UNIVERSITY OF WISCONSIN–MADISON
COLLEGE OF ENGINEERING

SPRING 2022 NEWSLETTER

MECHANICAL ENGINEERING

UNDERGRADS THRIVE

by solving real-world problems

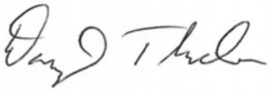
Greetings!

It is a pleasure to update you on happenings in the department; there is a lot going on! Our student numbers continue to grow. We admitted more than 300 students into the ME undergraduate program in fall 2021, a total that is 40% higher than five years earlier. This growth reflects both the tremendous interest among incoming students and the need for the broad problem-solving and design skills for which our students are known. We have undertaken an aggressive faculty hiring effort to help educate these students and lead the department in important new research directions. We have been very busy interviewing and recruiting faculty in an array of areas including robotics, autonomous systems, energy storage technologies, and data-driven design and modeling. These recruitments are part of a larger College of Engineering effort to develop expertise and leadership in innovative technological areas of strategic and national importance.

I am excited to share the news of the department's first two teaching professors—Mike Cheadle and Kris Dressler. Teaching professor is a new title at UW-Madison intended to provide an upward career path for individuals who focus on our educational mission and advance pedagogical techniques. Mike is instrumental in building and leading our two-semester capstone design sequence, in which teams of students design and build physical prototypes for clients from industry, the community and research labs. Kris is a fluid dynamicist by training, but has evolved into an integral and popular instructor in machine elements, mechanical testing and *Introduction to ME*. We are fortunate to have Mike and Kris on our team and are excited to see them recognized for the important role they play in educating our students and leading our educational programs.

I would like to extend my congratulations to our students who are graduating this spring. These students have been through a lot and are certainly worthy of recognition as our newest Badger engineers to enter the workforce or embark upon further education. We wish you all the best as you use your mechanical engineering degree to do good in the world.

On, Wisconsin!



Darryl Thelen
John Bollinger Chair of Mechanical Engineering & Bernard A. and Frances M. Weideman Professor
(608) 262-1902
dgthelen@wisc.edu

Support the Department of Mechanical Engineering

supportuw.org/giveto/me

ENGINEERING
FORWARD

Brad Green
608-224-9823
brad.green@supportuw.org

Caroline Sullivan
608-572-2002
caroline.sullivan@supportuw.org

Focus on new faculty

Michael Wehner, devising ways for robots and people to work together

For anyone who has ever suffered a back injury while lifting something heavy, Michael Wehner's research offers an exciting preview of a future where robots could assist humans with such tasks by helping carry the load, literally.

For his PhD dissertation at the University of California at Berkeley, Wehner developed a lower-extremity exoskeleton to assist people with lifting objects. He showed that the exoskeleton—a wearable robot—was able to reduce strain on users' back muscles while they lifted boxes. Wehner says this technology could one day help reduce on-the-job injuries for warehouse workers.

Wehner's research focuses on understanding how robots interact with their environment, including with humans. Ultimately, his goal is to devise ways for robots to interact with people safely and effectively.

"To take the field of robotics to the next level of progress, we need to get robots and people to cooperate with each other," says Wehner, who joined the department as an assistant professor in January 2022. "There is fundamentally a mismatch between the way robots behave and the way humans work. If you want a robot around people, the solution so far has been to make it small or slow, like a Roomba vacuum. I believe there is a lot of opportunity to create alternative methods for human-machine interaction to make inherently safe systems."

Wehner is particularly interested in the emerging field of soft robotics. Unlike their rigid counterparts, soft robots are built out of elastomers, or rubbery materials, which allow them to bend, twist and change shape. These characteristics enable soft robots to interact much more seamlessly with their environment than traditional robots, making them useful for new applications. In the future, soft robots could assist with surgeries or help patients with rehabilitation after an injury, among other applications.

Wehner helped create the world's first autonomous, entirely soft robot, dubbed the Octobot. Credit: Lori Sanders/Harvard University.

