News from the

Department of Mechanical & Aerospace Engineering

Fall 2013

THE OHIO STATE UNIVERSITY

Ahmet Selamet
Professor and Chairperson
Department of Mechanical
and Aerospace Engineering

A Message from the Chair

Again this fall, I have the privilege as the department chair to highlight some of the more distinct accomplishments of the faculty members who have earned their share of recognition for their contributions to academia. From year to year, the ways in which they distinguish themselves may change as their careers progress. But always, whether their reputation is built on novel research, educating bright young students, producing seminal papers and books, while also serving an array of professional societies and associations, they make us immensely proud of our community here at Ohio State.

To that point, I applaud Professor Joseph Heremans on his recent induction into the National Academy of Engineering and Rajendra Singh for being named the recipient of the 2013 Ralph Coats Roe Award by the American Society of Engineering Educators. In addition, the prestigious Fellow designations of our faculty by a number of professional societies delight those of us who teach alongside such dedicated individuals. I'm equally enthusiastic about the competitive grants, earned by several of our faculty, which will further aid their investigations. I am also encouraged and excited by the overall strong support that our mechanical, nuclear, and aerospace engineering programs attract from both industry and government in search of answers to complex engineering challenges, leading to new knowledge and practical discoveries that benefit society.

Whether we're striving to further: develop lightweight and cost-effective vehicle components with superior noise and vibration performance (related Smart Vehicles Concept Center article, pp 8-9); assist surgeons performing total knee replacement operations (pp 10-11); advance the understanding of thermo-fluid behavior of multiphase turbulent flows (pp 12-13); design compliant mechanisms for critical engineering applications (pp 14-15); improve gas turbine efficiency through unique heat transfer studies (pp 16-17); or maximize the energy output of the anaerobic digestion process (p 20), we firmly believe that our work fuels opportunities to partner with other organizations that wish to engage the exceptional engineering skills and creativity of our students and faculty. Two such partnerships, one well established (see article about Professor Marcelo Dapino and OSU/Honda MIX, p 4) and one that is on the cusp of a broad strategic relationship (see Parker Hannifin Foundation grant article, pp 6-7) are examples of our vision for continued collaborative research.

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Dapino Named Honda R&D Americas Designated Chair and ASME Fellow

Professor Marcelo Dapino was appointed the Honda R&D Americas Designated Chair in Engineering at Ohio State. Support for the Designated Chair comes from a renewable three-year gift made by Honda R&D Americas (HRA), located in Raymond, Ohio. The Honda R&D Americas Designated Chair was bestowed upon Dapino due to his significant leadership achievements in automotive transportation. The term of his appointment, which began in July, lasts for three years.

As Ohio State's director of the Honda/OSU Mobility Innovation Exchange (MIX), Dapino leads, jointly with Honda R&D's MIX Director Lara Minor, a unique collaborative program of research and education. The Honda/OSU MIX encompasses a broad research portfolio dealing with manufacturing, mechatronics, system dynamics, simulation, safety, and materials. Professor Ahmet Selamet, chair of the mechanical and aerospace engineering department, views the Honda/OSU MIX as an example of successful collaboration between industry and academia. Selamet stated, "The MIX includes a joint housing of Ohio State and Honda researchers in Scott Laboratory, home of mechanical and aerospace engineering, and is complemented by affiliated facilities on Ohio State's main campus such as the Driving Simulator Laboratory, which was developed in partnership among The Ohio State University, Honda R&D, and the Ohio Supercomputer Center. Support by Honda R&D toward our CATIA laboratory, capstone projects, and student internships and co-ops gives our students unique opportunities for industry-oriented education and training."

"The Honda/OSU MIX has realized significant growth since its creation, but our objectives remain the same in the creation of basic knowledge to serve the academic mission of Ohio State along with the development of practical solutions that directly translate into improved Honda products. I feel fortunate that Honda R&D chose to create the designated chair, a first for them." Dapino said.

Dapino also directs the Smart Materials and Structures Lab within the Department of Mechanical and Aerospace Engineering,

serves as Associate Director for Research of the National Science Foundation's Industry-University Cooperative Research Center on Smart Vehicle Concepts, and is a fellow of Ohio State's Center for Automotive Research.

Earlier this year, Dapino was elected a Fellow of the American Society of Mechanical Engineers. In the citation for his election, the society recognized him as an international leader in smart materials with a focus on magnetostrictive materials, dynamic smart systems, and additive manufacturing of adaptive structures.

Heremans Named to National Academy of Engineering

Joseph Heremans, a professor in the Department of Mechanical and Aerospace Engineering and an Ohio Eminent Scholar was inducted into the National Academy of Engineering (NAE) at the NAE's annual meeting in early October. The citation for his election stated that he was chosen for his discoveries in thermal energy transfer and conversion to electricity, and for the commercial devices employed in automobiles. Upon learning that Dr. Heremans had been elected to the 2013 Class of NAE Members, Professor Ahmet Selamet, chair of the Department of Mechanical and Aerospace Engineering, remarked, "This is a tremendous honor for Professor Heremans, our department, the college, and the university. We are proud of him and his accomplishments."

Heremans' research in the thermal transport properties of solids and nanostructures, aims to develop thermoelectric materials with improved efficiency for both electrical power generation and heat pumping applications. A decade of research in his Thermal Materials Lab as well as the research of others has led to improved efficiencies through a reduction of the thermal conductivity by adding nanostructures to thermoelectric materials. In June of this year, the journal *Nature Nanotechnology* published a paper co-authored by Heremans and past collaborators, which summarizes the current state of thermoelectrics research. The paper, titled "When thermoelectrics reached the nanoscale" provides a glimpse into the way thermoelectric materials work and new ways in which the motion of electrons may be engineered to behave in thermoelectric materials. In addition, a letter titled, "Giant spin Seebeck effect in a non-magnetic material," which was co-authored by Heremans, a previous graduate student and two other Ohio State collaborators, was prominently featured in the July 2012 issue of the journal *Nature*.

Since 2005, he has focused on developing bulk thermoelectric materials in which the increased efficiency is based on the details of the chemical bonds at sub-nanometer levels. He currently serves as the Principal Investigator (PI) of an Air Force Office of Scientific

Research Multidisciplinary University Research Initiative on cryogenic Peltier cooling. He is also the PI of a project sponsored by the National Science Foundation/Department of Energy that has a goal of developing elements for a practical automotive exhaust waste-heat recovery system that meets cost and durability requirements of the industry. With 38 U.S. patents to his credit, Heremans has significantly influenced the advancement of knowledge associated with thermoelectric power.

Over the past year, interactions between Parker Hannifin technical personnel and Ohio State faculty have been initiated in the following areas, and are expected to grow: electroactive polymer sensors, hydraulic hybrid drivetrain optimization and NVH issues, and chip waste reduction in manufacturing operations.

A two-day joint technical interchange meeting covering a broader range of technologies was recently held which involved about 18 Parker Hannifin technical personnel and about 30 Ohio State faculty and staff members. Parker Hannifin personnel outlined their needs and challenges, and learned about Ohio State's relevant expertise, resulting in the identification of other areas for potential collaboration. Pictured clcokwise from top right are: Peter Buca, Vice President for Technology & Innovation, Fluid Connectors Group, Parker Hannifin Corporation (Professor K. Cheena Srinivasan, background); Becki Ramsay, Engineering Supervisor at Parker; Professor Mike Mills; Oliver Neiske, New Process Development Manager at Parker; Assistant Professor Vishnu Sundaresan; and Mario Calvo, Business Unit Manager at Parker.

Mutually benefical partnerships with organizations such as Parker Hannifin are becoming increasingly attractive as research universities such as Ohio State seek to integrate broader market needs and perspectives.

