RICE AMPT

Additive Manufacturing, Performance & Tribology Center

INAUGURAL AMPT SYMPOSIUM

launching the **Additive Manufacturing, Performance & Tribology (AMPT) Center** at Rice University

AUGUST 15 - 16, 2019

RICE UNIVERSITY

HOUSTON, TEXAS

Welcome

Greetings!

As co-director of the new **Additive Manufacturing, Performance & Tribology (AMPT) Center at Rice University**, I am elated to welcome you to the Inaugural AMPT Symposium. The additive manufacturing industry, currently valued at $9.3 billion dollars, is projected to reach $23.3 billion by 2026, with a growth rate of over 14% annually. Engineering systems and applications that involve sliding surfaces and rotating parts have tribology-based performance challenges that additive manufacturing can uniquely meet. Moreover, 3D printing for industrial applications is still at a stage in which advanced research is required to fully progress from trial-and-error, user-directed machines to autonomous, material-independent devices similar to today's commercial printers. AM production systems can be further improved by incorporating Industry 4.0 techniques, in which data from sensors embedded in smart machines is used in real time with physics-based and AI modeling to improve the performance of machines while in service. By tying process design and manufacturing to the ultimate performance of products in their intended applications, the AMPT Center brings together Rice researchers with diverse expertise across numerous engineering and scientific disciplines to improve products and systems through novel and predictive additive manufacturing techniques. We believe that companies seeking to leverage additive manufacturing to improve the performance of their technologies – especially those which involve interacting surfaces – can achieve strong performance gains through focused research as Members of the new AMPT Center. On behalf of the entire community of scholars here at Rice, I welcome you to our campus and to our city of Houston, and I trust you will have a successful and productive Inaugural Symposium experience.

C. Fred Higgs III
John & Ann Doerr Professor of Mechanical Engineering
Co-Director of the AMPT Center at Rice University

Schedule at a Glance

For detailed agenda, see pages 6-8.

Thursday, August 15

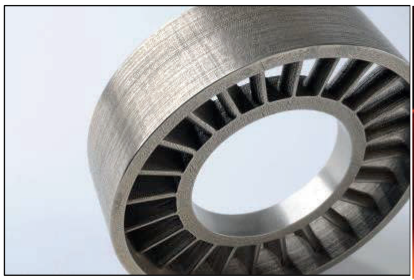
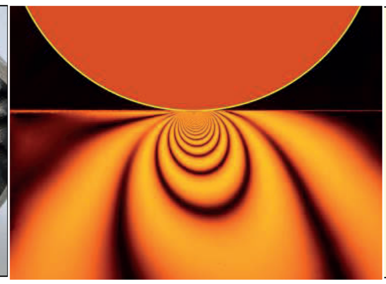
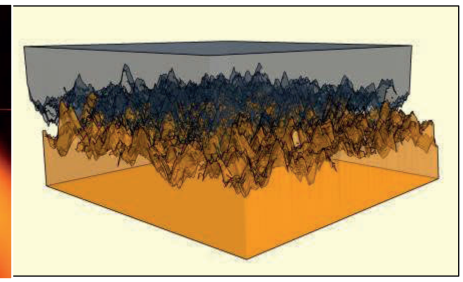
- 8:00 Light breakfast
- 8:30 Welcome
- 8:40 Symposium Overview
- 8:45 Technical Session 1 – Additive Manufacturing: Optimizing Process and Structure
- 10:30 Mini-break
- 10:35 Technical Session 2 – Tribology: Optimizing Design for Moving Contact
- 12:00 Networking Lunch
- 1:00 Guided tours of AMPT Center founding research facilities
- 3:15 Technical Session 3 – Performance, Characterization and Applications: Optimizing Systems and Components
- 4:20 Preview of Day 2 and evening directions
- 4:30 Poster competition and reception
- 6:00 Inaugural AMPT Symposium Dinner
- 8:30 End of Day 1

Friday, August 16

- 8:00 Light breakfast
- 8:30 Strategic Vision and Model of the AMPT Center
- 9:30 Small group discussions: AMPT-related Research Gaps and Goals for Industry-Academic Collaboration
- 11:30 Working Lunch: Trends and Research Directions
- 1:00 Inaugural Symposium adjourns

Vision of the AMPT Center

The Additive Manufacturing, Performance & Tribology (AMPT) Center at Rice University is an industry-focused, multidisciplinary research unit that leverages the deep expertise of Rice engineering faculty to solve the fundamental problems facing *Industry 4.0*. This designation refers to the companies driving the Fourth Industrial Revolution, in which technologies spanning the physical, digital, and biological worlds are changing how people work and live, and how products are produced and consumed.