After earning his PhD, Wehner worked as a postdoctoral fellow at Harvard University, where he made key contributions to several major breakthroughs in soft robotics. He helped invent the first soft exosuit—a soft wearable robot that, in this case, helped increase the wearer's endurance while walking. The low-profile exosuit actuated the wearer's legs, providing extra support to the muscles as they moved.

Then Wehner and his Harvard colleagues broke new ground in 2016 by creating the first autonomous, untethered, entirely soft robot, dubbed the Octobot. The octopus-inspired robot had no electronics and was instead powered by chemical reactions controlled by microfluidics.

Wehner came to UW-Madison from the University of California-Santa Cruz, where he was an assistant professor in electrical and computer engineering.

Alum elected to National Academy of Engineering

Daniel N. Miller, a senior fellow of the Skunk Works at Lockheed Martin Corporation, was elected a member of the National Academy of Engineering (NAE) in February 2022. Election to the NAE is among the highest professional distinctions accorded to an engineer and honors outstanding contributions to research, practice or education.

The NAE selected Miller for his theoretical contributions and practical innovations in flow control that improve the performance of aircraft propulsion systems.

Miller received a bachelor's and master's degree in mechanical engineering from UW-Madison. He has led numerous air vehicle innovations in the areas of propulsion, aerodynamics, thermodynamics, flight controls, high energy laser integration, and composite structures. These technologies have been used on major programs including the F-35, F-22, C-130, and are being evaluated for next-generation platforms.

His accomplishments include 24 U.S. and European patents granted with 20 additional patents pending; more than 50 technical publications; co-editor and co-author of an AIAA textbook on flow control; and 20 invited lectures hosted by academia, government and professional societies.

Making a difference

Seniors' design benefits Wisconsin company run by high schoolers

Students Armando Miracola, Kevin Chang, Reagan Hubbard and Rushi Patel applied their engineering skills to benefit Cardinal Manufacturing, a unique tech ed program at Eleva-Strum High School.

When people in the Strum, Wisconsin, area need a custom part machined or fixed, they often turn to a group of talented high school students to get the job done.

Cardinal Manufacturing is a highly unique tech ed course at Eleva-Strum High School that is also a real company run entirely by students at the school.

The students' capabilities include woodworking, welding, lathing, milling, grinding and metalworking, and they apply their education by working on real projects for clients. Cardinal Manufacturing takes on a wide variety of jobs, ranging from welding a railing for a church to cutting keyways for a local manufacturer to patching up rust holes on a dump truck.

"We can fabricate, weld and machine low-volume, custom parts using many different materials for a low cost," says Craig Cegielski, a tech ed teacher at Eleva-Strum High School who leads the Cardinal Manufacturing program. "The money we make all goes back into supporting the educational program. Clients usually come to us through word of mouth, and we're extremely busy trying to keep up with the very high demand for our services."

When Cardinal Manufacturing recently sought to make improvements to its facility, Cegielski turned to the ME senior design program for help with a significant project. For their 2021-2022 senior design project, students Reagan Hubbard, Rushi Patel, Kevin Chang and Armando Miracola were tasked with designing a decorative, yet functional, custom gate and fence system to enclose Cardinal Manufacturing's unsightly dumpsters and recycling bins, which are located near the company's storefront and highly visible to the public.

Over two semesters of work, the team has created a SolidWorks model that represents the entire skeleton structure with accurate dimensions, materials and aesthetics. The team has developed a preliminary bill of materials and is researching fastener components and developing an assembly method to fasten the posts of the structure to the concrete and asphalt bases. The students also designed custom hinges due to the weight constraints of the gates. As they continue to iterate and optimize their prototype, the students are performing FEA analyses and motion studies within SolidWorks to ensure proper functionality.

Beyond the technical challenges the team had to solve, the students say the project helped them develop soft skills and gain experience in understanding their clients' needs, expectations, and design constraints.

"This project has allowed me to apply knowledge that I've gained from many of my previous engineering courses to an open-ended problem," Hubbard says. "It has taught me effective communication skills and how to work efficiently as a team. The project has been a wonderful hands-on experience in learning about real-world engineering tasks, the design process and working with clients. I have developed many useful skills that I will carry over into my future career."

