

The MIT scientist proved to be prescient: Promising research is under way to develop manufacturing processes so small that they operate on the level of molecules. Although development of micro- and nano-manufacturing remains in its infancy, the expectations for it are high. Concepts such as micromachine design, nanomodeling, and molecule-level manufacturing represent a promising future approach to turning raw materials into precision finished products. Nano- and micro-technologies have the potential to dramatically disrupt entire industries and make enterprises far more agile across every industrial sector.

The term "nanotechnology" is often used rather loosely and may simply refer to any technology in which the focus of activity takes place on an infinitesimally small scale. But some subsets of the discipline are quite specific. Molecular manufacturing, for example, refers to the production of complex structures via nonbiological "mechano-synthesis." Simply put, this is the mechanical control of myriad tiny reactions so as to build complex structures. If and when this feat is accomplished, molecular manufacturing may be the most disruptive innovation to ever affect supply chains. That's because when manufacturers go directly from raw chemicals to a finished, atomically precise product in one step, there is no supply chain. And it's hard to envision a technology more disruptive than that.

Disruptive Technology #3: Modeling and Simulation

Instead of building expensive and hard-to-change prototypes, high-speed computers allow engineers to build virtual representations of parts, processes, and systems, and to simulate their interaction with one another under many conditions. While digital modeling is not new, the sophistication, accuracy, and low barriers to entry made possible by new software and low-cost but powerful computers portend disruption in a wide range of design and engineering disciplines.

More flexible and much less expensive than physical modeling, digital models and simulation technology allow the visualization of things before they are actually created. Thus, the ability to innovate is greatly enhanced because the time and cost required to experiment with new materials are dramatically reduced. The use of simulation-enhanced design early in the manufacturing process already enables significant benefits to manufacturing companies by way of cost reductions, scheduling improvements, and risk reductions.

Caztek Inc., a St. Paul company that designs parts for the aerospace industry, frequently uses finite element analysis software to model the performance of rocket engine components, such as valves and nozzles prior to making prototypes. "We use modeling packages integrated with CAD programs, such

as SolidWorks, to predict the performance of rocket engine parts before we begin fabricating," says company president Casimir Sienkiewicz. "Modeling and simulation of parts drastically reduce lead times and costs."

There are benefits on the manufacturing side as well as the design side. Aside from product design efficiencies, modeling and simulation innovations could also have significant impact upon manufacturing decisions. For example, factory process simulation could provide companies with the capability to virtually evaluate a subcontractor's skills, machine capabilities, and so forth, leading to better supply chain management.

Disruptive Technology #4: Reconfigurable Tools and Systems

Reconfigurable tools and systems allow manufacturers to perform sophisticated manufacturing operations not anticipated in the original design, without requiring new tool production. In its most common conceptualization, reconfigurable tooling resembles a pin art impression toy, the kind where people press their hands into hundreds of blunt no-stick pins to create 3D art designs.

On the shop floor, such industrial versions of that item are called "discrete-die" reconfigurable tooling. Similar to the aforementioned toy, the discrete-die tool is made up of bundles of closely spaced, individual elements, usually pins. The pins can be precisely moved up or down to change the tool shape. Besides reducing the time required to obtain tools for low-run products, reconfigurable tools can also reduce the number of machine tools, and therefore the shop space needed for manufacturing.

Reconfigurable systems expand this flexibility beyond individual machine tools and apply it at a factory level. A Reconfigurable Manufacturing System is one designed using digital hardware and software at the outset to allow rapid changes in shop layout and throughput, thus accommodating rapid adjustment in product designs and volumes.

Futurists ponder even further refinements in reconfigurable tools and systems, allowing machines to work directly from product designs, correct problems "on the fly," detect and perform maintenance adjustments, and adapt themselves to changing conditions.

Currently, the applications most suited to reconfigurable tooling and systems are short-run, high-value part manufacturing. Aerospace manufacturing is a natural fit, and reconfigurable tooling already is used to form some sheet metal parts for aircraft.

When fully developed, reconfigurable tools and systems will enable much shorter lead times, reduced lot sizes, and cheaper, more flexible manufacturing processes. These capabilities will help make mass customization a reality for many manufacturers.

