Georgia Tech Mechanical Properties Characterization Facility
Institute for Materials

MECHANICAL PROPERTIES CHARACTERIZATION FACILITY (MPCF)
STATUS AND SUMMARY OF ACCOMPLISHMENTS

http://mpcf.gatech.edu/

Fiscal Year 2020 Report
July 2019 – June 2020

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Institute for Materials
Georgia Institute of Technology

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Overview of the Mechanical Properties Characterization Facility

The Mechanical Properties Characterization Facility (MPCF) is an Institute for Materials facility that supports education and research programs related to processing-structure-properties relationships in structural materials. Its principal activities are directed towards the measurement and modeling of the mechanical properties of engineering materials, primarily related to deformation and reliability of materials. Other activities include component and non-standard mechanical testing, thermomechanical processing, and the aging and long-term reliability of materials.

The MPCF and its faculty users have 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 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.

We see the use of the MPCF growing with the push of the Materials Genome Initiative (MGI) and the growth of structural materials fabricated by additive manufacturing as well as the continued push for advanced materials with better performance. This facility gives GT a competitive edge.

The mission, vision, and research thrusts are fully described on our website, mpcf.gatech.edu. The MPCF has a direct impact on instructional and research programs across the Institute. Research projects that require the need for the MPCF involve over $4.8M expended in externally sponsored research each year, based on a survey a faculty who have used the facility in FY20. MPCF currently has capabilities that are known internationally and are among the top three universities in the USA. The MPCF is central to our competitiveness for industry funding in major auto, aerospace, and energy sectors. Georgia Tech is a Pratt & Whitney Center of Excellence in materials and is one of two institutions in the USA that have been named a Siemens Center for Knowledge Interchange (CKI). The presence of the MPCF was a key element in bringing these Centers to Georgia Tech. Advanced materials manufactured in our new Advanced Manufacturing Pilot Facility (AMPF), with Boeing and Delta being anchor sponsors, are regularly evaluated in the MPCF.

The MPCF occupies a total of 4250 sq ft across three buildings [2500 sq ft in Bunger-Henry (rooms 153, 158, and 173), 1250 sq ft in Callaway (MaRC) Hibay lab, and 500 sq ft in MRDC 2340]. A listing of MPCF equipment can be found at mpcf.gatech.edu/facilities. Major equipment and tools include:

- Servohydraulic test systems (14 with capacities ranging from 5 to 100 kips (22 kN to 440 kN), which gives us the flexibility to match the user with the appropriately sized test system
- Electromechanical test systems (7 with capacities from 500 lb to 20 kip (2.2 kN to 100 kN))
- Drop weight impact tester
- Charpy impact tester
- Fretting and reciprocating sliding tester
- Thermal aging and creep facilities

Major accessories and expertise include:

- Gripping / adapters for tension, compression, bending, fracture, etc.
- Various extensometers for axial, diametral, axial-torsion, high temperature, crack opening, etc.
- Digital image correction (DIC) accessories for full field, non-contact strain measurements
- Environmental chambers, ovens, and furnaces including inert atmosphere capabilities
- Induction heaters
- Temperature measuring devices (thermocouples, pyrometers)
- Long-focal length optical microscopes for in-situ observations
- Specimen preparation, microstructure characterization prep, and image analysis
- Portable hardness tester
- Low-force grips and load cells with 5 kN and 500 N ranges for smaller scale and flexible material testing

In addition, MPCF supports a wet lab with specific expertise on metallography and failure analysis to prepare samples for either mechanical property testing or for further analysis using tools in the Materials Characterization Facility (MCF) also administered through the Institute for Materials (IMat).

In its role as an interdisciplinary umbrella organization for experimental research in mechanical properties of materials, the MPCF coordinates equipment usage, and provides training, test planning support, and maintenance. The centralized facility provides a significant space and cost savings to academic units and faculty compared to the conventional university strategy of distinctly-controlled, single investigator equipment. The MPCF provides space savings by locating the test systems in a specially designed consolidated space with shared hydraulic power supplies and accessories. The space required for an isolated mechanical test system which includes the load frame, hydraulic power supply, control system, and accessories is roughly 750 sq ft because of space needed for heat dissipation and noise abatement. Systems in the MPCF occupy space

more efficiently because the hydraulic power supplies are consolidated in dedicated external rooms (usually the building utility room) which creates an efficient and low noise environment for the operators and experiments in the laboratory. Moreover, these systems have high power and thermal loads that are incompatible with typical laboratories on campus. The MPCF is the most efficient utilization of space and resources for this type of equipment and accessories.