Ohio State Receives Grant from the Parker Hannifin Foundation

Ohio State has received a generous grant from the Parker Hannifin Foundation for the calendar years 2013 and 2014. The grant is intended to promote faculty leadership and curriculum developments in the areas of advanced actuation and sensing by encouraging interactions and collaboration between Ohio State faculty and technical personnel from the Parker Hannifin Corporation. In addition, the grant is intended to strengthen the ability of Ohio State's engineering graduates to translate solutions from the laboratory and their implementation within industrial contexts. Advanced actuation and sensing are areas of core strategic importance to the Parker Hannifin Corporation, a leading $13 billion diversified manufacturer of motion control technologies and systems worldwide, serving a wide variety of mobile, industrial and aerospace markets.

Development and strengthening of faculty knowledge in these areas provides Parker Hannifin Corporation access to Ohio State expertise for the purposes of open innovation, problem solving, consulting, and workforce education. The proposed curricular changes and development of translational innovation capabilities among engineers educated at Ohio State make them attractive as prospective employees of companies with interests in these areas and industrial organizations in general.

The benefits to Ohio State from the activities to be supported by the grant are significant as well. Fundamental research in advanced actuation and sensing would be informed by greater faculty awareness of market needs and perspectives and further, opportunities for research collaboration with corporate partners would grow. Its graduates would benefit from valuable experiential learning in real-world applied engineering environments.

While Ohio State's College of Engineering and its Department of Mechanical and Aerospace Engineering have led their peers nationwide in industry-sponsored research, the grant funding breaks new ground in that, if successful, it would seed the formation of a broad strategic relationship between an academic and a corporate organization, namely, Ohio State and the Parker Hannifin Corporation. Prior interactions between universities and corporate organizations (individually or as part of consortia) have tended to be centered around individual faculty members or groups of faculty members in specific technology areas.

The breadth of technologies of importance to the Parker Hannifin Corporation makes a strategic relationship with a large academic organization such as Ohio State – offering breadth of academic expertise – a potentially rich partnership. The opportunity comes with its own unique set of challenges however, including a need for advocates from within both organizations and a platform for dialog that can accommodate a broad range of technologies and is sustainable across time.

The relationship, which is off to a very promising beginning, has champions from the both organizations: Peter Buca, Vice President for Technology & Innovation, Fluid Connectors Group, Parker Hannifin Corporation, Ohio State's K. (Cheena) Srinivasan, Professor (and former chairperson), Mechanical and Aerospace Engineering Department, and Daniel Kramer, associate vice president in Ohio State's Office of Research and director of its Industry Liaison Office.

A Noise, Vibration, & Harshness Technology Success Story

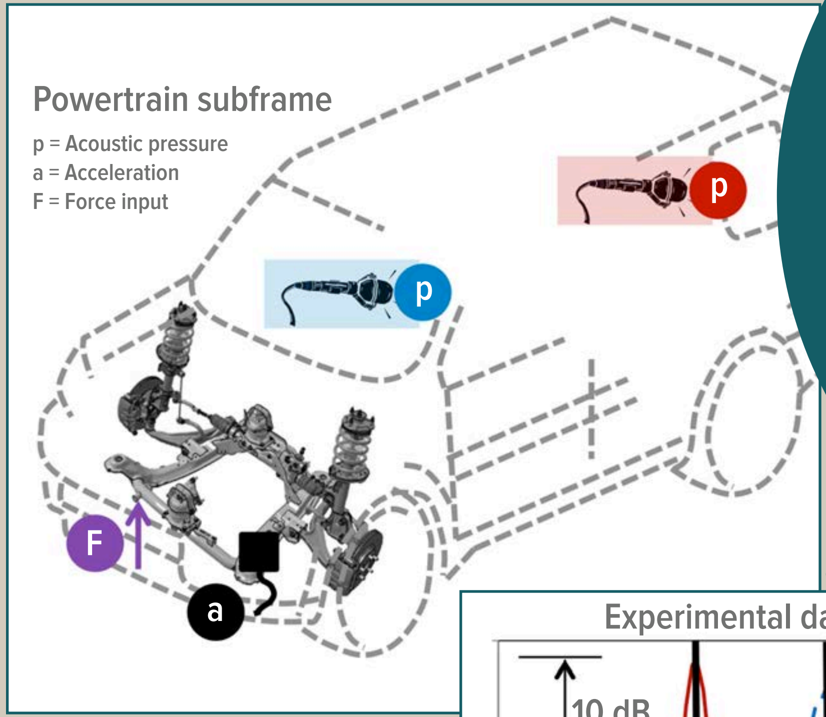
Within the Smart Vehicle Concepts (SVC) Center at The Ohio State University, researchers have been studying conventional elastomeric and hydraulic mounts, or bushings, and their interaction within body frame structures with respect to their impact on Noise, Vibration, and Harshness (NVH) performance. This work, initiated by the Transportation Research Center, Honda R&D Americas, F.tech, and YUSA, has led to improvements in component and sub-system models for both frequency and time domain applications. Refined and new characterization procedures for uni-axial and multi-axial dynamic properties of components within a sub-system have also been developed as part of these efforts.

One of the unique aspects of this project is the active collaboration among a vehicle manufacturer (Honda) and suppliers of mount and bushing (YUSA) and body frame (F.tech) components and the academic researchers (Ohio State). This work has been fueled by the contemporary demand for light weight and cost-effective vehicle components without compromising superior vehicle performance, such as NVH. For instance, this collaboration has provided an environment for a vehicle component supplier (F.tech) to develop a vehicle-level modeling tool to accurately assess the impact of design modifications of their frame components on the system (vehicle) NVH performance. Such tools involve both computational models and limited experimentally obtained parameters and, as a result, can eventually reduce the number of costly prototype builds and design iterations. The proposed method expands the current frequency response function based sub-structuring method implemented in the software package of one of the Center's invited observers (LMS Int.).

This platform permits the evaluation of many different virtual body frame designs through the integration of finite element based results along with available non-resonant test data for viscoelastic devices such as bushings or mounts. Although experimental and simulation results have yielded reasonable correlation, potential improvements in the modeling approach have been identified, including the need for refining multi-dimensional characterization procedures and a better understanding of the model complexity required for realistic on-vehicle predictions. The focus of this work has been on the body frame and joint system design, but it has also provided insight into improved specifications for mounts and bushings in the context of overall performance at the system level. These efforts and past Center activity in this area have identified leads into innovative frame designs with specific component layouts as well as improved modeling capabilities and understanding into observed on-vehicle phenomena.

Economic Impact: This work can lead to new cost-effective and light weight body frame designs and elastomeric component layouts with superior NVH performance. Such a simulation tool will also reduce the prototype builds and testing required during vehicle development, inherently reducing development costs for vehicles. The complementary work within the Center in this area can also lead to improved vibration isolator concepts, such as active and hydraulic bushings, that would be critical to address transmission noise problems, which often prevent many fuel efficient engine control schemes and designs (such as selective cylinder firing) from being commercially viable.

Smart Vehicle Concepts Center Focuses on Design of Quiet, Cost-effective, and Lightweight Vehicle Components



