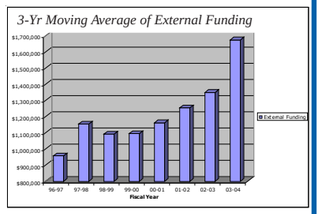
Exploring New Frontiers in Manufacturing Research

"*Space, the final frontier . . .*" This famous phrase is probably better known than the beginning phrase of our Declaration of Independence. But the opening line to Star Trek infers that in the future, all other fields of exploration will have been conquered. That's not the case today as we see many challenges that remain in manufacturing - the integration of design, manufacturing, and analysis; advances in ultra-wide band wireless communications to enable complex sensor networks or long range wireless computing networks; and material discoveries for thin film coatings and nanophase material synthesis that are bringing us one step closer to realizing a major shift towards a hydrogen economy. These are all active areas of research at the Center for Manufacturing Research (CMR). With the addition of two new faculty, the purchase of more than $625,000 in new equipment and laboratory renovations, and a record number of proposals submitted for external funding, the CMR reached an all-time high for project activations ***surpassing the previous record by more than 60%***. In fact, the ***$2.467 million*** in project activations exceeded last year's total by ***more than 80%***.

3-Yr Moving Average of External Funding



CMR Strategic Research Areas

As in any exploration activity, there are risks that must be taken, but not without precise calculation and careful thought for the overall success of the mission. The CMR is also taking risks by leveraging time and talents to enable us to collaborate on larger projects. We also have had to stretch our meager financial resources to the limit, utilizing a variety of projects and external sources to help support our growth. There is always some fear that after a phenomenal year such as we had this year that there might be a tendency to let down, but every indication is that FY 2004-05 may be better than this past year. Perhaps in just a few short years space may actually be the final frontier – but until that time the Center for Manufacturing Research will continue to bridge the gap between tomorrow's dreams and today's reality. As identified by the Center's Year 2000-2010 Technology Forecast, the following strategic focus areas: 1) Next Generation Materials and Manufacturing Processes, 2) Control of Processes and Equipment, 3) Integrated Product/Process Realization, and 4) Pervasive Simulation and Modeling will be instrumental in the enhancement of Tennessee's economic development through research, development, demonstration and technology transfer activities.

Next Generation Materials and Manufacturing Processes

Concrete is one of the world's most popular building materials, but faculty associate Joe Biernacki (ChE) is exploring its properties at an all-new level. Dr. Biernacki received a total of $94,969 as part of a three-year NSF grant to investigate the potential for using synchotron X-ray and neutron diffraction and Raman spectroscopy to measure micro- and meso-scale strains in concrete materials. This is a collaborative proposal with Oak Ridge National Laboratory (ORNL) and the National Institute of Standards (NIST) to measure the stresses generated mechanically in Portland cement-based materials. In a recent technology roadmap generated for the U.S. concrete industry entitled, "Roadmap 2030: The U.S. Concrete Industry Technology Roadmap," several high-priority research gaps were identified that will be a focus of Dr. Biernacki's research: development of new materials to reduce shrinkage and cracking, reduction of alkali-silica reactions in concrete, prediction methods and models for cracking, durability, and performance As part of this project, Dr. Biernacki also received supplemental funding to incorporate undergraduate students as research participants in the project. This exemplifies one of the hallmark characteristics of an academician – the lines between research and teaching are so blurred that one area (research or teaching) cannot be truly fulfilled without the other. Dr. Biernacki also received $24,000 from NSF to lead a two-day Indo-U.S. workshop to explore opportunities for next generation advances in high-performance cement-based concrete composites. The workshop will be held in December 2004 in India and will include world-renowned experts from both countries.

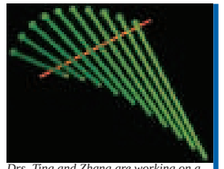
Since joining the CMR faculty in August 2003, Dr. Chunsheng Wang has continued research that he was involved in while working for his former employer, the Center for Electrochemical Systems and Hydrogen Research at the Texas Engineering Experiment Station affiliated with the Texas A&M University System. The NASA Glenn Research Center project entitled, "Advanced Lithium Ion Polymer Batteries for Aerospace Applications" is now in its third and final year and all totaled, Dr. Wang has received $75,167 in the past fiscal year. To date, Dr. Wang has generated almost two dozen combined publications and presentations from this line of research and was highlighted in a recent Technology Brief generated by NASA Glenn. Dr. Wang's specific research tasks include characterizing lithium-ion-conducting fiber- (and mat) PEO composite solid polymer electrolytes for advanced batteries.