The core competencies of the AMPT Center — additive manufacturing, advanced materials processing, tribology, and tribomechadynamics — underpin the Fourth Industrial Revolution technologies of production. The work of the AMPT Center:

- ***Broadly impacts*** the way engineering machines and devices (including biomedical, energy, and electromechanical systems) with *surfaces in relative motion* are manufactured, monitored, and maintained for extended lifetimes.

- ***Brings together*** Rice and industry researchers to use numerous tools to advance the performance of Industry 4.0 technologies, including artificial intelligence, the internet of things (machines, sensors, and the big data they produce), augmented/virtual reality, and multiphysics simulations-based engineering.

- ***Prepares*** the Industry 4.0 product-manufacturing workforce, by training engineering students from the undergraduate to post-doctoral levels to design customer-tailored products from the end to the beginning. AMPT students apply deep fundamental engineering concepts leading to products and components that are individualized to achieve extended lifetimes and custom-optimized tribological, mechanical, material, and dynamic performance.

Founding Faculty

The AMPT Center originated in the collaboration of three Rice Engineering faculty who understood that the problems they are working on, while historically viewed as distinct disciplines, involve intersecting challenges and powerful opportunities for research synergy.

C. Fred Higgs III

John & Ann Doerr Professor of Mechanical Engineering
Professor of Bioengineering
Vice Provost for Academic Affairs
Faculty Director, Rice Center for Engineering Leadership (RCEL)
https://higgslab.org

Bio:
Dr. Higgs joined Rice in 2016 after thirteen years on the faculty of Carnegie Mellon University, where he was the thrust leader of powder mechanics in CMU's Next Manufacturing Center. He is a member of the ASME Tribology Executive Committee and an Associate Editor for the STLE *Tribology Transactions* journal. His Particle Flow & Tribology Laboratory conducts coordinated high-performance computing and high-fidelity experimentation to predict the behavior of applications with particle media in sliding contacts. A Fellow of the American Society of Mechanical Engineers, he has received an NSF CAREER Young Investigator Award and the ASME Burt L. Newkirk Award, given to a tribology innovator under age 40. Dr. Higgs has published over 100 archival papers in journals ranging from *Nature Materials* to the *Journal of Tribology,* while generating significant IP in concert.

Matthew Brake

Assistant Professor of Mechanical Engineering
http://brake.rice.edu

Bio:
Dr. Brake joined the Rice faculty in 2016 from Sandia National Laboratories, where he worked for nine years after earning his Ph.D. at Carnegie Mellon University. He has been elected to numerous leadership positions, including chair of the ASME Research Committee on the Mechanics of Jointed Structures, vice-chair of the Nonlinear Dynamics Technical Division of SEM, and secretary of the ASME Technical Committee on Vibration and Sound. He is a recipient of the 2012 Presidential Early Career Award for Scientists and Engineers, the NSF CAREER Award, the 2018 C.D. Mote Jr. Early Career Award, and was recently named a Fellow of ASME. Dr. Brake's research is focused on interfacial mechanics, tribology, coatings, damage mechanisms (wear, fatigue, etc.), and dynamics in order to both design and optimize machinery to be more efficient and longer lasting.

Zack Cordero

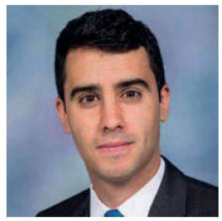
Assistant Professor of Materials Science & NanoEngineering
http://additive.rice.edu

Bio:
Dr. Cordero earned his B.S. in Physics and his Ph.D. in Materials Science and Engineering from Massachusetts Institute of Technology. His thesis work on tungsten powder metallurgy was licensed by the MIT startup Veloxint which was recently acquired by Braidy Industries. After completing his doctorate, Dr. Cordero spent one year as a post-doctoral fellow at the Manufacturing Demonstration Facility of Oak Ridge National Laboratory, where he developed improved process monitoring, quality control, and microstructure design tools for powder-bed metal additive manufacturing technologies. Dr. Cordero launched the Additive Lab at Rice University in 2016.

Faculty and Research Staff

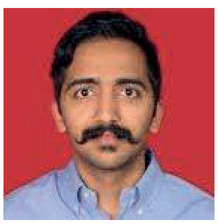
Leveraging Rice University's unique capacity for boundary-spanning research, the newly-formed AMPT Center already encompasses four of the nine departments of Rice's George R. Brown School of Engineering. AMPT Center Members (see pages 4-5) have the opportunity to work with this growing roster of researchers. Present faculty and research staff include:

Matthew Brake, FASME
AMPT Center Co-Director
Mechanical Engineering



Zack Cordero
Materials Science & NanoEngineering

C. Fred Higgs III, FASME
AMPT Center Co-Director
Mechanical Engineering

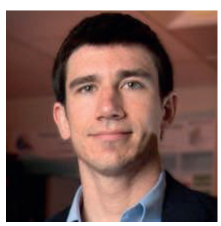


Prathamesh Desai
Mechanical Engineering

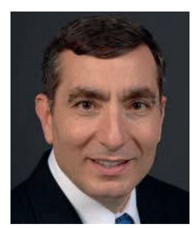
Nicholas Dunbar
Mechanical Engineering

B.J. Fregly
Mechanical Engineering

Jordan Miller
Bioengineering



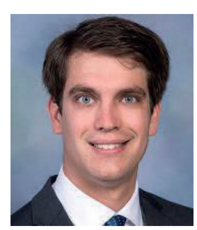
Daniel J. Preston
Mechanical Engineering



James Tour, NAI, FAAAS
Chemistry / Materials Science & NanoEngineering

Ned Thomas, NAE, AAAS
Materials Science & NanoEngineering

Rafael Verduzco
Chemical & Biomolecular Engineering



Geoff Wehmeyer
Mechanical Engineering

For more information on AMPT Center faculty, please see the Abstracts at pages 9-15.

Invitation to Membership

The AMPT Center at Rice University is poised to be the leading multi-disciplinary research center in the United States on the problems of advanced additive manufacturing, performance, and tribology.

Membership in the AMPT Center is open to corporations, Federal laboratories and other organizations approved by Rice who agree to support the mission of the AMPT Center. Members have the opportunity to learn from and collaborate with AMPT faculty and research staff, including working with AMPT researchers on mutually agreed research projects.

Charter Members

Charter Members are organizations that have committed to membership in the AMPT Center at its founding. Rice University is proud to recognize the first Charter Member of the AMPT Center:

VAREL INTERNATIONAL ENERGY SERVICES®

How to Join

Application information is available on the “Join the AMPT Center” page of the AMPT website (ampt.rice.edu). Application for membership begins by completing a Membership Agreement. To obtain a Membership Agreement or for any questions about joining the AMPT Center, please contact:

George Webb, AMPT Industry Liaison
Rice University – MS 363
6100 Main Street, Houston, TX 77005
(713) 348-2704
gwebb@rice.edu

Membership Tiers

The AMPT Center offers a tiered membership structure with different levels of strategic direction and corresponding investment. The following chart summarizes the AMPT membership tiers and benefits for 2019-2020. For ease of comparison, a typical stand-alone sponsored research agreement (which does not include any of the AMPT Center membership benefits) is summarized alongside.

	AMPT Member Benefits	**Executive Member**	**Standard Member**	**Associate Member**	Stand-alone research project
Dues	Annual dues	**$285,000**	**$150,000**	**$75,000**	**$125K - $150K**
Knowledge	Invitation to annual AMPT Symposium and other events	✓	✓	✓	
	Access to research results (e.g. annual reports, presentation slides, posters, etc.)	✓	✓	✓	✓ (per project)
	Facilitated access to AMPT faculty and students	✓	✓	✓	
Research Direction	Input in overall direction of AMPT Center research	✓	✓	✓	
	Seat on AMPT Center Advisory Board	✓	✓		
	Exclusive direction of **one** standard research project		✓		✓
	Exclusive direction of **two** standard (or 1 large) research projects	✓			
Training	Reduced-price training on AMPT machines and instruments	✓	✓	✓	
	Complimentary small-group training	✓	✓		
	Yearly on-site workshop or visit by AMPT Center leadership	✓			

AGENDA

Thursday, August 15, 2019

MORNING

Focus of Day 1: **Technical sessions and lab visits highlighting the unique research capabilities** of the AMPT Center. Each technical session has a general thrust, but the talks in each session intentionally span disciplinary boundaries, in order to stimulate ideas for research and collaboration.

NOTES

8:00 Light breakfast

8:30 Welcome — Reggie DesRoches, Dean of Engineering

8:40 Overview of the AMPT Center — C. Fred Higgs III, Co-Director

8:45 Technical Session 1 –
Additive Manufacturing: Optimizing Process and Structure

8:45	Additive Manufacturing at Rice: An Overview	Zack Cordero *session chair*
8:50	Controlling Form and Function through Metal Additive Manufacturing	Zack Cordero
9:10	Laser-Induced Graphene to 3-D Printed Structures	James Tour
9:30	Additive Manufacturing of Shape-Responsive Liquid Crystal Polymer Networks	Rafael Verduzco
9:50	From Dust to Dreams: Opportunities in Binder Jet Additive Manufacturing	Amy Elliott
10:10	Spreadify: AI-enabled Spreading Recipes for Additive Manufacturing	Prathamesh Desai