The MPCF provides cost savings by supporting new and established faculty. The MPCF allows new faculty who need to characterize mechanical properties to efficiently utilize their startup funds. The MPCF provides guidance to faculty when they develop new facilities, and counsels them so that systems are not unnecessarily duplicated. It is quite common for new faculty to request a mechanical test system in their startup package. We work with new faculty to identify special equipment or accessories to enhance the capabilities of MPCF while utilizing the existing equipment to greatly reduce the startup package cost. The cost savings to a new faculty startup is extreme; a new servohydraulic test system with the necessary accessories costs approximately $300K. Finally, the MPCF staff helps new faculty to establish successful research groups by removing some of the burden of acquiring equipment training for their graduate students to use the equipment safely and effectively.

The staff supported by the MPCF, which includes Research Engineer, Dr. James Collins, assisted by part-time graduate students, provide training on the use of a variety of mechanical test systems, including servohydraulic systems that can cause serious injury if used incorrectly. MPCF staff support both instructional and sponsored research projects in setting up test programs, designing accessories and adapters, developing new protocols, integrating new sensors and transducers, developing control algorithms, etc. MPCF staff also perform routine maintenance and repairs to keep systems in a state of readiness. Using staff to perform routine maintenance in a user facility is the most effective, responsible way to utilize state and federal funds. If each test system was "owned" by a faculty member, they would either spend about $25K per year on a service contract per system to perform such maintenance, or the equipment would be underutilized or in some cases not utilized for long periods of time taking up precious space. This cost savings is only possible when dedicated, trained staff are available, that is able to perform this routine maintenance.

MPCF staff also ensure all users comply with EH&S requirements. We have implemented a test proposal submission and lab management system to facilitate a quick response to users and to make sure everyone (advisor, student, and research engineer) is on the same page so that experimental programs conducted in MPCF are successful. The lab management system helps us maintain compliance with EH&S requirements by documenting all required Institute safety and equipment training for each user of the lab.

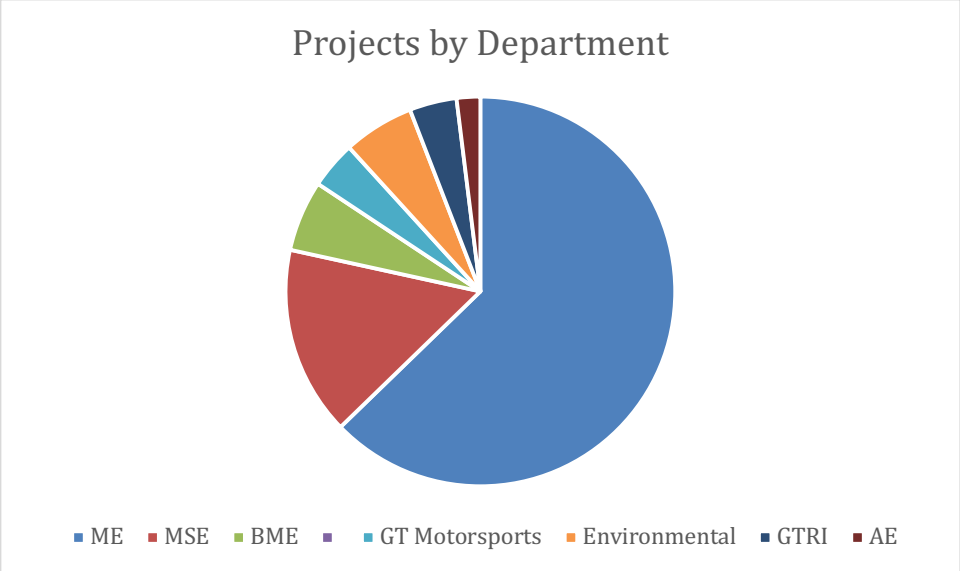
Support for the operation and maintenance of the facility comes from the Institute for Materials and revenue received from our recharge center using the Shared User Management System (SUMS).

A graduate multidisciplinary certificate in the Mechanical Properties of Materials is also offered and administered by the Director of the MPCF.

