Model-Driven Innovation in Machine Design

How virtual prototyping and dynamic load analysis can help you to reduce machine design costs and get to market faster

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Introduction

Many engineering organizations face major challenges when designing and delivering new products that are dynamic in nature. One of the most significant of these is the discovery of key, often basic, design issues very late in the development cycle, introducing unbudgeted costs and delays into the project. These delays often cause projects to overrun significantly, especially when the design issues are discovered during the prototyping or integration stages where real hardware is involved. Even worse is when the problems are discovered after a system has been commissioned and installed. Such unforeseen weakness can result in expensive on-site service calls, loss of production, and unhappy customers, leading to extremely expensive projects that hurt the company's bottom line.

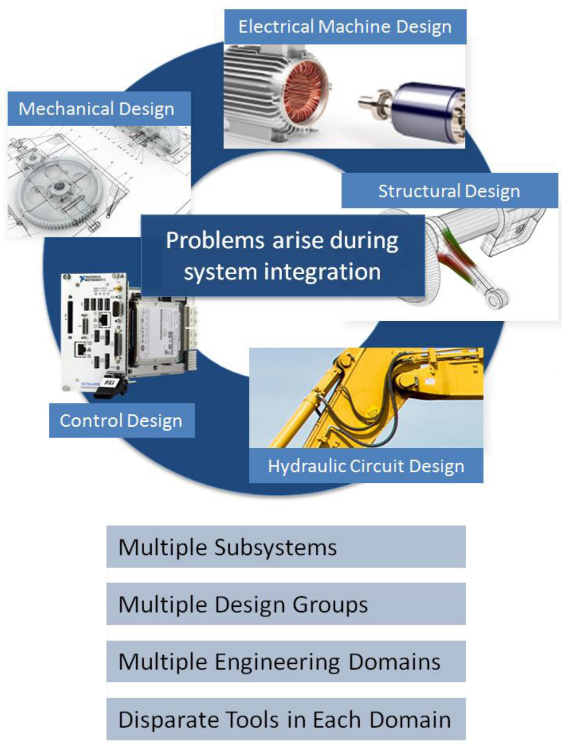

Figure 1: Common engineering design challenges

Many of these issues come about because there are several design groups involved in the process of designing a complex system, each focused on the development of one subsystem, using dedicated tools and methods to determine if their design will comply with the specifications for that subsystem.

However, often it is only when all the subsystems are integrated during prototyping, or even final assembly, that serious problems arise.

This is why many engineering organizations are turning to the use of system-level modeling to develop "virtual" prototypes of their systems. Virtual prototyping holds the promise of managing these challenges by integrating all the design information - such as requirements, functional specifications, costs etc. - in reusable objects, representing individual components, sub-systems and, ultimately, the complete system. With a model of the complete system in one environment, engineers can see how all the individual subsystems work together, identify weaknesses in the design, and make corrections earlier in the development cycle.

Using an interdisciplinary development platform enables designers to evaluate mechanical, electrical, hydraulic or pneumatic sub-system designs jointly, in a virtual prototype, long before any physical prototyping or testing is possible. And, the emergence of optimization tools that can integrate models and analyses from many different sources now allows designers to yield optimal design parameters much faster and with greater rigor than was possible before. Finally, the ability to capture knowledge from the design of components and store these in a virtual object library enables designers to reuse this knowledge in other projects.

We call this process **Model-Driven Innovation**: the ability to integrate functional models of components, subsystems and complete products in a readily reusable manner that allows companies to accelerate the development of complex engineered products while reducing project risk and costs.

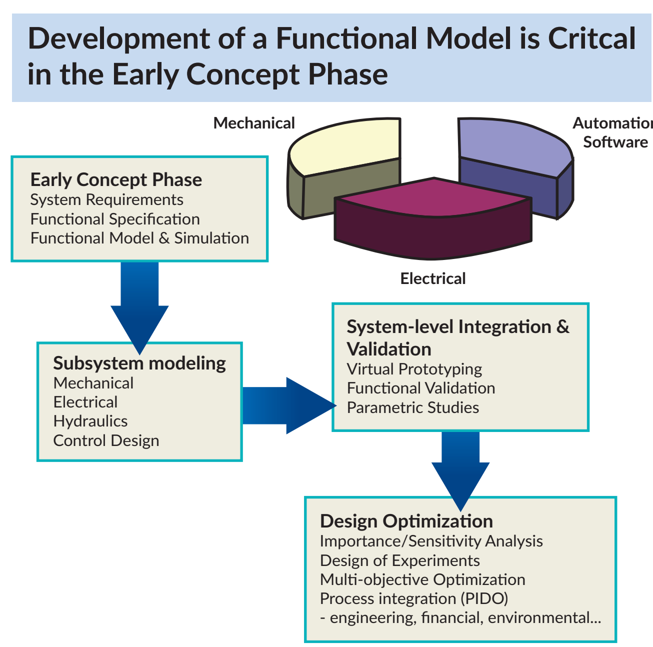

Figure 2: Virtual prototyping and the Model-Driven Innovation process

The Model-Driven Innovation process helps product development in several ways through the use of virtual prototypes within the design process. During the initial, conceptual stages, engineers can gain early insight into how the proposed design will fulfill the requirements for the system, or the subsystem, they are working on. By building a functional model that captures the dynamic behavior of the system, a lot of design decisions can be made based on investigations into how the system will respond to various "what-if" scenarios, thereby increasing confidence that the design is valid.