At the end of the spring 2022 semester, the team will deliver the final engineering designs, a bill of materials and assembly

The UW-Madison student team is designing a decorative, yet functional, custom gate and fence system to enclose Cardinal Manufacturing's unsightly dumpsters and recycling bins. The Cardinal Manufacturing students will manufacture and assemble the structure themselves.

instructions to the client. Then the Cardinal Manufacturing students will leverage their skills to manufacture and assemble the structure themselves.

"I'm excited to help the Cardinal Manufacturing students further develop their manufacturing skills and to see our design materialized in the real world," Patel says. "Seeing the end product successfully meeting the clients' expectations would be the most rewarding thing about this project."

The collaboration between Cardinal Manufacturing and the senior design program was sparked by Bjorn Borgen (BSME '62), a distinguished alumnus of Eleva-Strum High School and the department. Borgen went on to earn an MBA from Harvard University and built a highly successful career as a leading financial manager and entrepreneur. He has been a generous supporter of both Cardinal Manufacturing and the department, and he facilitated connections between the programs in the spirit of the Wisconsin Idea.

It's a relationship forged over time: ME students have worked on several other senior design projects with Cegielski and Cardinal Manufacturing as the clients in past years.

"I've been very impressed with the UW-Madison students' professionalism and high-quality work on all the projects," Cegielski says. "They're getting some real-world experience with leading full engineering design projects and, at the same time, they are certainly providing a valuable service to Cardinal Manufacturing, and we appreciate the great solutions the students come up with."

Winter commencement speaker embraced campus leadership roles

Jai Khanna was the student speaker for UW-Madison's 2021 winter commencement, which marked a sweet return to an in-person celebration at the Kohl Center following a one year pause and a virtual winter commencement in December of 2020 due to COVID-19.

"I believe everyone's journey at the University of Wisconsin-Madison has been a rollercoaster of emotions, and today, all those emotions and tears are justified," Khanna told his fellow graduates from the stage.

Khanna says he learned some life lessons during the pandemic, such as the importance of living life in the moment. When COVID-19 struck in March of 2020, he decided to stay in Madison and finish a few projects instead of quickly booking a flight back to his native India. By the time reality sunk in, borders had closed.

"It was a scary time—there was so much uncertainty," he says. "But I also have a lot of great memories from that time. Those of us left behind had to manage and adapt. We became very close."

Khanna brought long-established leadership skills and an international perspective to his time at UW-Madison—a combination that enriched campus and led to multiple accomplishments. Born and raised in India, he was an active member of the Relay for Life fund-raising effort at Oberoi International School, the high school he attended in Mumbai. As the organization's sponsorship chair, he helped raise 1 million rupees to support cancer education, prevention, and research. He also served as a key member of the school's student council and trained as a kickboxer, a sport he still enjoys.

Khanna continued his commitment to social causes and student-driven leadership at UW-Madison. Through all four years on campus, he served on the Student Advisory Committee for the Dean of Students Office. Beginning in 2020, he served on the COVID-19 Student Advisory Board. He was also involved in multicultural student organizations, including Wisconsin School of Bhangra, one of the premier dance groups on campus.

During his time at UW-Madison, Khanna completed five internships in three countries-India, the United States and the United Arab Emirates. He now works as a mechanical design engineer at Milwaukee Tool.

Henak and Smith honored with college awards

The College of Engineering recognized two outstanding members of the department with 2022 awards.

Assistant Professor Corinne Henak received the Faculty Equity and Diversity award for her work to better support women students. She has updated the Women+ in ME program to include regular mentoring meetings with current undergraduates as well as with ME alumnae who are both mentors and role models. Henak also was involved in designing the introduction to mechanical engineering course for all ME freshmen. The class serves approximately 250 students annually and features hands-on experiences designed to engage the students early and improve their retention.

