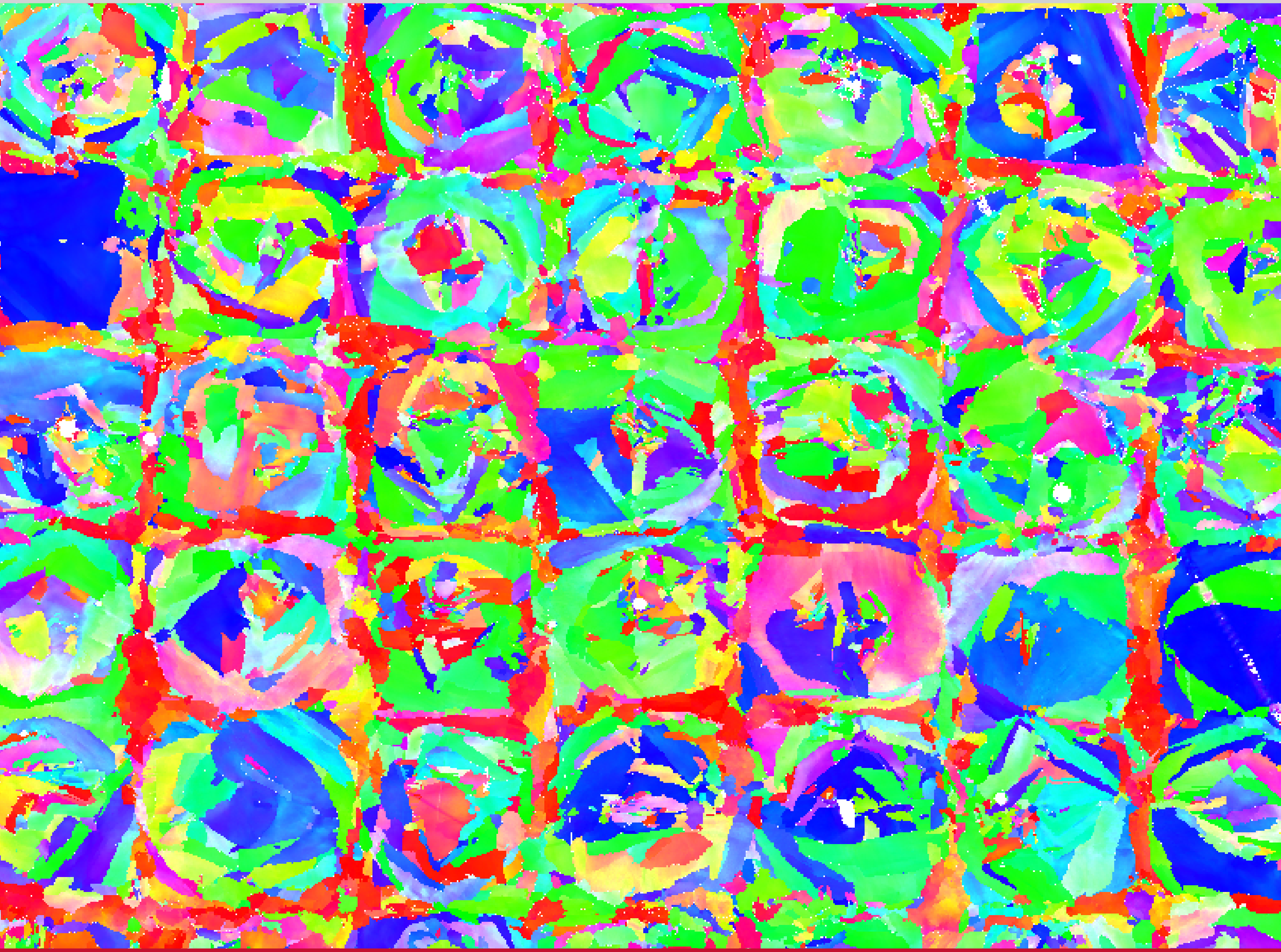
Department of
MECHANICAL ENGINEERING
THE UNIVERSITY OF UTAH

newsletter



FOSTERING INNOVATION

2023

Chair's Message

Dear Friends of Mechanical Engineering,

Greetings from the Mechanical Engineering Department. The last year has been a momentous one for us. We are excited to share some of the great things that have happened.