As the design evolves – and this is invariably an iterative process as more information is acquired – it is easy to incorporate any changes into the functional model to assess how they affect the complete system. Addressing any issues that come out of these studies will ensure that they won't become costly problems later on.

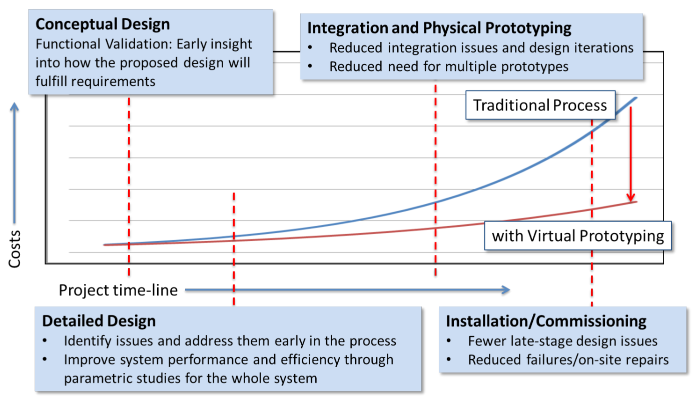

Figure 3: Early development of virtual prototypes of a design lead to significant reduction in problems and cost in the later stages

MapleSim is an example of a tool that supports Model-Driven Innovation. Part of the Maplesoft Engineering Solutions suite of products and engineering services, MapleSim is a system-level modeling and simulation tool that combines physical modeling with advanced symbolic computation techniques. MapleSim can be used to validate the functional behavior of complex dynamic systems. In addition, the MapleSim model provides a fully parametric definition of that behavior through the symbolically-generated equations of motion. These can be brought into the mathematical software, Maple, for analysis, including parametric studies, sensitivity analysis, and optimization, and the results can then be used to validate and even make improvements to the design. In addition, companies can build analysis and calculation tools in Maple that are based on the MapleSim model, which can be used by other members of the organization to address specific needs. Such tools provide services that range from simple calculations to advanced analysis such as vibration attenuation and eignvalue studies for stability analysis.

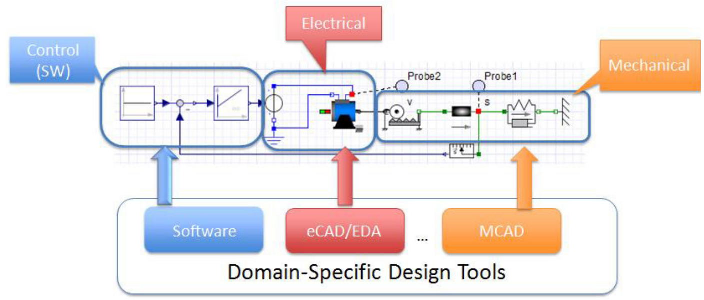

Figure 4: MapleSim brings together subsystems from different domains into a single environment

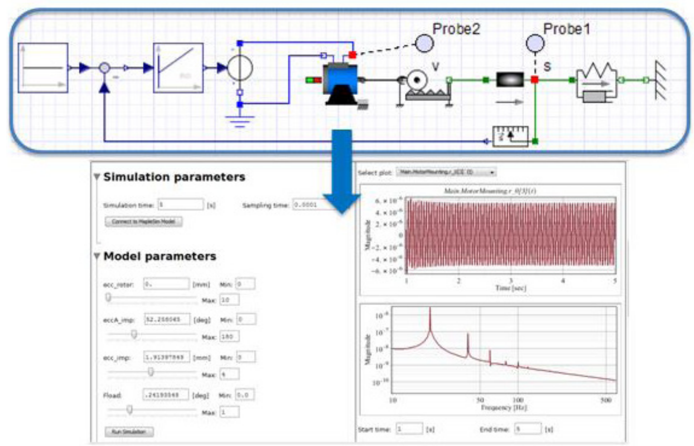

Figure 5: MapleSim and Maple together can be used to investigate and improve system behavior, such as performing parametric analysis of systems

One area where the Model Driven Innovation approach brings great value is in the analysis of dynamic loads. In machines that have complex mechanisms, it can be a challenge to determine the transient loads caused by the changing inertias of the mechanism. Getting a handle on these loads helps to avoid overloading the actuators and reduces costs when choosing components for your design.

