Simulation for the Shop Floor

Latest 3-D visualization software lends a hand to assembly workers on the factory floor, and to NC program verification for machinists cutting metal.

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Highly realistic 3-D simulation software can greatly improve manufacturing processes, lending sophisticated visualization tools that help increase manufacturing productivity and product quality.

Simulation software today includes a wide range of tools that offer 3-D views of factory-floor processes for assembly and factory layout, as well as software for NC simulation, verification, and optimization that help machinists determine machining accuracy.

In recent years, advanced 3-D visualization tools have been integral to many types of manufacturing software, ranging from the enterprise-wide PLM and digital manufacturing software suites’ factory-floor layout, robotic simulation and automation, and digi-

With the CAMplete TruePath TurnMill software package, users of Nakamura systems can simulate, verify, and optimize machining operations based on the machine tool’s 3-D kinematic model.
tal validation systems, to the very accurate full-machine simulations and animations of the NC cutting process on machine tools on the shop floor. By most accounts, the realism offered by today's simulations is far beyond what was available a handful of few years ago (see the article “Visualizing Manufacturing” in the June 2009 issue of Manufacturing Engineering).

Reaching to the shop floor, PLM software developer Dassault Systèmes (Paris) acquired MES software developer Intercim LLC (Paris and Eagan, MN) in March for $36.5 million. The acquisition of Intercim, a development partner with Dassault Systèmes in which Dassault took a minority stake in 2009, is said to tighten Dassault’s V6 PLM software suite's links with the shop floor.

Intercim’s strengths lie in the aerospace/defense and shipping industries, working with complex build-to-order products that have a lot of variance between individual products, notes Peter Schmitt, Dassault Systèmes vice president. “That’s their strength. We had a partnership and a minority equity ownership in Intercim,” says Schmitt, noting the companies have worked on integrating software for the past two years. “We built a joint roadmap, as well as some very successful custom engagements, and we did that to be able to convey engineering changes through the definition of the process sequence of the routings—that’s what it’s called in the aerospace terminology—down to the shop floor. We are able to deliver work instructions for a specific airplane configuration, in 3-D, on a portable electronic device, such as a touchpad. We are exploring the iPad option as we speak, and this allows you to have it always completely in sync with any kind of engineering changes that might apply.”

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Simulation to the shop floor rarely would be equivalent to a full simulation, but rather the results of a simulation, he notes. “You could make it a full simulation, but it doesn’t make too much sense,” Schmitt adds. “You want that to be done in the manufacturing engineering department and be able to communicate that in the context of what you have to do in your manufacturing assembly process down at the airplane.

“The key challenge we are addressing is that when they look at their paper printout, people are never sure if that is the right revision,” Schmitt adds. “They spend more than half their time looking for or validating that the information they have is accurate. So with the electronic system we are providing now, you can basically cut that unproductive search time in half. You can basically eliminate that, and double the productivity of the worker.”

With Intercim’s MES components, Dassault now has the right mechanism to deliver the information quickly to the shop floor, he adds. Dassault’s Delmia manufacturing suite of applications, together with its CATIA design software and Enovia data management, comprise the company’s V6 PLM systems, which also have been recently updated with newer collaborative tools. “Now one of our biggest customers is Boeing around the 787 program, where we have a couple thousand people
trained on the Delmia side in the creation and simulation of the processes and the process sequence, and about 20,000 users in the execution of those processes, between manufacturing assembly and quality, as well as partners who are working in the supply chain of the 787,” Schmitt says. “Specifically for the engineering changes, which are happening fairly late in the process, you want to make sure that you’re building to the right revision, otherwise you’ll have re-work.

“What we have with Intercim is a best-in-class application that delivers the sequence and the details of the operation, and embedded in that we have a 3-D viewer from Delmia that can visualize the process sequence, that can visualize the right part, and the right tools to be used. Everything that is executed down on the shop floor has been created and optimized using the Delmia suite, so we create it in Delmia and we execute it in Intercim.”

