

2026 International Maha Fluid Power Conference

West Lafayette, IN, USA

September 8-10, 2026

Final Program



2026 International Maha Fluid Power Conference

FOREWORD

Dear Attendee,

On behalf of the Organizing Committee and the Maha Fluid Power Research Center at Purdue University, it is our great pleasure to present you with the final program for the 2026 International Maha Fluid Power Conference.

This is the fourth event organized by Maha at Purdue to foster networking, exchange ideas, and showcase the latest research trends in fluid power and motion control technologies. It is also our third gathering since the establishment of the Maha Industry Consortium in 2022. This year's conference continues to build on our strong tradition of bringing together global academic and industry leaders.

Throughout the three-day program, five academic leaders, ten industry executives, and two association representatives will deliver keynote addresses, unveiling current technology trends, industry needs, and future challenges. In addition, the schedule features 48 technical presentations from industry and research institutions worldwide. Several of these are presentation-only, while others are accompanied by peer-reviewed original publications. To recognize outstanding contributions to our field, the conference will also feature a Best Paper Award (selected from the peer-reviewed submissions) and a Best Presentation Award, generously supported by River Publishers.

During our Gala Dinner on September 9th, we will honor the memory of Maha's founder, the late Prof. Monika Ivantysynova. The Monika Ivantysynova Medal will be awarded to distinguished Purdue alumni who have demonstrated exceptional career achievements in fluid power and motion control.

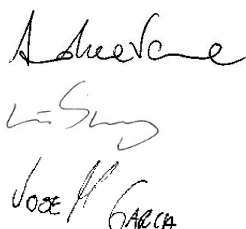
On September 9th, a technology exhibition will also take place, designed to engage both conference participants and the broader Purdue community. Concurrently, Purdue students will have the opportunity to participate in a dedicated recruitment event supported by the National Fluid Power Association.

We would like to extend our deepest gratitude to the authors, presenters, session chairs, and advisory committee members for their dedication to building this outstanding technical program. We are also incredibly grateful to the member companies of the Maha Industry Consortium for endorsing the event, and to the Industry Advisory Board for their organizational guidance and their assistance in the difficult task of selecting this year's medal winners. We further recognize our Gold, Silver, and Bronze Sponsors, whose generous support has allowed us to keep this event affordable for students and faculty members.

Finally, a special thank you goes to the Maha staff and students for their crucial help in coordinating all the conference details.

We hope you enjoy the conference, and that you leave with inspiration for new ideas and enriched professional connections.

Sincerely,



The Conference Chairs:

Andrea Vacca, Lizhi Shang, Jose Garcia-Bravo

2026 International Maha Fluid Power Conference

COMMITTEES

SCIENTIFIC COMMITTEE

From Academia:

Paolo Casoli, University of Parma, Italy
Victor J. De Negri, Federal University of Santa Catarina, Brazil
Liselott Ericson, Linköping University, Sweden
Wieslaw Fiebig, Wrocław University of Science and Technology, Poland
Emma Frosina, University of Sannio, Italy
Nigel Johnston, University of Bath, United Kingdom
Bernhard Manhartgruber, Johannes Kepler University Linz, Austria
Noah Manring, University of Missouri, United States
Tatiana Minav, Tampere University, Finland
Massimiliano Ruggeri, Italian National Research Council, Italy
Massimo Rundo, Polytechnic University of Turin, Italy
Katharina Schmitz, RWTH Aachen University, Germany
John Schueller, University of Florida, United States
Adolfo Senatore, University of Naples Federico II, Italy
Nariman Sepehri, University of Manitoba, Canada
Andrzej Sobczyk, Cracow University of Technology, Poland
Brian Steward, Iowa State University, United States
James Van de Ven, University of Minnesota, United States
Juergen Weber, Dresden University of Technology, Germany

From Industry:

John Bekker, Bucher Hydraulics
Pierre Bernard, Poclain Hydraulics
Filippo Boiardi, Settima Meccanica
Enrique Busquets, Bosch Rexroth
Germano Franzoni, Parker Hannifin
Ryan Jenkins, CNH Industrial
Eric Lanke, NFPA
Antonio Lettini, Casappa
John Mahrenholz, John Deere
Pedro Martins-Ferreira, TotalEnergies
Davide Mesturini, Walvoil
Steve Weber, Sun Hydraulics

