurrent multidisciplinary design
- Common environment for engineering design tools
- Virtual machine commissioning with automation controller emulation
- Virtual machine commissioning with Hardware In the Loop

Siemens PLM provides an approach focusing on three primary areas: Engineering Process Management, Machine Design Strategies, and Rapid Mechatronic Engineering (RMI).



Machine Design Strategies, Mechatronic, and Engineering Process

Engineering process management is the area in which Siemens PLM develops solutions to integrate the different disciplines in the engineering

environment. Traditionally, office documents such as Microsoft Word and Excel have been used to manage all non-mechanical data, for example instance project data, requirements, electrical schemes, and even work instructions. However, sequential changes to products may not be reflected in these office documents, highlighting the criticality of employing a backbone to manage all the data, increase control, and reduce risk.

Machine Design Strategies is the second area in the AME solution environment which has been a major source of investment from Siemens PLM. There is a growing need for companies to improve their engineering efficiency by using predefined industry working- methods. Siemens PLM specifically developed an industry Catalyst (template) for machine tool builders that contain workflows to significantly speed up the engineering process. The workflows are able to support a configure-to-order, as well as an engineer-to-order process. Modular design is the first step to break down product configurations into more comprehensible functional and logical pieces. A modular design approach is a common design approach in the machinery industry and is used to design machines from modular architectures. To support this concept, the following key definitions are used:

- Product family: A set of similar products that are derived from a common platform and possess specific features or functionalities to meet specific requirements. Each individual product in a product family is called a product variant or instance.

- Product platform: A collection of common elements implemented across a set of products, such as a product family.
- Platform design: The platform-based product family design

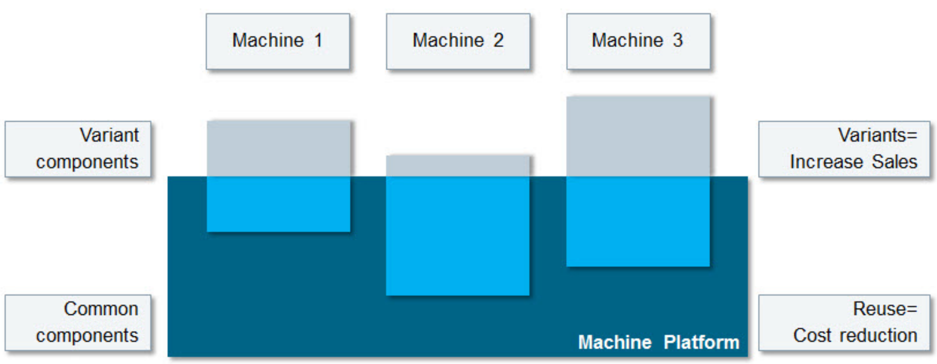
Siemens PLM's Machinery Platform Management process designs a generic and flexible product platform that can be configured and modified to adapt to a specific machine design.

Engineers can choose and combine appropriate modules from a predetermined group to design and manufacture a machine with the required dimensions, performance, and functionality specifications. The defined modules must meet certain design principles, for example:

- The modules must be interchangeable.
- The modules must be standardized.

The modules must be self-contained to implement specific functionalities.

The following figure describes the concept of platform design in the machinery industry. Consider an example of a machinery company that provides a product family of machines with variants to comply with different customer-specific needs. To reduce cost, the company also needs to maximize the reuse of common components (for example, the machine platform) across different variants of machines in the product family.



Modular Design Approach

Following the module design methodology, Siemens PLM provides a mechanism for the engineers to systematically reuse common components or even whole modules to build new machines.

First, the configuration capability of the software ensures the requisite components of the correct revision included in a reused module is correctly and completely referenced in the new machine design. It saves the effort and time for the engineers to search, identify, and copy the right revision of the existing module. More importantly, it minimizes the errors introduced in the otherwise manual process. Therefore, the engineers can focus their efforts on the design of new modules.

Secondly, the software allows a new module to be modified from a separate copy from an existing module. Therefore, it avoids the unintended changes of the existing design. Furthermore, the new module can be included in the machine platform for future reuse.

With this mechanism, for any machine, the engineers can easily identify and track which component of which revision is used throughout its product lifecycle. If any change or problem is identified in the future, the impact can be easily determined.