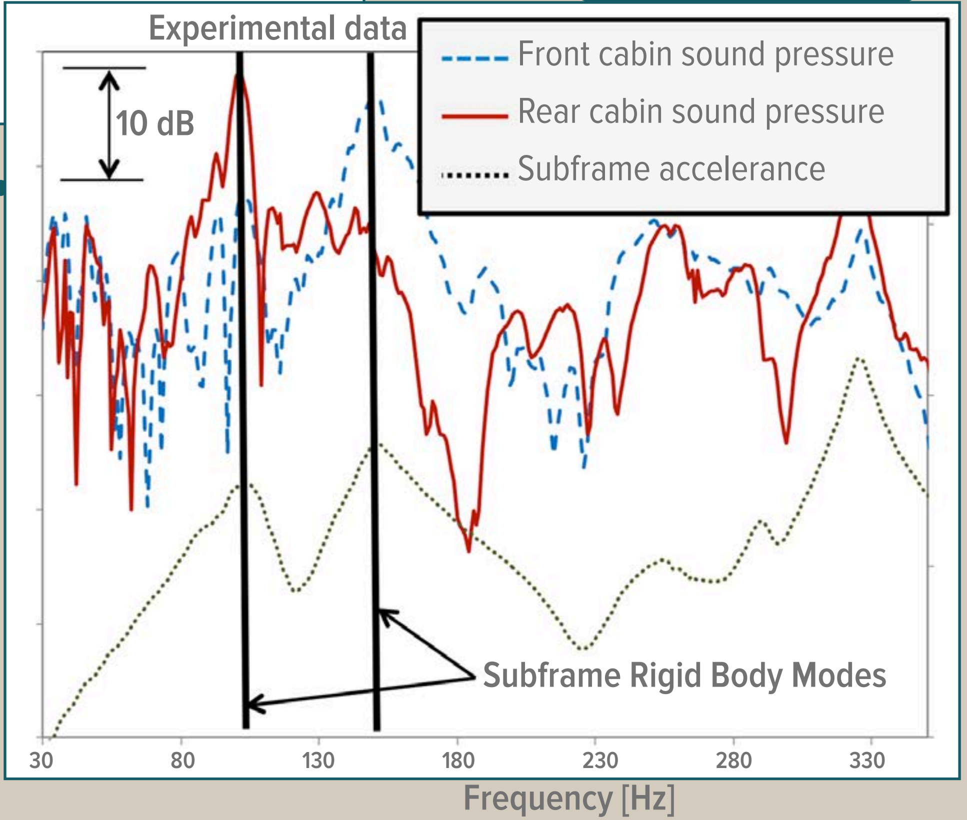
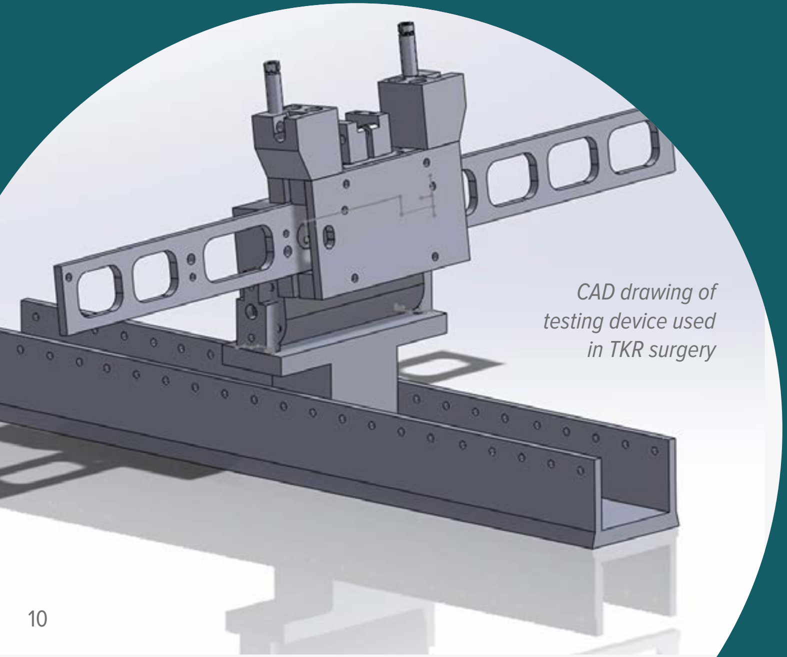


Illustration of the strong influence of body subframe on sound pressure level within vehicle cabin. The frame acts as path from powertrain or road noise (source) to cabin sound pressure (receiver).

Examining the Biomechanics of TKR Surgery

Orthopedic surgeons tasked with total knee replacement (TKR) operations can certainly use every possible advantage available to them when focused on the precision work of sculpting new knees. Helping those surgeons at Ohio State's Wexner Medical Center is Associate Professor Rob Siston. His biomechanics research is meant to equip surgeons with better data by determining how current surgical techniques influence TKR outcomes and how those techniques might be more finely tuned to help patients achieve improved knee function and active lifestyles after surgery.

The research being conducted by Siston and his co-investigators has been made possible through two National Institutes of Health grants. The larger of the two grants is an R01 Research Project, titled "Using Intraoperative Measurements to Predict Postoperative Outcomes of TKA." Siston and his co-investigators at Ohio State's College of Medicine are now about halfway through their R01 study. Their novel approach incorporates biomechanics data about how stiff or lax a knee typically appears during surgery. To aid in this endeavor, Siston's first master's student built a tool that makes it possible to take range of motion measurements of the knee while a surgeon applies a known load to the leg during TKR surgery. Previously, this assessment of flexibility and stability, of how to best "balance" the knee was only estimated in a subjective way, rather than an objective way, during surgery.



CAD drawing of testing device used in TKR surgery

By recording quantitative data about the actual motion of the knee during surgery, Siston and his colleagues are driving toward a more evidence-based approach to TKR – a move they hope will improve the eminence-based methods most commonly used by surgeons. One of collaborating surgeons on the project describes eminence-based medicine, as a surgical technique that is passed from one, more experienced or renowned surgeon to his or her surgical residents and cohorts. This method typically results in the establishment of a technique that becomes the standard operating procedure used by ever greater numbers of surgeons. Specific to TKR, Siston notes that assessments made during surgery with regard to an individual's ligaments – and how tight or loose the knee feels – almost always varies from one surgeon to another and from one patient to another. Consequently, achieving excellent outcomes for those undergoing a TKR would certainly vary depending upon each surgeon's interpretation of how "loose" or "tight" a knee appears.

As part of the R01 funded study, willing TKR patients agree to participate in a multi-part study. First, about a month prior to surgery, they agree to come into the gait analysis laboratory to complete some questionnaires and undergo a series of tests to assess their pre-operative level of function. Second, they agree to add 15 minutes to the length of their operation so that researchers might use the aforementioned surgical instrument to measure the movement of the knee based on the force applied to the joint both before and after the artificial knee components are implanted. The measurements from this tool supplement the subjective "feel" that surgeons currently use to assess the "looseness" or "tightness" of the knee. Finally, patients agree to return to the gait lab for follow-up assessments at six months and again at two years after surgery. Collecting the patient data aligns with the principles of evidence-based medicine, where objective measures of what a surgeon does inside of the operating room can be related to how well a patient does after surgery.

The research aims to enable total joint surgeons to make more informed, evidence-based decisions during surgery; physical therapists to individualize post-operative rehabilitation programs; and patients to gain more realistic expectations of their own surgery.

Naturally, recovering normal function and returning to an active lifestyle is also influenced by a number of variables. A person's pre-operative condition, the correct alignment of the components of the new artificial knee, their participation in rehabilitation therapy, and a positive mindset, all influence outcomes. While Siston applauds the surgeon's intuitive sense of what constitutes a stable knee, he believes that the data that he and other researchers are currently collecting, and will yet collect from approximately 40 TKR patients, will not only lead to more precise intra-operative work and positive post-operative outcomes, but also better surgical instruments and medical devices. And beyond the return of greater mobility for each TKR patient, there's certainly the expectation that collectively, these advancements should reduce associated healthcare costs. When you consider that four million people in the United States are estimated to have undergone TKR, that's a significant healthcare expenditure, which further highlights the importance of mitigating the risk of costly revision surgery and possible long-term complications.

Dr. Beal and ME PhD candidate Erin Hutter work collaboratively in the operating room to collect data. Dr. Beal attaches optical trackers to the bone and performs all testing using the stability device. Hutter manages the camera and computer that record the motion of the knee.