One of the most exciting was the opening of the Stephen C. and Lynda M. Jacobsen Tower addition to the Rio Tinto Kennecott Mechanical Engineering Building. The addition includes more than 20,000 sq. ft. of space housing our new senior design lab, a new mechatronics teaching lab, painting and welding booths, and a space for our formula SAE team, in addition to 7 new research lab spaces and faculty and staff offices. Our entire department is finally all in one building and we have a little room to grow. Spring semester saw the teaching labs in heavy use and great results on student projects because of it. We were also able to completely renovate our student teaching machine shop and are preparing to renovate the project and research machine shop (hopefully with your help!).

We just had graduation for the class of 2023 and it was one of the largest in the history of the department. I was pleased to hear about the great experiences that students had in our department and was amazed at how many students had excellent jobs lined up. We have seen incredible demand for our students and many companies that want to connect with the department to find great students. Our new rocket club even had a successful launch this summer to cap off a great first year.

The department has continued to grow. We added three new faculty this past year and have at least 4 new faculty coming this year. These new faculty will have a big impact on the courses we can offer. We have three new faculty with expertise in aerospace that will allow us to offer a wide range of aerospace related classes, one of the specialty areas in highest demand from our students. We have expanded our faculty in the robotics, ergonomics and safety, biomechanics, and systems engineering areas as well, and are now teaching new classes related to these areas.

Looking to the future, we are adding a variety of new programs that should be of interest to many of our alumni. We are adding degree and certificate programs in Robotics: MS and PhD degrees, as well as graduate and undergraduate certificates and a minor. We are also starting an MS degree in Systems Engineering this Fall and preparing courses so the degree can be completed entirely online, if desired.

Our freshman class starting in August looks like it will exceed 400 students, nearly 20% larger than last year and 60% larger than before the pandemic. Many of these students are coming from out of state to enjoy the great opportunities that Utah provides for education and employment. We are excited to have a full building with student energy radiating through the halls. We hope you will come and visit us soon!

Best regards,
BRUCE K. GALE, Ph.D.
Professor and Chair

Microstructure of SLM Ni alloy

About the Cover: Electron beam scattering diffraction (EBSD) image revealing the unique microstructural patterns in nickel (Ni) superalloy by selective laser melting (SLM). These colorful patterns captured by diffraction techniques are the um-scale "fingerprint" for different alloy systems and their processing history. SLM, as a novel additive manufacturing technique, facilitates the Ni superalloy fabrication and creates their distinct microstructures for property enhancements. The beauty of advanced manufacturing and materials science coalesces here when the EBSD beam shines.

Photo courtesy of professor Shuaihang Pan. Learn more at https://loam.mech.utah.edu/

Highlighted Grants

Over 40 new projects awarded, more than $12.5 million in funding since last September!

Jake Abbott – NSF, 3 yrs, "Dexterous Magnetic Manipulation of Conductive Nonmagnetic Objects with Electromagnetic Dipole-Field Sources"
Air Force Office of Scientific Research, 4 mos, STTR (R4): Use of Rotating Magnetic Fields to Detumble Irregular Asymmetric Space Debris-Like Objects
Air Force Office of Scientific Research, 4 mos, "STTR (R11): Detumbling of Space Debris with Robotic Magnetic Field Sources"

Jake Abbott, Shad Roundy, Jake Hochhalter – NSF, 3 yrs, "Magnetic Cogging Parallel-elastic Actuators for Energy-efficient Robot Legs"

Edoardo Battaglia – C-STAR,. 6 mos, "C-STAR Collaborative Mentorship Career Development Funding"

Edoardo Battaglia, Haohan Zhang – DHS Agency for Healthcare Research, 1yr, "Reconfiguring the Patient Room Using a Fall Protection Strategy to Increase Patient Stability During Ambulation"

Marc Calaf – NSF, 3 yrs, "Collaborative Research: Transport and mixing processes in turbulent boundary layers over ground-elevated surface roughness"

Brittany Coats, Ken Monson – NSF, 3 yrs, "Tissue Damage Progression in Repeated Mild Traumatic Brain Injury"

Mike Czabaj – Michigan Technology University, 1 yr, "Institute for Ultra-Strong Composites by Computational Design (US-COMP)"

Todd Easton – U of U, "SEED2SOIL program: Optimizing HVAC for Carbon, Cost and Comfort"

