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➤BY BILL KENNEDY, CONTRIBUTING EDITOR

FROM Research TO Reality

A machine tool research conference explained how today's R&D is shedding light on the future of manufacturing.

In this age of video gaming and electronic trading, many people view manufacturing as a backwater of progress, an outdated vestige of our "smokestack" past. This perception is wrong in several respects, according to Dr. Marvin F. DeVries, professor emeritus of mechanical engineering, University of Wisconsin, Madison.

"Actually, history shows a remarkably consistent causal pattern where evolutions in manufacturing correspond to profound social change," he said. Developments in manufacturing technology replaced individual craftsmanship with mass production, which helped transform the U.S. economy from primarily rural-agrarian to urban-industrial while powering the globalization trend, according to DeVries. Those changes, in turn, gave rise to social issues such as the changing role of labor, the need for pollution control and a widening gap between the world's "haves and have-nots."

A key consideration, predicted DeVries, is that the next 25 years will see greater development of technology than occurred in the past 250.

DeVries made his remarks in accepting a Distinguished Service award at the MTTRF/OMNI-CNC 2006 annual meeting, held July 6-7 in San Francisco. The research projects associated with the MTTRF (Machine Tool Technologies Research Foundation) and OMNI-CNC (a 5-year project to develop a new CNC system) are strong examples of manufacturing technology development driven by real-world issues (see sidebars on pages 74 and 76).

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Dr. Kazuo Yamazaki of MTTRF and University of California, Davis, (left) and Dr. Masahiko Mori, president of Mori Seiki Co., at the MTTRF/OMNI-CNC 2006 annual meeting.

The award recognized DeVries' long and productive career in education and manufacturing technology. That career began in 1959 with a summer job operating a manual drill press. It included, in addition to his teaching duties, work with colleagues of Fredrick Taylor and other pioneers of manufacturing technology, serving as a senior program director with the National Science Foundation, and consulting.

Even with a solid historical foundation, predicting the future is difficult, but Devries feels some things are certain: the world will have more people and fewer resources, and the gap between the world's rich and poor will grow. The manufacturing technology needed to deal with those issues will include green manufacturing; miniaturization and nanomanufacturing; robotic and other forms of automation; and application of Internet-based knowledge systems.

The machine tool research work described at the MTTRF/OMNI-CNC meeting addressed those areas and more, including:

■ **Microendmills:** A project at Keio University, Japan, studied the use of microendmills to replace chemical etching in creating complex, 250μmwide 3-D features in glass components used in biochemical analysis. The microtools accurately produced the features, but tool wear still needs to be addressed.

■ **Micromilling:** Also in response to the trend toward smaller workpieces and tighter tolerances, a National University of Singapore project examined micromilling. Specifically, the investigation sought reasons why micromilling tools often fail prematurely at low DOCs and experience less wear as axial DOC increases. Regarding the latter, researchers found that the relatively higher ratio of tool engagement to tool size when micromilling, compared to macroscale milling, produces higher process damping and, therefore, reduces stress on the tool.

■ **Burrs in micromachining:** The trend towards making smaller, more precise parts in nearly every facet of manufacturing makes burrs a bigger problem than with larger parts. A University of California, Berkeley, research project examined process conditions, tool geometry and workpiece material properties related to burr formation while micromachining. The goal was to gather information that could be integrated into design and manufacturing software so engineers can reduce the likelihood of burr formation at the product design stage. One study finding was that climb milling at a high cutting speed and low feed rate helps minimize burr formation.

■ **Minimum-quantity lubrication:** Researchers at Kanazawa University, Japan, used color pyrometers to devise innovative temperature-measuring systems and accurately determine the influence of minimum-quantity lubrication (MQL) on temperature at the tool/chip interface when turning, endmilling and drilling. The study found that use of the oil mist coolant when drilling produced the greatest reduction in cutting tool temperature.

■ **Coolants for titanium:** Coolant supply and cutting condition strategies for titanium were the subjects of a study by the National University of Singapore. The study found that, at the same DOC, application of MQL when endmilling titanium extended tool life and increased material-removal rates compared to machining dry or with flood coolant. The maximum possible DOC was 8mm—above that, all test inserts failed quickly.

■ **Estimating cutting forces**. To maximize the productivity of a modern, high-speed machine tool, even an expert machine operator requires accurate process monitoring and the ability to adapt to changing machine conditions. A study at Kyoto University, Japan, proposed a method of estimating cutting forces by geometrically combining information regarding electrical current use by both the machine tool's servomotor and its spindle. In addition to validating that force measurement approach, the researchers also applied it as a prediction model in a canned endmilling cycle, and used it as the basis of a feed rate control scheme. The result was increased machining efficiency and reduced load on the cutting tool.

■ **Process optimization:** Researchers at the University of British Columbia, Canada, presented a process optimization strategy for 2.5-D milling operations aimed at increasing removal rates. The optimization took place in two steps, beginning with preprocess optimization during the CAM stage and followed by postprocessing optimization, which tuned the feed and speed for an existing part process without reprogramming.

