TEES
TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

2019
YEAR IN REVIEW

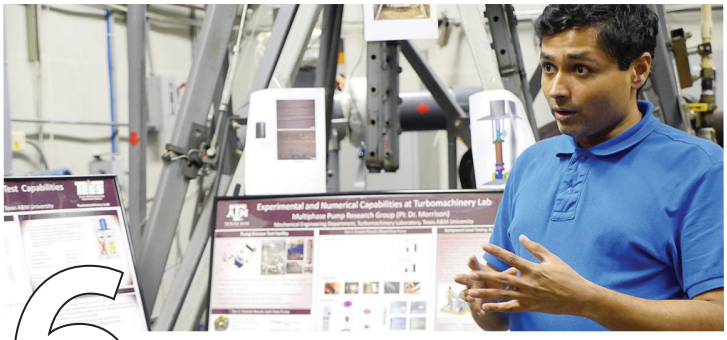
IMPACTING INDUSTRY
Turbo & Pump Symposia draws nearly 5,000 unique attendees

ADVANCING TECHNOLOGY:
Researchers secure temporary patent for new invention

GLOBAL INFLUENCE:
Students, staff recognized for leadership and service

INSIDE:

2 2019 Turbomachinery & Pump Symposia recap



6 Researchers develop new multiphase flow metering device

8 Show Report: Asia Turbo & Pump Industry Summit

10 PETRONAS backs Turbo Lab's Asia Turbomachinery & Pump Symposium

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THANK YOU FOR MAKING 2019 A WONDERFUL YEAR!

Thank you for being such an important part of the Turbomachinery Laboratory. Your support through our symposia, short courses, the TRC and other education and research initiatives makes it possible for us to carry out our mission of research, education and workforce development. Cheers to 2020!

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TEES TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

TEXAS A&M UNIVERSITY

OUR MISSION

The Turbomachinery Laboratory, a center of the Texas A&M Engineering Experiment Station (TEES) and a member of The Texas A&M University System, makes a vital impact on turbomachinery and related industries through three pathways:

RESEARCH

A variety of fundamental and applied research is performed by Turbo Lab faculty, post docs, and students. This research is sponsored by a combination of government and industry sources through traditional grants and contracts and covers the entire range of specialties of the Turbo Lab research groups. These specialties include rotordynamics, turbine blade heat transfer, combustion, optical diagnostics, bearings, machine learning, uncertainty quantification, chemically reacting flows, computational fluid dynamics, and seals, among others. Unique test rigs and extreme environments are among the many reasons why the Turbo Lab continues to be a leader in turbomachinery-related research.

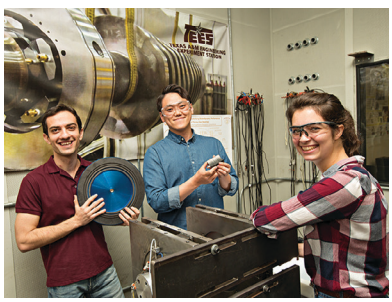
Another way Turbo Lab faculty and students team up with industry partners is through the Turbomachinery Research Consortium. The TRC is a unique organization of major turbomachinery developers and users who have joined with the Turbo Lab to find answers to important questions through research.

EDUCATION

The Turbo Lab produces engineers ready to work by offering undergraduate and graduate engineering education primarily through Texas A&M's J. Mike Walker '66 Department of Mechanical Engineering. The Turbomachinery Research Consortium blends the Turbo Lab's impact areas of education and research by teaming graduate students with industry to find solutions to real-world problems. Turbo Lab students are highly sought after for industry positions upon graduation.

WORKFORCE DEVELOPMENT

The Turbo Lab provides platforms for the continuous exchange of ideas among working professionals. These platforms include large industrial symposiums and various extended short courses held throughout the year.



2019 TURBOMACHINERY & PUMP SYMPOSIA CONTINUES EDUCATING, CONNECTING INDUSTRY

Symposia Tops Recent Attendance Records

HOUSTON, Texas —The Turbomachinery Laboratory at Texas A&M University hosted another Turbomachinery & Pump Symposia, a vital conference designed for the industry, by the industry.

The 48th Turbomachinery and 35th International Pump User's Symposia (TPS 2019) attracted 56 new companies to the George R. Brown Convention Center, for a total of 355 exhibiting companies. The exhibition featured full-size equipment and emerging technology and industry trends from leading turbomachinery, pump and related organizations. At the close of TPS 2019, 80 percent of the exhibit floor for TPS 2020 was reserved.

Cody Cox, director of business development for Houston-based Ram Alloys, said exhibiting at TPS became a necessity when the company first joined the symposium two years ago.

"This is the market," Cox said. "The market is here, it's not inside the walls of your office. You've got to network, you've got to meet people. There's not a better opportunity for us, and it's fun. This is our passion, this is what we do. It's about helping people through building relationships, and that's what we get to do at TPS."

The symposia attracted 4,875 unique delegates representing 51 countries to the exhibition or technical sessions, an increase from the 2018 symposia.

Engineers and technicians, from novice to experienced, chose from a combination of short courses, lectures, tutorials, discussion groups and case studies. The technical program is selected by the turbomachinery and pump advisory committees and led by engineers and technicians with experience in particular disciplines. Topics included compressors, steam and gas turbines, expanders, pumps and drivers, and auxiliary equipment such as couplings, bearings, gearboxes, dry gas seals and annular seals.

First-time TPS delegate Margaret Mesera, rotating equipment engineer with S&B Engineers and Constructors, Ltd., said one of the most memorable sessions she attended was a pump discussion group on mechanical seals.

"They are a very complex thing," she said. "It was great to talk to operations staff, end-users and OEMs about different questions that repeatedly come up in the office. We'll be able to take a lot of that information back and implement it on future projects."

Technical content from TPS 2019 will be available to the public in March 2020. Proceedings from all previous symposia are free for perusal and download at turbolab.tamu.edu/proceedings.

TPS 2019 celebrated the 35th anniversary of the Pump Symposium, and hosted the inaugural Women of TPS Luncheon. Plans are underway for the second annual luncheon at TPS 2020.

TPS 2020 is set for Sept. 15-17 in Houston. Short courses will be held in conjunction with the symposia on Sept.14. To learn more about TPS and see photos from this year's event, visit tps.tamu.edu. To reserve exhibit space, email mbarton@tamu.edu.

Inaugural Women of TPS Luncheon

Delegates encouraged to share challenges in male-dominated industry

More than 45 male and female delegates to the 2019 Turbomachinery & Pump Symposia (TPS) gathered on Wednesday of the conference for the inaugural Women of TPS Luncheon to network with colleagues and interact with a panel of women who shared their experiences and challenges in a male-dominated industry.

The Women of TPS luncheon—to which men are also encouraged to attend—is a forum for women of TPS to share experiences and challenges in the industry. It is also an avenue in which those experiences and challenges can be heard and understood by others, including upper management.

Panelists included Judith Hodgson, P.E., president of JE Hodgson Consulting Enterprises; Charli K. Matthews, founder and CEO of Empowering Brands and Empowering Pumps & Equipment; Jane Ploeger, head of portfolio management within the technology and innovation group at Siemens; and Meera Day Towler, P.E., research engineer in the Rotating Machinery Dynamics Section at Southwest Research Institute. The panelists' backgrounds represented the wide breadth of attendance at TPS, from heavy technical to non-technical careers. Panel discussions ranged from retrospective advice to encouraging personal experiences. Themes repeated among the panelists included the importance of mentors and the necessity of finding confidence in oneself.