Dr. John Zhu (ME) is in the second year of his five-year CAREER award funded by the National Science Foundation ($78,410). Dr. Zhu's project is investigating novel conductive oxide coatings on metallic interconnect materials for intermediate-temperature Solid Oxide Fuel Cell (SOFC) applications. SOFC offer the potential to generate electricity in an environmentally friendly, highly efficient, and cost-effective manner. Significant materials-related issues must be overcome before SOFC can be economically deployed for commercial-scale power generation. Particularly challenging is the development of a low cost interconnect material. This research is investigating a double-layer coating approach to address issues of thermal expansion, corrosion, and electrical conductivity performance. Integrated within the research plan are a number of educational activities to expand the understanding of high school students and teachers about the role materials science plays in development of fuel cells.

Oak Ridge National Laboratory extended two research projects that had been funded last year to examine basic materials research with far-reaching impacts. The first is a project entitled, "Alloying Effects on Alloy Preparation and Microstructural Features in TbFe2" ($40,000) and is being led by Dr. John Zhu. The crux of the research deals with a material property known as "magnetostriction." Magnetostriction is a change of a material's physical dimensions in response to changing its magnetization, via processes such as the migration of domain walls within the material in response to external magnetic field and/or the rotation of the domains. Many materials are known to exhibit the magnetostriction effect, however the rare earth compounds show the largest magnetostriction also referred to as Giant Magnetostriction Alloys (GMA). Applications for GMA may include sensing and activating devices in microsystems, which offers the advantage of higher load capability and shorter response time, as compared to shape-memory effect and piezo-electric effect. The second project, led by Dr. Ying Zhang (ME), is examining NiAl and FeAl coatings on boiler tube ferritic steels and their resistance to corrosion. Dr. Zhang had received three prior years worth of research funding from ORNL, and this year's funding ($78,000) represents the first installment in another three years of future funding.

Integrated Product/Process Realization

CMR faculty member, Dr. Kwun-Lon Ting, received his second year of funding ($91,488) on a three-year, NSF funded project entitled, "Theory and Practice of Point Line Kinematics." Many physical operations are best described as a point-line motion, such as CNC machining, water jet cutting, laser machining, or robotic motion. Such tools or objects can be characterized by an end point and an axis. They may be used in systems with 1 to 5 or higher degrees-of-freedom. As the point moves, the configuration of a point-line must coordinate while the rotation about the axis is irrelevant. In many situations, point-line motion synthesis and programming, such as the situations in mechanism synthesis, robotics, and five-axis CNC tool path generation, can be very complex and difficult. Dr. Ting's research will offer an integrated and comprehensive treatment for point-line motion and establish the foundation and infrastructure for the analysis, characterization, synthesis and control of point-line motion, especially in complicated situations.



Drs. Ting and Zhang are working on a 3-yr, NSF project entitled "Theory and Practice of Point-Line Kinematics." Shown is a twist motion of a point-line.