10:30 Mini-break

10:35 Technical Session 2 –
Tribology: Optimizing Design for Moving Contact

10:35	Session Overview	C. Fred Higgs III *session chair*
10:40	Elucidating friction and wear in AMPT-related applications via *in situ* and *in silico* tribology	C. Fred Higgs III
11:00	Illuminating Progress on 3D Bioprinting of Vascularized Tissues and Organoids	Jordan Miller
11:20	Fluidic Control through Surface Engineering	Daniel J. Preston
11:40	Prevention is Better than Cure: Machinery Health Monitoring through Lubricant Analysis	Gagan Srivastava

AGENDA

Thursday, August 15, 2019

AFTERNOON

NOTES

12:00 Networking Lunch

1:00 Guided tours of AMPT Center founding research facilities

	Group I	Group II	Group III
1:10	*Leave for GRB Hall*	*Leave for Ryon Bldg.*	*Leave for GRB Hall*
1:20	Higgs Lab	Brake Lab *Leave at 1:50 for GRB*	Cordero Lab *Leave at 1:50 for Ryon*
1:55	Cordero Lab *Leave at 2:25 for Ryon*	Higgs Lab	Brake Lab *Leave at 2:25 for GRB*
2:30	Brake Lab	Cordero Lab	Higgs Lab
3:00	*Leave for Duncan Hall*	*Leave for Duncan Hall*	*Leave for Duncan Hall*

3:15 Technical Session 3 –
Performance, Characterization and Applications: Optimizing Systems and Components

3:15	Session Overview	Matthew Brake *session chair*
3:20	AMPT Assemblies: Using AM and Tribology to Improve Structural Performance and Efficiency	Matthew Brake
3:40	Characterizing Thermal Performance of Materials with High Spatial Resolution	Geoff Wehmeyer
4:00	High-Performing Personalized Medical Devices	Nicholas Dunbar

4:20 Preview of Day 2
and evening directions — Matthew Brake, Co-Director; George Webb, Industry Liaison

4:30 Poster competition and reception

5:40 Poster competition ends – ballots due

6:00 Inaugural AMPT Symposium Dinner — *Rice University Faculty Club (Cohen House)*

AGENDA

Friday, August 16, 2019

Focus of Day 2: Discussion among industry representatives and Rice faculty to **identify current research gaps and near-term research priorities**.

NOTES

8:00 Light breakfast

8:30 **Strategic Vision and Model of the AMPT Center** — C. Fred Higgs III, Co-Director; George Webb, Industry Liaison

9:30 Small group discussions
AMPT-related Research Gaps and Goals for Industry-Academic Collaboration

	GROUP I	GROUP II	GROUP III
Facilitator	Zack Cordero	Fred Higgs	Matthew Brake

11:30 Working Lunch
Trends and Research Directions

1:00 Inaugural AMPT Symposium adjourns

For further information
about the AMPT Center,
please contact:

George Webb
AMPT Center Industry Liaison
Rice University - MS 363
6100 Main Street,
Houston, Texas 77005
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or visit:
ampt.rice.edu

Technical Session 1
Additive Manufacturing: Optimizing Process and Structure

Controlling Form and Function through Metal Additive Manufacturing

Zack Cordero
AMPT Center Founding Faculty

Assistant Professor of Materials Science & NanoEngineering
Rice University
http://additive.rice.edu

Abstract:
Current metal additive manufacturing techniques can create complex parts, but they offer limited control over microstructure, making it difficult to directly print high-performance components for demanding mission-critical applications. My research group seeks to overcome this limitation by developing hybrid additive manufacturing processes that can print objects with tailored structures that impart specific desirable mechanical properties. In pursuit of this goal, we study the physics of materials processing and plastic deformation, with a view towards establishing quantitative process-structure-property linkages for additively manufactured materials. This talk will summarize our methods for printing next-generation structural materials, including net-shaped nanocrystalline materials, mesostructured composites, and grain boundary engineered oligocrystals. I will discuss the exotic mechanical properties of these designer materials and their potential to address key challenges in materials engineering.

Laser-Induced Graphene to 3-D Printed Structures

James Tour, NAI, FAAAS

T. T. & W. F. Chao Professor of Chemistry
Professor of Materials Science & NanoEngineering
Professor of Computer Science
Rice University
www.jmtour.com

Abstract:
Described will be the development of laser-induced graphene foams wherein graphene can be prepared using a commercial CO_2 laser interacting with a host of substrates. This has been extended from thin film formation of graphene to the manufacture of 3D graphene foams using laminated object manufacturing methods and powder bed manufacturing.

