MECHANICAL PROPERTIES RESEARCH LABORATORY (MPRL)
http://mprl.me.gatech.edu/

2010-2011 Annual Report

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(also interfaces with AE, CEE, ECE, GTRI and Emory)

College of Engineering
Georgia Institute of Technology

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MPRL STATUS AND SUMMARY OF 2010-2011 ACCOMPLISHMENTS

The MPRL is an interdisciplinary laboratory that supports research and education programs primarily related to deformation and failure/reliability of structural materials. Principal activities of the MPRL include the measurement and modeling of the mechanical behavior of engineering materials, particularly deformation, fatigue and fracture processes. The MPRL has a direct impact on educational and research programs of the College of Engineering. In its role as an interdisciplinary umbrella organization for research in mechanical properties of materials, the MPRL provides a degree of coordination of equipment usage, training and maintenance that would otherwise be much more costly to the sum of academic units in the conventional university setting of distinctly controlled single investigator equipment. The MPRL has an international reputation for excellence in several areas:

- Fatigue and fracture studies of structural materials, structures, and joints/attachments.
- Development of constitutive equations for deformation and damage, incorporating these advances into life prediction methodologies.
- Multiscale modeling and simulation of materials and microstructure-sensitive fatigue and fracture approaches, making contact with experiments to discern mechanisms and validate models and methodologies, both deterministic and probabilistic (e.g., supporting the NSF Center on Computational Materials Design).
- Characterization and quantitative analysis of microstructure and damage in engineering materials such as structural alloys, composites, metal foams, biomaterials and nanostructured materials and alloys.
- Durability and degradation of aging materials and structures.

Participating faculty (16) and students are drawn principally from ME and MSE (Appendix A). The MPRL is administered by the Director. MPRL staff during the past year included Richard C. Brown (Research Equipment Specialist) and 1/6 time for GRA Robert Amaro. Mr. Brown principally serves the MPRL facilities located in Bunger-Henry and Love Buildings, and provides technical oversight and support for systems within the MaRC Hi-Bay. Mr. Amaro, a PhD student in Mechanical Engineering advised by Dr. Rick Neu, graduated in December 2010; he scheduled machine usage, trained students in test methods and protocol, calibrated extensometers, and set up testing protocols in the MaRC Hi-Bay MPRL.

A listing of MPRL facilities can be found at http://mprl.me.gatech.edu/facilities/, summarized as:

- Tensile and fatigue testing facilities
- Small scale testing laboratory
- High temperature testing (TMF)
- Drop weight impact tester
- Thermal aging and creep facilities
- Fretting test rig
- High strain rate facility (gas gun and split Hopkinson bars)
- Specimen preparation and image analysis

In addition, SEM, TEM and surface analysis facilities are available to MPRL faculty through the the GT Nanotechnology Research Center (NRC) and the Center for Nanostructure Characterization. Various MPRL faculty members have access to computing clusters to pursue work at the interface of materials characterization, behavior and modeling.

Participating MPRL faculty members contribute to a wide range of courses in fatigue, fracture, deformation and damage of engineering materials, mechanics of materials, quantitative image analysis and nondestructive evaluation, and mechanical behavior of materials. A graduate certificate in the Mechanical Properties of Solids is also offered through the MPRL. It is estimated that over 20 graduate students were involved during the past year in MPRL-related research.

MPRL accomplishments from July 1, 2010 to June 30, 2011 are summarized in the Table below, with 15 of 16 MPRL faculty responding (A. Antoniou did not report), 11 of whom had active funded research projects within the MPRL during the past year. These numbers pertain to research that is facilitated by access to MPRL facilities.

# Faculty Reporting Funded Activity	Published Refereed Papers	# Funded Projects	Students Graduated M.S.	Students Graduated Ph.D.	Faculty & Student Honors /Awards
11	57	41	11	10	9

MPRL faculty reported 103 conference presentations and seminars during this period. Approximately $3.35M was expended in externally sponsored research during the past year on projects related to use of MPRL facilities, for an average of approximately $305K per each of the 11 MPRL faculty members who reported activity in the MPRL during this period. The distribution of per capita funding of the 11 faculty respondents this past year whom were actively involved in MPRL research was as follows: at or above $300K (4), between $200-299K (2), $100-199K (3), $1-99K (1), $0K (1). There was a significant (factor of two) increase in both MS and PhD students graduated in 2010-11 relative to 2009-10. The PhD student production was the 2nd highest of any year in the past decade.