Intelligent Control of Processes and Equipment

The area of Intelligent Control of Processes and Equipment saw two of the largest contracts awarded this past fiscal year. First was the U.S. Department of Energy funded contract entitled, "In-Situ, Real Time Monitoring and Control of Mold Making and Filling Processes," which is part of the Office of Industrial Technologies' "Advanced Melting or Innovative Casting Processes for Metal Casting" solicitation. Dr. Mohamed Abdelrahman (ECE) is the PI and project leader, managing an effort that will spend $1.5 million of DOE funds and another $1.5 million of matching commitments from the participating partners over the next three years. The primary principals in the contract are the Center for Manufacturing Research, Oak Ridge National Laboratories, and Walford Technologies with other industrial participation coming from the following companies or organizations: General Motors, Metal Casting Technologies, Citation, D8, Foseco Morval, Hirsch-USA, Styrochem, American Foundry Society, U.S. Pipe, Mercury Marine, Unimin, FlowSim, US Pipe, Carbo Ceramics, and Metal Tek International. The project goal is to introduce technologies for real time characterization of sand molds, lost foam patterns and monitoring of the mold filling process. The proposed technologies will enable better control over the casting process. It is expected to reduce scrap and variance in the casting quality. A strong educational component is integrated into the research plan to utilize increased awareness of the industry professional, the potential benefits of the developed technology, and the potential benefits of cross cutting technology. The program also aims at enhancing the image of the metal casting industry where high technology opportunities exist. The latter is especially effective in encouraging highly qualified engineering students and technologists to choose the metal casting industry as a career. This integration aspect is considered to be one of the key factors in the selection of TTU for this contract. Assisting Dr. Abdelrahman are Dr. Fred Vondra (MIT) and Dr. Ken Currie (CMR). First year funding was $348,078 with another $180,000 going directly to ORNL for their efforts. Abdelrahman is aptly suited for leading such an ambitious project having recently (2001) completed a three-year, $505,642 DOE project to model and control the cupola process for manufacturing steel under a project entitled, "Integrated Industrial Process Sensing and Control System Applied to and Demonstrated on Cupola Furnaces."

DOE Project entitled " In-Situ, Real Time Monitoring and Control of Mold Making and Filling Processes." Foam Patterns Like the One Pictured are used to Create Near Net-shape Castings.

The second large project ($369,000) in this research area is being led by Dr. Stephen Canfield (ME) and is entitled, "Capture Concepts and Model Development for MXER Tether Systems w/ Model Development" (See front cover for an artist's rendering). This project is being funded by NASA Marshall Space Flight Center (MSFC) and includes research partnerships with the University of Delaware and BD Systems, Advanced Technology Division. Momentum-exchange/ electrodynamic reboost (MXER) tether systems, as currently conceptualized, will enable high-energy missions to the Moon, Mars and beyond by serving as an "upper stage in space" transport system. A MXER tether station would boost spacecraft or payloads from lower Earth orbit to a high-energy orbit quickly, similar to a high-thrust rocket through the exchange of momentum between a rotating tether and an orbiting payload. MXER is still at a conceptual stage and the goal of this project is to advance the technology readiness so that the next step in its maturation cycle, prototyping, can proceed with detailed specifications, higher certainty of success, and identification of risk and the means to minimize that risk. There are two primary tasks in the project: the first is to develop advanced dynamic models to be used as part of a simulation tool providing a detailed evaluation of MXER systems and to serve as a future development tool for such systems. These models will be integrated to provide a comprehensive model that demonstrates all phases of MXER operation. The second task is to enable the advance of MXER in Technology Readiness Level (TRL) through design, development, and demonstration of capture subsystems with high probability of success, and to provide a tool for evaluation, parametric study, and design of capture systems. Assisting Dr. Canfield on this project are Dr. John Peddieson and Dr. Joe Richardson.

Pervasive Simulation and Modeling

With the addition of two new faculty in the Wireless Communications area, there is a burgeoning research group that is taking shape around the theme of Networks and Communication Systems. Recent advances in broadband internet and wireless protocols for data and voice transmissions are blurring the lines of demarcation between computer networks and voice communication networks. Issues such as voice and data security, data storage, transmission rates, and Quality of Service (QoS) are advancing at rapid paces and faculty members Rajan, He, Qiu, and Ghani (all of Electrical and Computer Engineering) are seeing to it that it moves even faster by taking an active role in: signal processing, image compression & processing, Ultra Wide Band (UWB) wireless communications, Many-in Many-out (MIMO) wireless communications, electromagnetics for UWB radar, communication networking strategies, IP networks, and data storage networks.

Dr. P. K. Rajan and Dr. Nasir Ghani are in the second year of a project ($34,000) entitled, "Shipboard Wireless Networking Techniques" funded by the Naval Surface Warfare Center in Dahlgren, VA. Objectives of the project include the following: (1) a survey of techniques for network fault tolerance that are applicable to shipboard sensor and computer wired and wireless network environments and recommend at least two of the more promising techniques for further investigation, and (2) produce a detailed analysis of each identified fault tolerant technique, including a literature search, along with a test plan for further functional and performance analysis of each.