ABSTRACTS

Additive Manufacturing of Shape-Responsive Liquid Crystal Polymer Networks

Rafael Verduzco

Professor of Chemical & Biomolecular Engineering
Rice University
http://polymers.rice.edu

Abstract:
Liquid crystal elastomers (LCEs) are shape-responsive materials that combine the elasticity of rubbery polymer networks with the responsiveness of liquid crystals. Shape changes in LCEs are coupled to changes in the liquid crystal order parameter but typically limited to simple deformations such as uniaxial extension or contraction. In recent work, we have shown that through optimization of the double network composition of LCEs, complex, three dimensional shape changes can be programmed including curling, twisting, and the formation of imprinted textures. Here, we expand this work through the additive manufacturing of LCEs to achieve more complex form factors including auxetic materials, non-planar surfaces, and multilayer solid materials. Double network LCEs are synthesized through a thiol Michael addition reaction to define the first network followed by radical photopolymerization of residual acrylate functional groups to produce a second interpenetrating network. The first reaction step is performed by printing an LCE oligomeric mixture into a desired shape in a bath with a strong base which rapidly catalyzes the crosslinking reaction. After removing and drying the sample, mechanical deformation is used to program a desired shape. We demonstrate a series of shape-responsive materials possible using this approach and discuss potential applications including soft robotics and dynamic surfaces.

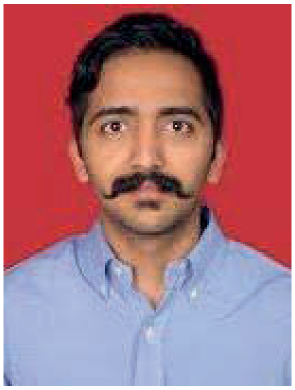
From Dust to Dreams: Opportunities in Binder Jet Additive Manufacturing

Amy Elliott

R&D Staff, Energy and Transportation Science Division
Oak Ridge National Laboratory
https://www.ornl.gov/staff-profile/amy-m-elliott

Abstract:
Binder jetting is an additive manufacturing (AM) process that combines a powder bed system with an inkjet print-head to produce net-shaped parts that can be post-processed to achieve desired physical properties. Owing to its relatively low hardware cost and high throughput, binder jetting is proving to be the most economic AM process. Further, because of the range of powdered that can be shaped with the technology, binder jetting is also poised to be the most versatile of all AM processes. Researchers at Oak Ridge National Laboratory (ORNL) seek to demonstrate the potential of binder jetting capabilities by exploring printing parameters for different powder feedstocks as well as novel post-processing techniques for strategic materials such as steels and carbides. Further, ORNL researchers are developing new binder systems to improve the quality of printing and post-processing. This talk will discuss efforts in developing printing parameters, new binder systems, and post-processing techniques to push the boundaries of binder jet technology.

Spreadify: AI-enabled Spreading Recipes for Defect-free 3D-printed Parts



Prathamesh Desai

Research Scientist in Mechanical Engineering
Rice University
https://sites.google.com/site/pratnsaiweb/

Abstract:
Powder bed additive manufacturing (AM) is comprised of two repetitive steps: spreading of powder and selective fusing or binding the spread layer. In the first step, a spreader forces a shear flow of powder between itself and the substrate. A rheometry calibrated model based on discrete element method (DEM) with polydispersed particle sizes is applied to simulate the spreading process. The DEM model has been parallelized using the massive parallelism offered by GPUs. The DEM results are validated against the experimental findings from single layer spreading of an industrial grade Ti-6Al-4V powder using a retrofit, designed in-house, to a commercial 3D printer. Since the DEM simulations are computationally expensive, artificial intelligence (AI) was employed to interpolate between the highly non-linear results. A few DEM simulations were executed by following a Design of Simulations (DoS) approach. The AI model served as the surrogate to the higher fidelity DEM model. Finally, the AI model is used to generate a spreading process map to determine the spreading process parameters that yield the desired surface roughness and porosity of the spread layer constrained to maximizing the spread throughput and minimizing part deformation. This AI model forms the core of a mobile application called Spreadify.

Technical Session 2
Tribology: Optimizing Design for Moving Contact

Elucidating friction and wear in AMPT-related applications via *in situ* and *in silico* tribology

C. Fred Higgs III
AMPT Center Co-Director and Founding Faculty

John & Ann Doerr Professor of Mechanical Engineering
Vice Provost for Academic Affairs
Rice University
https://higgslab.org

Abstract:
In silico tribology refers to the application of time-evolving, physics-based computer models and graphic simulations to uncover the science behind surfaces in sliding contact, namely their friction, lubrication, and wear. *In situ* tribology refers to the use of fundamental physical experiments that measure the friction, lubrication, and/or wear processes occurring between the surfaces in sliding contact, in real-time. Sliding surface applications that involve particle media are in many engineering systems. These tribosystems exist in applications such as oil and gas drilling, orthopedic implants, and powder-bed additive manufacturing. Advanced numerical treatments such as computational fluid dynamics (CFD), fluid-structure interaction, the discrete element method (DEM), and agent-based modeling are employed to build *in silico* modeling simulations that mimic physical systems (often called "digital twins" in industry). We then design fundamental experiments that measure the expected tribology *in situ*, and coordinate them with the *in silico* modeling to uncover the principles governing the applications' performance. If product performance can be improved through additive manufacturing, we employ a proprietary AI-enabled design for additive manufacturing (DFAM) process to recommend design changes based on our understanding of the expected tribology challenges during operation.