Highlights

Administrative highlights of 2010-2011 included the following:

- Continued to monitor and set priorities for repair and replacement of aging MPRL equipment based on critical path assessment for ongoing research and research opportunities, utilization, and other factors. We were able to solve a problem with the main pump in the MaRC Hi-Bay MPRL facility by finding a flow constriction in the piping, thereby avoiding a $100K pump replacement cost.
- This past year, $105K was received from the CoE to conduct vital upgrades of two TMF test controllers that are key to research within the Pratt & Whitney/GT CoE Center of Exellence.

Research program highlights and development activities include:

- The Center for Computational Materials Design (CCMD), a NSF I/UCRC joint with Penn State, completed its 5th year in June 2010, and involves a substantial number of MPRL
- faculty (McDowell, PI/PD, Neu, Zhou, Gokhale, Garmestani, and Zhu). MPRL funding related to integrated experimental and computational fatigue and fracture studies is at an all-time high; current funding trends emphasize combining experimental studies with modeling and simulation (cf. recent materials genome initiative recently announced by the White House, http://www.whitehouse.gov/blog/2011/06/24/materials-genome-initiative-renaissance-american-manufacturing), a duo for which the MPRL is well-positioned. A renewal for a five year Phase II NSF funding period for the CCMD was approved in summer 2010.
- The MPRL (Johnson, McDowell, Neu) completed its third year as a substantial component of the Pratt & Whitney/Georgia Tech Center of Excellence, serving as a preferred supplier of experiments and modeling related to advanced aircraft gas turbine engine materials (e.g., Ni-base superalloys), and is receiving a substantial related annual research funding ($300-400K) as a result. Companies such as Pratt & Whitney, GE, Siemens, etc. have high regard for the faculty and facilities of the MPRL and are relying on us to deliver cutting edge research to assist in developing more efficient and durable transportation/propulsion systems.
- Rick Brown's MPRL salary support was again out primarily provided by ME faculty. Accordingly, Rick Brown's level of support for the Hi-Bay MPRL will continue to increase.
- The part time assistance offered by Robert Cooper from ME was discontinued in 2010 when his ME position was eliminated.
- PhD student (fall 2010) and post doc (January 2011-June 30, 2011) Robert Amaro was engaged to provide training and technical support in the MaRC Hi-Bay facilities of the MPRL.
- Starting May 15, 2011, Mr. J.D. Huggins was engaged with part time ME support for a trial period of three months to support MPRL research as a part-time technician. He is being mentored by Rick Brown, and is under evaluation for continued, longer term part-time MPRL support as a potential replacement for Mr. Brown upon his eventual retirement. Mr. Huggins has served to support the NSF ERC activities of Professor Wayne J. Book in ME for a number of years and is well prepared in servohydraulics and controls.

Plans for 2011-2012

- Conducting an update of the 2003 MPRL Strategic Plan in view of addition of new faculty and related facilities to the MPRL. This has been delayed relative to original plans owing to (i) the GWW School strategic planning process, and (ii) the campus materials strategic planning process, both led by MPRL Director D.L. McDowell over the past 24 months. We expect that major new and/or updated elements of the plan will consider interfaces of experiments and computational modeling, development and integration of miniaturized test systems for small scale devices, MEMs, etc., digital image correlation and interferometry, and multiscale in situ testing. All of these are opportunity areas for future MPRL growth and funding, and we are actively pursuing hiring of new faculty in these areas. Accordingly, MPRL expansion and upgrading can interface with start-up packages, ensuring broad and

robust utilization of equipment. It is noted that the 2003 plan also cited long term underfunding of equipment maintenance and upgrades, which will continue to be a priority to address in the updated plan. MPRL faculty wrote a NSF MRI proposal that was selected by Georgia Tech as one of two from the Institute in January 2011; the proposed equipment consists of an in situ micron scale mechanical test capability that is sorely lacking in terms of present GT capabilities.