■ **Reduced setup time.** A study by Osaka University, Japan, involved developing an "area division" method to quickly determine the position of the tool relative to the workpiece in a 5-axis machining application. The goal was to eliminate interference between the tilting tool and a complex workpiece. As opposed to the slow, point-by-point toolpath analysis technique traditionally applied to avoid interference, the area division method finds an interference-free position for the tool and then determines the entire area where the tool can operate freely. The procedure is repeated until the whole workpiece is covered, at which time toolpaths are generated.

■ **Circular vibration milling.** A new method for improving surface finishes when milling difficult-to-machine materials was the focus of a study performed at Kobe University, Japan. The method, called "circular vibration milling," is based on a milling attachment that moved an endmill in a 0.5mm eccentric circular path at the same time as the cutter rotated normally. Researchers found that interference with the tool flank face made commercially available, 4-flute, 30º helix-angle endmills unsuitable for circular vibration milling, but custom-made 2-flute, 0º helix-angle endmills with 15º relief angles worked well. The researchers concluded that surface finishes imparted with the attachment could potentially reduce or eliminate manual parts polishing.

■ **Machining free-form surfaces:** The University of Sao Paulo, Brazil, outlined its efforts to date in machining complex 3-D surfaces on hardened steels as applied in mold injection tooling. The work involved study of cutting parameters, tool geometries and monitoring technologies, as well as the effects of workpiece material properties on surface roughness. With the new equipment, the researchers plan to examine the machining of microcavities.

Concluding his acceptance presentation, DeVries said manufacturing must be redefined more broadly, changing the description from "transforming raw materials into goods" to "the general transforming of resources to meet human needs." The research efforts described at the MTTRF/OMNI-CNC annual meeting are good examples of manufacturing technology development driven by issues that ultimately reflect global human needs. △

MTTRF brings industry and academia together

The Machine Tool Technologies Research Foundation (MTTRF) is a joint effort of the Intelligent Manufacturing Systems and Mechatronics Laboratory of the Department of Aeronautical and Manufacturing Engineering at the University of California, Davis, and Japanese machine tool builder Mori Seiki Co. Ltd., through its U.S. subsidiary, Mori Seiki U.S.A Inc., Rolling Meadows, Ill. The foundation, established in 2004 to support research and educational activities in machine tool technology, began with equipment loans and scholarships to educators, students, professional researchers and technical specialists.

Dr. Masahiko Mori, president of Mori Seiki Co., said his company helped establish the MTTRF in response to a need for more machining technology researchers. Including this year's equipment awards, a total of nine universities in Japan, Canada, Singapore, the U.S. and Brazil are now performing research using machines on loan from Mori Seiki. Mori noted that, traditionally, when a university purchases a machine tool, it may have the equipment for 10 to 20 years due to relatively light use by students and the expense of buying a new machine. The equipment loaned by Mori Seiki through the MTTRF can be replaced every few years, assuring that researchers work with new machining technology.

Another component of the MTTRF loan program involves providing licenses for ESPRIT CAM software from DP Technology Corp., Camarillo, Calif., to all equipment loan participants. DP Technology CEO Daniel Frayssinet explained his company's participation in the MTTRF as part of a response to the rapid growth of computing technology, which, combined with the relatively small size of the CAM market, makes adequately funding CAM R&D difficult. Working with universities, commercial partners and customers permits co-development of specific software applications based on the core operating system of ESPRIT, much like Windows serves as the basis for specific PC applications. The goal is to enable a machine tool to be "CAD compatible," Frayssinet said, with the CAM software acting as the machine tool's "printer driver" for CAD data.

—*B. Kennedy*

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Daniel Frayssinet, CEO of ESPRIT CAM software provider DP Technology Corp.

OMNI-CNC seeks 'nifty' technology

In 1990, the Department of Aeronautical and Manufacturing Engineering at the University of California, Davis, established an Intelligent Manufacturing Systems (IMS) and Mechatronics Laboratory. Among its research efforts, the lab has pursued a series of projects dedicated to further development of CNC technology.

From 1996 to 1999, its TRUE-CNC project focused on machine infrastructure for planning, analysis, machine control and monitoring. VIVID-CNC, from 1999 to 2002, emphasized autonomously intelligent application technology. In 2002, the lab began its OMNI-CNC project, a 5-year effort intended to create an integrated CNC system for the future. The system will consist of three parts: the human/machine interface, a high-performance CNC core and a versatile motion/logic control engine. The acronym OMNI stands for Operability, Multiview, Nifty intelligence and Informative data provision.

Each year, OMNI-CNC researchers offer a series of presentations on their progress. At the 2006 OMNI-CNC meeting, IMS-Mechatronics Laboratory professor and director Dr. Kazuo Yamazaki (also president of the MTTRF) outlined the OMNI-CNC group's progress and set the stage for the presentations.

Researchers explained the project's model-based approach to designing the high-performance core of the CNC system. The approach utilizes computer-aided control system design tools, making debugging and redesign during development much easier than it would be with a hardware-based design method.

One component of the OMNI-CNC project that is moving toward practical application is a 3-D vision system that creates an accurate model of the entire work envelope, including the workpiece, fixturing and table. According to Marlow Knabach, Mori Seiki U.S.A's marketing vice president, the model can enhance collision avoidance and eliminate trial machining. Mori Seiki President Dr. Masahiko Mori said the vision system could be commercialized within 2 years.

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The following companies contributed to this report:

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