Tianli Feng – DOE UT-Battelle LLC, 2.3 yrs, "Develop Multiscale Simulation and Machine Learning Models to Predict the Thermal Conductivity of Porous Insulation Materials"
NSF, 3 yrs, "Prediction of Thermal Transport in Dielectrics and Insulators at Ultra-High Temperatures"
DOE UT-Battelle LLC, 8 mos, "Phonon Transport in Superior Heat Conductors Under Irradiation"
Qorvo Inc, 2.5 mos, "Phase 1: Demonstrate high thermal conductivity of the AlN-filled epoxy materials with appropriate moldability on Si wafer"

Bruce Gale – Viome Life Sciences, Inc, 6 mos, "Viome Phase I: Microfluidic Sample Processing"

Jake Hochhalter – DOE, 1.25 yrs, "Nonlinear Topology Optimization and the Need for Surrogate Material and Stochastic Models"
NSF, 3 yrs, "Interpretable Machine Learning for Microstructure-Sensitive Fatigue Crack Initiation Models from Defects in Additive Manufactured Components"
NSF, "MRI: Acquisition of an Xradia Versa 620 to Enable Nat'l Capabilities for High-Througput, Multiscale 3D/4D Materials Research"

Jungkyu Kim – NCATS--NIH, "A Biometric Cornea Chip For Studying Fuchs' Dystrophy"

Yong Lin Kong – NIH Nat'l Institute of Biomedical Imaging & Bioengineering 4 yrs, "Ingestible Gastric-Resident Electronic Metamaterials Architecture (IGEM) for the Treatment of Obesity"
Army Medical Research Acquisition Activity 2 yrs, "Ingestible Microneedles-based Electronics for Programmable Drug Delivery"
Office of Naval Research 3 yrs, "Gastric Resident Electronics for Marine Mammals Health"

Tommaso Lenzi – Otto Bock Healthcare Products 1 yr, "Development of an Active Knee Prosthesis with Variable Transmission"
DOD, 4 yrs, "Motorized Hip Orthosis for Individuals with Transfemoral Amputations"

Mark Minor – Utah System of Higher Education, 2 yrs, "Robotics Certificates and Graduate Degree Programs"

Steven Naleway – American Chemical Society, 2 yrs, "Biotemplating of Plant Tissues with Tailored Hydrophilicity for the Next Generation of Petroleum Filters"
NSF, 3 yrs, "Discovering the Biomechanics of Filamentous Fungi and their Hyphae"

Pania Newell – VPR Office, 1 yr, "In-Situ Characterization of Nature Inspired by Architected Porous Materials Activity"

Eric Pardyjak (co-pi) - NSF, 3 yrs, "Observational Evaluation of the Effects of Atmospheric Temperature and Turbulence on Hydrometeor Fallspeed"

Ashley Spear – DOE Battelle Energy Alliance, 9 mos, "University of Utah in Support of Augmented Machine Intelligence for Critical Infrastructure"

Pai Wang – VPR Office, 1 yr, "FY23 Seed Grant: Variational Quantum Computing for Instability and Nonlinear Deformation in Mechanics"

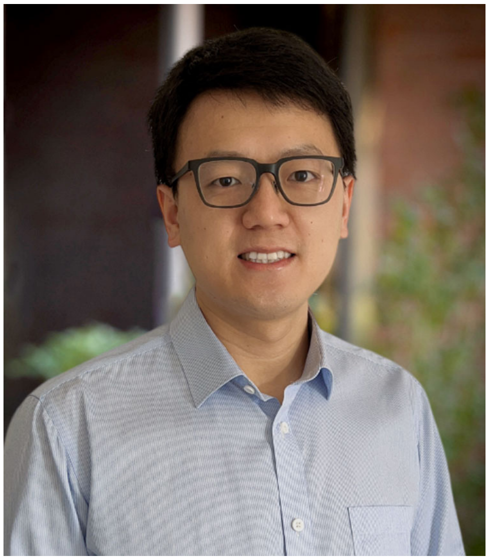
Roseanne Warren – Electric Power Systems, 3 yrs, "All Solid State Lithium Metal Batteries for Electric Aviation"
NSF, 3 yrs, "Collaborative Research: Harnessing Mechanics for the Design of All-Solid-State LI Batteries"

Haohan Zhang – NSF, 3 yrs, "Adapting to the Human Body: Shape-Adaptive Attachment for Parallel Wearable Robots Using Jamming"

Congratulations

to our team of undergraduate students for winning the 2023 IEEE/EPS ASME K-16 Student Heat Sink Design Challenge! The team included Preston Bodily, Taylor Cox, Chandler Elliott, Zach Julien, and Xander Lehnardt. They were co-advised by Dr. Samira Shiri, Dr. Tianli Feng, and Dr. Sameer Rao.