Illuminating Progress on 3D Bioprinting of Vascularized Tissues and Organoids

Jordan Miller
Assistant Professor of Bioengineering
Rice University
http://millerlab.rice.edu

Abstract:
Solid organs transport fluids through distinct vascular networks that are biophysically and biochemically entangled, creating complex three-dimensional (3D) transport regimes that have remained difficult to produce and study. We establish intravascular and multivascular design freedoms with photopolymerizable hydrogels by using food dye additives as biocompatible yet potent photoabsorbers for projection stereolithography. We demonstrate monolithic transparent hydrogels, produced in minutes, comprising efficient intravascular 3D fluid mixers and functional bicuspid valves. We further elaborate entangled vascular networks from space-filling mathematical topologies and explore the oxygenation and flow of human red blood cells during tidal ventilation and distension of a proximate airway. In addition, we deploy structured biodegradable hydrogel carriers in a rodent model of chronic liver injury to highlight the potential translational utility of this materials innovation.

Fluidic Control through Surface Engineering

Daniel J. Preston

Assistant Professor of Mechanical Engineering
Rice University
https://pi.rice.edu

Abstract:
Rational design of surfaces, from the macroscale to the molecular scale, enables control over fluidic behavior, including the manipulation of droplets and bubbles. Surface geometry, intrinsic chemical nature, and the interplay between these two design parameters govern fluidic interactions with surfaces. One important application space includes condensers, which are universal within industry. Tuning the surface wettability of a condenser can improve system-level efficiency by several percent, but the appropriate surface modification varies depending on the system. For example, condensation of water within a steam cycle used to generate electricity can be improved over 10x by utilizing a superhydrophobic surface coating, causing droplets to shed from the surface at the microscale. On the other hand, condensation of a refrigerant, as in air conditioning systems, benefits from a surface with a high affinity for the refrigerant, which can improve heat transfer rates by up to 400% by forming a thin film that is wicked away from the surface. In our work, surface modifications are performed using scalable approaches that can be translated to industrial applications, with a focus on durability and long-term performance, and an interest in new materials and coatings.

Prevention is Better than Cure: Machinery Health Monitoring through Lubricant Analysis

Gagan Srivastava

Adjunct Professor of Mechanical Engineering, Rice University
Senior Engineer, Dow Chemical Company

Abstract:
While Industry 4.0 involves the use of sensors, data, and the internet to monitor machine conditions, the lubricant itself is a data stream rich in tribological information which can also be interrogated to monitor machine health. In an industrial setting, “maintenance” of machinery components primarily involves ensuring adequate lubricant levels. With increasing emphasis on lean manufacturing and productivity enhancements, the importance of the nature of the lubricant, together with the amount of the lubricant is being recognized for optimal performance. Defining the nature of the lubricant typically involves detailed analysis of the fluid through a variety of complex physical and chemical tests. This array of data can help monitor critical system characteristics such as machine wear, contamination, and fluid degradation. Additionally, lubricant analysis has also been shown to be one of the earliest indicators for machine damage, and can be instrumental in preventing unexpected breakdowns and catastrophic failures. Therefore, understanding the composition of a lubricant and its characterization can be very helpful for equipment designers and engineers. This talk will share the basics of lubricant composition and its utilization in understanding the condition of in service oils. Next generation, online, continuous monitoring tools that have the potential to enable long term performance improvements would also be discussed.

Technical Session 3

Performance, Characterization and Applications:
Optimizing Systems and Components

AMPT Assemblies: Using AM and Tribology to Improve Structural Performance and Efficiency

Matthew Brake, FASME
AMPT Center Co-Director and Founding Faculty

Assistant Professor of Mechanical Engineering
Rice University
http://brake.rice.edu

Abstract:
What if you could make your engines 10% more efficient through simple, minimally invasive changes to your design process? This concept is at the heart of a new field of mechanical engineering termed Tribomechadynamics, which is comprised of tribology, contact mechanics, and structural dynamics. These three sub-disciplines of mechanical engineering are each concerned with the study of interfaces in mechanical systems. Despite this, these three sub-disciplines have remained separate due to length scale considerations, solution techniques, and response metrics. As a result, common problems solved within one of these sub-disciplines rarely affects research within the other sub-disciplines.