Summary of Activities in FY20

As an interdisciplinary and multi-user facility, the MPCF serves researchers at Georgia Tech and external industry and university partnerships. Internal projects included sponsored and non-sponsored research, senior capstone projects, extracurricular clubs and organizations (e.g., GT Motorsports), and undergraduate class support. External projects included short-term and long-term consulting and research with industry partners. The following is a summary of the various projects MPCF supported during fiscal year 2020:

- 57 sponsored, non-sponsored, class, and capstone design research projects
- Projects from the Mechanical Engineering, Materials Science and Engineering, Aerospace Engineering, Civil Engineering, Environmental Engineering, Biomedical Engineering, and GTRI



- Class support for training TA's, guidance for design of experiments, and testing support for undergraduate classes for MSE 3021 and MSE 4022

MPCF accomplishments from July 1, 2019 to June 30, 2020 are summarized in the Table below, with 6 of 27 current or past faculty users responding, 6 of whom stated that they had some level of sponsored funded research activity that benefitted from the MPCF during the past year.

# Faculty Reporting Funded Activity	# Funded Projects	Journal Articles	Conference Proceedings & Seminars	Students Graduated		Honors and Awards
				Ph.D.	M.S.	
6	25	42	47	7	7	3

Approximately $2.6M amount in externally sponsored research during the past year, as reported by faculty who used the facility, was enabled by the tools available in the MPCF. The distribution of per capita funding of the 6 faculty respondents this past year who were actively involved in sponsored MPCF research was as follows: at or above $300K (2), between $200-299K (2), $100-199K (2), $1-99K (0).

It is estimated that over 18 graduate students were involved during the past year in MPCF-related research. In addition, it is estimated that over 9 undergraduate students used the lab during the past year for either undergraduate research or a capstone design project. This is in addition to the instructional use of MPCF for both undergraduate and graduate courses in both ME and MSE. MPCF staff provide support for these instructional services covered through either direct salary support from the School or through the recharge center.

Highlights

Administrative highlights of 2019-2020 included the following:

- Continued to work with the Executive Director of the Institute for Materials (IMat), Dr. Dave McDowell, to make MPCF a strategic user facility in IMat and participated in both large center proposals and cooperative partnerships with industry where MPCF will have a significant role. Some specific major events with close links to MPCF included
    - Dr. Richard Neu is the Georgia Tech lead on a proposal for a NSF ERC for Scalable, Customizable, Rapid, Additive Manufacturing (SCRAM) for Health Care. Duke University is the lead. Texas A&M University and University of Texas – El Paso are additional partners. Mechanical testing of new materials and implants made with new manufacturing processes are critical components of the proposed ERC. MPCF has been identified as one of the key facilities to showcase in our proposal with GT being the lead on the mechanical property characterization.
    - Georgia Tech EVPR's office is targeting Hypersonics as a thrust area where Georgia Tech collectively has the expertise to be the leader among all US academic institutions. A committee has been formed by the EVPR's office to develop a white paper on how Georgia Tech can cultivate this research. One objective of this committee is to identify critical infrastructure that is needed to support attracting and establishing large interdisciplinary research programs in hypersonics. Research on the development of high temperature materials for hypersonic vehicles has been identified as leading critical need. MPCF is a leader in high temperature mechanical testing and we have considerable expertise in this area. However, even higher temperature capability than our current capability is needed to make us a unique showcase facility for characterizing the mechanical behavior of materials for hypersonics. MPCF can become the premier user facility for characterizing hypersonic materials with some strategic infrastructure funding.