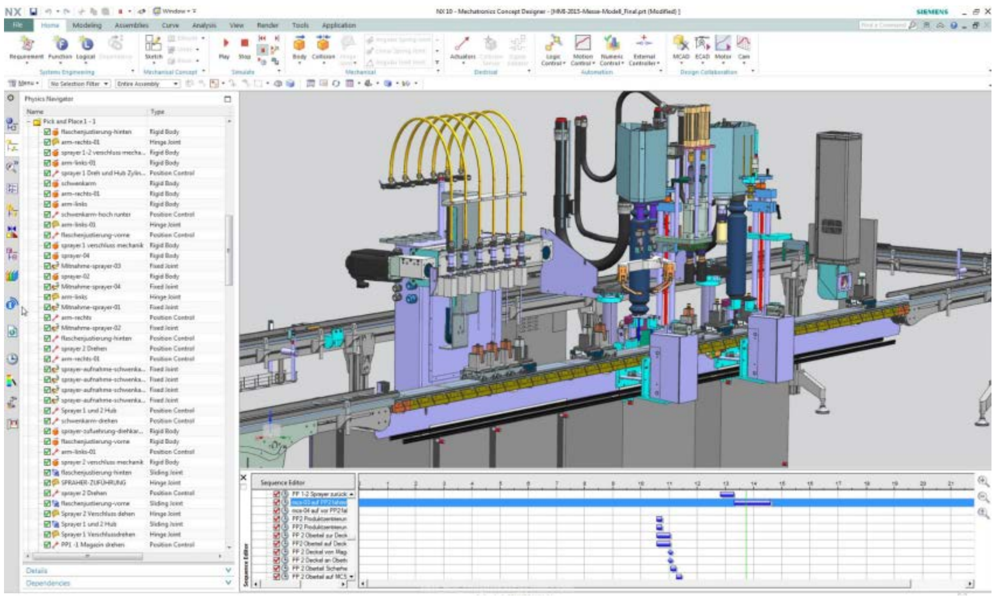
Rapid Mechatronics Innovation is the third area where the Digital Factory division of Siemens combines all its machinery expertise from PLM together with MC and MES building MIL (Model-) SIL (Software-) and HIL (Hardware-in- the- loop) solutions. The ultimate goal is to simulate through a digital twin the machine in all its aspects.

Eliminate Conventional Sequential Design Processes

AME's approach is important due to its engagement with the engineering organizations at the earliest point in the conceptual design process. Virtual prototyping and virtual testing displaces the sequential development process of mechanical design, which is then followed by electrical design and selection of electrical components, physical prototyping and testing. Machine builders have access to a multi-discipline design approach that provides a comprehensive development environment for virtual machine design that offers each engineering domain the ability to integrate their design solution in a simulation environment. Prototyping, module testing, system integration and final commissioning have been incorporated in the AME approach to machine development. This significantly reduces development time, cost, and time to delivery.

Enabling Concurrent Multi-Disciplinary Design

Siemens PLM has packaged a suite of engineering and design capabilities under the Advanced Machine Engineering (AME) umbrella. AME is an environment that supports design tools, models, and data bases that encompasses the entire project cycle from the customers RFQ through the final integration of automation systems for machine deployment. Siemens refers to AME as its end-to-end solution, which embraces a multi-disciplinary approach from conceptual machine design through engineering, machine assembly, and commissioning. Siemens PLM's Teamcenter collaborative platform manages mechanical, electrical, fluid power, and automation software engineering design cycles across the model/design/build/validate/commission lifecycle environment. AME is comprehensive in that it incorporates capabilities for virtual commissioning of machines through final commissioning of the actual build for factory acceptance test.



Filling Machine Design

AME streamlines the traditional machine development process by eliminating the constraints on the design/build process, such as disconnected requirements between the engineering disciplines. Employing AME can virtually eliminate schedule overruns leading to late deliveries and financial penalties prevalent in today's machine development projects. AME's approach enables machine builders to use parallel development methods that allow for early stage involvement of each engineering design group.

The pervasive use of simulation of mechanical systems and emulation of automation controllers and I/O subsystems provides the ability to evaluate automation software as well as constraints on each engineering discipline. This is accomplished in an entirely virtual environment.