NEW!
MapleSim CAD Toolbox

Use the MapleSim CAD Toolbox to import CAD models into MapleSim, automatically capturing the kinematic and kinetic properties of the model components.

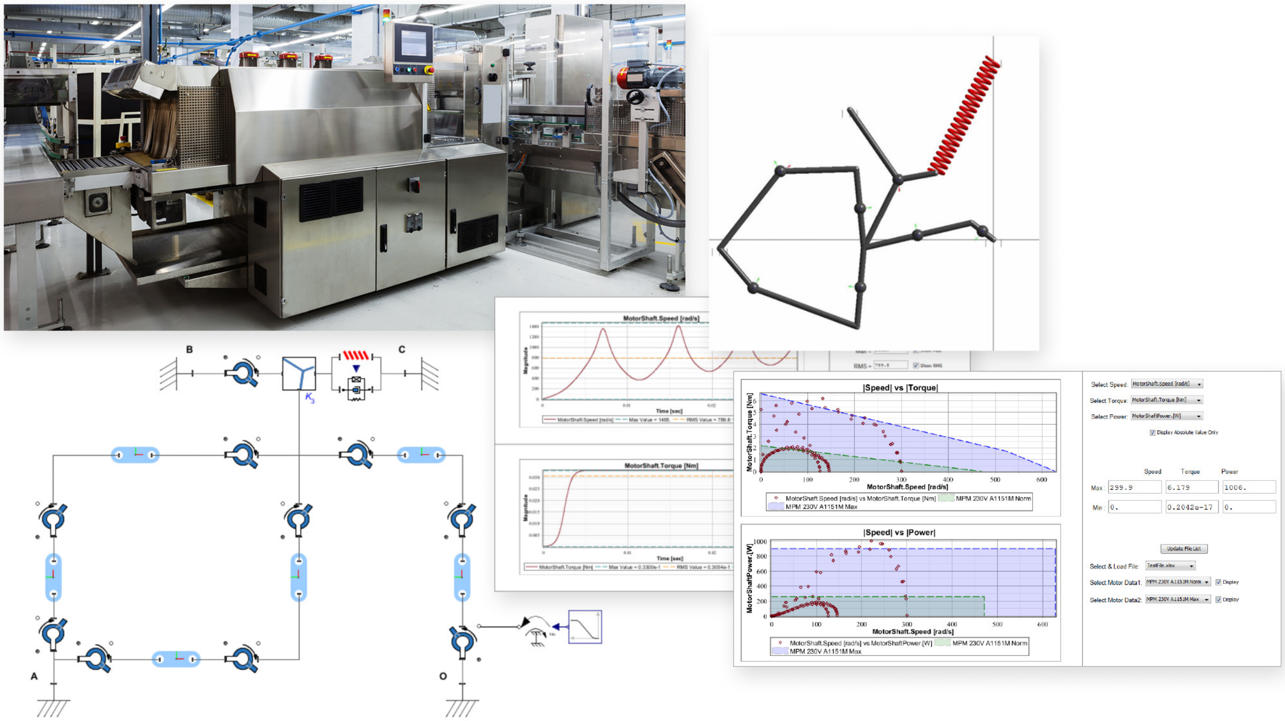

Figure 6: Servo-actuator sizing tool for complex manufacturing machine

For example, the Maplesoft Engineering Solutions team recently helped a client who was having problems with actuators over-heating in a complex manufacturing machine. Through the use of MapleSim and Maple, it was possible to show that the transient loads due to the inertia of the mechanism exceeded the safe limits of the motor. This could only be done through a dynamic analysis of the mechanism and was missed because the clients' designers could only perform steady-state loading analyses with the tools they had.

Once the problem was identified, it was possible to develop a mathematical tool to define a speed profile that would slow the mechanism during the peak inertial loads, thus reducing the load on the motor to within safe limits. In this way, instead of a costly refit of a larger motor in the machine, the client was able to address the problem with a simple change to the controller. They have since employed these techniques in the design of a new machine, which has led to 100% reliability and zero costs in on-site repairs.

The Model-Driven Innovation approach, and its emphasis on employing virtual prototyping at the system-level, is an invaluable technique when designing complex, dynamic machines. By using tools such as MapleSim, engineers can detect, and correct, problems that arise due to the interactions between different subsystems, long before the system integration and physical prototyping stages. Early detection means problems can be fixed at considerably less cost, and project delays avoided. In addition, with access to the underlying mathematics, systems can be analyzed, and designs validated and improved during the development process. By employing this approach, machine design companies can reduce development risks, develop better products, and get to market faster.