CENTER FOR PRECISION METROLOGY (CPM)

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The University of North Carolina at Charlotte

Advanced manufacturing metrology leads to improved product capability

A National Science Foundation Industry/University Cooperative Research Center since 1998

Center Mission and Rationale

As manufacturing dimensional tolerances continually shrink, the requirements for production machines and inspection instruments to meet these demands become increasingly vital for manufacturers to remain competitive. Integral to these demands, precision metrology encompasses the methods of inspection in manufacturing, the metrology of both inspection and production machines, measurement algorithms and tolerance representation, and the integration of metrology into factory quality systems. The mission of the Center for Precision Metrology is the furtherance of applied research and technological progress in the field of precision metrology as applied to manufacturing problems. In order to realize this mission, the following mission-specific tasks are set forth to guide the CPM:

- Education of a new generation of production engineers who are practical but highly educated technologists, fully capable of using existing and developing technologies
- Continuous assessment and application of international research, development, and standards results and activities
- Conducting original research on and development of innovative metrology technology, including quality control and virtual metrology systems
- Involvement with private companies capable of commercializing innovative measurement processes, tools, and equipment
- Acquisition of significant private industrial support for both the generic program and specific research applications
- Continuous interaction with other centers, universities, and government laboratories through joint research and development programs and shared planning
- Experimentation in the use of evolving information technologies to perform distributed research, development, and education
- Experimentation with multimedia technology to provide high-quality education with a large component of multidisciplinary input.

Students often work on Center research or class projects in the controlled-environment Metrology Laboratory.

Research Program

Although the Center has existed as an I/UCRC only since July of 1998, intensive applied research has previously been conducted for over a decade though the Center's precursor, the Precision Engineering Laboratory. The CPM conducts a broad-based interdisciplinary research program involving faculty and students from mechanical engineering, electrical engineering, applied physics, computer science, manufacturing engineering technology, and business fields. Research spans all dimensional-related domains of manufacturing, including product specification, production, and quality assurance. Advances in the areas of product specification are effected by involvement with national and international standards committees, and by direct research in computer-aided tolerancing and virtual manufacturing. In addition to machine design, production metrology research involves the process measurement, error measurement, error modeling, and software correction of production machines. Algorithms, probes, sensors, instrumentation, calibration techniques, and standards are developed or used to handle particular metrology issues in the area of quality assurance.

Current and previous research projects include:

- Sub-Atomic Measuring Machine
- Tool Tuning for Machining Centers
- Wavelength Stabilization of Laser Diodes
- Robust Engineering Methods
- Nanocut – A Nanometric Cutting Force Measurement Instrument
- Virtual Manufacturing
- High Speed Dynamic Machine Checking
- Post-Process Metrology Research
- Scanning CMM Capabilities and Calibration Techniques
- Rotary Axes Modeling and Measurement
- Uncertainty of 3D Measurements
- Calibration of Interferometric-Based Cylinder Measuring Machine
- White Light Interferometry Techniques for Dimensional Measurement
- Vectored Touch Sensor
- CAD-based Thermal Soak-out Prediction

Students receive practical metrology experience. Here a student uses a grid encoder to investigate the dynamic errors of a machining center.

- Profile Tolerance Definitions
- Nanometric Hardness Indentation Instrumentation
- Metrology Applications of Wireless Network Technology
- Internet Based Surface and Form Metrology Analysis
- CMM Contact Scanning of Edges and Corners
- High Speed Optical Metrology
- National Standards Development
- Enabling Technology for Extreme UV Optics Measuring Machine
- Machine Tool Accuracy Initiative
- Computer-aided Textured Surfaces
- Silicon Point Pressure Effects
- Precision Machining Simulation
- Variational Geometry Software
- Tolerance Specification Consistency
- 3-D Tolerance Control
- Object-oriented Machine Tool Controller
- ASIC Vision Measurement
- Molecular Dynamics of Machining
- Whitelight Fiber-Optic Interferometry Probe
- Instrumentation for Crankshaft Metrology
- Machine Tool Thermal Error Compensation
- Machine Tool Geometric Error Correction
- Long-Range Nanometric Stage
- CMM Capacitance Probe Tests
- Heterodyne Polarimetry
- Giant Magnetoresistive Sensor Design
- Real-Time Error Corrector Evaluation
- Vibration-Assisted Diamond Turning
- Ceramic Machining
- Vision CMM Calibration Techniques
- Surface Normal Probing Techniques
- Flexure Design & Analysis
- Long-Range Fast Tool Servo
- Six-Degrees-of-Freedom, Non-contacting Metrology Frame
- Tuning Fork-based Resonating Sensor
- MilliKelvin Temperature Control
- Diamond Films for Manufacturing

Virtual manufacturing research includes finite element analysis for preprocess determination of manufacturing errors related to geometrical accuracy and thermal variations due to machines and environment. Shown is a graphically represented analysis for a gear pump housing.

Facilities

In order to sustain research, development, and training, facilities are maintained to manufacture components and measure their tolerances at the required levels. Among these is a 1,400-square-foot controlled-environment Metrology Laboratory, which accommodates five computer numerically controlled (CNC) optical and contact-based coordinate measuring machines (CMMs) along with many other measuring machines and instruments, in addition to special-use gages and devices. Additional laboratories exist for Computer Integrated Manufacturing, Computational Assembly Analysis, Precision Motion Systems, Instrumentation Development, Precision Electro-Optical, Mechatronics, Manufacturing and Precision Electromechanics, Scanned Probe Microscopy, and Applied Physics. Other resources include a staffed Machine Shop, Electronics Shop, and Microelectronics Fabrication Facility.

Special Center Activities

(Inter)National Standards Involvement

Faculty serve on various national and international standards committees, with chairing and writing responsibilities. Research is also conducted concurrent to the standards development for testing, evaluation, and expansion purposes. Faculty members are active as members, chair, and experts on the following standards committees or their U.S. technical advisory committees:

- ASME B5.52 Committee, which produced the following B5.54 and B5.57M Standards:
  - ASME B5.54 “Methods for the Performance Evaluation of Computer Numerically Controlled Machining Centers”
  - ASME B5.57M “Methods for Performance Evaluation of Computer Numerically Controlled Lathes and Turning Centers”
- ASME B46.1 “Surface Texture (Surface Roughness, Waviness, and Lay)”
- ASME B89.4.1 “Methods for Performance Evaluation of Coordinate Measuring Machines”
- ASME B89.3.1 “Measurement of Out-of-Roundness”
- ASME Y14.5.1 “Mathematical Definition of Dimensioning and Tolerancing Principles”
- ASME Y14.32.2 Draft “Surface Specifications for Car Body”
- ASME Board on Standardization
- ISO/TC 213 “Dimensional and Geometrical Product Specifications and Verification”
  - WG 2 “Datums and Datum Systems”
  - WG 14 “Vertical GPS Principles”

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