Dr. Ghani is also serving as the PI on another project ($49,966) entitled, "Unified End-to-End Provisioning in Multi-Domain, Metro-Core Networks" funded by Sprint via the University of Houston. Capitalizing on his many years in the telecommunications industry, Dr. Ghani's initial research objective has been to study private line and bandwidth-on-demand service performance in multi-granularity SONET networks using two different control plane architectures.

Finally, in a project entitled, "High Performance and Reliable Storage Support for Clusters," Dr. Xubin He received the prestigious 2004 Ralph E. Powe Junior Faculty Enhancement Award by Oak Ridge Associated Universities. Ralph E. Powe Awards provide seed money to allow faculty members in the first two years of their tenure track to enhance their research. Dr. He received a $5,000 unrestricted research award that will be matched by TTU. This year, 24 winners were chosen from almost 100 applicants. In the past decade, faster processors and increased network bandwidth have allowed a cluster, which is a collection of computers, to perform as well as a dedicated super-computer but at a lower cost. However, a bottleneck occurs because of the slow transfer rate between individual computers comprising the cluster and the storage devices they use to access data. Dr. He has proposed a three-level hierarchy of storage that reduces this botteneck and increases the speed, reliability and security of the data transfer process. Working with Oak Ridge National Laboratory, he has introduced this "multi-layer, distributed shared IP storage system" that features a small storage level for retrieval of frequently accessed data, an intermediate larger level for quick caching of intermediate operations, and an even larger storage area for backup data. Data is placed in different storage levels depending on the frequency the data is needed and how secure it needs to be. This research is supported by active collaboration with ORNL that will allow Dr. He access to network clusters made up of dozens, even hundreds, of computers so that he and his graduate students can work on improving network security.

Development of Facilities and Equipment

The CMR saw a sizeable increase in equipment and facilities development this past year highlighted by a $304,000 Major Research Instrumentation grant from NSF to develop a Design and Manufacturing Integration Laboratory. All totaled, the CMR initiated three new laboratories and oversaw equipment, supplies, and facility expenditures exceeding $625,000. That brings the total investment in facilities and equipment over the last four years to well over the $2 million mark.

New Development **- NSF Design & Manufacturing Integration Laboratory:**

Dr. Kwun-Lon Ting has been the recipient of many NSF grants of a theoretical nature over his twenty-two year career at TTU. Recently, however, Dr. Ting, along with Co-PIs Darrell Hoy (ME), Mark Jackson (ME), Peter Li (ES), and Jane Liu (CEE), were awarded NSF funding for a Major Research Instrumentation program entitled "MRI: Acquisition of Research and Education Equipment for Geometric Design and Manufacturing Integration." The $304,143 grant, along with other significant support (more than $72,000) from Mechanical Engineering, Manufacturing & Industrial Technology, the College of Engineering, the Office of Research, and the CMR, provided the equipment and laboratory needs listed below. In addition, the laboratory will be available for industrial testing/prototyping and classroom demonstration/instruction:

- Brown & Sharpe Global Image 777 5P Coordinate Measurement Machine (CMM) ($66,500)
- 3D Laser Digitizing Scanning Head ($45-55,000)
- Fadal VMC-4020 Box Ways Series, 5-axis Computer Numerical Control (CNC) Vertical Machining Center ($79,350)
- 3D Systems Viper si2 SLA System for Rapid Prototyping ($114,000)

3D Systems Viper si2 SLA System

New Development **– Fuel Cell and Advanced Battery Laboratory:**

With the addition of Dr. Chunsheng Wang to the Center's faculty ranks, we were able to make an immediate impact on our research capabilities in the following areas; fuel cells, rechargeable batteries, supercapacitors, and hydrogen storage materials. However, Dr. Wang also arrived with a long list of equipment and laboratory needs since he brought research work with him from Texas A&M's Center for Electrochemical Systems and Hydrogen Research. The CMR, with assistance from ChE, has invested more than $80,000 of equipment and supplies into the research program of Dr. Wang. To support research associated with rechargeable batteries, Dr. Wang purchased an OMNI-Lab Glove Box System for handling lithium materials and assembly of rechargeable batteries ($14,640), an Arpin Battery Testing Station for life cycle testing of batteries ($21,075), and a Coin Cell Press for creating coin cell Li-ion batteries ($3,456). In support of testing materials synthesized for hydrogen storage or fuel cell membrane materials, Dr. Wang purchased an Electo-Impedance Spectroscopy unit with frequency response analysis capabilities ($40,790). This purchase received significant matching from ME and ChE due to the synergistic efforts that are currently underway in the area of fuel cells research. The CMR has also had to make a sizeable investment in supplies and furniture to support the development of this new laboratory facility.