Hodgson said she was struggling to feel comfortable in her field early on in her career. It was her mentor's advice that eventually led her to start her own consulting company.

"He told me, 'To stand out in your field, you have to learn something you don't already know,'" Hodgson said. "So that's what I did. People had to start coming to me for information, because I was the one who had it."

Both men and women took note during the engaging discussions and were invited to pose questions to the panel, all of which seemed to resonate with the audience.

"The way the panelists interacted with one another and the attendees, and shared such meaningful ideas made this event an unforgettable experience," said Brooke West, communications director for the Turbo Lab and a coordinator of the event. "I left feeling encouraged at their advice and the buzz of important conversation between attendees. I am grateful to all the panelists and

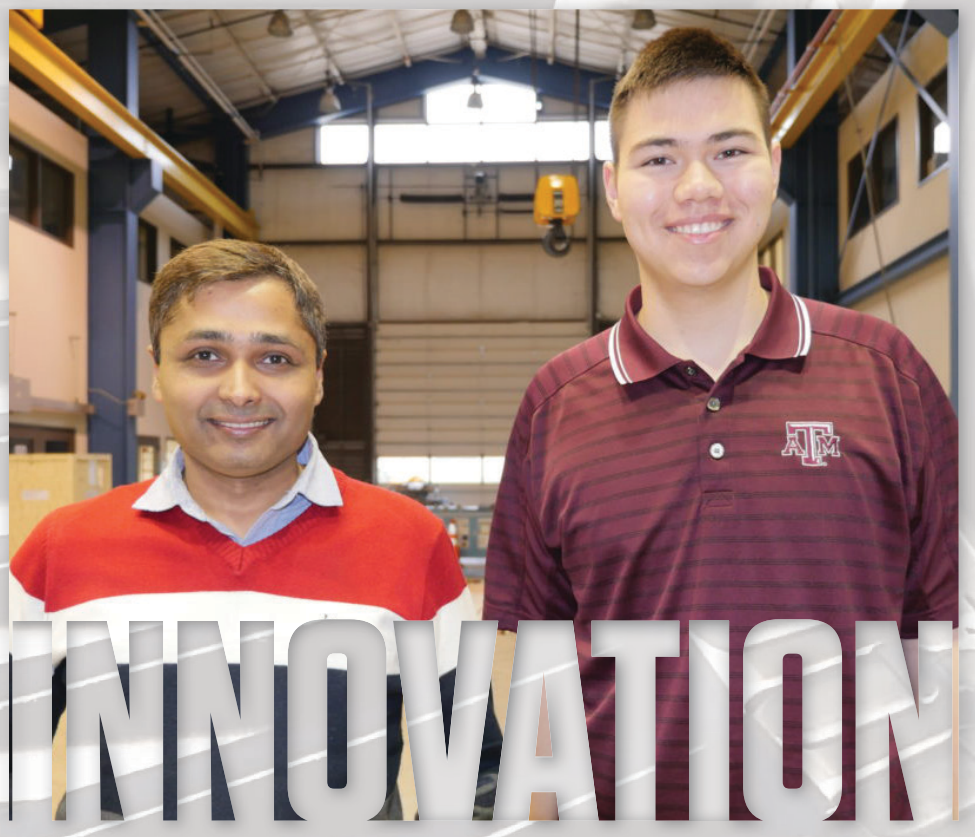
An Unforgettable Experience

attendees, and look forward to making the luncheon a staple event for the men and women of TPS for years to come."

The luncheon opened with a game of "bag bingo" where participants could win one of three designer bags purchased by bag sponsors Ariel Corporation, Empowering Pumps & Equipment, and the TPS Advisory Committees. The event concluded with more networking, and fun poses and props in the selfie booth.

To nominate a panelist for the 2020 Women of TPS Luncheon, contact Brooke West, Communications Director, brookewest@tamu.edu.

RESEARCHERS DEVELOP NEW MULTIPHASE FLOW METERING DEVICE



> Simplicity in the design, yet equivalent accuracy makes this flow meter quite attractive. We are in the process of evaluating different options to realize its full potential."
>
> **~ Dr. Abhay Patil**

COLLEGE STATION, Texas — Three Turbomachinery Lab researchers have developed a new way to measure multiphase flow that is less expensive than and equally accurate to current multiphase flow devices on the market. Inventors Dr. Abhay Patil, Dr. Gerald Morrison, and Joshua Vandervort in the Turbo Lab, have received a temporary patent for the invention.

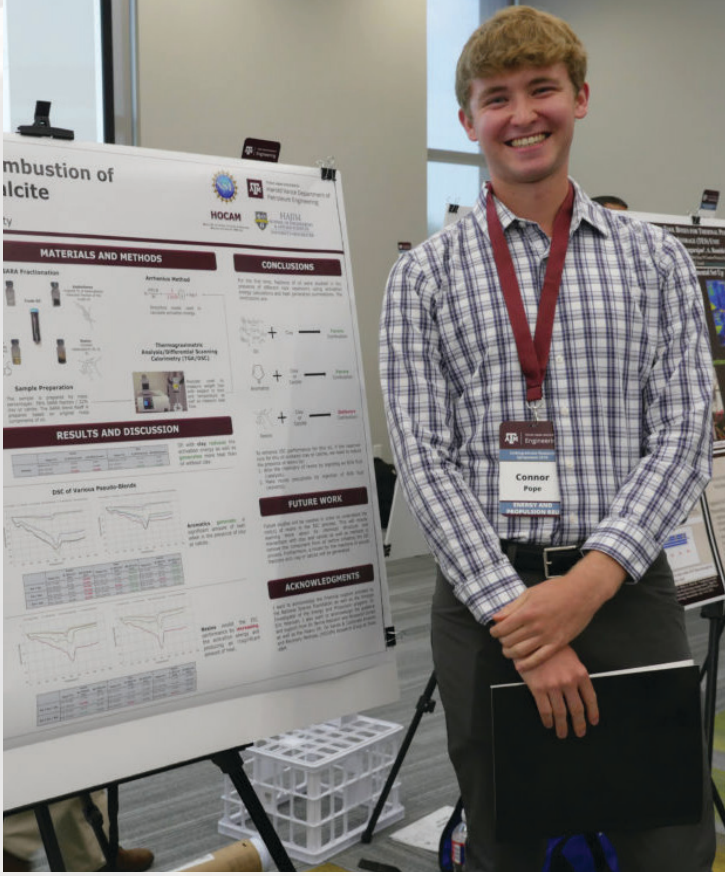
Lead inventor Dr. Abhay Patil credits an oil and gas technical session on multiphase flow meters for the new flow meter device inspiration. It was during this session two years ago that he realized the existing gaps and necessity for economical multiphase flow meters.

Co-inventor Joshua Vandervort, a graduate student in the Turbo Lab, is no stranger to partnering with Patil. He worked three semesters as a mechanical engineering undergrad with Patil on flow meter investigation before becoming his research assistant. "I love working in the lab and working with my hands," Vandervort said. "I touch every part of mechanical engineering. That's what I love."

The proposed technology utilizes the simple, yet robust design of a flow meter to withstand multiphase flow conditions with sound algorithms to predict the Gas Volume Fractions or liquid hold up. "Simplicity in the design, yet equivalent accuracy makes this flow meter quite attractive," Patil said. "We are in the process of evaluating different options to realize its full potential."