Early Concept and Mechatronic Validation

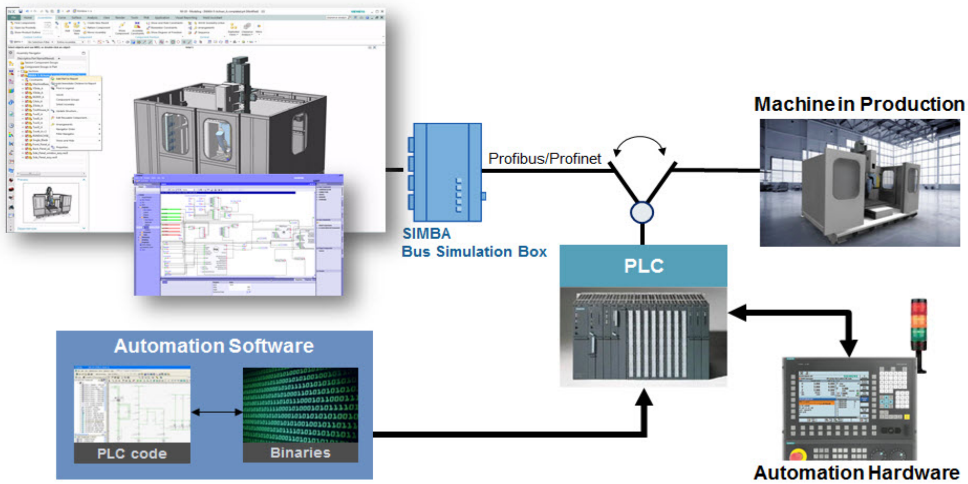
Within AME, evaluation of early stage machine design concepts using a simplified modeling and simulation solution, NX Mechatronics Concept Designer (MCD), provides benefits to both the machine builder and its customer. NX MCD modeling provides mechanical evaluation of the machine functions in terms of energy consumption, production throughput, and cycle times, using first order electromechanical models. Rapid first order modeling allows designers to evaluate numerous alternatives. NX MCD capabilities transcends evaluation of interferences, instead determining the actual forces and power required to move mechanical elements. In this way, the engineer can identify the optimal mechanical motions that will extend the life of the machine while optimizing its performance. As machine designs become more complex due to multi-function production systems, it is critical for machine builders to make the most effective design decisions that result in an efficient production solution.

Capture and Re-use of Design Knowledge and Methods

AME incorporates the capabilities of the rich NX design environment in terms of engineering reuse and knowledge capture. Machine builders that reuse a high percentage of pretested engineering design modules achieve faster integration and higher reliability in solutions. AME provides a repository and revision management system to manage engineering models, automation software, and to design and test information. All of this resides on the Teamcenter collaborative platform. Teamcenter acts as the single repository for all mechanical and electrical design, simulation, manufacturing process, virtual commissioning, and automation software and simulation information for the end-to-end machine design/build/commission process.

Replace Physical Prototypes with Virtual Commissioning

At the critical stage of commissioning a machine, AME continues to be an asset to the engineering team. AME incorporates virtual commissioning as an integral part of the overall machine development process. Virtual commissioning takes the automation engineers through successive stages of testing the machine design before actually going to the physical prototype. Commissioning relies on a common virtual model referenced throughout the entire design cycles. There are three key phases of virtual machine



Virtual Simulation of Hardware in the Loop

commissioning that are integral to AME:

- Virtual machine model and emulated automation controller
- Virtual machine model, virtual I/O and "Hardware in the Loop"
- Virtual machine model, fully configured "Hardware In the Loop"

Iterative Design is Core to Slashing Design Costs

"Hardware in the Loop" is an iterative and progressive development process of proving out machine mechanics and machine control logic. This is a significant step forward as it brings the Siemens' portfolio of automation solutions into an integrated design and development environment used throughout every facet of machine design. As design iterations are conducted at a much earlier stage in the design cycle, the cost of evaluating alternative design concepts is significantly lowered. Iterative design will always remain an integral part of the engineering process, but, with AME, the total cost and risk associated with iterative machine design is significantly reduced.

Conclusion

AME brings common models and design tools to a single platform that allows machine builders to streamline the engineering processes to address business challenges. Lower internal design costs will open up opportunities to strategically position machinery pricing in line with emerging markets or to offer custom engineered solutions that have a higher value proposition to the customer. Streamlined processes lower the machine builder's cost of development and quicken the time it takes to not only get the machine up and running, but also delivery to the customer. As the machine builder is paid upon delivery, Advanced Machine Engineering positively impacts cash flow.

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Editor: Paul Miller

Acronym Reference: For a complete list of industry acronyms, refer to our web page at www.arcweb.com/Research/IndustryTerms/

AME	Advanced Machine Engineering	**MCD**	Mechatronics Concept Designer
HIL	Hardware In the Loop	**PDM**	Product Data Management
I/O	Input / Output	**TCO**	Total Cost of Ownership

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