    - Dr. Aaron Stebner was hired by ME and starts July 1, 2020. Georgia Tech is in discussions to acquire two test systems and various DIC equipment from his former institution that is anticipated to be located in the MPCF footprint, expanding the number of tools and capabilities. In addition, Dr. Stebner will be a primary user of the facility.
    - The Novelis Innovation Hub has been stood up at Georgia Tech in FY20. MPCF is one important component of the hub.
- Our Research Engineer Dr. James Collins has successfully completed 3.5 years of 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. He is also engaging with potential external industrial sponsors to establish new research projects for MPCF.
- New user rates and fees were implemented in FY2020 after the completion of a cost study. Even with the shutdown due to COVID-19, from 3/19/2020 to end of the FY, revenue more than doubled.
- Utilized a standard template for Specialized Services Agreements to facilitate setting up new external projects successfully.
- Fatigue of additively manufactured alloys is a growing research thrust. A DOE-funded project on developing a Digital Twin Material Model to predict the performance of high temperature alloys under cyclic loading was a major activity in FY20 and will continue in FY21.
- Established a long-term project plan for plastic resin mechanical and environmental properties research with GTRI
- Increased the readiness of the lab to rapidly handle requests through systematic equipment maintenance, repair, and upgrades. Some of these items included creating test protocols for Poisson ratio and diametral strain recording and analysis spurred by renewed interest, implementing test procedures and best practices for strain-controlled fatigue particularly for plastic strain control and isothermal elevated temperature strain control, expand testing procedures for biomedical and viscoelastic low force testing, and protocol development for inert atmosphere furnace heat treatment and thermal cycling.

Plans for 2020-2021

- Identify key areas to expand MPCF test equipment and facilities to accommodate research interests in high performance alloys and aerospace materials.
- Continue to work with the Director of IMat, Dave McDowell, to make MPCF a strategic user facility in IMat and participate in both large center proposals and cooperative partnerships with industry where MPCF will have a significant role.
- Engage recent new faculty hires in ME, MSE, and AE that may be potential users or interested in adding new capabilities to the facility critical for their research.
- Communications outreach to make more Georgia Tech units aware of MPCF facilities including GTRI and BME as interest in novel plastic and biomaterial mechanical property research grows

- Publicize the Mechanical Properties of Materials Certificate Program.

COVID-19 Effects on the End of FY20

Georgia Tech's research ramp down prevented MPCF facility use from March 19, 2020 to June 18, 2020, impacting both sponsored, non-sponsored, and capstone research projects. Effectively, a quarter of the fiscal year productivity and revenue was lost. Impacts on FY21 are expected to be minor since MPCF lab spaces are amenable to social distancing and staggered rotation of researchers to avoid crowding lab spaces in addition to newly establish cleaning and PPE protocols.

MPCF User and PI Statistics

The following statistics break down in more detail the usage and fees for MPCF projects. Users include graduate and undergraduate researchers.

MPCF Usage Statistics

	FY19	FY20*
Total user days	77	51
Total user weeks	35	49
Total user hours†	3517	3528
Total user fees	$10,449.60	$24,509.67
Internal users	36	27
External users	0	1
PIs	24	17

**FY20 end date for charges and hourly usage is 3/19. Research ramp down closed MPCF facilities 3/19-6/18. All charges and fees after 6/18 will be posted in FY21.*

†*MPCF equipment is rented on a daily or weekly basis and can occur overnight or weekends. Hourly usage was estimated using the following conversions:*

1 day = 12 hours
1 week = 84 hours

MPCF Research Group Breakdown

Research Group	Type	Organization	Total Hours Used	Total Charges*
Richard Neu	GT	ME	1702	$ 12,674.54
Yongsheng Cheng	GT	Civil Engineering	180	$ 769.13
Josh Kacher	GT	MSE	218.5	$ 1,425.00
Christopher Saldana	GT	ME	680.5	$ 2,810.00
Stephen Sprigle	GT	Biomedical Engineering	222	$ 775.00
Surya Kalidindi	GT	ME	62	$ 470.00
Jonathan Colton	GT	ME	75	$ 515.00
Aerospace, Transportation, and Advanced Systems	GT	GTRI	45	$ 555.00
Christopher Eberste	Industry	Weave3D	20	$ 726.00
Kyriaki Kalaitzidou	GT	ME	26.5	$ 350.00
David Ku	GT	ME	75.5	$ 690.00
Meisha Shofner	GT	MSE	13	$ 160.00
Glaucio Paulino	GT	Civil Engineering	52	$ 360.00
Hamid Garmestani	GT	MSE	52	$ 480.00
Jie Xu	GT	GTRI	104	$ 1,750.00

**Projects started in FY19 were charged FY19 rates until project completion. Charges can include training, labor for setting up equipment, tool rentals, and supplies and materials.*

Educational and Other Support Activities

Educational Activities	Total Hours Used	Number of Students
MSE 3021	50	75
MSE 4022	50	75
Capstone - ME*	121	5
Capstone - MSE*	35	4
High School Senior Project	4	1