Patil completed his Ph.D. in mechanical engineering at Texas A&M University in 2013 under the direction of Dr. Gerald Morrison, Professor Emeritus of Mechanical Engineering who retired from the Turbo Lab in 2017. This is Patil's second patent in his time at the Turbo Lab.

Patil is working with The TEES Commercialization and Entrepreneurship Office, who has initiated the process to secure a temporary patent. The team is developing a final prototype for complete characterization to improve the confidence in proposed multiphase flow metering technology.



REU Summer Program Culminates with Undergraduate Research Symposium

COLLEGE STATION, Texas — Sixteen students successfully completed a summer of research at Texas A&M University.

Six faculty members in the Turbomachinery Laboratory and eight others throughout the College of Engineering served as mentors to the students working closely on currently active research projects in energy and propulsion research.

This is the third summer the Turbo Lab has facilitated the Research Experience for Undergraduates (REU) site in Energy and Propulsion and overall the eighth summer of the site under the direction of Dr. Eric Petersen, director of the Turbo Lab, and Dr. James Thomas, a postdoctoral researcher at the Turbo Lab. Funded primarily by the National Science Foundation (NSF) with contributions from the Turbo Lab, this REU site is a ten-week summer program that immerses undergraduate students from across the U.S. in graduate-level research.

Selected participants work closely with the faculty mentors and prepare a research plan, abstract, technical paper, and research poster. This year's Undergraduate Research Symposium poster session represented the culmination of engaging science exploration. The students' work was a part of more than 100 poster presentations from a variety of engineering disciplines.

Seventy-five percent of participants from the Energy and Propulsion REU site end up going to grad school, Petersen said. Petersen finalizes the student participant list and assigns each student chosen for the program to their faculty mentor based on research interests. This year the program accepted a total of 16 students, eight of whom are sponsored by the Turbo Lab. These eight students from the University of Massachusetts, Lowell; University of Texas, Permian Basin; Rutgers University; Le Tourneau University; Southern Illinois University, Edwardsville; Trinity College; University of Cyprus; and Texas A&M University were mentored by Turbo Lab professors Petersen, Dr. Luis San Andres, Dr. Waruna Kulatilaka, Dr. Adolfo Delgado, Dr. Alan Palazzolo and Dr. Lesley Wright.

"This is a great opportunity for undergraduates to do high-quality research and to see what it's like to go to grad school," Petersen said. "The goal is to encourage participants to pursue an advanced degree in a STEM field."

Students conducted research with guidance from university professors and graduate students—an experience they might not have otherwise gained at their own university. Their research can have a global impact, as they investigate issues that could ultimately affect global warming, finite fossil fuel resources, pollution and providing energy to an increasing world population. In addition to their daily research activities, students attended lunchtime seminars, participated in REU functions, delivered two oral presentations and presented a final poster.

The program covers room and travel expenses as well as a stipend of $5,000 for student participants. The 10-week site began May 29 and ran until August 2, 2019.

SHOW REPORT

By Kalyan Kalyanaraman

This article first appeared in the September/ October 2019 edition of Turbomachinery International.

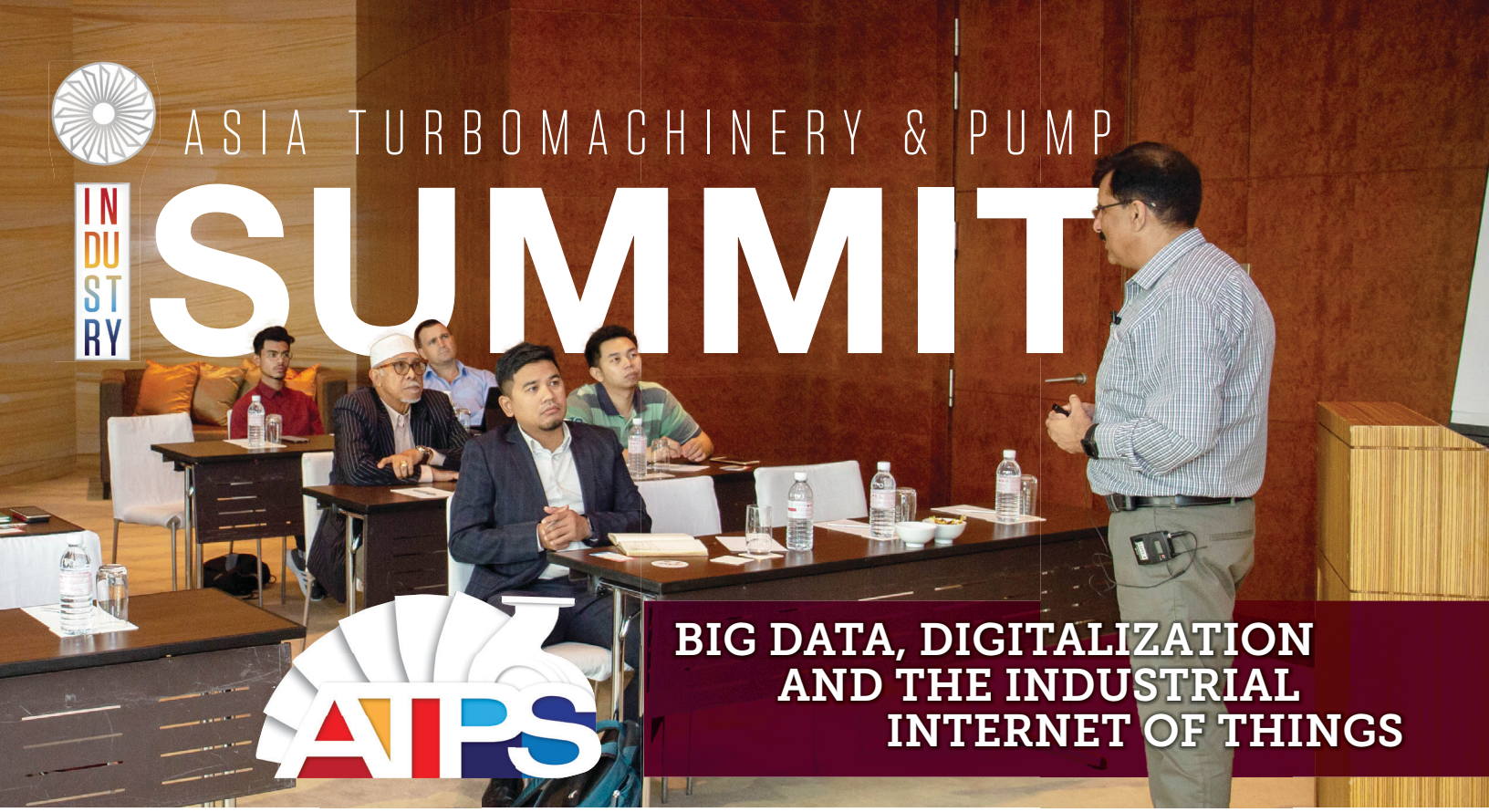
KUALA LUMPUR, Malaysia — The biennial Asia Turbomachinery & Pump Symposium (ATPS) grew out of Texas A&M Turbomachinery Laboratories' (TAMU) annual Turbomachinery & Pump Symposia (TPS). This year's Industry Summit was conducted in Kuala Lumpur, Malaysia. The welcome address by Dennis Lawrence, Head of Wells at Petronas, touched upon the development of young engineers and machine learning applications for asset management. Further speakers emphasized trends, such as big data, digitalization and the Industrial Internet of Things IIoT). Viewpoints ranged from skepticism through grudging acceptance to wholehearted endorsement of these mega trends. Eight case studies covered a cross-section of rotating machinery problems. "More and more, the participants want to return to their workplace and apply what they learn," said Eric Petersen, Director of Turbomachinery Laboratories. "That's why content is weighted in favor of case studies." Petersen sees supercritical CO2, high pressures in compression, advanced materials to handle corrosive gas use, combustion at different operating conditions, and bearings as the areas where cutting-edge research and technology development is happening. He raised concern about the knowledge gap created because of the retirement of a generation of turbomachinery engineers. ATPS chair Dag Calafell said current buzzwords, such as big data and predictive analytics are often driven by this knowledge gap. "Asset management that improves safety and operability while reducing cost is a big trend," he said. "Due to attrition in expertise, assets are vulnerable to declining reliability, especially in offshore production." He called for greater collaboration to break down the barriers imposed by proprietary development. Otherwise machinery domain knowledge may not be available to end users.