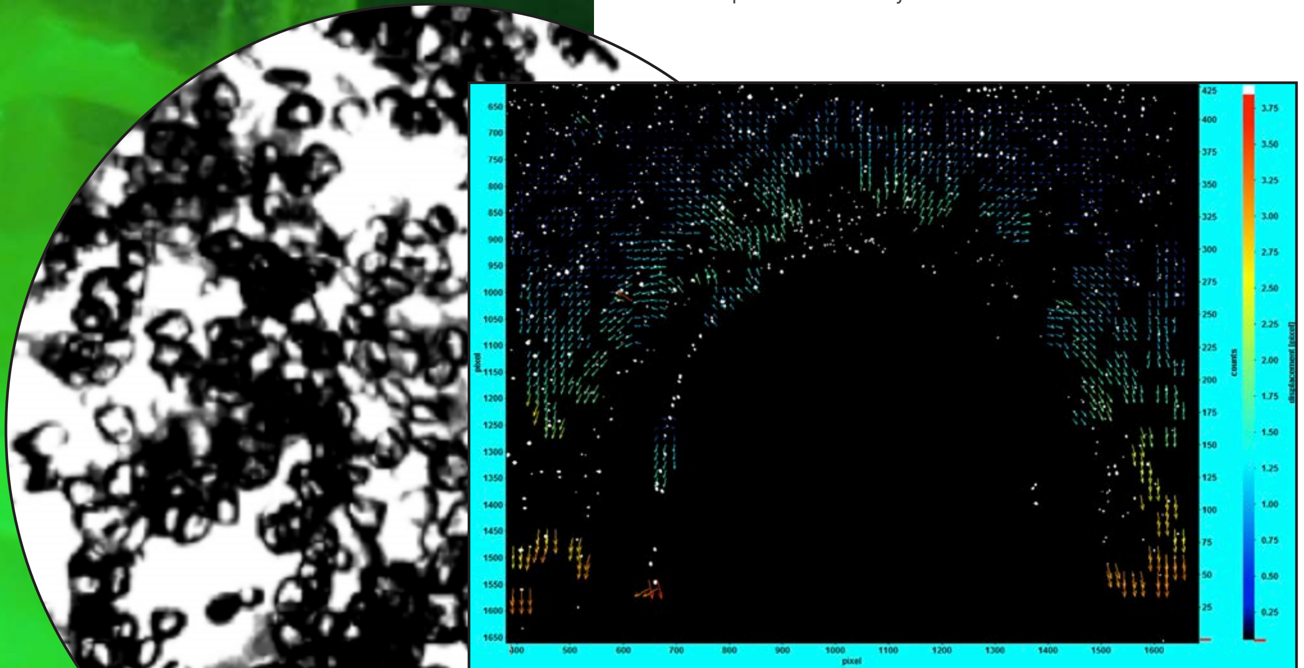
About the Research Team

Siston's work is evidence of the important, ongoing "Discovery Theme" work that is shaping Ohio State's institutional research efforts. His research in improved total knee replacements and outcomes relates directly to the university's Health and Wellness Discovery Theme, which encourages faculty from across Ohio State's seven health sciences and the Wexner Medical Center to work with partners across the university on issues such as disease prevention, community health, and health systems. Siston's co-investigators at Ohio State include Ajit Chaudhari, assistant professor of orthopaedics and sports medicine with a courtesy appointment in The Department of Mechanical and Aerospace Engineering; Laura Schmitt, assistant professor of physical therapy; Drs. Andy Glassman M.D., Jeff Granger M.D., and Matt Beal M.D., all faculty in orthopaedics; and Xueliang "Jeff" Pan, a research scientist in biostatistics.

PIV-PLIF set up in two phase flow facility. The graph (bottom right) represents the instantaneous liquid-phase velocity vector field around a slug bubble. Part of the work was sponsored by the U.S. Nuclear Regulatory Commission. The research team consists of Dr. Xiaodong Sun; PhD students Ben Doup and Xinquan Zhou.

Studying High-resolution Local Measurements in Gas-liquid Two-phase Flows

Accurate predictions of thermal-hydraulic behavior are essential for various gas-liquid two-phase flow systems, which are widely employed in mechanical, nuclear, and chemical engineering fields. Associate Professor Xiaodong Sun and his research team in the Thermal Hydraulic Lab (THL) at The Ohio State University have been working in the areas of thermal-hydraulics and reactor safety analysis since 2004. Part of their work focuses on gas-liquid two-phase flow experimentation, modeling, and numerical simulation, with the objective of furthering the predictive capability of various two-phase flow phenomena in flow regimes of large void fractions, such as slug and churn-turbulent flows. Special efforts have been made in obtaining complete sets of high-quality data for both the gas- and liquid-phase in those flow regimes. This will facilitate the development of two-phase flow modeling and validation of two-phase computational fluid dynamic codes.



Measurements in gas-liquid two-phase flows are challenging due to physical and optical interferences of one phase to the other, especially when the void fraction is greater than 20 percent. The THL is equipped with a state-of-the-art particle image velocimetry-planar laser-induced fluorescence (PIV-PLIF) system for liquid-phase turbulence measurements, including the mean velocity and its fluctuations. The PLIF technique, as an optical phase separation method, uses fluorescent particles and an optical filter to extract the liquid-phase velocity information from the signals that are typically contaminated by the noises due to the reflections of the fluorescent lights by the bubble surfaces. In addition to the PLIF technique, a new image pre-processing scheme was developed to remove these noises presented in the raw PIV images. With a combination of the PIV-PLIF technique and the image pre-processing scheme, the liquid-phase turbulence in two-phase flows of void fractions up to 30 percent have been satisfactorily resolved (*Nuclear Engineering and Design*, 2013, 263, pp. 273-283). Measurements in more complex flow regimes, such as slug and churn-turbulent flows (which typically have void fractions greater than 30 percent) are currently being investigated.

In addition to the liquid-phase measurements, an integral part of the two-phase flow study is the measurement of important gas-phase parameters, such as the local gas-phase velocity, void fraction, interfacial area concentration, bubble frequency and size. These local gas-phase measurements are complemented with images obtained from a high-speed imaging system to determine the flow regime for each of the flow conditions studied. The flow regime information and the combined gas- and liquid-phase measurements are being used to develop a dynamic flow regime transition model and a liquid-phase turbulence model. These models will help improve the accuracy of CFD simulation of multiphase flows.

Meeting the Challenge of Designing Compliant Mechanisms for Critical Engineering Applications

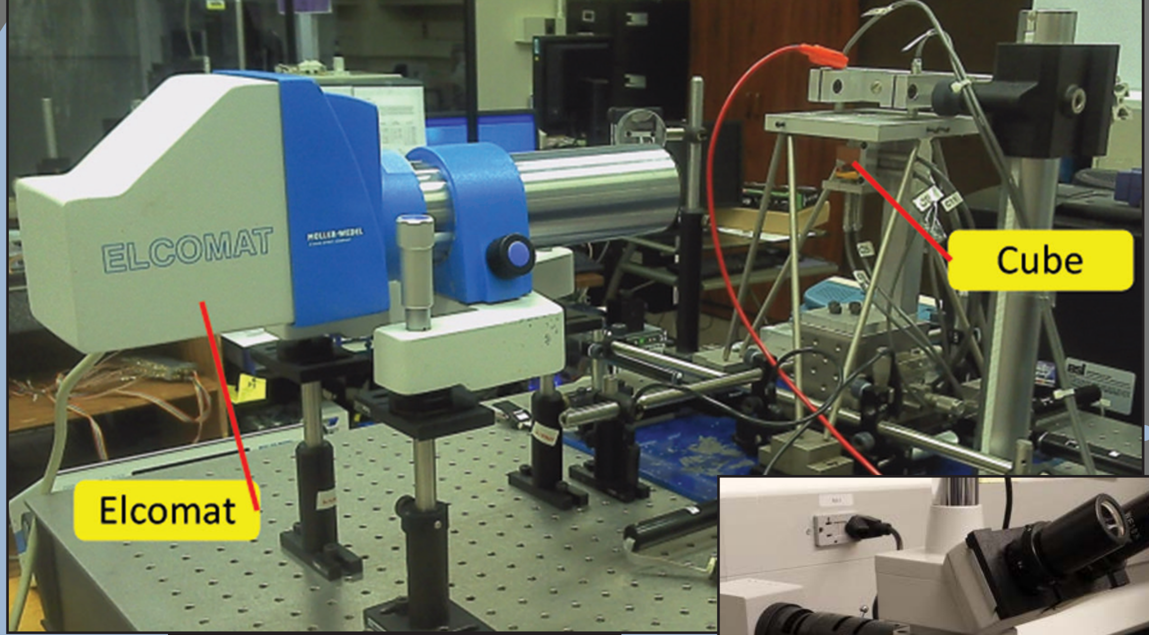
Compliant (flexible) mechanisms achieve well controlled motions via deflection of flexible members (compliant joints) rather than traditional kinematic joints. Due to their inherent advantages of reduced part count, simplified manufacturing and high precision, compliant mechanisms have been used in numerous applications ranging from aerospace structures, micro and nano mechanical devices, precision instruments and robots. However, design and synthesis of compliant mechanisms is still a challenging task due to lack of efficient design tools and theories.