To address this, the field of Tribomechadynamics was founded to bridge the scales from the nano- and micro-structural characterizations of tribology to the macroscale modeling of structural dynamics. The goal of this new field is threefold: to develop predictive models of jointed assemblies that can be used to affect the design phase of a product, to predict the degradation of an assembly over time due to wear, and to enable the optimization of assemblies to reduce weight, be wear resistant, or have advantageous properties. This talk presents the emerging field of Tribomechadynamics in the context of both the applications that it addresses (such as aeroturbines) and the basic research being used to advance our physical understanding of assembled systems. Several examples are used to highlight how a new Tribomechadynamical modeling framework can be used to develop optimal maintenance schedules and to improve performance of a system over its lifetime, not just when it’s brand new.

Characterizing Thermal Performance of Materials with High Spatial Resolution

Geoff Wehmeyer

Assistant Professor of Mechanical Engineering
Rice University
http://wehmeyerlab.rice.edu

Abstract:
Thermal management and thermal control are key issues affecting reliability, lifetime, and performance in a wide variety of engineering applications. In order to achieve the optimal thermal design, the thermal properties of thin-film coatings, composite systems, and or additively-manufactured components must be known with high accuracy. However, it is often difficult to quantify the thermal performance of these systems using standard ASTM methods due to their small lengthscales and/or complex geometries. Here, I will discuss two measurement techniques used in our group to quantify thermal performance of such systems. I will first introduce the "3-omega" technique that leverages the temperature-dependent resistance of microfabricated heater lines to measure the thermal conductivity of thin films. I will then discuss our recent demonstration of high-spatial resolution temperature mapping using transmission electron microscopy. Looking forward, new methods to combine high spatial resolution and high temporal resolution temperature measurements open further opportunities for improving the thermal performance of systems used in energy and manufacturing applications.

High-Performing Personalized Medical Devices

Nicholas Dunbar

Postdoctoral Research Associate in Mechanical Engineering
Rice University
https://rcnl.rice.edu

Abstract:
Several emerging technologies are being developed at Rice University to improve the performance of personalized medical devices and treatment decisions for bone tumor removal surgery. In the hospital of the future, treatments will be increasingly personalized using detailed medical imaging and patient-specific functional data. New medical devices are manufactured as-needed rather than one-size-fits-all or several-sizes-fit-all. Personalization, however, does not guarantee performance. Bone tumor removal surgery in the hip joint is an opportunity to put patient-specific approaches into practice to achieve the best result for the patient. For this to happen, all aspects of treatment decisions and device customization need to be quantitatively optimized. This talk will explore the integration of neuromusculoskeletal simulation, additive manufacturing, and tribology that is necessary

Symposium Locations

The **Inaugural AMPT Symposium** takes place in **Duncan Hall** (Building 46 on the main Rice campus map).

The main entrance to Duncan Hall is at the southeast corner of the building, next to the inner campus loop, as indicated on the Engineering map (see back cover). AMPT Symposium events take place in the main foyer and in the auditorium and conference rooms adjoining.

The **AMPT Symposium Dinner** for industry participants, invited speakers, and Rice faculty is held at the Rice University Faculty Club in historic **Cohen House** (Building 9 on the campus map).

Parking

The two best options for visitor parking are:

1. **Founders Court Visitor Lot (FC)** (next to Cohen House, Building 9):
   ~ 6 minute walk (0.3 miles) to Duncan Hall

   Access via one of the following campus entrances:
   - Entrance 2 (Main St. opposite Hermann Park), then turn left
   - Entrance 3 (Main St. at Cambridge St.), then turn right at inner campus loop

   At this lot, use a credit card at the gate to enter, and the same credit card at the gate to exit.

2. **Central Campus Garage** (underneath McNair Hall, Building 57):
   ~ 10 minute walk (0.5 miles) to Duncan Hall

   Access via one of the following campus entrances:
   - Entrance 2 (Main St. opposite Hermann Park)
   - Entrance 4 (Main St. opposite UT Health Science Center Professional Bldg.)
   - Entrance 8 (University Blvd. at Stockton St.)
   - Entrance 20 (Rice Blvd. at Kent St.)

   The garage entrance is on the campus loop road, between bus stops 16 and 17. The loop road is one-way counterclockwise.

   At this garage, take a ticket when you enter, and take the ticket with you. Before returning to your car, pay at one of the pay machines in the garage.

