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

2013-2014 Annual Report

Prepared by:

Richard W. Neu, Director
Telephone: (404) 894-3074

Christopher Muhlstein, Associate Director
Telephone: (404) 385-1235

Participating Units:
G.W. Woodruff School of Mechanical Engineering
School of Materials Science and Engineering
(also interfaces with AE, CEE, ECE, GTRI)

College of Engineering
Georgia Institute of Technology

July 1, 2014

MPRL STATUS AND SUMMARY OF 2013-2014 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, particularly in extreme environments including high temperature applications.
- 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 for Computational Materials Design, Integrated Computational Materials Engineering (ICME), and Materials Genome Initiative (MGI)).
- Characterization and quantitative analysis of microstructure and damage in engineering materials such as structural alloys, composites, metal foams, thin films, biomaterials and nanostructured materials and alloys.
- Durability and degradation of aging materials and structures.

Participating faculty (20) 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 ¼ time Research Engineer J.D. Huggins assisted by part-time post-doc Ben Adair early in the fiscal year and ME graduate student Kyle Brindley in the latter part of the fiscal year. The plan is for J.D. Huggins to increase his time commitment to MPRL as his other appointment with Professor Emeritus Wayne J. Book winds down. Until J.D. Huggins is full-time with MPRL, additional support of graduate students or post-docs will be used.

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

- Tensile, compression, and bending test facilities
- Fatigue crack initiation and growth testing
- Fracture toughness testing
- Small scale testing laboratory
- High temperature testing (TMF)
- Drop weight impact tester
- Fretting test rig
- Instrumented indentation

- Thermal aging and creep facilities
- 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 GT Institute for Electronics and Nanotechnology (IEN), the Center for Nanostructure Characterization and Fabrication (CNCF), and a SEM recently procured by S. Kalidindi. 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, materials selection and design, and mechanical behavior of materials. A graduate multidisciplinary certificate in the Mechanical Properties of Materials 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, 2013 to June 30, 2014 are summarized in the Table below, with 16 of 20 MPRL faculty responding, 14 of whom stated that they had some level of research activity within the MPRL during the past year.

# Faculty Reporting Funded Activity	Published Refereed Papers	# Funded Projects	Students Graduated M.S.	Ph.D.	Faculty & Student Honors /Awards
16	83	40	5	15	14

Active MPRL faculty reported 113 conference presentations and seminars during this period. Approximately $3.96M was expended in externally sponsored research during the past year on projects related to MPRL facilities or thrusts, reported by MPRL faculty members. The distribution of per capita funding of the 16 faculty respondents this past year who were actively involved in MPRL research was as follows: at or above $300K (6), between $200-299K (2), $100-199K (2), $1-99K (6). Several non-MPRL-affiliated faculty also utilized MPRL or its research engineer during this period including David Ku (ME), Krista Walton (CHBE), Abdulhamid Zureick (CEE), Donggang Yao (MSE), and Lauren Stewart (CEE). Those projects are not reported in these numbers.

Highlights

Administrative highlights of 2013-2014 included the following:

- Our Research Engineer J.D. Huggins has successfully completed three years of part-time service to the lab. He is now well entrenched in its operation and can agilely handle requests of faculty, students, post-docs, and external organizations.
- First floor of Bunger-Henry is being established a world-class materials thermomechanical processing, mechanical properties testing and characterization facility with new lab spaces established by C. Muhlstein (MSE), S. Xia (ME), and S. Kalidindi (ME/MSE/CSE). Highlights this year include C. Muhlstein moving into his newly renovated laboratory and office.
- Reviewed Institute inventory records for all MPRL equipment and updated Custodian information on items either without custodian or custodian retired / no longer at Tech.
- Engaged ME IT to develop online test proposal and lab management system that includes streamline documentation to track / verify laboratory safety training of users.
- Acquired two test frames and a set of wedge grips being surplused by AE to be used for parts and added capability.
- Increased the readiness of the lab to rapidly handle requests through systematic equipment maintenance, repair, and upgrades. Some highlights include (a) refurbished a hydraulic power supply that powers two test systems in B-H, (b) refurbished two hydraulic actuators, (c) upgraded computers on a couple of servohydraulic test frames to improve efficiency of retrieving data, (d) acquired an extensometer for fracture toughness testing, (e) acquired an additional set of collet grips, (f) updated controller and data acquisition on one creep frame, (g) acquired a furnace with 1100°C capability filling a gap in temperature capability, (h) acquired better lighting and cameras to improve capability for Digital Image Correlation (DIC) including refurbishing a Questar long-focal distance microscope to improve optics, (i) acquired a pyrometer for non-contact temperature measurement that is able to be used for feedback control.
- Installed a 46" flat screen TV in the MPRL Instructional Center in 153 B-H for class demonstrations and large group tours of the lab.
- Annual force transducer calibrations were performed by outside vendor to maintain compliance required by DOD and other sponsors.
- Continued to work with the Director of the Institute for Materials, D.L. McDowell, to make MPRL a strategic user facility in the Institute for Materials (IMat) and participate in large center proposals where MPRL will have a significant role.
- Held a successful Make/Break Camp summer high school program organized by O. Pierron with CEISMC and sponsored through the NSF amp-it-up program.
- Created a new video demonstration on high cycle fatigue testing.