Eliminating nonconformances is another key element to visualization systems, Schmitt says. “For example, you get the specification to which you are supposed to build, but then a part is not showing up from vendor A but from vendor B, which triggered a nonconformance—we’re able to manage
that,” he says. “There are different types of nonconformances. If the manufacturing engineer did the wrong planning of a process or across a sequence, you can feed that nonconformance back from the shop floor into the planning system to ask for a revision of that, so the next time around when you come to the same or a similar process sequence, you can correct it. It's properly tracked, so that you have accurate as-built information, plus you can feed that back into the manufacturing engineering system so that the next time orders are released to the shop floor, this problem has been fixed.”

**Simulations of shop-floor processes** can greatly improve manufacturing productivity and quality. “With 3-D, dynamic process documentation, and work instructions, the factory-floor worker is now able to receive detailed work instructions that bring the operations to life on the shop floor,” notes Tom Hoffman of Siemens PLM Software (Plano, TX). “Better process documentation and the use of 3-D models and simulation output allow for improved training and communication of process intent. Virtual commissioning allows factory-floor workers to have the opportunity to configure and test production systems in a virtual environment, easing the process of implementation leading up to the start of production.”

New simulation capabilities are helping improve assembly productivity. “The speed and efficiency of producing realistic simulations allows engineers to validate more operations than ever before,” Hoffman states. “This allows for greater visibility to assembly issues, whereas in the past only those operations that were critical, or that had already been identified as problematic, were simulated and validated in the virtual factory. Event-based simulation technology and improved human simulation and ergonomic analysis tools, for example, ensure that the simulation models are accurate and provide valid answers early on in manufacturing process development.”

Enhanced realism in 3-D also has improved for manufacturing users. “Event-based simulation and ESRC [Emulated Specific Robot Controller] capability, along with continued
integration of RRS [Realistic Robot Simulation] technology, ensure that robotic simulation models are as accurate as possible in the virtual world,” Hoffman adds. “Advanced human modeling, simulation, and analysis capability allow for very realistic modeling and validation of manual operations. Improved graphic performance and visualization techniques allow for much more realistic look and feel of the simulation environment. This helps to give decision makers and workers additional confidence in the results of the simulation.”

Virtual reality is also part of the visualization toolkit. “Motion capture for human simulation has been successfully used for quite some time now and continues to be used in support of assembly simulation and ergonomic assessment,” Hoffman observes. “Most recently, body-suit trackers and gyro-based trackers, which do not require a camera line-of-sight for tracking, have been implemented within the simulation environment.”

Siemens PLM has added a host of features to its Tecnomatix 9 digital manufacturing solutions. Hoffman notes that some of the latest simulation developments include updates to Tecnomatix Robotics’ event-based simulation engine, ESRC, and virtual commissioning. The Process Simulate Human has updates with clothed, deformable-mesh human figures, additional anthropometric databases, force-influenced posturing and analysis, and the ability to simulate workers performing tasks at elevation (nonzero position). The suite’s Factory/Plant application includes enhanced simulation of material transport devices and modeling of 3-D conveyor systems, and virtual commissioning.

On the machining side, Siemens also offers toolpath simulation in its NX CAM package. “The ability for Siemens PLM Software’s NX CAM to offer more complete and more accurate machining simulations allows the machinist to use machining simulation for the task of preparing for the next job on the shop floor,” says Vynce Paradise of Siemens PLM Software. “This includes checking the NC program in the full context of a 3-D model of the machine tool, the workpiece, and workholding/fixtures. The machinist can check for possible collisions, ensure the correct tool selection, check tool offsets, and so on.

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“This capability, undertaken on the virtual version of the machine tool running on a PC on the shop floor, can reduce job setup time on the real machine tool by as much as 90%,” Paradise contends. “To achieve this, a very complete kinematic model is required. For Siemens-controlled machines, we can utilize the core software from the real Sinumerik controller to drive the 3-D simulation model, ensuring a high level of simulation capability including all of the Sinumerik cycle commands and high-performance codes. These virtual machine tools are typically built by the machine tool vendors, using combinations of their own or Siemens’ modeling, simulation, and controller software, and offered as an option with selected advanced machine tools.”