Tianli Feng Receives 2023 Brillouin Medal



Congratulations to assistant professor Tianli Feng from the Department of Mechanical Engineering for receiving the 2023 Brillouin Medal, along with Professor Xiulin Ruan from Purdue University "for their formulation of four-phonon scattering theory and associated computational studies."

The Brillouin medal, awarded every two years by the International Phononics Society (IPS), honors a specific seminal contribution in the field of phononics (including phononic crystals, acoustic/elastic metamaterials, nanoscale phonon transport, wave propagation in periodic structures, coupled phenomena involving phonons, topological phononics, and related areas). Phonon is a quantized vibration of atoms in solids, responsible for many materials' properties and functions.

Prof. Feng works on the interdisciplinary research areas of phonon physics and engineering. In the past, three-phonon scattering was the dominant phonon-phonon scattering mechanism. The higher-order four-phonon scattering was ignored due to the lack of general theory and perceived computational challenges. Ruan and Feng have been working on this problem since 2012, initially establishing a general theory of four-phonon scattering, and then extending the method to first principles. Their predictions explained the experimental temperature dependence of thermal conductivity in silicon. Later work also predicted that four-phonon scattering can significantly contribute to linewidth in infrared and Raman spectra for a wide range of materials.

"Four-phonon scattering is an intrinsic process in all crystals and determines the materials' thermal transport ability and thermal radiative properties," said Feng. "It is critical for discovering and designing materials for thermal barrier coatings, thermal management with ultra-high or ultra-low thermal conductivity, hypersonic vehicles, 2D functional devices, thermoelectrics, nuclear power plants, and radiative cooling."

This research has led to the confirmation of high thermal conductivity and the four-phonon theory in boron arsenide, which has significant potential in electronics thermal management. The four-phonon scattering theory has gained wide acceptance across the fields of engineering, materials, physics, and chemistry. This has opened a new research area of higher-ordered phonon scattering and inspired numerous uses and further developments in a broad range of applications including high thermal conductivity materials, low thermal conductivity materials, high-temperature applications, two-dimensional materials, batteries, nuclear materials, thermoelectrics, infrared and Raman spectra, and thermal radiative transport. One highlight is that the theory has also assisted Ruan in creating $BaSO_4$ radiative cooling paint, which earned a Guinness World Record title of the "World's Whitest Paint."

"It is a great honor for me to receive the Brillouin Medal for our work on four-phonon theory," said Feng. "I am grateful to see that our research has been widely embraced by hundreds of researchers worldwide, who are using our theory and tools to advance their own research."

Prof. Feng holds a B.S. degree in Physics from the University of Science and Technology of China (USTC) in 2011. He received his M.S. and Ph.D. degrees in Mechanical Engineering from Purdue University in 2013 and 2017, respectively, where he was awarded the Bilsland Dissertation Fellowship Honor. From 2017-2020, he worked as a Postdoc, and from 2020-2021, as an R&D Associate Staff Scientist at Oak Ridge National Laboratory. Prof. Feng's research interests lie at the intersection of phonon physics and engineering, and he has participated/managed several interdisciplinary projects funded by NSF, DOE, and DOD. He has over 70 published papers, 3000+ citations, and an h-index of 33. He developed several open-source simulation packages, Windows-based applications, and online simulation tools. He has also been invited to give talks at several seminars and conferences and serves as an editorial board member of Energy and Environment Focus and an Early-Career Editorial board member of ES Energy & Environment, a journal of Engineered Science. He has also organized and chaired sessions at ASME and MRS conferences.

You can learn more about Professor Feng's research through the Feng MEX Lab Website: https://feng.mech.utah.edu/.

Utah Nanofab's New X-ray Microscope

Photo of the new microscope and the team that helped bring it to the U taken by Tara Mleynek, Office of the Vice President for Research

The newest piece of equipment in the Utah Nanofab is the The Zeiss Xradia Verza 620 X-ray Microscope, a state-of-the-art instrument that is unique in the Intermountain West region. Mechanical Engineering Assistant Professor Jacob Hochhalter was PI on the NSF proposal that funded the acquisition. This microscope will allow for 3D, sub-micron imaging resolution of hard, soft, and biological materials. Additionally, it can study materials under varying mechanical loads (up to 5 kN) and temperatures (-20 to 160C). This is valuable in a range of fields including aerospace materials, semiconductor devices, additive manufactured materials, geology, biology, medicine, and more.