New Development **– Wireless Networking Systems Laboratory:**

Although Dr. Robert Qiu's research interests into Ultra Wideband (UWB) wireless communications are grounded in the mathematical nature of signal processing, the key to fundamental breakthroughs in this evolving field of research is in prototyping and simulation of real-world communications scenarios. Dr. Qiu received a donation of two (2) Omnidirectional Antennas from Research Electronics International (REI), a local Cookeville company, valued at $10,500. Also purchased was a Digital Oscilloscope and Communications Signal Analyzer from Tektronix valued at $20,015. In addition, UWB-specific equipment and supplies were purchased to complete Dr. Qiu's laboratory setup to simulate a UWB wireless communications system – a UWB Educational kit with both a transmitter/receiver and Field Programmable Array board for customizing signal processing operations ($4,890) and a UWB Dual Polarity Pulse Generator ($1,995). In its entirety, the Wireless Networking Systems Laboratory is fully functional with an investment of more than $37,000 and already additional proposals have been submitted to further enhance its functionality.

Major Laboratory Renovation **– Foundry/Metal Casting Facility:**

As part of a $1.5 million, 3-year grant from the U.S. Department of Energy entitled, "In-Situ, Real Time Monitoring and Control of Mold Making and Filling Processes," the foundry has received an infusion of new capital equipment. Led by Dr. Mohamed Abdelrahman (Electrical & Computer Engineering) with help from Dr. Fred Vondra (Manufacturing & Industrial Technology), this project has added approximately $73,450 in additional foundry equipment listed below:

- Hitchiner Customized Counter Gravity Casting System ($37,350) -In addition, MCT provided Tennessee Technological University with a limited site license to operate the counter gravity process as part of our research project valued at $100,000.
- Sand testing equipment ($3,325)
- Used Sinto Automated Sand Molding Machine ($16,000)
- Used Compaction Table ($4,500)
- Emsco Tilting Induction Furnace ($8,470)
- Precision LCR Meter ($3,805)

As this project progresses and as additional projects are included in the metal casting research portfolio, the expectation is that the additional equipment listed above will pale in comparison.

Additional Major Equipment Purchase:

One other major equipment purchase rounds out the CMRs investment in major equipment and facilities. Drs. Ismail Fidan and Ahmed ElSawy (MIT) received funding from an NSF grant to the Coursework and Curriculum Laboratory Improvement program for a Z Corp Z406 Rapid Prototyping System ($70,000) for premium, high-speed, full color printing. The CMR, MIT, the College of Engineering, and the Office of Research provided additional funds. Whereas the NSF Geometric Design and Manufacturing Integration equipment grant provided for a stereolithography rapid prototyping system that creates plastic resin parts, the Z Corp system actually prints a CAD generated part using a starch/plaster/or composite-type material. Its work envelope is 10" x 8" x 10" and it's dimensional accuracy is only slightly less than the 3D SLA System. The goal of the grant is to adapt and implement rapid prototyping experiences and educational practices that have been developed and tested at various engineering schools. Dr. Fidan has provided multiple workshops for high school and technology school instructors into the latest advances in rapid prototyping utilizing the equipment.

Dr. Fidan also hopes to integrate hands-on activities using the RP equipment into two junior-level courses as well as the MIT senior-level capstone course.

Extension Services

The CMR is continuing to reach out to an ever-expanding list of manufacturing organizations across the state as our services and capabilities expand. The CMR fulfilled its mission to Tennessee industries by identifying faculty and students to advance technology transfer activities in specific areas such as software development, ergonomics, materials testing, prototyping, and manufacturing design/processing.