Sponsored by the National Science Foundation and the Air Force Office of Sponsored Research, Ohio State's Design Innovation and Simulation Lab (DISL) is developing novel kinematic and static synthesis theories and advanced design/simulation tools for designing compliant mechanisms. Under the direction of Assistant Professor Haijun Su, the DISL is developing reduced physical or mathematical models of compliant elements, screw theory based synthesis theories, computational algorithms and related design software. Powered with these design tools, Dr. Su and his research group hope to systemize design innovation of compliant mechanisms and apply them to solve real-world design problems.

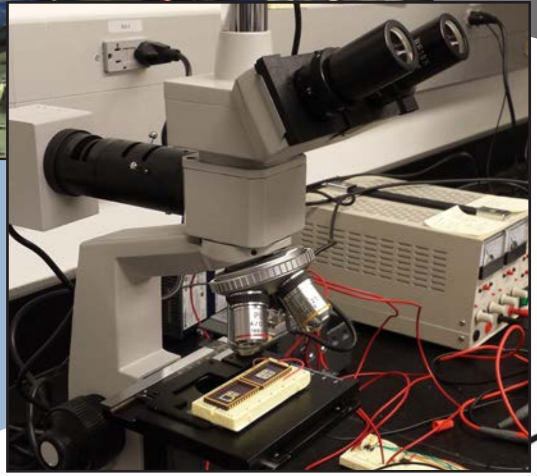
In recent decades, micro air vehicles (MAVs) have received increasing attention from the U.S. Air Force and U.S. Army as surveillance and reconnaissance functions become more and more important to the war on terror. One limiting factor of MAVs preventing their applications in military as well as civilian areas is power consumption per unit payload. Currently, researchers at DISL are investigating the effect of compliant mechanisms to power consumption in flapping wing MAVs. Recently, they have discovered that a smart use of compliant joints can reduce power consumption 73.8 percent while keeping the lift force nearly unaffected.

A nanopositioner, a device widely used for motion control in high-precision engineering, plays an important role in emerging nanotechnology and medicine. DISL is now collaborating with research scientists at the National Institute of Standards and Technology (NIST) in design and kinematic calibration of a hexapod nanopositioner. Novel kinematic and stiffness models have been developed to calculate the workspace of a meso scale and a micro hexapod nanopositioner. To improve the accuracy of the device, a novel kinematic process has been developed to calibrate the error of the controller.

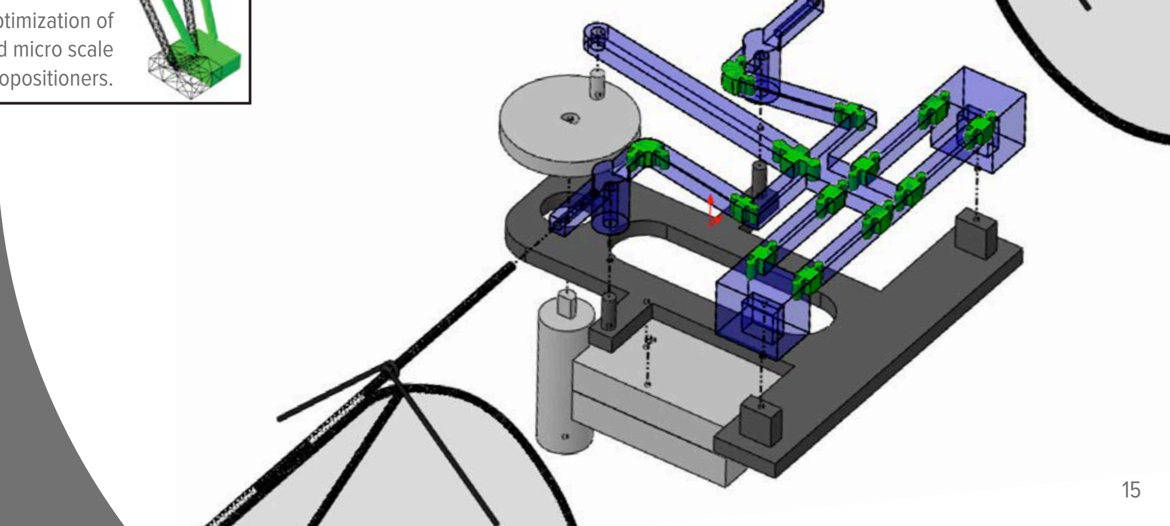
One challenge of designing compliant mechanisms lies in the manufacturing of flexible joints. Currently, DISL is also investigating various methods for prototyping compliant mechanisms. Among the processes used by and equipment available to the DISL are shape deposition manufacturing (SDM) for making plastic and elastomer parts, a CNC mill for metal part and mold design, and a 3-D printer for making parts with a complex shape.

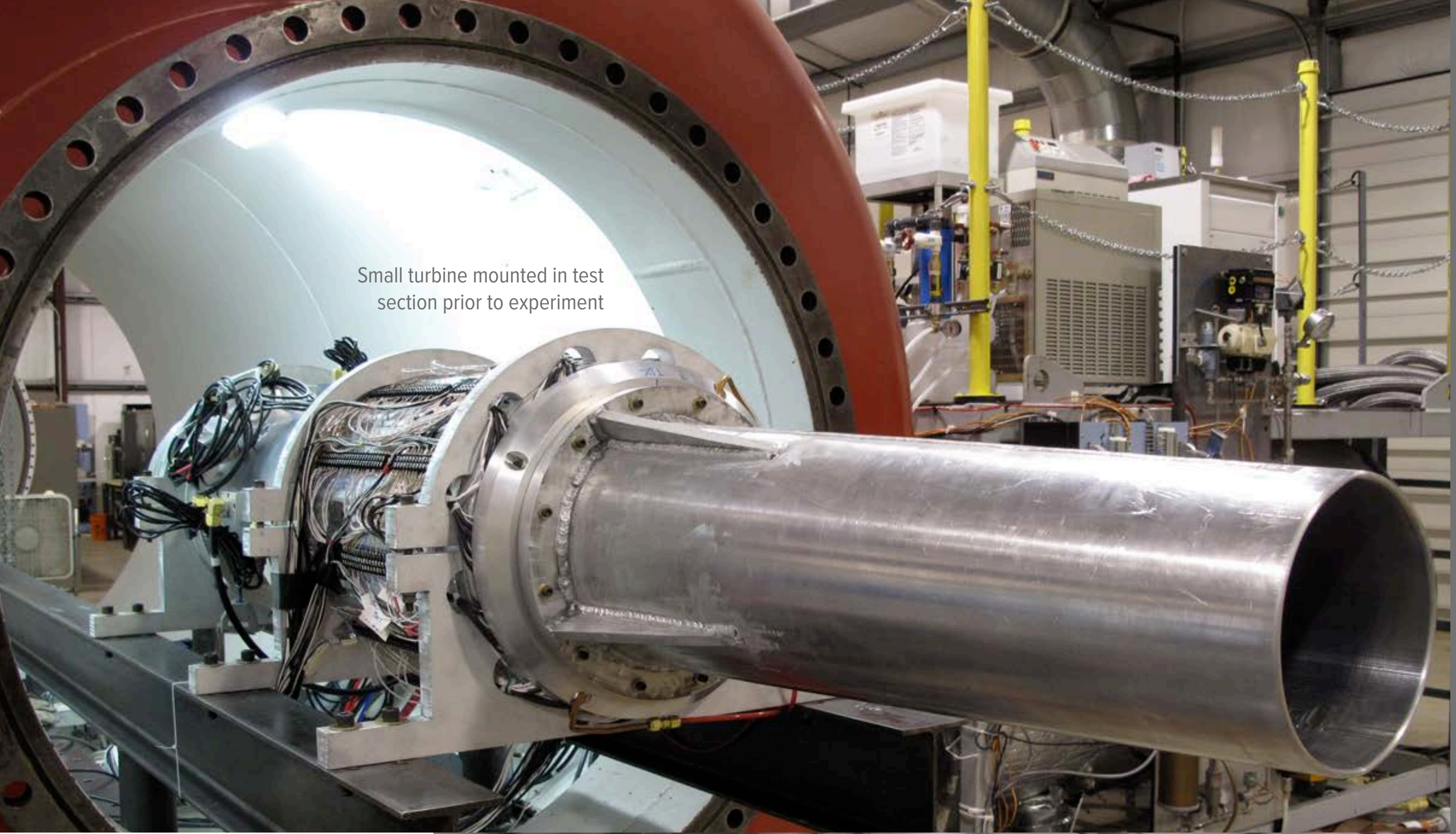


Design, simulation, calibration and optimization of meso and micro scale nanopositioners.