Previously, faculty at the U interested in conducting this type of research had to travel to one of only a handful of beamline facilities in the U.S. Because those resources are heavily utilized, researchers are required to write proposals for access, which even if granted, only allow for an abbreviated study. This restricted the impact of these methodologies.

"With the Versa at the U, researchers now have a lab-scale surrogate for beamline resources," said Hochhalter. "This enables more widespread, inclusive adoption of exciting experimental students which help accelerate materials development. An exciting impact is that this accessibility will increase the quantity of data available, which will be leveraged by researchers to advance a new frontier for data analytics and machine learning in materials research."
Success with this large grant required persistence and an exciting proposal. Over the course of four revisions, the team refined the proposal and built out a group of regional and national collaborations. They were able to generate over 50 letters of support from around the country, demonstrating impact and application across aerospace, structural, biological, and geological materials applications. We believe this is the first 'Track 2' (above $1.4M) NSF MRI award that Utah has led.

In addition to impact on research, this tool will also be used to promote research among young students. Over the next year, the team will create an inter-high school competition that mimics the scientific process. In phase one Utah faculty will pose an open question and students would propose what should be scanned and how the data should be analyzed. In phase two, students would receive the data and use their own creative processes to analyze and describe what they were able to learn.

"Using the microscope as a scientific tool is great," said Hochhalter. "It helps us learn new things and develop new. But in the end, the reason why we're at the U is because we like to make an impact. I came to the U because I wanted to be closer to the impact on our future generations of scientists and engineers. Getting students excited about the future of materials research and providing this new level of insight into material behavior is priceless."

You can learn more about the Utah Nanofab through their website: nanofab.utah.edu.

To watch the Versa 620 in action, visit: https://bit.ly/zxvmicro

Alumni Spotlight - Cristian Clavijo

Cristian Clavijo is a Sr. R&D Project Manager at Thermo Fisher Scientific, where he works on protein purification and cancer therapy instrumentation. He is a University of Utah Department of Mechanical Engineering alum with a combined BS/MS. He went on to complete a PhD in Mechanical Engineering at BYU with a specialization in Fluids Mechanics and Heat Transfer.

Mechanical engineering was a leap into the unknown for Clavijo. No one in his family had been a mechanical engineer, but he had always been good at math. With his family's encouragement, he came to the U and studied mechanical engineering. Classes like numerical methods, thermodynamics, and heat transfer were his favorites.

"I got into Fluid Mechanics and Heat Transfer because they were heavy in math. I was never a very hands-on, tinkering type of engineer. I preferred to solve math problems," said Clavijo.

Clavijo also discovered an interest in medicine during his tenure at the U. At the end of his bachelor's program, he had an internship in tissue engineering / regenerative medicine, then went on to work on heat transfer for medical devices during his masters. Going into the medical industry after his PhD was a natural progression.

Over his career, Clavijo has worked with medical device companies, first Becton Dickinson, before eventually moving to Thermo Fisher Scientific. In his current role, Clavijo drives new product ideas from concept to commercialization. He leads cross-functional teams from R&D, quality, manufacturing, product management, supply chain, and more. He coordinates with representatives from these departments daily to facilitate internal alignment and ensure customer commitments are delivered in a timely manner. He also presents regularly on these projects to senior leadership.

When talking about his path from school to career, Clavijo highlighted the importance of the fundamentals of physics and engineering.

"The fundamentals will give you a strong foundation for your future career regardless of which direction you go, even outside of engineering," Clavijo said.

He also highlighted the importance of skills beyond engineering in the workforce.

"Get involved with projects or programs where you have to translate unmet customer needs into solutions," said Clavijo. "This is what every company seeks to do. You should also seek opportunities to grow your leadership skill, whether engineering related or extracurricular. The point is to help grow your soft skills which are essential whether you go into highly technical or leadership roles."

Growing Systems Engineering at the U

The ME Department is continuing to grow its Systems Engineering program to address an increasing demand for the profession from companies across Utah. With support from the Utah Legislature, the U brought on two faculty members in 2021. Since then, 45 Systems Certificates have been awarded. The program is being expanded to offer more online content to support those in the workforce. Additionally, the department will be able to award Master of Science in Systems Engineering degrees starting in Fall of 2024. The department is also bringing on a new tenure track faculty member in Fall of 2023 to support the program.