Dr. Joe Biernacki (ChE) worked with Memphis-based Buckeye Technologies, Inc. to test composite cements with a variety of added fibers. Dr. Biernacki used Differential Scanning Calorimetry (DSC) to determine the rate of hydration both with and without the fibers and also the effect of freezing on the cement both with and without the fibers. Dr. Dale Wilson also assisted local Cookeville company, Flexial, Inc. with a Phase 1 - Small Business Technology Transfer Research (STTR) contract through the Missile Defense Agency (MDA) and in conjunction with Raytheon's larger contract with MDA to develop kinetic kill missiles. As a world-leader in specialty bellows manufacturing, Flexial answered the call by developing a welded bellows made of titanium. Phase 1 goals included researching appropriate material alloys, coatings, and manufacturing processes.

A Top View of the Automated Prescription Verification System (APVS) for Automated Inspection of Mail Order Prescriptions. Funded by the NSF Grant Entitled "Enabling Innovation Opportunities in Tennessee with Additional Support by Cookeville-based TechWerks.

The Software Applications & Intelligence Laboratory (SAIL), affiliated with the Department of Computer Science, and faculty members, Dr. Doug Talbert and Dr. Michael Rogers, were involved in two development projects with Tennessee companies. The first project involved the design and development of a website and associated database for NextRoof Realtors located in Brentwood, Tennessee. In a similar application field, the second project involved development of software to facilitate data collection and mailings related to a real estate agent in Hendersonville, Tennessee.

Last year the CMR developed a prototype for automatically verifying prescriptions (APVS) at a mail order pharmaceutical facility. Sponsored by local small business TechWerks, the project was also supported by the NSF Partnerships for Innovation grant entitled, "Enabling Innovation Opportunities in Tennessee." As a follow-on project to last year's prototype development, TechWerks supported the incorporation of a checkweigh station into the APVS to provide additional validation of data in order to improve APVS accuracy.

A work-study program with local industries secured $228,343 in external funding during this fiscal year and provided 25 undergraduate students the opportunity to obtain hands-on experience while being employed part-time in a manufacturing environment. In addition to the work-study program, a number of undergraduate students were also included on externally/internally funded research projects bringing the total number of undergraduate students supported in 2003-2004 to 78. In a related program, Arvin Meritor's Cookeville-based Computer Aided Engineering group has entered into an Engineering Analysis Services Agreement with the CMR ($33,718). Through this agreement, Arvin Meritor has arranged with the CMR to supply temporary engineering support for finite element analyses, design optimization studies, and development of user interfaces for parametric-driven design templates of common Arvin Meritor products.

The U.S. Small Business Administration, the Tennessee Board of Regents, the Tennessee Department of Economic and Community Development, the College of Business Administration, and the Center for Manufacturing Research fund the Tennessee Small Business Development Center (TSBDC) located in Cookeville. TSBDC's primary goal is to assist small business owners across the State helping them grow and develop by providing one-on-one counseling for management and technical issues. This program was funded at a total of $77,211 for the 2004 calendar year. The TSBDC conducted more than 1,000 hours of one-on-one counseling service to approximately 220 entrepreneurs in 16 counties to achieve their goals. Ms. Marcia Reel serves as the Director of the TSBDC with help from part-time Business Specialist, Vicky Henley.

The Center continues to provide assistance to industries through its Testing Services Program. The total value of external funding supported through testing accounts in FY 2003-04 was $22,323 or a 26% improvement over last year. In addition, the CMR instituted a new program, referred to as an Equipment Affiliateship, to stimulate greater use of our testing facilities. The Equipment Affiliateship was established to provide additional value to industrial clients who anticipate testing services that require large amounts of equipment usage fees within a twelve-month period. There are three levels of the Affiliateship Program with three increasing levels of discounts:

1. ***$1,000 Annual Affiliateship ⟶ 25% Reduction in Equipment Usage Fees***
2. ***$2,500 Annual Affiliateship ⟶ 30% Reduction in Equipment Usage Fees***
3. ***$5,000 Annual Affiliateship ⟶ 35% Reduction in Equipment Usage Fees***

Following are examples of the testing projects completed during this fiscal year:

- Dr. S. Deivanayagam, Associate Dean of Engineering and Professor of Industrial and Systems Engineering, conducted ergonomic assessments and reviews for Koyo Steering Systems Company in Vonore, Tennessee, and LTD Supply/Parts, Inc. in Sparta, Tennessee. Metallographic tests were conducted for various local industries including Fleetguard, Flexial, and the Identity Group, as well as Memphis-based Smith & Nephew, Inc. and Midwest Air Technologies, in Jackson, Tennessee.
- Specialized metallography training courses were developed for Sunbeam-Oster in McMinnville, Tennessee and Federal Mogul in Smithville, Tennessee.
- The University of Tennessee Center for Industrial Services Program (UT-CIS) continues to be an avenue by which the CMR serves industrial clients across the State of Tennessee. Faculty investigators are identified based on each company's request and the expertise necessary to provide consulting in the manufacturing arena.
- Dr. Meenakshi Sundaram of Industrial & Systems Engineering, whose area of expertise is plant layout, lean manufacturing, and material flow analysis, assisted Cassemco, Inc., located in Cookeville, in improving material flow and redesign of their plant layout. He also assisted the Louisville Ladder Group, LLC out of Smyrna, Tennessee to identify potential productivity improvements in the plant from manufacturing to the warehouse.
- Dr. Ken Currie established a benchmark work standard for the mail order fulfillment and postage applications at MediaMail in Lebanon, Tennessee.

Educational/Curriculum Initiatives

On the heels of his NSF funded Major Research Instrumentation grant, Dr. Kwun-Lon Ting introduced a graduate level course in Mechanical Engineering entitled, "Computer Aided Design/Computer Aided Manufacturing (CAD/CAM)." Included in the class were advanced topics such as subdivision methodology for geometric representation, GD&T implications of translating CAD geometries to CAM software, and rapid prototyping/reverse engineering impacts on modern CAD/CAM operations. This course was offered in Spring 2004, but unfortunately the new equipment purchased from the NSF grant was not available at the time the course was offered.

In a spirit of collaboration, Tennessee Technological University's Department of Chemical Engineering has entered into a three-phase agreement with the University of Tennessee Space Institute's (UTSI) Department of Chemical Engineering. Dr. Don Visco will be spearheading this effort to develop a collaborative educational and research initiative between the two campuses. In Phase 1, UTSI supported CMR faculty associate, Dr. Don Visco, to develop a distance-delivered graduate course in Fall 2004 entitled "Advanced Chemical Engineering Thermodynamics." Phase 2 will involve a strategic research activity partnership to achieve greater synergy and higher probability of successful joint proposals. The third and final phase is the distance-delivered curriculum from UTSI to TTU students.

Graduate Student Mr. Zigui Lu and Two High School Students Test a Fuel Cell Stack during the Fuel Cell Camp Sponsored by NSF this Summer

Seminars/Workshops/Conferences

In October 2003, in collaboration with the Integrated Manufacturing Technology Initiative (IMTI) and the National Center for Advanced Manufacturing (NCAM), the CMR helped support a national workshop in Nashville to develop a technology roadmap for "Knowledge Management for Design and Manufacturing (KMDM)." This workshop was attended by more than 60 invited industry and government leaders from across the nation. Approximately 30 visitors from across the state attended.

In collaboration with the University of Tennessee's Energy Environment Research Center and the U.S. Department of Energy's Rebuild America program, the CMR hosted a "Higher Education Energy and Environment Conference in June 2004. The purpose of the conference was to disseminate the most recent information to higher education physical plant engineers/maintenance personnel on effective workplace control and management of lighting, heating/ventilation/air conditioning (HVAC), and water conservation. Approximately thirty individuals from across the state attended.

Dr. Ismail Fidan (MIT) provided several outreach opportunities as a result of two equipment and software grants that he received in FY 2003-04. First, shortly after receiving word that TTU had received a software grant for GibbsCAM software (valued at $21,250), a representative of 3DATUM CNC Solutions visited TTU in April 2004 to offer an introductory seminar on use of the software. The seminar was well attended by faculty and students who have interest in CAD/CAM integration. Secondly, as a part of his NSF-supported Course Curriculum Laboratory Improvement (CCLI) grant, Dr. Fidan conducted two workshops utilizing his newly purchased Z Corp rapid prototyping equipment. Dr. Fidan targeted faculty at technology centers, university engineering technology programs, and secondary education vocational technology programs. Included in the workshops were faculty and student-led presentations, hands-on projects, lab activities, educational and industrial exercises, and expert talks.