Energy consumption minimization of flapping wing micro air vehicles.





Small turbine mounted in test section prior to experiment

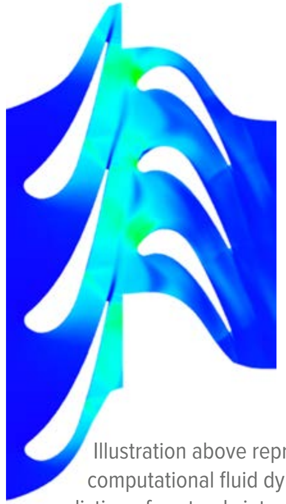


Illustration above represents computational fluid dynamics prediction of unsteady interactions in a transonic turbine

Right: Turbine test facility used to perform turbine experiments.

Improving Understanding of Turbine Cooling to Boost Efficiencies

Gas turbines are becoming ever more important tools in the global push to make better use of our energy resources. Whether used for aircraft or marine propulsion, oil and gas production, peaking or balancing power generation, or baseload power generation, gas turbines of all sizes rely on the same core technologies to improve efficiency and reliability while reducing emissions.

The central thrust of gas turbine development is to raise the efficiency by increasing the temperature of the air leaving the combustor and entering the turbine section. This effort has spurred the development of new high-temperature materials as well as a range of cooling techniques that use cooler air bled from earlier stages of the engine to protect the hottest components. Modern cooling techniques allow turbines to operate with inlet temperatures up to 500° F higher than the maximum allowable material temperatures. Because there is a performance penalty for removing this cooling air from the working stream, it is important to maximize the cooling effectiveness to allow higher temperatures while minimizing the amount of cooling required. Continued improvements will require a detailed understanding of the physics governing heat transfer to the coolant in internal passages as well as the coolant interaction with the main flow.

The Gas Turbine Laboratory (GTL) has been working on these challenges for some time under the direction of Professor Mike Dunn. Detailed measurements for turbines operating at properly scaled conditions have provided valuable insights into the relevant flow physics as well as a benchmark for evaluating the accuracy of computational fluid dynamics (CFD) tools. Recent experiments have shown that while CFD predictions of the heat transfer can be quite satisfactory for turbines without cooling, the addition of cooling causes significant differences between the data and predictions.

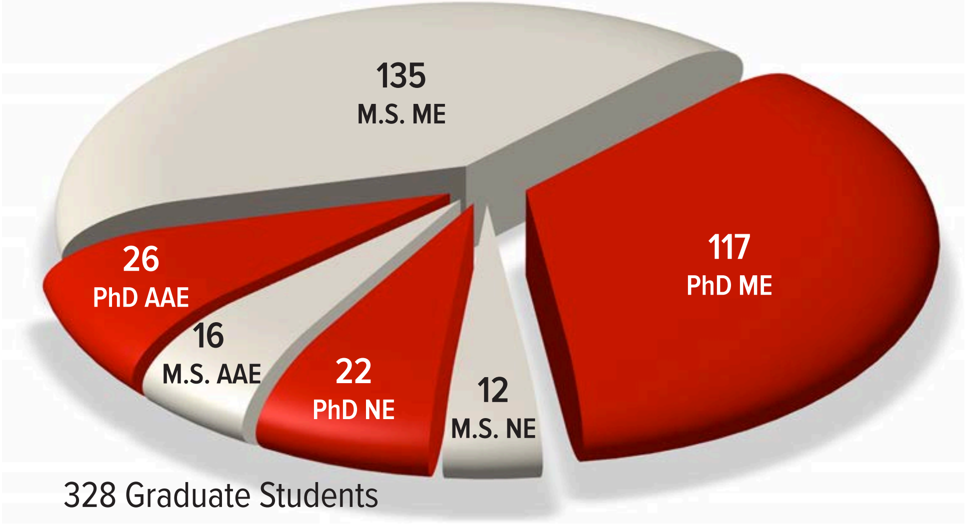
Assistant Professor Randall Mathison is working to continue developing these data sets along with computational techniques that can better capture the behavior of cooling flows. New efforts to develop full-coverage heat transfer measurements utilizing infrared thermography will provide substantially more insight into the mixing and migration of coolant injected to the mainstream and enable better resolution of sharp thermal gradients that can cause thermal stresses in blades. Mathison will also investigate new methods of modeling cooling injection through computer simulations. The higher-resolution measurements will provide the basis for more thorough evaluation of these models and clarify where computer predictions require improvement.

Additional research at the GTL seeks to better understand the heat transfer within the passages that supply coolant from the inside of the rotating blade. This complicated flow has been studied in detail for passages similar to a square cross-section, but additional data is needed as designs move toward taller and narrower (high aspect-ratio) passages. To enable this new generation of experiments, GTL researchers have developed signal conditioners that work with microprocessors to perform data acquisition, heater control, and storage for hundreds of instruments on a single circuit board that is mounted on the rotating hardware and communicates wirelessly with stationary monitoring computers.

Through detailed data sets and improved computational techniques, researchers at Ohio State will continue to provide the understanding that designers use to push gas turbines to higher inlet temperatures and higher efficiencies.

Graduate Enrollment

Autumn Semester 2013



Graduate Degrees Granted (SU12-SP13)

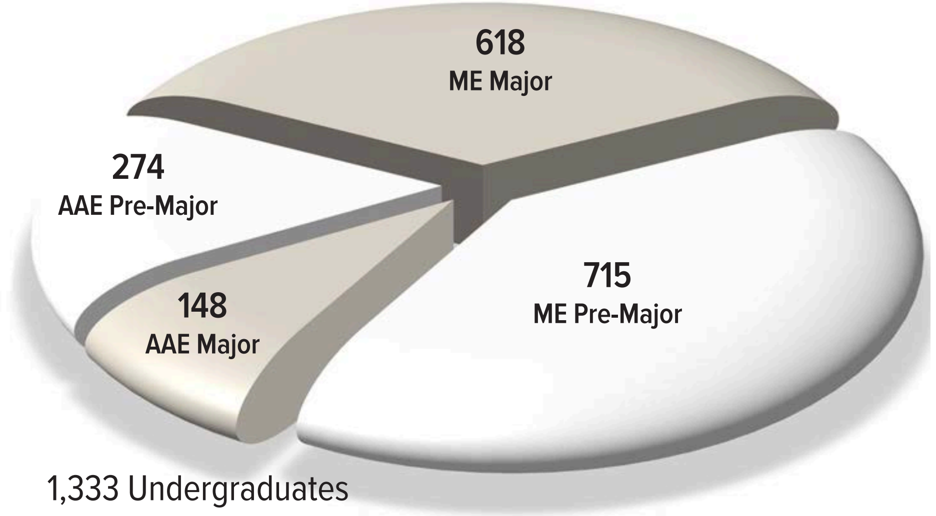
Mechanical Engineering 101
- M.S. 75
- PhD 26

Aerospace Engineering 14
- M.S. 8
- PhD 6

Nuclear Engineering 18
- M.S. 15
- PhD 3

Undergraduate Enrollment

Autumn Semester 2013



B.S. Degrees Granted (SU12-SP13)