FUTURE TECHNOLOGY

Junya Ujiie, Senior Vice President of Asia Pacific at Mitsubishi Heavy Industries, said his company is focused on technologies to sharply lower carbon emissions. Products for the future will be high-efficiency, large-capacity gas turbine (GT) combined cycles, GTs burning hydrogen, integrated gasification combined cycle, solid oxide fuel cells and machinery for nuclear power. Its next generation combined cycle will have a projected efficiency of 65%. With integrated SOFCs, this could reach beyond 70%. In post-combustion CO2 capture, Mitsubishi delivered the Petra Nova plant in Texas that started operations in 2016. Five thousand tons of CO2 are captured every day and used for enhanced oil recovery. The Mitsubishi equipment includes an eight-stage integrally geared compressor and a CO2 inline compressor with a discharge pressure over 200 bars (2,900 psig). To cater to remote, off-grid areas near coasts, Mitsubishi developed a floating LNG power plant with an integrated supply chain. It leverages MHI's capabilities in LNG shipbuilding and power plants. The DNV-approved solution is economical if fuel costs do not exceed $10 Mbtu. Mitsubishi offers several power ranges. For large outputs of 150 to 350 MW, the lead time is under three years. The combined cycle plant onboard would have efficiencies in the range of 50% to 56%. For up to 100 MW, the prime mover can be either gas turbines or gas engines, with delivery in one year. Efficiency would range from 35% to 50%. The supply chain would include small LNG shuttles to transport fuel from bigger vessels.

DIGITAL TWIN

A lecture by representatives of Tri-Sen and Elliott Group outlined the compressor digital twin. Klaus Brun, Elliott's R&D director, said trends like Artificial Intelligence (AI), digital twin and IIoT have two drivers. One is a generational change among those working in the industry. They are accustomed to computers and prefer simulations. The second reason: veteran turbomachinery experts who can predict machinery condition are retiring. AI is required to help replace their expertise. Jim Jacoby, VP of engineering at Tri-Sen, explained the nuances of the digital twin. A physics-based simulation of the machine generated by OEM-supplied parameters is compared with the actual equipment. The digital twin allows the operator to compare predicted results with real-world performance to identify emerging malfunctions or opportunities. Jacoby explained that head, flow, speed, as well as gas molecular weight and conditions such as pressure and temperatures are required inputs for the model. The digital twin lecture prompted lively discussion. A key point emerged: compressor surge lines may have altered in the field because of changed impedances due to piping. Brun explained that so much effort goes into simulation and modeling, yet instrument errors can introduce errors in predictions. Dr. Masdi bin Muhammad from UTP presented a keynote on predictive analytics. We need to use maintenance and operational insights, he said, and ensure operational efficiency through alarms prioritization and recommendations. But challenges such as unreliable data, selecting the right model, and frequent changes in the field must be overcome.



ASIA TURBOMACHINERY & PUMP

INDUSTRY

SUMMIT

BIG DATA, DIGITALIZATION AND THE INDUSTRIAL INTERNET OF THINGS

INDUSTRIAL REVOLUTION 4.0

On Day Two of the summit, Hj Khairol Anuar Shukri, Head of Group Technical Solutions, Project Delivery and Technology of Petronas, outlined the broad trend of what is known as the Industrial Revolution 4.0. The first industrial revolution involved steam power and mechanization. The second phase in the 1870s brought about mass production. The next revolution came about through computers and electronics starting in the late 60s. The features of the present one, IR 4.0, are cyber physical systems, IIoT and networks, he said. The key enablers are AI, cloud, system integration, simulation, robots, big data and digitalization. Market disruptors are operating in tandem to IR 4.0 are U.S. shale production, technological innovation, environment concerns and the public's perception of the industry. During every industrial revolution to date, some large companies disappear without trace. To stay relevant, it is necessary to adapt, digitalize and collaborate. This means working together with governing bodies, standards organizations, higher learning institutions and engineering fraternities where all participate, said Shukri. For instance, even a few years ago, the big oil and gas companies had difficulty achieving standardization of commonly used equipment. Today, the Christmas tree, switch gear and other equipment are standardized.

This reduces the need for specification overlays, reduces costs and cuts delays, said Shukri. "Transparency and communication are the key to facilitate networking within organizations and without." The last session on IIoT was kicked off by Girish Kamal, Principal Rotating Engineer from Petronas Upstream. He talked about the need to become a datadriven organization and how the world's top performing companies harness data for insights to make smarter and faster decisions and unlock new value. Dr. Ir. Harris A. Rahman Sabri, Staff Rotating Engineer f rom Pet ronas Upstream showcased his company's journey in developing Petronas Rotating Equipment Analytics (Protean), an inhouse predictive maintenance solution that covers 79 GTs, 35 pumps, 50 compressors and 29 generators. Some decisions are referred to humans while others are made by computers. Arun Kumar, General Manager for Reliability and Maintenance at HPC, Mittal Energy of India, gave a presentation about his company's digitalization plans and how AI had reduced downtime. Polypropylene, for example, could sometimes solidify in the reactor during process upsets and lead to weeks of shutdowns. AI prevents solidification via a closed-loop feedback system. Sandip Jadhav, CEO of CCTech, a software solutions firm based in Pune, India, used big data to design butterfly valves to maximize the flow coefficient and minimize the hydrodynamic coefficient. A lively interaction followed among the panelists. Rainer Kurz, Manager of Systems Analysis at Solar Turbines, asked how to choose between physics-based models and big data. Jadhav responded that in the butterfly valve case, the traditional approach would be to use CFD and attempt a solution to the Navier Stokes equation. This would require a trade-off between speed and accuracy. "The effectiveness of machine learning models depends on the data," said Jadhav. "We used a combination of physics and machine learning to reduce cycle time. Physics-based models are not adaptive." A four-day ATPS Symposium and Exhibition is scheduled for April 7–11, 2020 at the Kuala Lumpur Conference Center.

PETRONAS backs Turbo Lab's ATPS

KUALA LUMPUR, Malaysia — The Turbomachinery Laboratory, a center of the Texas A&M Engineering Experiment Station (TEES) has entered into a collaboration with Petroliam Nasional Berhad (PETRONAS) to be the top sponsor of the upcoming Asia Turbomachinery and Pump Symposium (ATPS) scheduled for 7-9 April 2020 at the Kuala Lumpur Convention Center, Kuala Lumpur, Malaysia. Short courses will be held in conjunction with the symposium on 6 April.