NC toolpath simulation, verification, and optimization are all critical to ensuring machining accuracy. “In our experience with Vericut, many factory-floor workers are aware of the impact of simulation, and how it significantly improves the quality of the NC programs that run in the workshop,” notes Bill Hasenjaeger, product manager, CGTech Corp. (Irvine, CA). “In fact, it was a shop-floor machinist who first used ‘Vericut’ as a verb, by asking the NC programmer, ‘You did Vericut that NC program, didn’t you?’
“Making a virtual CNC simulation available to staff on the factory floor is not really a new idea, and one that seems like a logical and useful application of simulation,” Hasenjaeger states, “but it has been minimally adopted. Whether that’s due to hardware costs, software costs, complexity, reliability, or other factors is not really clear, but it’s likely a combination of factors. We have several customers using Vericut animations on the factory floor, but not the majority.” Hasenjaeger says the company recently introduced Vericut’s Reviewer tool, which allows a low-end computer to interactively replay a Vericut simulation. The user can dynamically rotate/pan/zoom the animated image, as well as measure features and inspect NC program lines.

“We’ve seen an increase in Vericut being used to simulate automated airframe assembly equipment—specifically automated drilling and fastening machinery,” he says. “To meet these demands, we’ve added features to Vericut that support these machines, including the ability to simulate the addition of fasteners, as commanded by the NC program.” This increasing interest prompted CGTech to create its Vericut Drilling and Fastening [VDAF], a new package specifically tailored to simulating and programming automated drilling and fastening machinery.

Can the need for highly realistic 3-D simulations be overstated for some applications? “That’s an interesting question, because it depends on what you mean by ‘realistic,’” Hasenjaeger states. “Humans are visual animals, and we’re easily superficially impressed by computer graphic tricks that look cool. This is great for the entertainment industry, but not necessarily what’s most important in an engineering application.

“For something as critical as validating the correct behavior of an NC program, a program responsible for moving a multi-ton machine at a high rate of speed and creating forces capable of severely injuring the operator and bystanders, you need more than a cool-looking animation,” he adds. “For CGTech, ‘realistic’
means correctly and accurately emulating the behavior of the CNC and the motion kinematics of the machine, as well as very accurately representing the material-removal operations on the workpiece. These are the important ‘realistic’ features of a good NC program simulation.”

In the latest release of Vericut version 7.1, the company has included further improvements to user interaction, simulation capabilities, cutting-tool creation, and CAD/CAM integration. Some of the new simulation capabilities include those for gear hobbing, general broaching operations, helical milling, back spot-facing tools, and the ability to stop the simulation at an “exact” collision point between the machine components. In addition, Vericut now supports a full range of six-axis robots to simulate machining, waterjet trimming, fiber-placement, drilling, and fastener insertion.

“Simulation speed is very important to our customers, but so is the amount of time spent preparing a simulation,” Hasenjaeger points out. “In response, we look to invent new ways to reduce the time required to set up and run a simulation. For example, when importing CAD solid models of tools, a new window allows easy identification of which parts of the CAD model file corresponds with holders, cutters, or inserts. This simplifies the creation of the Vericut tool library. We also constantly refine our CAD/CAM interfaces to help integrate the simulation step into our customers’ workflow.

“One of our projects underway right now is creating the ability to read 3-D cutting-tool geometry directly from the tool manufacturers. This not only includes reading the 3-D models, but also the cutting technology information. Getting this information directly from the tool manufacturers is absolutely the right way to do it because it ensures that our customers have the latest and most up-to-date tool information. We hope to soon get to where users can simply browse to a tool supplier’s Web site, download, and directly select a tool from Vericut, and begin using it in the simulation immediately.”

For complex machining, advanced simulations of the NC cutting process are critical to the machining process. Over the past few years, Methods Machine Tools Inc. (Sudbury, MA) has worked with software developer CAMplete Solutions Inc. (Waterloo, ON, Canada) in developing five-axis, multitasking, and turn-mill applications for customers using Matsuura and Nakamura machine tools that employ the CAMplete TruePath software.