Rice University Campus Map

7/19/18

Map Key

- Entrance Gates
- Visitor's Entrances
- Bus Stops
- One-way Road
- BCycle Stations

Parking Key

- Faculty/Staff Parking
- Resident Student Parking
- Commuter Parking
- Visitor Parking
- Accessible Parking

Parking Lots:

B	Baker College–Housing & Dining Lot
BA	BioScience Research Collaborative (BRC) Annex
BG	Biology–Geology Lot
BRC	BioScience Research Collaborative Garage
C	Campanile Lot
CG	Central Campus Garage
E3G	Entrance 3 Garage
FC	Founder's Court Visitor Lot
FE	Facilities, Engineering and Planning Lot
G	Greenbriar Lot
GA	Greenbriar Annex
K	Keck Lot
LN	Lovett North Lot
LS	Lovett South Lot
L6	Lot Six
M	Moody Lot
N	North Lot
NA	North Annex Lot
NC	North Colleges Residents Lot
SC	South Colleges Residents Lot
SS	South Stadium Lot
W	West Lot

Parking Rates:

Greenbriar Lot: $3 per entry, per day
BRC Annex Lot: $10 per entry, per day
All Other Visitor Parking Facilities: $1 each 10 minutes, $12 daily maximum

Payment Methods:

BioScience Research Collaborative Garage and Central Campus Garage: cash or credit card
All Other Visitor Parking Facilities: credit card only; used to enter and exit

Buildings

Abercrombie Engineering Laboratory 11
Allen Business Center 33
President's Office
Anderson Biological Laboratories, M.D. 22
Anderson-Clarke Center 74
Dean of Susanne M. Glasscock School of Continuing Studies, Hudspeth Auditorium
Anderson Hall, M.D. 10
Dean of Architecture
Baker College, James Addison 5
Baker College Magisters House 18
Baker Hall, James A. III 47
Dean of Social Sciences, James A. Baker III Institute for Public Policy
BioScience Research Collaborative 63
Brochstein Pavilion, Raymond and Susan 61
Brockman Hall for Physics 72
Brown College, Margarett Root 28
Brown College Magisters House 29
Brown Hall, Alice Pratt 44
Dean of Shepherd School of Music
Brown Hall, George R. 45
Dean of Wiess School of Natural Sciences
Brown Hall for Mathematical Sciences, Herman 34
Brown Tennis Center, George R. 75
Butcher Hall, Dell 48
Cambridge Office Building 78
Cohen House, Robert and Agnes 9
Duncan College, Anne and Charles 67
Duncan College Magisters House 68
Duncan Hall, Anne and Charles. 46
Dean of George R. Brown School of Engineering
Facilities Engineering and Planning Building 26
Fondren Library 12
Gibbs Recreation and Wellness Center, Barbara and David 62
Greenbriar Building 36
Greenhouse 59
Hamman Hall 24
Hanszen College, Harry C. 6
Hanszen College Magisters House 20
Herring Hall, Robert R. 41
Herzstein Hall 4
Holloway Field 7
Wendel D. Ley Track
Housing and Dining 19
Huff House, Peter and Nancy 13
Alumni Affairs
Humanities Building 49
Dean of Humanities
Jones College, Mary Gibbs 16
Jones College Magisters House 55
Keck Hall 8
Keith-Wiess Geological Laboratories 23
Lovett College, Edgar Odell 35
Lovett College Magisters House
Lovett Hall 1
Admission Office, Welcome Center
Martel College Marian Fox and Speros P 53
Martel College Magisters House 54
McMurtry College, Burton and Deedee 65
McMurtry College Magisters House 66
McNair Hall, Janice and Robert 57
Dean of Jesse H. Jones Graduate School of Business
Mechanical Engineering Building 42
Mechanical Laboratory 2
Media Center 37
Moody Center for the Arts 77
Mudd Computer Science Building 40
North Servery 56
Oshman Engineering Design Kitchen 31
Patterson Sports Performance Center, Brian 76
Rayzor Hall 25
Reckling Park at Cameron Field 50
Rice Children's Campus 60
Rice Stadium 15
Rice University Police Department 43
U.S. Post Office
Rich Student Health Center, Morton L. 30
Richardson College, Sid W. 38
Richardson College Magisters House
RMC 21
Campus Bookstore, Ley Student Center, Rice Memorial Chapel
Ryon Engineering Laboratory 27
Seibel Servery, Abe and Annie 70
Sewall Hall 39
South Plant 64
South Servery 52
Space Science and Technology Building 32
Tudor Fieldhouse and Youngkin Center 14
Autry Court, Fox Gymnasium
Turrell Skyspace at Booth Pavilion 73
West Servery 69
Wiess College, Harry C. 51
Wiess President's House 58
Will Rice College 3
Will Rice College Magisters House 17
Wilson House 71
Wiess College Magisters

Academic Schools

Architecture, School of 10
Business, Jesse H. Jones Graduate School of 57
Continuing Studies, Susanne M. Glasscock School of 74
Engineering, George R. Brown School of 46
Humanities, School of 49
Music, The Shepherd School of 44
Natural Sciences, Wiess School of 45
Social Sciences, School of 47

Off-Campus Facilities

Rice Graduate Apartments
Rice Village Apartments

GEORGE R. BROWN SCHOOL OF ENGINEERING

RICE UNIVERSITY