As the top-tier (Platinum) Sponsor, PETRONAS has taken a lead role in assuring the success of ATPS through its extensive outreach and partnerships in the region.

Support from PETRONAS, furthers the Turbo Lab's global footprint in turbomachinery and pump education, research and workforce development. PETRONAS is joined by Mitsubishi Heavy Industries (Mitsubishi Compressor Corporation and Mitsubishi Hitachi Power Systems) as the ATPS 2020 Gold sponsor. Both organizations bring additional prestige to a world-class symposium now moving to Kuala Lumpur after two successful events in Singapore in 2016 and 2018.

Dr. Eric Petersen, director of the Turbo Lab, said that without this sponsor support, the Lab would not be able to sustain the vital ATPS program long-term.

"I am grateful for the leadership position that both PETRONAS and MHI are taking in support of training and education," Petersen said. "We are heading into the 2020 Symposium with a strong foundation that we feel will support a sustained presence in Southeast Asia. Our mission of educating working practitioners in rotating equipment with up-to-date information, techniques, and trends in cutting-edge technology will be greatly enhanced with this association."

ATPS is organized by the Turbo Lab and developed by the industry through a peer-review process steered by advisers of both Original Equipment Manufacturer (OEM) and end-user companies. ATPS follows the same structure as the annual Turbomachinery and Pump Symposia (TPS) in Houston, Texas. Now in its 48th year, TPS has built a stellar reputation of impacting company bottom lines through sharing of best practices and top-of-the line equipment and services.

As a precursor to the April 2020 ATPS, the Turbo Lab hosted a free, two-day Industry Summit, 10-11 July 2019 at the

Kuala Lumpur Convention Centre. The Industry Summit is an information-sharing and networking event that introduced ATPS to a new contingent of engineers and technicians.

"The value of the ATPS program cannot be overestimated," said Girish Kamal, ATPS adviser and principal rotating equipment engineer with PETRONAS. "ATPS advisers work hundreds of hours soliciting and reviewing papers for presentation and sharing ideas on improvements that can be made in reliability, maintenance, and performance of rotating equipment. Aside from attending technical sessions led by industry experts from around the world, delegates are able to network and share ideas among themselves, and this is a valuable, industry-focused platform that has no equal for our business. At the same time, the array of companies involved in the exhibit floor also provide valuable knowledge sharing opportunities."

PETRONAS

ATPS

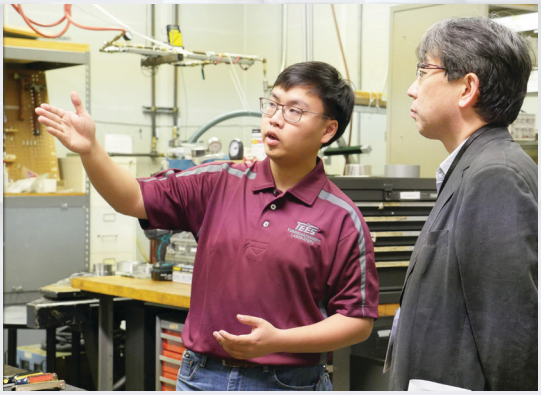
ASIA TURBOMACHINERY & PUMP SYMPOSIUM

Since 1981, the Turbomachinery Research Consortium at Texas A&M University has solved problems for major industry leaders through student-led research.

The Turbomachinery Research Consortium is a group of 33 companies that contribute annual fees of $25,000 to fund projects that are investigated by 15 to 20 Texas A&M graduate students and faculty in the Turbomachinery Laboratory. Each year, the Turbo Lab, a center of the Texas A&M Engineering Experiment Station (TEES), hosts a meeting for the TRC representatives where faculty members and students present the results of the past year's projects in addition to new or follow-on research proposals. Thirty-two reports and proposals were presented during the meeting held May 14-16 in College Station. The goal of the research projects is to find answers to questions relating to performance and reliability of turbomachinery—rotating equipment that extracts or adds energy to fluids.

39TH ANNUAL TURBOMACHINERY RESEARCH CONSORTIUM MEETING UNITES INDUSTRY & ACADEMIA

> "TRC brings a lot of value to our company and it is great to have partnerships such as this one. Some of the research papers and proposals for new research we've seen this year are very practical for topics that we work on a daily basis.
>
> **Jacek M. Jarosz, Global Rotating Equipment Leader, Flint Hills Resources Co.**



TRC representatives provided feedback on the projects to select which proposals receive funding. TRC member companies get access to all TRC research dating back to its foundation in 1981, a suite of platinum software, and highly qualified students for hire.

Jacek M. Jarosz, Global Rotating Equipment Leader at Flint Hills Resources Co., represented his company during the meeting. Jarosz said TRC gives him the opportunity to talk to professors and graduate students about real-time problem solving.

"TRC brings a lot of value to our company and it is great to have partnerships such as this one," he said. "Some of the research papers and proposals for new research we've seen this year are very practical for topics that we work on a daily basis."

TRC representatives reviewed the proposal materials through June, with awards for the next cycle announced in July. Work on selected projects began in September.

TRC
TURBOMACHINERY RESEARCH CONSORTIUM
EST 1981

TRC MEMBER COMPANIES

Atlas Copco

BHEL

U.S. ARMY

DEVCOM ARMY RESEARCH LABORATORY

ConocoPhillips

ELLIOTT GROUP EBARA CORPORATION

equinor

ETU i+D INVESTIGACIÓN Y DESARROLLO EN TURBOMAQUINARIA

ExxonMobil Research and Engineering

Garrett ADVANCING MOTION

GE Oil & Gas

Hanwha Techwin

HITACHI

Ingersoll Rand

Kawasaki

KOBELCO

KOCH INDUSTRIES INC

MAN Energy Solutions Future in the making

MITSUBISHI HEAVY INDUSTRIES

BR PETROBRAS

Pratt & Whitney A United Technologies Company

PRAXAIR SURFACE TECHNOLOGIES

SAFRAN

Schlumberger

SHENYANG BLOWER WORKS GROUP

Shell Global Solutions

SIEMENS Ingenuity for life

Solar Turbines A Caterpillar Company

SULZER

SwRI

TORISHIMA

WAUKESHA BEARINGS A DOVER COMPANY

2019-2020 PROJECTS LIST

Experimental Investigation of Morton Effect ME (Thermally Induced Rotor Instability)
(Dr. Palazzolo)

A Computational Model for the Forced Performance Analysis of Self-Equalizing Tilting Pad Thrust Bearings
(Dr. San Andres)

Solid Modeler Implemented Rotordynamics
(Dr. Palazzolo)

A Flow Starvation Model For Radial and Thrust Bearings Towards Better Computational Analysis Tools
(Dr. San Andres)

Morton Effect Prediction Software
(Dr. Palazzolo)

Evaluation of Mechanical Seal Failures due to Lateral Vibrations
(Dr. Delgado)

An Experimental and Computational Investigation of the Rotordynamic Coefficients of a Labyrinth Seal (Continuation)
(Dr. Delgado)

An Improved Bulk Flow Model for Dry and Wet Gas Pocket Damper Seals
(Dr. San Andres)

Making Better Swirl Brakes Using CFD Performance Assessment and Geometry Optimization
(Dr. San Andres)

Torsional/Lateral Rotordynamics Software with Variable Frequency Drives and Motor Eccentric Force Prediction
(Dr. Palazzolo)

Dynamic Characterization of 3D-Printed Damper Seals
(Dr. Delgado)

Experimental Identification of Force Coefficients in an Integral Squeeze Film Damper
(Dr. San Andres)

Rotordynamic Performance of a Turboexpander Supported on Gas-Lubricated Bearings
(Dr. Delgado)

An Efficient CFD Model for Qualification of Heat Oil Carry-Over Coefficients in Grooves and Ready Integration into XLTRC^2 Predictive Tools
(Dr. San Andres)


FACULTY, STAFF, STUDENTS SHARE INSIGHTS AT INTERNATIONAL ASME CONFERENCE

PHOENIX, Arizona — The Turbomachinery Laboratory furthered its global impact during the Turbomachinery Technical Conference & Exposition (Turbo Expo) in Phoenix, Arizona.

