Center for Machine-Tool Systems Research (CMTSR)

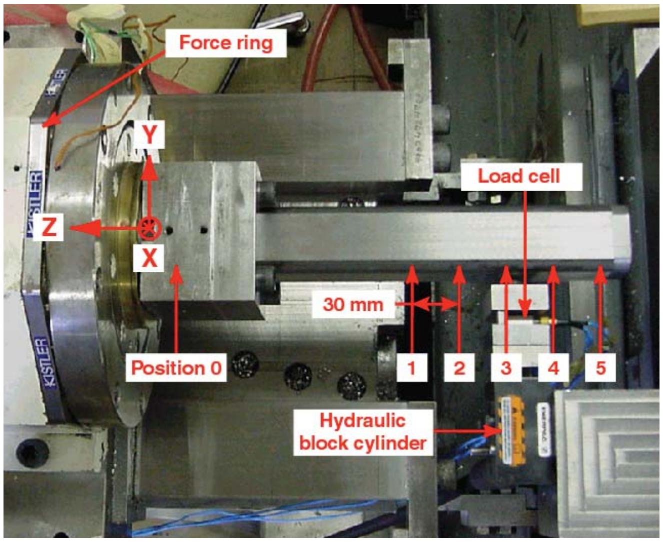
University of Illinois at Urbana-Champaign

National manufacturing competitiveness depends on increased attention to machine-tool development and better use of existing machine tools

A National Science Foundation Industry/University Cooperative Research Center since 1995

Center Mission and Rationale

The goal of the Center for Machine-Tool Systems Research (CMTSR) is to develop and transfer to industry innovative machine-tool concepts and systems based on technologies representing both incremental and fundamental advances; to train students in the expert development and deployment of these systems; and to improve the use of existing machine tools through increased understanding and modeling of machining processes. The Center's ultimate mission is to spur marked improvement of national manufacturing competitiveness through the deployment of advanced machine-tool systems.



Sensor Integration in a Spindle Housing of Milling Machine.

Research Program

Team projects in the CMTSR focus on the following three areas:

- ***Agile/flexible machining and machine-tool systems*** — Processes and equipment that can provide a strong response to change and better serve smaller runs and broad part families
- ***Machine-tool system planning and control*** — Tools for effective use of machine-tool systems — e.g., planning, scheduling, control
- ***Machining process development and innovation*** — Modeling and prediction of product and process quality performance – such as surface finish and error, dimensional accuracy, etc. – including both off-line design-based considerations and on-line monitoring and control applications.

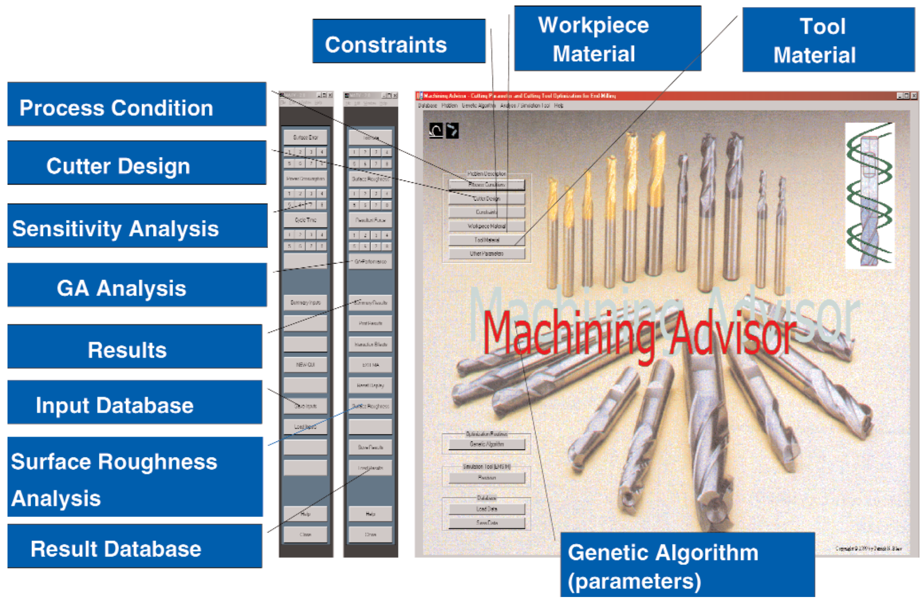
Together, faculty, students, and company members deal with these topics in ways that shed new light on both the principles of agility in machine-tool systems and the relationships between technological and cultural issues. Technology integration themes are also thoroughly explored.

Center Research Activities

Company members participate in both *company-designated* and *Center-designated* projects. Company-designated projects are initiated by each member company; company researchers collaborate closely with university faculty and students on these projects. Collectively, the member companies also solicit and fund faculty proposals for Center-designated projects in areas determined to be of particular interest by the Center's industrial advisory board.