Mechanical Engineering 205
- Latin Honors 62
- Honors in Engineering 13
- Research Distinction 18

Aerospace Engineering 66
- Latin Honors 16
- Honors in Engineering 4
- Research Distinction 4

Center will foster growth of the next generation of aerospace researchers

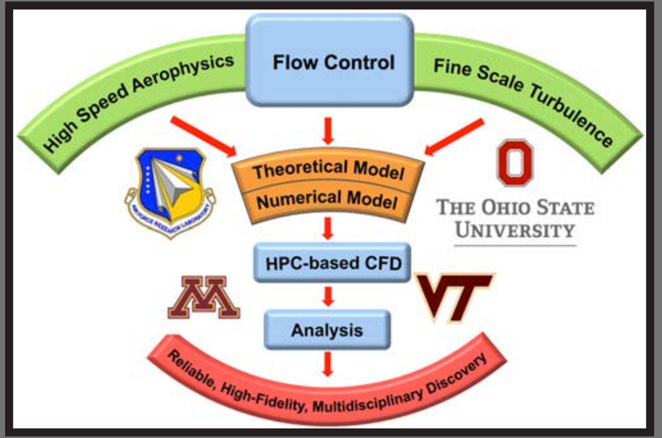
Ohio State Leads Collaborative Center for Aeronautical Sciences

A team led by researchers at The Ohio State University was selected by the Aerospace Systems Directorate to collaborate with its Computational Sciences Center. The goal is to develop and apply pioneering computational technologies for the design of future Air Force systems. The research will generate robust and reliable tools that exploit current and emerging supercomputer systems for reliable, high-fidelity, multi-disciplinary analysis of flight in all speed regimes. The target environments encompass diverse phenomena associated with long-endurance highly maneuverable low speed vehicles, as well as the harsh conditions encountered in hypersonic flight for space-related missions. Research at Ohio State will generate enabling insight into non-linear phenomena associated with turbulence, aero-acoustics and optics, fluid-structure interactions, plasma-based flow control and supercomputing technologies. According to Aerospace Engineering Professor Datta Gaitonde, who is serving as the Principal Investigator, the payoff will be substantial. "In addition to fostering new concepts for revolutionary design advances, the research will lift limits on current systems, reduce life-cycle costs and enhance reliability," he said.

The five-year Collaborative Center, initially funded at $2.5 million, will be a national resource for the advancement of aeronautical science, while fostering the growth of the next generation of aerospace researchers. In addition to faculty and students in Ohio State's mechanical and aerospace engineering and computer science and engineering departments, the University of Minnesota and Virginia Tech will partner with Ohio State in this endeavor.

About the Aerospace Systems Directorate

The largest and newest of eight Technology Directorates, the Aerospace Systems Directorate develops advanced technologies for propulsion, power and airframes. Its goals are to realize future systems as well as to sustain current systems by enhancing their safety, affordability and capability. Recent areas of research include hypersonic propulsion engines, unmanned vehicles, next generation airframes, collision avoidance, and aircraft energy optimization.



About the AFRL Aerospace Systems Directorate (AFRL/RQ) Computational Sciences Center

The Center is comprised of researchers from several branches, including the Hypersonic Sciences Branch, the Vehicle Technology Branch, the Aerodynamic Technology Branch, and the Design and Analysis Branch. The center uses supercomputers to generate enabling basic and applied research into all aspects of aerodynamics, including algorithm development for new architectures, low Reynolds number flows, fluid-structure interactions, high-speed and high-altitude flight, revolutionary flow control techniques and performance of full aircraft configurations.

Professor Gaitonde is the John Glenn Chair in the Mechanical and Aerospace Engineering Department. Prior to joining the department in 2010, he was Technical Area Leader of the High-Speed Flows Group in the Computational Sciences Branch of the Air Vehicles Directorate, Air Force Research Laboratory, Wright-Patterson AFB, OH. His research focuses on understanding and controlling fluid phenomena encountered in all speed regimes. Recent areas of research include shock/boundary layer interactions, laminar-turbulent transition, drag and heat transfer prediction, scramjet-based airframe propulsion integration and various types of plasma-based flow control.

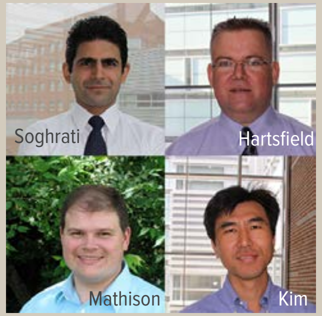
Maximizing Energy Output of the Anaerobic Digestion Process

The Microsystems and Nanosystems Laboratory led by Assistant Professor Shaurya Prakash is working to push the notion of waste as a resource for energy and material use. This approach is essential as it has been estimated that the energy content of solids in municipal wastewater can account for nearly 2 percent of the equivalent U.S. electrical energy demand, and food waste in the US could yield equivalent hydrogen for over 1 GW power each year. In a recent research article, published in Biomass and Bioenergy, Prakash's team has investigated a detailed thermodynamic model for an integrated anaerobic digester and energy harvesting system to maximize the utility of extracting usable products from waste streams.

Typically, an anaerobic digester system converts organic waste into biogas, which is a methane rich stream of fuel and can be used for electricity generation. By modeling a novel engineering concept with a highly modular design, the integrated Anaerobic Digestion Bioammonia to Hydrogen (ADBH) system, Prakash and his research team have concluded that the anaerobic digestion process designed to net methane from biogas, holds even greater capacity for increased energy output if additional fuel-rich sources are harvested along with biogas. Their integrated ADBH system tacks on an ammonia recovery and reforming module that provides for the harvesting of additional hydrogen fuel, and consequently, a sizable increase in overall energy generation. Their model shows that the construction of integrated ADBH systems could lead to increased harvesting of bio-ammonia and, ultimately, more usable fuel feedstocks. They were able to demonstrate an impressive energy gain of greater than 20 percent with dual fuel recovery (hydrogen and methane) over a system generating only methane-rich biogas. Another advantage of the ADBH system is the modular design, enabling harvesting of ammonia itself without the need for reforming to hydrogen, providing access to an essential industrial and agricultural material feedstock.

The research was a collaborative effort with contributions to the research article by Donna E. Fennell of Rutgers University, Department of Environmental Sciences, with Ph.D. students David Babson and Karen Bellman. The paper entitled, "Anaerobic digestion for methane generation and ammonia reforming for hydrogen production: A thermodynamic energy balance of a model system to demonstrate net energy feasibility" appears on pages 493-505 of the September 2013 issue of Biomass and Bioenergy. The Microsystems and Nanosystems Laboratory has other active projects for novel approaches to energy savings or generation by using a variety of methods. For example, in another project, Prakash and his research team have been investigating use of biomimetic structures for drag reduction in large ground fleet vehicles.

New MAE Faculty & Promotions



Recent additions to the Department of Mechanical and Aerospace Engineering include assistant clinical professor Carl Hartsfield, hired in January 2013, along with tenure-track assistant professors Randy Mathison, Soheil Soghrati, and Seung Hyun Kim who began teaching this autumn.

In promotion news, three faculty members within the department rose to the rank of tenured associate professor at the beginning of Autumn Semester. The three individuals are Jim Gregory, Rob Siston, and Junmin Wang.

Multi-Year Collaborative Center for AFRL's Aerospace Systems Directorate Established

Thanks to funding awarded by the Aerospace Systems Directorate, Associate Professor of Aerospace Engineering Jack McNamara now leads a new collaborative research center focused on the technical challenges that are obstructing the development of the next generation of aerospace aircraft. The Air Force Research Laboratory (AFRL) Structural Sciences Center is working in tandem with the collaborative research program to better predict the life of structures operating in extreme environments for extended periods of time. The center, which is initially funded for five years at $2.5 million with a possible two-year extension that would bring total funding of the center to $3.5 million, is one of only four centers established by the Aerospace Systems Directorate.