Research Administrator Zach Smith received the University and Academic Staff Distinguished Achievement award in recognition of his exemplary competence and attention to detail that resonates well beyond his department. His tools and processes have enhanced the efficiency and effectiveness of administrative tasks associated with research, and those tools have become models at the college and campus levels. Smith is clearly invested in the success of the principal investigators he works with.

Breakthrough opens applications for metal 3D-printed parts

Compared to conventional manufacturing methods, additive manufacturing (also known as 3D printing) is far better at producing metal parts with very complex geometries, and this ability makes 3D printing attractive for applications in the aerospace and biomedical industries, among many others.

But there's a big downside. Metal parts created with additive manufacturing have defects, such as pores and cracks in the material, that significantly compromise the finished part's strength and durability.

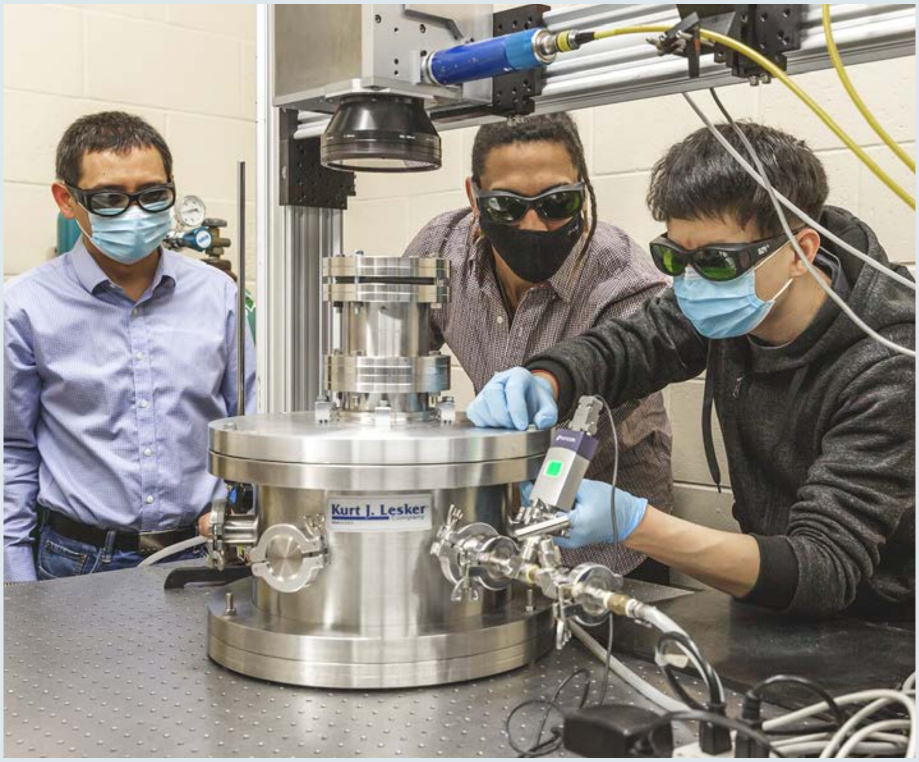
"Using metal 3D printing, we haven't been able to consistently produce parts with the same high quality and reliability as those made by conventional methods, which means we have big concerns about using 3D-printed parts for critical or load-bearing applications where failure isn't an option," says Assistant Professor Lianyi Chen. "This quality problem is the biggest barrier for using metal 3D printing in various applications."

Now, Chen and his students have discovered a way to enable a prominent additive manufacturing technique called laser powder bed fusion to produce metal parts that have significantly fewer defects. They detailed their findings in a paper published Feb. 28, 2022, in the journal *Nature Communications*.

"In this paper, we demonstrate a potential way to solve the quality problem by making metal 3D printing technology much more reliable, enabling it to produce consistent, defect-lean parts," Chen says. "Using our unique method, we were able to 3D print a metal part that has very few defects and a comparable quality to that of a commercially manufactured part that you could buy off the shelf."

It's a promising solution to a longstanding problem in metal additive manufacturing, and it opens a door to widespread industry adoption of this manufacturing technology.

The researchers' technique involves using ceramic nanoparticles to control instabilities in the laser powder bed fusion additive manufacturing process that cause defects.