Currently, 10 faculty and more than 20 students participate in over 20 ongoing company- and Center-designated projects. Some recent projects are explained below:

Deep Hole Drilling of Steel and Aluminum Alloys — Drilling and deep-hole drilling operations account for almost 25% of machining time and 33% of all machining operations. Deep-hole drilling is often the major bottleneck in high-volume automobile component production because of chip clogging. The objectives of this research are to (1) phenomenologically understand the factors involved in the chip-evacuation mechanism and (2) mitigate the effects of chip clogging in deep-hole drilling. The results of this research will aid the industry in gaining a better understanding of the factors affecting chip evacuation, which will in turn result in less tool breakage, reduced machining time, and improved workpiece quality. A chip-evacuation force model that predicts chip-evacuation thrust and torque has been developed for arbitrary flute geometries. It is shown that a parabolic flute geometry drill produces lower chip-evacuation forces than the standard flute geometry drill and a 30% increase in critical depth. In addition, the model can be used to predict the depth when the chip clogging occurs, indicating the need for a pecking cycle.



The initial screen of the Machining Advisor software (featured in June 1999 issue of Cutting Tool Engineering) that can generate process parameters that simultaneously satisfy economic, productivity, and quality design constraints, while providing sensitivity analysis allowing the user to make necessary trade-offs.

Environmentally Conscious Manufacturing — Environmentally conscious manufacturing has become increasingly important in recent years. Center research in this area has revolved around the metal cutting fluids. The disposal of cutting fluid places a significant burden on the environment. In addition, bacteria and the biocides used to control their growth in cutting fluids can be a significant health hazard. One project in this area aims at determining the compatibility and productivity of microfiltration technology with common cutting fluid chemistries through identification of the chemical characteristics of cutting fluid ingredients. Another project in this area has been devoted to study of the impact of tramp oils, bacteria, and chips absorption on elective depletion of metal working fluids.

Machining Process Modeling and Diagnostics — This research area includes 1) modeling of machining processes, such as turning, milling, drilling and tapping; 2) process monitoring and diagnostics; and 3) models for the prediction of machining performance. For example, a mechanistic torque and thrust model for internal thread forming has been under development in one of the projects, based on given tap/hole geometry, process parameters, and common faults such as tap runout. Modeling and analysis of turning processes with contoured and interrupted surfaces such as found in automobile wheels is the focus of the turning process modeling project. Another project aims at determining the performance of a spindle-based monitoring system and its effectiveness in measuring machining forces and assessing spindle conditions such as bearing wear. A microstructure-level finite element model is being developed for calibration of mechanistic model force coefficients that will eliminate the need for costly, time-consuming and instrumentation-intensive calibration experiments.

Recent Accomplishments
Two patents on constant velocity (CV) joint wear measurement and analysis have been filed. *Method and Means for Measuring Wear in Constant Velocity Joint* is an instrument that provides a direct, quantitative measure of CV joint track wear, and *Spline Counting Mechanism* is a handheld device for measuring certain important parameters of splines.

A three-axis kinematic parallel-link mechanism for ceramics machining has been designed and delivered to Caterpillar, Inc. Modularity was used in design, analysis, and fabrication stages of this next-generation machine-tool concept.

A model-based machining advisor system for turning straight and contour surfaces has been developed and a CD has been delivered to member companies for testing and implementation. The machining advisor system will allow the member companies to optimize their machining processes and reduce dependence on ad hoc methods of process planning and undue reliance on highly skilled machinists.

A membrane filteration hardware testbed has been developed with the ability to acquire microfilteration research data in flexible operating environments. The reconfigurable design of the testbed permits modification to run membranes of a variety of sizes, geometries, and materials. The testbed uses larger ceramic membrane systems commonly employed in industrial applications.

A low-inertia spindle with high-bandwidth speed control has been developed with the help of Ingersoll Milling Machine Co. The spindle has been retrofitted to an open-architecture milling machine for the investigation of chatter prevention through spindle-speed variation. Analytical models have also been developed to study the stability of variable-spindle-speed machining.

Facilities

Research facilities and equipment at the Center include: a variable-spindle-speed machining testbed, a modular machining fixture testbed, a vertical machining center, two CNC lathes, a tapping-drilling machine, a spindle-based monitoring system, and an environmentally conscious manufacturing testbed. The Center also has a variety of metrology equipment and instrumentation including dynamometers, accelerometers, instrumented hammers and force sensors, an 8-channel signal analyzer; two Coordinate Measuring Machines (CMM), surface characterization equipment, a tool-analyzer microscope, and other high-speed data acquisition systems.

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