For the second year in a row, Dr. John Zhu conducted a three-day workshop for local secondary science teachers and a select group of high school students as part of his NSF funded CAREER grant. Participants were instructed on the basic concepts of fuel cells including the construction of a simple fuel cell that operated a small fan using a small amount of hydrogen. The third day of the workshop culminated in a trip to ORNL to visit their materials science and fuel cell facilities as well as the Oak Ridge Science Museum.

Recognitions/Honors

CMR faculty, faculty associates, and students have received significant recognition for their hard- work and longtime service to their professions. Dr. Kwun-Lon Ting was named a Fellow of the American Society of Mechanical Engineers in recognition of his lifetime contribution in the area of kinematics and machine design. Dr. Ting represents the fifth current, full-time Mechanical Engineering faculty member to hold the title of Fellow of ASME and only one of ten TTU faculty members ever to receive the award. Mechanical Engineering Associate Professor, Dr. Chris Wilson received the Keith J. Miller Young Investigator Award from the American Society for Testing and Materials. Dr. Wilson was recognized for his significant contributions in the area of fatigue and fracture mechanics. The recognition also reflects excellent publication, presentation, and standard development activities and potential shown during the early stage of his professional career. Finally, the student chapter of the Society of Manufacturing Engineers, led by faculty advisor Dr. Ismail Fidan (MIT), returned from the 2004 SME International Meeting in Cincinnati, Ohio with three first-place finishes in student competitions and monetary awards for outstanding students. The TTU students finished first place in: Student Chapter Best Practices in Member Recruitment, Student Chapter Events Contest, Student Chapter Display Competition, and Outstanding Chapter Youth Program Award. The students received special recognition for their innovative programs, including their involvement with the region's science fair programs. The "Young Engineers Program" was developed by the TTU SME student chapter to promote engineering education through science and math by donating their time to act as judges for area Youth Science Fairs. Also recognized at the SME conference were students Zane Mosley and Tamara Trotter who both received $1,000 SME Education Foundation Scholarships.

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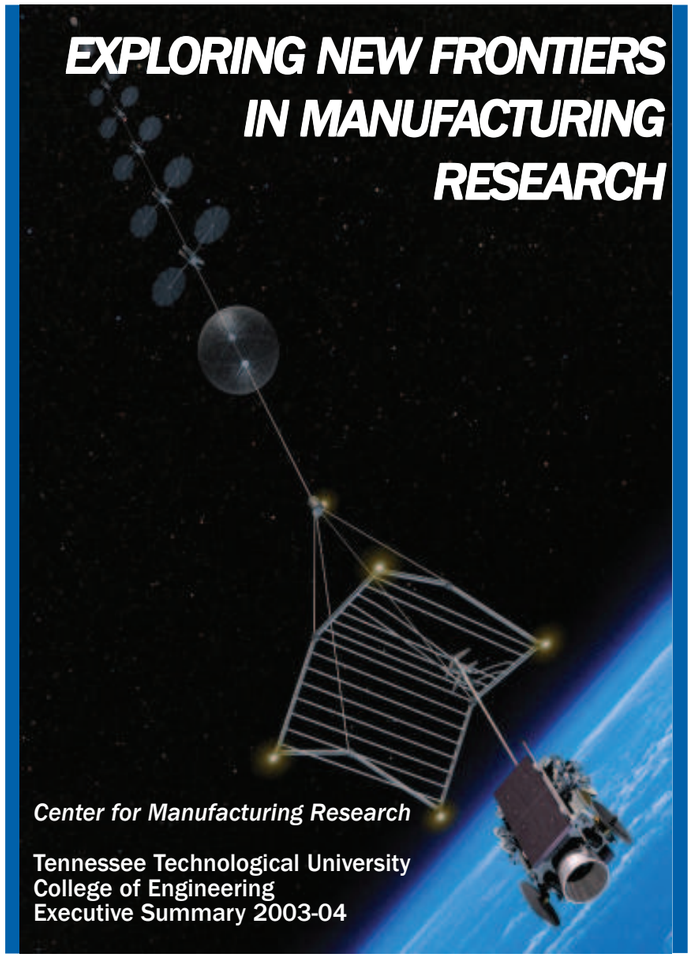
EXPLORING NEW FRONTIERS IN MANUFACTURING RESEARCH



Center for Manufacturing Research

Tennessee Technological University
College of Engineering
Executive Summary 2003-04