A UW-Madison team discovered a way to make metal 3D printing technology much more reliable, enabling it to produce consistent, defect-lean parts. From left: Assistant Professor Lianyi Chen, and graduate students Luis Escano and Minglei Qu.

Laser powder bed fusion uses a high-energy laser beam to melt thin layers of metallic powder in select locations. The material then cools, forming the finished metal part.

However, as the laser interacts with the powdered material, the powder surface heats to boiling temperature and creates hot vapor. This vaporization creates pressure that pushes down on the melt pool—the melted powder bed—causing droplets to splash out of the pool. These droplets can cause unpredictable defects in the printed part.

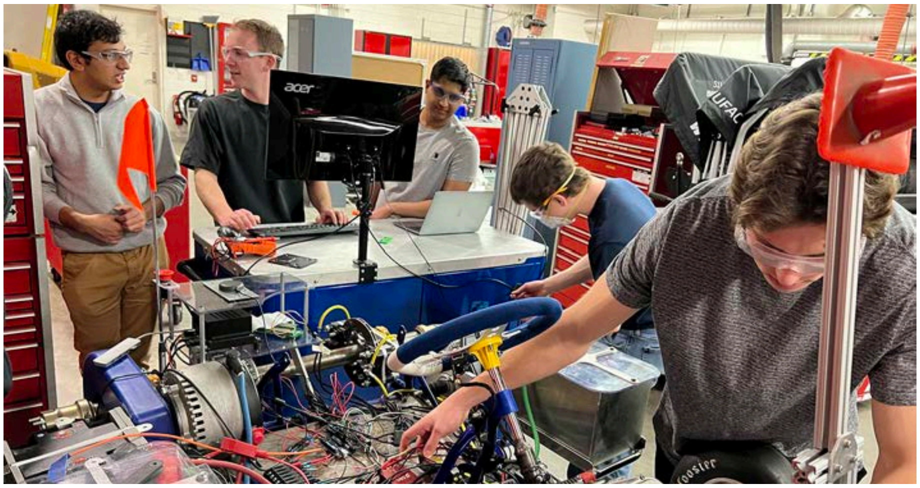
Droplets also can collide during flying and merge to form a larger droplet, or "large spatter," creating even more problems in the additive manufacturing process and leading to subpar printed parts.

By coating the metal powder with ceramic nanoparticles, the researchers could control these instabilities. Using both high-speed synchrotron x-ray imaging and theoretical analysis, they found that the nanoparticle coating stabilized the melt pool, preventing liquid droplets from spraying out and forming the larger spatters.

"When we introduced the nanoparticles, we found that they made the liquid droplets almost have an 'armor' on the surface, so that when they collided, they didn't merge together," says PhD student Minglei Qu, the lead author of the paper. "For the first time, we were able to get rid of the problematic large spatter."

In addition to the possibilities it holds for 3D manufacturing, Chen says the advance could lead to improvements in a broad range of applications, including laser polishing, laser cladding, welding, casting, and fluid stability control, among others.

In autonomous competition, students drive the solutions



The Wisconsin Autonomous team is among 10 teams participating in the AutoDrive Challenge II, a four-year SAE International/General Motors competition.

For an autonomous vehicle, navigating a dense, busy urban environment presents almost limitless scenarios that require split-second reactions and accurate decisions.

Designing such a vehicle that can operate safely is a formidable challenge, even for automakers.

But for Wisconsin Autonomous, a team of UW-Madison students, it's an opportunity to apply their engineering education to a complex and rapidly evolving technology.

The students are among 10 teams participating in the AutoDrive Challenge II, a four-year SAE International/General Motors competition in which the teams will develop and demonstrate an autonomous vehicle that can navigate urban driving courses as described by the SAE Standard (J3016) Level 4 automation.

Each year of the competition has a different focus. The 2021-22 academic year lays the foundation for future success; currently, teams are preparing, designing and implementing software so that their vehicles can perceive and navigate the various objects in their environment.