- Working with the Dean's office as necessary in the coming year or two to address the issue of supporting J.D. Huggins as a part time support person mentored by R.C. Brown. This is a critical element of bridging MPRL support as Mr. Brown contemplates retirement at some point. See the special request below for an additional allocation for his part time salary support.
- Continuing to pursue funding for repairs and upgrades in the MPRL. We are quite grateful for the timely response and positive support received in that regard from the CoE in spring 2011 ($105K for two TMF test system controller upgrades).

APPENDIX A

List of Participating MPRL Faculty

A. Antoniou, G.W. Woodruff School of Mechanical Engineering - Micromechanics of deformation in cellular materials and metallic glasses, using both experimental measurements and numerical modeling; synthesis and mechanical behavior of nanostructured materials.

K. Gall, School of Materials Science and Engineering/ME - Development and characterization of advanced material systems for implementation into emerging technologies; experimental and computational studies emphasizing the mechanical behavior of materials at multiple length scales. Biomaterials and biomimetics.

H. Garmestani, School of Materials Science and Engineering - Quantitative characterization of materials, diffraction methods, statistical continuum mechanics treatments of heterogeneous materials; materials design.

A. Gokhale, School of Materials Science and Engineering - Quantitative fractography and microscopy (stereology), modeling of microstructures, quantitative relationships between microstructure and mechanical behavior of materials.

S. Graham, G.W. Woodruff School of Mechanical Engineering - Thermophysical property measurement at small scales; nanoscale heat transfer in materials and interfaces.

W.S. Johnson, School of Materials Science and Engineering/ME - Experiments and modeling of fatigue and fracture behavior of advanced materials, including nonlinear and temperature dependent behavior; development of life prediction methodologies.

K. Kalaitzidou, G.W. Woodruff School of Mechanical Engineering - Development and characterization of advanced polymer based particles or composites with superior properties for a wide range of applications.

D.L. McDowell, G.W. Woodruff School of Mechanical Engineering/MSE - Cyclic viscoplasticity; microstructure-sensitive fatigue; multiscale modeling from atomistics to continuum; finite strain inelasticity, defect field mechanics; damage and deformation of metallic systems; materials design.

S. Melkote, G.W. Woodruff School of Mechanical Engineering - Characterization of the effects of machined surface integrity on fatigue life of hardened bearing steels; constitutive models for high strain, strain rate and temperature processes such as machining.

R.W. Neu, G.W. Woodruff School of Mechanical Engineering/MSE - Thermomechanical fatigue, environmental effects, composite materials, fracture mechanics, creep, fatigue life prediction methods, mechanics of phase transformations.

O. Pierron, G.W. Woodruff School of Mechanical Engineering - Experimental and analytical characterization of fracture and fatigue of small scale materials (thin films, nanostructures), structural reliability of MEMS/NEMS devices, environmental effects.

P. Singh, School of Materials Science and Engineering - Damage accumulation in metal matrix composites (MMCs), environmental sensitive fracture of Al alloys and MMCs, and high temperature oxidation of composites.

S. Sitaraman, G.W. Woodruff School of Mechanical Engineering - Thermo-mechanical modeling, reliability, and design of electronic packages.

N. Thadhani, School of Materials Science and Engineering/ME - Materials aspects of dynamic deformation, including fracture and flow behavior of solid and porous materials, synthesis of intermetallics and ceramics materials utilizing effects of high-strain-rate loading.

M. Zhou, G.W. Woodruff School of Mechanical Engineering/MSE - High strain rate behavior of materials, experimental and computational studies of shear banding and deformation of heterogeneous materials; atomistic simulations of functional oxides and nanowires.

T. Zhu, G.W. Woodruff School of Mechanical Engineering - Atomistic modeling of defect nucleation in materials; transition states and defect kinetics; coupled multiphysics problems at nanoscales.

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* /ME denotes joint appointment in the Woodruff School of Mechanical Engineering
/MSE " " School of Materials Science and Engineering