Research program highlights and development activities include:

- Antonia Antoniou received NSF CAREER Award.
- Arun Gokhale received the Sorby award from the International Metallography Society. This is a life-time achievement award and highest honor from this society.

- Surya Kalidindi received the Alexander von Humboldt Research Award.
- The MPRL (Johnson, Neu, McDowell, Antolovich) completed its 7th 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 for the hot components (e.g., Ni-base superalloys, TiAl, MoSiB).
- MPRL (Neu) completed its 8th year working with Siemens Energy Inc. on industrial gas turbine structural integrity.

Plans for 2014-2015

- Support for J.D. Huggins will go up from ¼ time to ½ time at the start of the fiscal year. This is still not the level of support needed to fully support the lab. Therefore, we plan to continue to employ graduate students or post-docs part-time to assist.
- Complete the update of the online test proposal and lab management system that includes streamline documentation to track / verify laboratory safety training of users.
- Work with the Director of the Institute for Materials, D.L. McDowell, to make MPRL a strategic user facility in IMat.
- Enhance cooperative laboratory relationships among affiliated labs housed on the first floor of the Bunger-Henry building (i.e., Muhlstein, Xia, and Kalidindi).
- Organize an internal workshop on Digital Image Correlation (DIC) in collaboration with IMat.
- Through O. Pierron, continue the summer enrichment program for high school students, coordinated with the large NSF "amp-it-up" program run by CEISMC centered around manufacturing.
- Update website to better publicize the capabilities of the lab aimed at potential users and provide links to the capabilities of the affiliated labs.
- Hold a users meeting to get feedback and publicize the capabilities of the lab.
- Engage new ME faculty in Tribology, Michael Varenberg, who will be arriving in August 2014, to coordinate lab startup.
- Market the Mechanical Properties of Materials Certificate Program.

- **APPENDIX A**

List of Participating MPRL Faculty

S.D. Antolovich, School of Materials Science and Engineering/ME – Fatigue, deformation and degradation of materials, high-temperature behavior of materials, application of mechanics and materials to structural failures, and fracture mechanics.

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 microscopy, modeling of microstructures, quantitative relationships between microstructure and mechanical behavior of materials.

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

W.S. Johnson, School of Materials Science and Engineering/ME - 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/MSE - Development and characterization of advanced polymer based particles or composites with superior properties for a wide range of applications.

S. Kalidindi, G.W. Woodruff School of Mechanical Engineering/MSE – Designing material internal structure for optimal properties and performance and identifying hybrid processing routes for its manufacture.

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; constitutive models for high strain, strain rate and temperature processes.

C. Muhlstein, School of Materials Science and Engineering - Deformation, fatigue, fracture mechanics, degradation mechanisms, structural materials, composite materials, nanomaterials, thin films.

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

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 – Environmental-induced damage and failure in structural alloys and composites, corrosion kinetics, stress corrosion cracking, high temperature oxidation.

S. Sitaraman, G.W. Woodruff School of Mechanical Engineering – Fabrication, characterization, thermo-mechanical predictive modeling and reliable design of micro-scale and nano-scale structures.

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.

S. Xia, G.W. Woodruff School of Mechanical Engineering - Experimental solid mechanics, nano and micromechanics, mechanics of energy storage and conversion materials, mechanics of heterogeneous media, fracture and fatigue of active materials.

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/MSE - Atomistic modeling of defect nucleation in materials; transition states and defect kinetics; coupled multiphysics problems at nanoscales.

---

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