Collaborating with McNamara are Somnath Ghosh, M.G. Callas Chair Professor, Departments of Civil Engineering and Mechanical Engineering at Johns Hopkins University; Marc Mignolet, Professor, Mechanical and Aerospace Engineering at Arizona State University; and C. Armando Duarte, Associate Professor, Department of Civil & Environmental Engineering at the University of Illinois at Urbana-Champaign.

The research led by McNamara will target platforms that include those with embedded engines, as well as ultra high-speed vehicles. The research will broadly focus on the structural behavior of aircraft during missions with a focus on simultaneously considering evolving surface conditions, stress, deformation and damage encountered during missions and throughout the prior life of the platform.

About the Aerospace Systems Directorate
Created last year, the Aerospace Systems Directorate, is a research organization at Wright-Patterson Air Force Base in Dayton, Ohio that combines the former AFRL Propulsion and Air Vehicles Directorates into one entity whose mission it is to advance Air Force science and technology.

About the AFRL Structural Sciences Center
Formed in 2005, and directed by Dr. Ravinder Chona (ST), the Structural Sciences Center is a core team of over 10 Air Force Researchers focused on critical Air Force Structures needs, in particular those for combined, extreme-environment structures.

Bhushan
Serving as ASME Science and Technology Policy Fellow for US Congress

Professor Bharat Bhushan began his new year-long role as a Policy Fellow at the US Congress at the beginning of September 2013 and now serves on the House Committee on Science, Space & Technology, Subcommittee on Research and Technology. His duties, while on research leave from Ohio State, will include working on science policy and arranging important hearings for the subcommittee. He commented, "As the world of education and research funding continues to change, it's vital that our critical thinking skills be utilized to help our politicians better understand the technology and innovations that are emerging." Professor Bhushan is an Ohio Eminent Scholar and a Howard D. Winbigler Professor at Ohio State. He directs the Nanoprobe Laboratory for Bio- & Nanotechnology and Biomimetics within the Department of Mechanical and Aerospace Engineering.

Srinivasan Receives NSF CAREER Award to Study Human Locomotion

Assistant Professor Manoj Srinivasan's proposal, titled "Towards An Optimization-Based and Experimentally Verified Predictive Theory of Human Locomotion," has earned support from the National Science Foundation's Early CAREER Development program. The five-year, $400,000 award will aid Srinivasan's research, which seeks to obtain a sufficiently accurate, and broadly applicable, predictive theory of how people walk, run, and stabilize their movements. According to Srinivasan, "It is already possible to predict some aspects of human walking and running, by computing motions that minimize energy consumption. However, it is not known if such minimization can simultaneously predict the results of many different experiments, or the differences between different subjects, or how accurate such predictions could be in general." Results of his research may eventually enable the systematic model-based design of prosthetic and orthotic devices, and aide the diagnosis and treatment of movement pathologies, including possibly guiding surgical interventions.

Lempert Named APS Fellow

Professor Walter Lempert has been named a Fellow of the American Physical Society (APS). The citation for Lempert's APS Fellow designation notes, "For innovative and insightful contributions to the development and application of optical diagnostic methods for the study of nonequilibrium molecular plasmas and turbulent flows." Lempert's nomination was put forward by the APS Division of Plasma Physics.

Sutton Named PI for Two NSF Projects

Assistant Professor Jeffrey Sutton will be the principal investigator on two new projects sponsored by the National Science Foundation (NSF). One project totaling $305,000 in funded research, and entitled "Multi-scale Fluid Turbulence-Scalar Mixing Dynamics in Gas-Phase Turbulent Jets", is sponsored by the NSF's Fluid Dynamics program for three years. The objective of the project is to quantify the dynamics governing the mixing of a passive scalar quantity by turbulent fluid motion, with a specific interest in detailing the time- and scale-dependent coupling between the turbulent flowfield and the scalar field. The project will involve the use of simultaneous high-speed (> 10 kHz) 3D velocity and 2D conserved scalar measurements, which are facilitated by the unique kHz-rate imaging capabilities within Sutton's research group.

The second project, entitled "Acquisition of a High-Pulse-Energy, Narrow-Linewidth, UV Laser Source: Improved Quantitative Gas-Phase Mixing Measurements in Turbulent Spray Flows", was funded by the NSF's Combustion, Fire, and Plasma Systems program. The $100,000 instrumentation award will be used to procure components to develop and assemble an ultra-high-pulse-energy, ultraviolet to infrared wavelength tunable, narrow linewidth laser system. This new laser design is based on a novel approach which involves combining an Nd:YAG-pumped titanium:sapphire laser with an alexandrite amplifier stage into one "hybrid" system. Once completed, the new laser system will be the primary component used within a UV filtered Rayleigh scattering imaging system to investigate vaporization and gas-phase mixing processes within turbulent spray flows.

Yedavalli Named AAAS Fellow

Professor Rama Yedavalli has been elected a Fellow of the American Association for the Advancement of Science (AAAS) for his distinguished contributions to the fields of robust and distributed control of mechanical and aerospace systems, and for service to multiple professional societies.

Singh Named ASEE's 2013 Outstanding ME Educator

Professor Rajendra Singh was named the recipient of the 2013 Ralph Coats Roe Award by the Mechanical Engineering Division of the American Society of Engineering Educators (ASEE). The award recognizes a mechanical engineering educator who is an outstanding teacher and has made a notable contribution to

the profession. Formal presentation of the coveted award took place during the ASEE Annual Conference in Atlanta, Georgia, June 23-26. Professor Singh also gave a 30-minute talk on his pedagogical approaches and experience at the conference. Recognized by many of his peers as an eminent educator in machine dynamics and noise and vibration control, the nomination for his award was supported by nine fellow academics from eight different universities in the United States, several of whom are themselves past recipients of the Ralph Coats Roe Award. One noted professor stated, "Dr. Singh is the consummate classroom educator. He is constantly exploring and implementing more effective teaching methods. As a result of his industry based research program he exposes his students to a wide range of pragmatic problems and asks them to design and develop solutions. Furthermore, his practical classroom teaching approach is constantly evolving and forward looking as evident by his reliance on the National Academy of Engineering principles to provide the underpinnings of his course content."

Sundaresan Awarded NSF EAGER Grant

Assistant Professor Vishnu Sundaresan has received a National Science Foundation Early-concept Grant for Exploratory Research (EAGER) to fund his investigation of the coupled transport processes in an active nanoporous membrane. His research will focus on the applicability of elastic deformation of nanopores for fluid transport and mimic the functionality of transport through biological channels. Sundaresan believes that his research concept, if proven successful, could lead to a new class of membranes that would enable the separation of dissolved salts in water through controlled cyclic elastic deformation. Sundaresen joined the Department of Mechanical and Aerospace Engineering in 2012 and directs the Integrated Material Systems Lab.

Gilat

Bons

Gilat and Bons Named ASME Fellows

The Board of Governors of the American Society of Mechanical Engineers (ASME) elected Professors Amos Gilat and Jeffrey Bons to ASME Fellow status.

The citation for Gilat's ASME Fellow designation notes, "Amos Gilat is an internationally recognized pioneer in the development of novel experimental methodologies in mechanics with focus on plasticity. He is a leader in the area of experimental dynamics and its applications for investigating material behavior at high strain rates and/or elevated temperatures. His texts on numerical methods are among the most popular for undergraduate teaching, and he is an excellent instructor and mentor to students. Gilat has served ASME by organizing symposia for several congresses, and presenting invited papers. The experimental techniques developed by him and his research results are recognized by aerospace and automotive researchers."

Bons' citation states, "Jeffrey Bons is an internationally recognized researcher and engineer in the areas of roughness in gas turbine engines with regard to its characterization, the evolution of particulate deposition, and its influence on heat transfer and aerodynamics. He has also conducted seminal research in low pressure turbine separation control, the influence of high intensity turbulence on film cooling and the acquisition of flow and heat transfer data in rotating turbine passages. Six of his papers have won best paper awards in IGTI's Gas Turbine Heat Transfer Committee and one in ASME's Heat Transfer Committee."

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