“We got involved with CAMplete on a five-axis platform for our Matsuuras about six or seven years ago,” notes Rich Parentau, Methods Machine Tools director of applications development. “We were struggling, like everybody was, to convince our customers that five-axis was a simple process, and we were having difficulty taking a customer’s existing program from a five-axis machine, putting it in our machine, and getting what we considered better results, even though we feel we had a better machine. The results of that was really how we discovered CAMplete, because CAMplete brought our machine to the level of performance that we know it is, and it took out all the guesswork of the programming format, the posting, the kinematics, and all those things that made us to not look as good as the machine was.”

With CAMplete TruePath software, which is bundled with Methods’ five-axis Matsuura machines, users get full machine simulation including the 3-D model of the machine
kinematics. “The software is a simulation postprocessor, focused around a detailed model of the machine tool from the factory,” notes Mike Kaminski, Methods applications engineer. “The software is not a CAM system—it’s a verification/optimization system and a postprocessor for a majority of the top-end CAM systems out there on the market. It basically bridges the gap between the CAM system and the machine tool, so you do not need a postprocessor from the CAM company. What we do is we read the native cutter location [CL] file from the CAM system, and CAMplete TruePath takes that cutter location file and applies a template unique to the machine.

“Back 7-10 years ago, five-axis was really a niche market,” Kaminski notes, “where every time you thought of five-axis, it was always for impellers, blades, and blisks. We had a different focus at that point—to try to make five-axis simple—and we heard of a product that worked with a couple of other machine-tool manufacturers. Since that time, we have customers that are buying the five-axis products and using them for a lot more than just simultaneous work, but more for how they can attack a part and almost get a complete part out of one setup. So the customer confidence level on our end has risen dramatically with that product, and we really have kept five-axis simple.”

With CAMplete providing proven templates, users can take advantage of all of the high-end control features available, Kaminski adds, noting that CAMplete specialists listen to customers and often provide feedback the same day. And while Methods initially brought in the CAMplete system to focus on the five-axis Matsuura machines, Kaminski says the software has trickled down to horizontal Matsuuras and also to Methods’ RoboDrill products with five-axis bolt-on tables and to Matsuura vertical machines with bolt-on tables.

The companies demonstrated the CAMplete TurnMill software for simulation, verification, and optimization at IMTS on a Nakamura-Tome WT-150 multitasking turning
center. “We worked with CAMplete to develop a new product from the ground up, based on the problems in multitasking,” Kaminski says regarding turn-mill applications. “The problems in five-axis are actually quite different than the problems in multitasking. The problems in five-axis are the postprocessing of the G-code. And the problems in multitasking are not so much the G-code programming, because it’s actually quite simple; it’s the organization of the G-code and the optimization of wait time, and balancing cycle time.”

Simulations based on the 3-D kinematic model of the machine tool allow CAMplete to render fully accurate views of machine movements on these complex machine tools, with the system enabling the simulation to get as close to 100% accuracy as possible. “The big thing with the milling system was it’s just one tool in the cut at one time, so that the simulation you know is based off the CL data and it takes into effect how the machine moves,” Kaminski adds. “But on the turn-mill side, since we have multiple tools in the cut at one time, we really need to focus our attention at that time.

“The way the new CAMplete TurnMill simulation works is it’s like a movie player—we break down every piece of motion into a time slice so that we can optimize time at any moment,” Kaminski explains. “What I mean is the instances between points, because in the turn-mill software, we actually account for the acceleration and deceleration of the machine tool. So as the different axes have different acceleration and deceleration rates, we are very accurate, knowing the time slice and what is happening at any instance.”

Methods now offers the CAMplete TurnMill solution exclusively in the US and Mexico. The software includes a full G-code editor, and the package’s optimization features wait-code editing, reorder and move operations, the ability to fine-tune and optimize to simplify multitasking, and analysis tools that monitor all aspects of machine motion, including true cutting speeds, axis velocity and acceleration, and motion deviations. ME