The conference, presented by the American Society of Mechanical Engineers (ASME) International Gas Turbine Institute, took place June 17-21. Experts from around the world came together to share the latest academic findings in turbine technology, research, development and application.

Turbo Lab faculty and students presented or hosted more than 30 technical papers and sessions, and Turbo Lab staff represented the Lab in the expo, booth 323.

Turbo Lab papers submitted to the conference were also accepted to the ASME Journal of Engineering for Gas Turbines and Power. Papers underwent a stringent review process in order to be journal-ready. They had to be interesting, original, innovative and of significant relevance to the gas turbine industry, according to ASME evaluation guidelines.

> "It's a big honor to get accepted to journal. This is common for the Turbo Lab. It speaks to the high-quality research, and the high-quality students and faculty behind the research."
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> **Dr. Eric Petersen, Turbo Lab Director**

"It's a big honor to get accepted to journal," said Dr. Eric Petersen, Turbo Lab director. "This is common for the Turbo Lab. It speaks to the high-quality research, and the high-quality students and faculty behind the research."

Dr. Luis San Andrés, Mast-Childs Chair professor, Mr. Bonjin Koo, and Dr. Sunghwa Jeung, former students in the Turbo Lab, received an ASME Best Paper Award from the Structures and Dynamics Committee for "Experimental Force Coefficients for Two Sealed Ends Squeeze Film Dampers (Piston Rings and O-rings): An Assessment of Their Similarities and Differences."

The Best Paper Award is given to papers that rank in the top one percent of all conference submissions. They are high-quality, original and contribute uniquely to the science of engineering.

Visit **turbolab.tamu.edu/news** to view all student and faculty contributions at the 2019 ASME Turbo Expo.

Turbo Lab members receive Young Engineer Turbo Expo Participant Award

COLLEGE STATION, TX — Three members in Dr. Luis San Andrés Tribology group and one of Dr. Dara Child's former graduate students were honored with a prestigious award for up-and-coming engineers.

Dr. Jing Yang, assistant research engineer in the Turbo Lab, and former students Dr. Bonjin Koo and Dr. Tingcheng Wu, and Nathan Balke, each received the 2019 Young Engineer Turbo Expo Participant Award from the American Society of Mechanical Engineers (ASME) International Gas Turbine Institute.

The burgeoning engineers received the award at the 2019 Turbomachinery Technical Conference & Exposition (Turbo Expo) in Phoenix, Arizona, June 17-22, where they each presented papers. The award included funding for travel expenses and registration to attend the conference.

The Young Engineer Turbo Expo Participation Award was implemented to encourage more early-career engineers to participate in the annual Turbo Expo. It is intended for young engineers working in industry, in government or in academia, and engineering graduate students in the gas turbine or related fields. Nominees must have obtained an academic degree in an engineering discipline related to turbomachinery, and present a paper or poster at the conference.


Nathan Balke


Dr. Bonjin Koo

Yang served as a session organizer for the Structures and Dynamics Committee, chaired a session in the Bearings & Seals Dynamics track, and presented a research paper titled "Leakage and Dynamic Force Coefficients of a Pocket Damper Seal Operating Under a Wet Gas Condition: Tests vs. Predictions." The project was funded by the Turbomachinery Research Consortium (TRC), a group of industrial firms whose annual membership fees support a broad range of member-selected research projects.

"I feel honored to have been selected and to work at a top-ranked turbomachinery laboratory," Yang said.

Koo, product engineer for Daikin Applied, presented "A Model and Experimental Verification of the Dynamic Forced Performance of a Tightly Sealed Squeeze Film Damper Supplied with a Bubbly Mixture." Koo, former student Dr. Sunghwa Jeung, and Prof. San Andrés also received a best paper award.

Dr. Wu, presently employed with Siemens as a senior rotordynamics engineer, presented three papers: "Pump Grooved Seals: A CFD Approach to Improve Bulk-Flow Model Predictions;" "Leakage and Cavity Pressures in an Interlocking Labyrinth Gas Seal: Measurements vs Predictions; and "Leakage and Force Coefficients of a Grooved Wet (Bubbly Liquid) Seal for Multiphase Pumps and Comparisons with Prior Test Results for a Three Wave Seal."


Dr. Tingcheng Wu


Dr. Jing Yang

All six conference papers from San Andrés group have been accepted for publication in the Journal of Engineering for Gas Turbines and Power.

Mr. Balke, mechanical engineer with Kuraray America, Inc. co-authored "Comparisons of a Liquid Annular Seal for Pump Applications with and without a Swirl Brake."

"I am incredibly proud of each of these engineers," said Dr. San Andrés, Mast-Childs Chair professor. "While at the Turbo Lab I enjoyed seeing their technical growth and desire to serve the professional society, so it's not a surprise that they continue to do well and are still producing quality research."

Nominations for the 2020 Turbo Expo young engineer award will close February 1. The 2020 Turbo Expo will be held in London, England June 23-25.

Turbo Lab's exhibitor services director takes home national saleswoman award

CHICAGO, Illinois — The Turbomachinery Laboratory's most veteran staff person was recognized with an award for her expertise and service in sales.

Martha Barton, CEM, director of exhibitor services in the Lab's Symposium Office took home the "Saleswoman of the Year" award at the inaugural Empowering Women in Industry one-day conference and gala in Chicago in September. Barton was among eleven other women who were celebrated with awards in categories including leadership, manufacturing, marketing, engineering, advocacy and innovation.

More than 60 nominations were collected by the Empowering Brands team, host of the conference and gala, and reviewed by a steering committee of 20 women who work in male-dominated industries.

"I've watched Martha dramatically redefine how an industry interacts with rotating equipment and engineering teams," read the nomination letter from Andy Martin, director of marketing and social media at PumpWorks. "I've watched Martha drive attendance targets with meaningful deliverables, actively engaged on many levels."

Barton has served as exhibitor services director for 16 years. In this role, she oversees all aspects of exhibitor services for the Lab's continuing education events, which include the Turbomachinery & Pump Symposia and the Asia Turbomachinery & Pump Symposium.

"I am both blessed and humbled at being nominated and then to receive the Saleswoman of the Year award for 2019," Barton said. "I have always felt relationship building was a strong gift of mine and made it the basis for both my personal and professional life. I firmly believe genuine relationships are the catalyst for success in every walk of my life."

> *From nomination letter:*
> I've watched Martha dramatically redefine how an industry interacts with rotating equipment and engineering teams.
>
> **– Andy Martin, Director of Marketing and Social Media, PumpWorks**

Organizations from across the industry were invited to sponsor an award and send a representative to the gala to announce the recipient. The Turbomachinery Laboratory sponsored the "Leadership in Reliability and Operations" honor, earned by Heather Hey, director of operations for FS-Curtis in St. Louis, Missouri. Brooke West, communications director for the Turbo Lab, presented the award.