Teams also are required to participate in several additional challenges—among them, a concept design report and presentation, the software requirement specification, project management deliverables, and innovation challenges focused on multidisciplinary development, among others. In February 2022, for example, Wisconsin Autonomous wrapped up its report on a multidisciplinary innovation challenge. For that endeavor, team members chose to focus on keeping irritants such as allergens or wildfire smoke out of the vehicle.

In early June, the team will travel to the University of Michigan for the first round of the competition. "My goal for my graduation is that we want to be a competitive team against the other powerhouse schools," says senior Aaron Young, the team's president.

He joined Wisconsin Autonomous when it began in 2018. Back then, the group participated in a formula competition and the Indy Autonomous Challenge, but struggled because of the financial barriers associated with purchasing a competition vehicle.

This time around, with a Chevy Bolt EUV provided by competition sponsor GM, the team hopes to leverage UW-Madison's strengths in areas that include control, sensing, and software and hardware development—as well as its long history of competitive student vehicle teams and a burgeoning focus on autonomous vehicles.

The growing team of approximately 30 members includes the contributions of both undergraduate and graduate students.

Victor Freire is a master's student working with Xiangru Xu, an assistant professor and one of the team's co-advisors. In his research, Freire had been focusing primarily on control theory, particularly for quadcopters used for everything from package delivery to search and rescue efforts.

Now, funded in part through the competition, he is applying that theory. "Last year, I was looking at motion controllers; from that, I ported something to cars and am using that as our motion planner for the vehicle," he says. "The competition has given Professor Xu and I an opportunity to show that the control theory we work on works in the real world."

Faculty recognized for research of COVID transmission in classrooms

Three ME professors have been selected as recipients of the 2022 Science and Technology for the Built Environment Best Paper Award from the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE).

Professors David Rothamer, Scott Sanders and Douglas Reindl together with Chemistry Professor Tim Bertram were honored for their paper titled, "Strategies to minimize SARS-CoV-2 transmission in classroom settings: combined impacts of ventilation and mask effective filtration efficiency."

The award recognizes the best referred paper published in the volume year of the ASHRAE research journal *Science and Technology for the Built Environment*, and preceding the ASHRAE winter conference papers.

College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

engineering.wisc.edu/me

Department of Mechanical Engineering
1513 University Ave., Room 2107
Madison, WI 53706

Modeling neuronal mechanics and injury to shed light on concussions

Assistant Professor Shiva Rudraraju is working to improve understanding of how concussions originate in the brain at the cellular level. With a grant from the U.S. Office of Naval Research, Rudraraju is leveraging his expertise in computational mechanics and biophysics to model the mechanical and electrical response of a neuron as it undergoes deformation and injury.

"We're working on high fidelity modeling of single neuron physics and investigating how applying load on a neuron causes it to break down or fail, and how this translates into small-scale injury in the brain," he says.

Although it's only a single cell, a neuron is quite complex. For example, a neuron has many structural layers, and different layers can experience different loading conditions. That can mean some layers fail while others remain functional. In addition, mechanical loading triggers a variety of chemical reactions inside a neuron. Injury can also affect a neuron's ability to conduct electricity, a phenomenon that's critical for memory and thinking.

Given the complex interplay of these various physical phenomena within a neuron, Rudraraju and his graduate students are developing a multiphysics-based theoretical and numerical representation of the structural elements of a single neuron.

"We're focusing on the multiphysics coupling aspects, including mechanical loading, chemical diffusion, chemical reactions and electrical conduction, to gain a better understanding," he says. "We want to quantify and develop a rigorous numerical model of this neuron multiphysics with respect to injury."

Rudraraju says he ultimately wants to use the model to make predictions about small-scale brain injuries under different loading conditions. This capability could enable Rudraraju and his collaborators to provide practical information to clinicians and the public about the types of head motions and impacts that are most harmful to the brain.

This project is part of the PANTHER program, an interdisciplinary research initiative also funded by the U.S. Office of Naval Research that brings together scientists from academia, industry, and government to study traumatic brain injury through a range of approaches.

"I'm very excited about this project because of the real-world applications and potential to benefit human health," Rudraraju says.