Systems Engineering is a rapidly growing field. As engineered products, services, and processes have become more complex, it has become imperative to consider the interactions of those systems with humans, software, electrical components, mechanical devices, nature, and a host of other elements. Improper consideration of these interactions has caused catastrophic losses of life, property, and money.

“Engineered products are incredibly complex,” said Todd Easton, lecturing professor. “Because of this, systems engineers do a lot of product development and testing. Frequently, they move into a leadership role due to the number of different groups/divisions that they interact with daily.”

The expanded options in Systems Engineering at the U give students more options than ever. Systems engineering classes are available both on campus and online every semester. Students don’t need to be enrolled in a graduate program at the U to enroll in their first few classes. This allows them to enroll in Systems Engineering classes just before a semester begins to explore the program and gain valuable knowledge with a minimal application process and planning.

The Systems Engineering Certificate provides a credential that can be used to improve job perspectives, as well as a steppingstone toward a variety of MS degrees in the Price College of Engineering. Frequently, students will transfer classes from the certificate to pursue the MS in Systems where they will gain more advanced knowledge in product development, testing, modeling, and product lifecycle.

“Our systems engineering courses are tailored to relevant engineering industries in Utah,” said Pedro Huebner, lecturing assistant professor. “This includes aerospace, defense, healthcare, manufacturing, and more. We frequently discuss case studies in those areas and have also established partnerships with local companies that bring ‘real world,’ industry-relevant problems for the students to work on.”

THE UNIVERSITY OF UTAH

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Senior Design - Generant Compaction Station

Completed Compaction Station

Autoliv produces 43% of the world's airbags. An inflator module in each airbag fills the bag with gas by igniting the enclosed generant tablets. It is critical to consistently package these tablets in order to ensure proper airbag function.

As new steering wheels trend smaller, the challenge becomes compacting the same mass of pellets into a smaller inflator module. Autoliv worked with a senior design team to design a machine capable of testing and recording the effects of different vibration and compaction parameters on generant packaging. This new system will allow Autoliv to determine the ideal parameters for packaging airbag inflator modules.

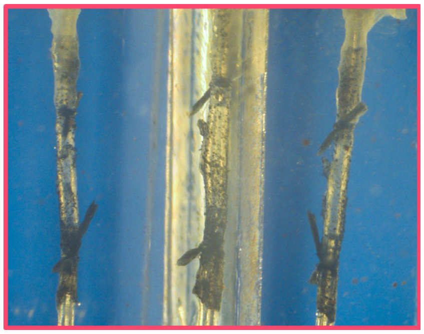
The team conducted tests on the vibration, compression, rotation, and HMI subsystems in order to verify that the machine would be meet the design metrics. After addressing issues noted in testing, such as the unwanted support rod vibrations, all subsystems achieved their respective design metrics.

The system achieved the design metrics through implementation of the vibration, compression, rotation subsystems and the human-machine interface. Through rigorous testing and analysis of these systems, the team demonstrated that their prototype can vary and record a range of critical generant compaction parameters.

Senior Design - Panoramic Digital Image Correlation in Blood Vessels

The Head Injury and Vessel Biomechanics Lab aims to analyze and characterize injury-induced changes in cerebral vessel behavior. Dr. Ken Monson's lab performs tension tests on vessels to simulate head trauma and gathers stretch values using digital image correlation (DIC) techniques. DIC tracks patterns on a specimen as it deforms. It analyzes the elongation between points in the pattern to calculate the stretch of the specimen.

The current tester only gathers stretch values from one view of the blood vessel, which limits the usefulness of the data. To address this issue, the senior design team modified the tester to gather and analyze three-dimensional stretch values around the entire circumference of the blood vessel during testing. This will enable us to better understand the biomechanical properties of cerebral vessels and their response to head trauma, ultimately leading to improved treatments and outcomes for patients.



An example image taken with a small blood vessel in the improved testing apparatus

The results demonstrate that the updated testing apparatus and DIC software provide highly accurate tracking of stretch data around the entire circumference of a blood vessel. Remarkably, even with just 15 tracked speckles, the manually measured points match the DIC-generated data average within one standard deviation. These findings highlight the potential of the technology to greatly enhance our understanding of blood vessel stretch and its implications for head trauma. To maximize the precision of this technique, it's recommended to increase the number of speckles tracked and evaluated.