The next Empowering Women in Industry conference and gala will be held in New Orleans, October 8, 2020.

It's A DREAM COME TRUE

Turbo Lab student researcher earns J. Mike Walker '66 Impact Award

COLLEGE STATION, TX — Any mention of shampoo and conditioner generally conjures up images of hair washing for most people. But for a young Catherine Dillier, it meant chemical reactions and science experiments.

Dillier recalls her first tour of the Turbomachinery Laboratory's Energetics Lab affectionately known as the "Rocket Lab."

"'You're going to let me do this—let me mix and test rocket propellants?'" Dillier, then an undergraduate, remembers asking rhetorically. "It was my childhood fantasy come to life."

Dillier is a mechanical engineering doctoral student and a member of the Petersen Research Group, where Dr. Eric Petersen, Turbomachinery Laboratory Director, Professor and holder of the Nelson-Jackson Chair, is her primary adviser. She was nominated by the Graduate Office of Mechanical Engineering and selected to receive the J. Mike Walker '66 Impact Award for her academic and innovative excellence and the impact her work has had on the department and field of study. Dillier received a $5,000 financial stipend and plaque during the fall Scholarship/Fellowship banquet in early November.

Dillier's research focuses on solid composite propellant. She takes novel additives and tailors formulations to meet certain criteria, such as burning rates or burning profiles. She looks at what is causing the burning rates and how the additives are reacting in the propellants. Currently, she is researching high pressure effects.

"No one has done this kind of research since the 60s and 70s," Dillier said. "I could go on and on about that, because they are so cool." Sensitive research projects limit how much she can elaborate for the general public, though.

Dillier points to new technology as key for improvements in motor performance through increased rocket motor pressures. Think space shuttle rocket boosters, which are actually solid rocket motors. Propellants are also found in airbags.

Outside of the Turbo Lab, Dillier organizes a graduate student group at St. Mary's Catholic Church. Each week she leads a small home group for graduate student women.

Dillier has her sights set on graduating in December 2020. She is interested in working for a Department of Defense laboratory and continuing her research in combustion.

"I love what I do," she said. "Why would I not just continue to do what I love?"

MACHINERY VIBRATION & ROTORDYNAMICS

Short Course Aids Staff In Solving On-The-Job Challenges

COMPANIES SEARCHING FOR A WAY TO ENHANCE EMPLOYEE KNOWLEDGEBASE

HOUSTON, TX — Thanks to a Machinery Vibration & Rotordynamics (MVRD) short course, Jason Cook was able to bridge a skills and education gap for his company.

Cook, researcher at Oak Ridge National Laboratory in Tennessee, knew his supervisor was searching for a way to enhance the staff's knowledge on rotordynamics. A quick internet search led him to the MVRD short course, and Cook knew it was just what he and his supervisor had been looking for. New to rotordynamics altogether, Cook said the course resulted in new ideas he could take back to the lab.

"I wanted a course that was academic, in that it was a classroom setting, but I also wanted something with practical application, Cook said. "This course has given me both."

The course, which took place in Houston in early January, was taught by former Turbo Lab director Dara W. Childs and Turbo Lab professors Adolfo Delgado and Luis San Andres as well as Fouad Zeidan, independent consultant and former president/owner of KMC Bearings, Plus, Inc.

Cook wasn't the only short course attendee who found valuable skills through the MVRD course.

Rob Pascarella, turbine generator subject matter expert at Entergy, was looking for a way to bridge the generation gap that he says is becoming more prevalent in companies today.

He sought out the course to strengthen his knowledge and share with others

"I've attended the Turbomachinery & Pump Symposia and took a course there that I enjoyed. I knew after attending that course that this course will be a helpful resource for my company moving forward," Pascarella said.

2020 SHORT COURSES

JANUARY | HOUSTON, TX

MACHINERY VIBRATION AND ROTORDYNAMICS

The course is designed to benefit both young engineers and veterans who want to freshen their skills and learn about what practices are helping others achieve success. During the four days, the course will cover basic vibration theory and how to use it to solve mechanical vibration problems experienced in the field. Rotordynamics terminology in common use will be defined and explained, including critical speeds, critical speed inversion, unbalance response and rotordynamic instability.

Date: January 6-10, 2020 | **Location:** DoubleTree, 15747 JFK Boulevard, Houston, TX 77032 | **CEU Credits:** 3.0
Cost: $2,700 (Early Registration thru December 27, 2019); $3,000 regular cost
Who should attend? The course offers concepts and techniques to engineers involved in design, operation, and maintenance of rotating equipment. Participants should have some experience with rotating machinery. For sessions of vibrations analysis and computer simulation, a Bachelor's degree or equivalent knowledge of basic college-level mathematics is assumed.
Instructors: Fouad Zeidan, Luis San Andres, Dara Childs, and Adolfo Delgado

MARCH | SAN ANTONIO, TX

NEW RECIPROCATING MACHINERY DYNAMICS

This new course will help you understand the fundamentals of machinery and piping vibration and assist you in determining their safety and reliability. You will gain insight into methods for analyzing systems in the design stage to eliminate/prevent problems.

Date: March 23-26, 2020 | **Location:** Embassy Suites by Hilton, San Antonio Airport, 10110 US Highway 281, Northern Blvd., San Antonio, TX 78216 | **CEU Credits:** 2.6
Cost: $1,800 (Early Registration thru March 11, 2020); $2,000 regular cost
Who should attend? The course is intended for engineers/analysts who work with plant machinery and piping and must make decisions about the reliability and safety of systems experiencing high vibration.
Instructors: Ken Atkins, Charles Hill, Troy Feese, and Stephen Price

CENTRIFUGAL COMPRESSOR OPERATIONS FOR 21ST CENTURY USERS (CCOPS)

Centrifugal Compressor Operations for 21st Century Users (CCOPS) is intended for beginning-and intermediate-level professionals to accelerate their understanding of centrifugal compressors and how they are used in oil & gas applications. The course covers design aspects, aerodynamics, rotordynamics, the practical applications of installation, testing, commissioning and procurement.

Date: March 23-26, 2020| **Location:** Embassy Suites by Hilton, San Antonio Airport, 10110 US Highway 281, Northern Blvd., San Antonio, TX 78216 | **CEU Credits:** 2.6
Cost: $2,040 (Early Registration thru March 11, 2020); $2,400 regular cost
Who should attend? This course is for beginning- and intermediate-level professionals interested in Centrifugal Compressor Operations.
Instructors: Jim Sorokes, Mark Sandberg, Jeff Moore, and Jigger Jumonville

ROTORDYNAMICS

The Turbo Lab's Rotordynamics course, offered each spring, is for beginning- and intermediate-level engineers in the petroleum, chemical, power and gas industries. It provides a basis for understanding the rotordynamics—the behavior and diagnosis— of turbines, compressors, expanders, motors, pumps and generators and their subcomponents to help select, analyze, troubleshoot and repair them for maximum reliability. The course is packed with case studies and workshops for hands-on evaluation of actual machines.

Malcolm Leader, owner of Applied Machinery Dynamics in Durango, Colo. has instructed the course for ten years. He is involved in the design, testing, modification, and installation of rotating equipment, and has written several papers on experimental rotordynamics, bearing design, design audits for rotating equipment and practical implementation of rotordynamic programs.

Date: March 23-26, 2020 | **Location:** Embassy Suites by Hilton, San Antonio Airport, 10110 US Highway 281, Northern Blvd., San Antonio, TX 78216 | **CEU Credits:** 2.6
Cost: $2,040 (Early Registration thru March 11, 2020); $2,400 regular cost
Who should attend? The course is intended for beginning and intermediate engineers in the petroleum, chemical, power and gas industries, as well as individuals interested in the dynamics of rotating machinery.
Instructors: Malcolm Leader

To learn more and register, visit turbolab.tamu.edu/short-courses.

TEES
TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

FACULTY & STAFF

DR. ERIC PETERSEN

TURBOMACHINERY LABORATORY DIRECTOR

- Gas turbine combustion
- Gas dynamics and propulsion
- Chemical kinetics
- Rocket propellants
- Optical diagnostics and spectroscopy

DR. DOUGLAS ALLAIRE

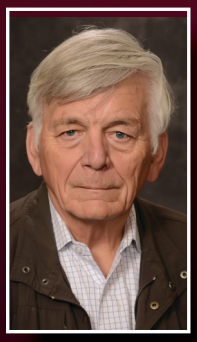
ASSISTANT PROFESSOR

- Machine learning
- Artificial Intelligence
- Optimization
- Uncertainty quantification

DR. PAUL CIZMAS

PROFESSOR

- Computational Fluid Mechanics'
- Internal flows of turbomachines
- Reacting flows



DR. DARA CHILDS

EMERITUS PROFESSOR, RETIRED

- Rotordynamics
- Reliability

DR. ADOLFO DELGADO

ASSOCIATE PROFESSOR

- Rotordynamics and seals
- Bearings
- Mechanical seals, ESPs

DR. JE-CHIN HAN

DISTINGUISHED PROFESSOR

- Heat transfer
- Turbine blade cooling
- Experimental heat transfer

DR. WARUNA KULATILAKA

ASSOCIATE PROFESSOR

- Laser diagnostics and spectroscopy
- Optical techniques for reacting flows
- Gas turbine combustion

DR. OLIVIER MATHIEU

ASSOCIATE RESEARCH PROFESSOR

- Chemical kinetics
- Experiments for reacting flows

DR. ALAN PALAZZOLO

PROFESSOR

- Rotordynamics and fluid film bearings
- Magnetic bearings for turbomachinery
- Flywheel energy storage

DR. LUIS SAN ANDRÉS

MAST-CHILDS CHAIR PROFESSOR

- Rotordynamics and bearings
- Fluid film bearings
- Oil-free turbomachinery

DR. LESLEY WRIGHT

ASSOCIATE PROFESSOR

- Heat transfer
- Turbine blade cooling
- Optical diagnostics for fluid flows

ASHTON DROLLINGER
Director of Operations

GREG GAMMON
Director of Global and Corporate Partnerships

MARTHA BARTON
Exhibitor Services Director

DEBBIE MAGGS
Program Specialist

JEANNIE GALINDO
Business Administrator, Registrar

STEPHANIE HIDALGO
Exhibitor Services Assistant

TIM MEEKMA
Business Coordinator

BROOKE WEST
Communications Director

CARL JOHNSON
Laboratory Facilities Manager

BY THE INDUSTRY

FREE TECHNICAL CONTENT

THE INDUSTRY

TOPICS:

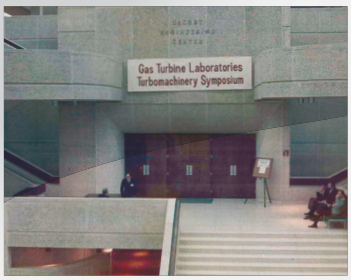
EMERGING DESIGNS AND TECHNOLOGY

MAINTENANCE

RELIABILITY

TROUBLESHOOTING

BEST PRACTICES



First Annual Symposium
Oct. 1972

Access program content from Turbo Lab-organized conferences dating back to 1972.

The professional continuing education programs at the Turbomachinery & Pump Symposia and Asia Turbomachinery & Pump Symposia are relied upon by rotating equipment and pump engineers and technicians worldwide. The programs are hand-picked by advisory committees of recognized leaders in the turbomachinery and pump communities, and led by highly-respected practitioners and pioneers in their fields.

The Founding Members of the Turbomachinery Advisory Committee (TAC)

FOR

The Proceedings from each Symposia become available to the public at no cost six months after the event. The Turbomachinery Laboratory at Texas A&M is proud to host a platform for the exchange of ideas that impact turbomachinery, pump and related industries.

turbolab.tamu.edu/proceedings

TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

TEXAS A&M UNIVERSITY

RESEARCH LAB ADDRESS

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1485 George Bush Drive W
College Station, Texas 77843

SYMPOSIUM OFFICE ADDRESS

NOTE: Symposium staff is expected to move to the Research Lab in December 2020.

Turbomachinery Laboratory
Texas A&M University
202 Spence Street
College Station, Texas 77843-3254

POSTAL (MAILING) ADDRESS

NOTE: Symposium staff is expected to move to the Research Lab in December 2020.

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SOCIALLY SPEAKING...

TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

Turbomachinery Laboratory at Texas A&M

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TURBOMACHINERY & PUMP SYMPOSIA

Turbomachinery & Pump Symposia

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ASIA TURBOMACHINERY & PUMP SYMPOSIUM

Asia Turbomachinery & Pump Symposium

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2020 CONTINUING

JAN 2020

EXTENDED SHORT COURSE

January 6-10, 2020
Machinery Vibration & Rotordynamics
Houston, TX

JAN 2020

EXTENDED SHORT COURSES

March 23-26, 2020
(Courses run concurrently)
San Antonio, TX

- Reciprocating Machinery Dynamics **NEW**
- Centrifugal Compressor Operations for 21st Century Users (CCOps)
- Rotordynamics

MAR 2020

APR 2020

Asia Turbomachinery & Pump Symposium

April 7-9, 2020
(Short Courses: April 6)
Kuala Lumpur, Malaysia

ATPS offers a world-class educational forum in combination with an international exhibition for working engineers and technicians in both the turbomachinery and pump industries.

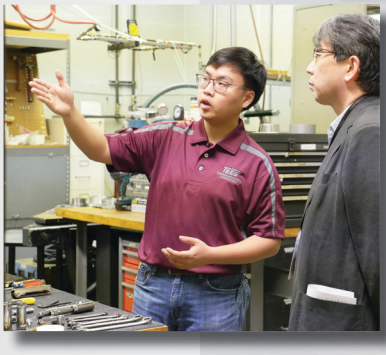
TEES
TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

EDUCATION OPPORTUNITIES

Turbomachinery Research Consortium (TRC) Annual Meeting

MAY 2020

May 12-14, 2020
Bryan-College Station, TX



TRC member company representatives review current project results; review new and continuing project proposals; tour the Turbo Lab facility; and network with students, faculty and colleagues.

OCT 2020

Call for Papers for TPS 2021

OCTOBER 2020
Abstracts Due

Be a part of the TPS 2021 technical program by submitting an abstract for a case study, lecture, tutorial or short course. Note that TPS 2021 will be held Dec. 14-16, 2021, with short courses on Dec. 13.

SEP 2020

Turbomachinery & Pump Symposia 2020

September 15-17, 2020
(Short Courses: Sept. 14)
Houston, TX

TPS is a vital industry event, offering a forum for the exchange of ideas between rotating equipment engineers and technicians worldwide through its technical program and exhibition.

Learn more about each of these opportunities at turbolab.tamu.edu.

OCT 2020

TEES

TURBOMACHINERY
LABORATORY

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