ORGANIZING COMMITTEE

Andrea Vacca, avacca@purdue.edu
Lizhi Shang, shangl@purdue.edu
Jose Garcia-Bravo, jmgarcia@purdue.edu

KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 8, 1:15 pm Fowler Hall

Jean-Charles Mare (INSA Toulouse, France)

Trends in Actuation for Aerospace

Abstract: On basis of the author's experience, this keynote aims at taking the stock of the evolution and future of actuation for airplanes, helicopters and launchers. It starts by introducing the specificity of the aerospace domain in terms of market, needs and constraints for safety-critical actuation (flight controls, landing gears and engines). Then, the candidate actuation concepts are reviewed, with both considerations to incremental and step changes. The trends are addressed for Power-by-Pipe and Power-by-Wire architectures, without forgetting to show how they call for new equipment or components. Finally, the main challenges are listed and discussed, highlighting the opportunities offered by the fluid power domain to serve the future of aerospace actuation.



Jean-Charles Mare

Jean-Charles Mare is Emeritus Professor at Institut Clément Ader - INSA in Toulouse, France.

He was recruited at INSA Toulouse to teach mechanics and controlled mechanical systems. Between 2001 and 2008, he has directed the Mechanical Engineering department. In 2005, he co-initiated a new engineering degree in Systems Engineering of Technological Systems.

In parallel to his teaching activity, Jean-Charles Mare prepared his French Doctorat d'Etat about the modelling, simulation, identification and control of electrohydraulic actuators. He applied his work to safety-critical aerospace actuation. His research is centered on the system-level, addressing architecting, preliminary power sizing and control design, and virtual prototyping. Since 2000, J-C. Mare contributed to numerous national and European projects for the more electrical aircraft. As a member of the steering committee of SAE A-6 (Aerospace Actuation, Control and Fluid Power Systems), he contributes to the issuing of reference technical documents. From 2001 to 2025, J-C. Mare organized in Toulouse the international conference on Recent Advances in Aerospace Actuation Systems and Components. He is also the author of Aerospace Actuators, a book series in 3 volumes.

KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 8, 1:15 pm Fowler Hall

Jürgen Weber (TU Dresden, Germany) **Digitalization in Fluid Power**

Abstract: Fluid power is a key technology of mobile machinery, and large amounts of data are generated across the entire lifecycle, from static product descriptions through design and simulation data to operation, maintenance and condition data. However, this information often remains isolated in different formats and systems, and its potential remains unused. The collaborative project Fluid 4.0 closed this gap by developing digital solutions for fluid power in a cross-industry format based on the Asset Administration Shell (AAS), with its standardized descriptions, predefined submodels and various means of connectivity. Focusing on mobile-machinery examples, we demonstrate how the AAS can be utilized throughout the product lifecycle and turn data into value in its various phases, from engineering through commissioning and operation to recycling. Across all these phases, the full value of this cross-industry, cross-manufacturer approach can be unlocked through the joint commitment of all stakeholder along the lifecycle and with this contribution, the concept will reach its full potential.



Jürgen Weber

Jürgen received his PhD degree in Mechanical Engineering at TU Dresden in 1991. Over 30 years of experience in technology development, research and education followed his graduation. For 13 years he has worked in executive positions at CNH: - 4 years Head of Hydraulic Department and Head of Design Department - 5 years Global Head of Systems Architecture for Construction Equipment in CNH worldwide - 4 years Global Head of System Integration, Pre-development and Innovation for Construction Equipment in CNH worldwide; for all CNH Construction Machine Platforms: Excavator, Loader, Dozer, Grader, TLB, SSL, TH In 2010 Jürgen returned to TU Dresden as appointed university professor and chair of Fluid-Mechatronic Systems "Fluidtronic" and he heads up the Institute of Mechatronic Engineering at TU Dresden hosting the International Fluid Power Conference held every 2 years since 1998, alternating between Aachen and Dresden. Furthermore, Jürgen has been head of the Consulting Board for HYDAC, Sulzbach/Saar, for 10 years, still being a member, and was also appointed as a member of the Supervisory Board of Musashi Europe GmbH. He is a fellow and now chair of the Global Fluid Power Society. The membership of 5G Lab Germany at TU Dresden is a further indicator for more than 15 years of experience in management and coordination of research alliances as well as the activities as surveyor, PhD supervisor, over 300 publications, technical books and lecture notes. As CEO of the newly founded innovation center Construction Future Lab (CFLab gGmbH, Dresden) Jürgen will keenly continue with applied research and technology transfer with focus on digitization technologies in construction machines and processes.

KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 8, 1:15 pm Fowler Hall

Eric Lanke (NFPA, USA)

Future Trends in the U.S. Fluid Power Industry

Abstract: This is a time of remarkable opportunity for the U.S. fluid power industry. The pace of technological evolution continues to accelerate, with the industry on the leading edge of the challenges associated with an increasingly hybridized environment. Electrification, autonomous functions, and IoT-integrated technologies are helping OEMs and other customers drive towards greater efficiency and productivity. And in response, fluid power industry players are finding ways to reduce their product development cycles and are bringing more and more innovative technologies to market. This presentation will provide an overview of these technological drivers of change, and the ways in which the fluid power industry, and its industry association, are adapting.



Eric Lanke

Eric Lanke is the President and CEO of the National Fluid Power Association, a trade association of more than 300 organizations serving the hydraulic and pneumatic industries. He is responsible for setting NFPA's strategic direction, and overseeing the programs and communications needed to achieve its objectives. He also serves as the President and CEO of the NFPA Education and Technology Foundation, an affiliated charitable organization that supports outreach, education and research programs in fluid power. During his tenure with NFPA, he has worked to build coalitions that have launched, developed and grown numerous initiatives focused on the future of the fluid power industry, including the Technology Roadmap for the Fluid Power Industry and its pre-competitive research agenda for the development of new fluid power technologies.

KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 8, 3:15 pm Fowler Hall

Tatiana Minav (Tampere University, Finland)

EMA Implementation and Its AI-Based Condition Monitoring/Predictive Maintenance

Abstract: Today, Electro-mechanical actuators (EMAs) seen as an emerging transformative technology for heavy-duty mobile machinery. They offer a clear pathway toward higher energy efficiency, improved controllability. By converting electrical energy directly into mechanical motion, EMAs eliminate throttling losses inherent to hydraulics and enable precise, dynamic actuation that supports advanced automation and intelligent machine functions. Their compatibility with hybrid and fully electric powertrains positions EMAs as an attractive solution for next-generation low-emission equipment; yet this apparent simplicity conceals significant engineering challenges

Reliability under shock loads, vibration, and extreme thermal conditions remains a central concern, particularly where traditional hydraulics have a long track record of robustness. Integrating EMAs with the machine base and powertrain requires rethinking system architecture to ensure durability without compromising performance and reliability. This complexity creates a growing need for advanced health-monitoring and prognostic capabilities. This keynote will explore whether EMAs can truly be positioned as a key enabler in the transition toward low-emission, high-efficiency heavy-duty mobile machinery, and what technological developments are still required to unlock their full potential.



Tatiana Minav

Tatiana Minav (ASME and IEEE member) is Associate professor in IHA -Innovative Hydraulics and Automation lab, Tampere University, Finland. She over 20 years' experience working on improving the efficiency of non-road mobile working machines. She has authored in total 165 scientific publications. Her current interests include zonal hydraulics, electro-hydrostatic and electro-mechanical actuators, sensorless position control with direct electric drive in hydraulic systems, AI-based condition monitoring and predictive maintenance, thermal management, energy balance and energy recovery systems in non-road mobile working machines.

KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 8, 3:15 pm Fowler Hall

Jim Van De Ven (University of Minnesota, USA)

Investigation of Alternative Powertrains for Mobile Machines: Agricultural Sprayer Case Study

Abstract: Selecting the best powertrain architecture, component sizing, and control rules for a given mobile machine is highly dependent on the vehicle size, task, and drive cycle. This talk will explore emerging powertrain architectures for mobile machines with an example case study of comparing multiple alternatives for an agricultural sprayer.



Jim Van De Ven

James D. Van de Ven is a Professor at the University of Minnesota in the Department of Mechanical Engineering where he operates the Mechanical Energy and Power Systems (MEPS) Laboratory. Dr. Van de Ven's expertise is in the areas of machine design and dynamics, with specific interest in fluid power systems. Dr. Van de Ven has mentored over 50 graduate and undergraduate research assistants, published over 100 journal and conference papers, given over 70 technical presentations, and holds 12 provisional or utility patents. He is the past Chair of ASME Fluid Power Systems & Technology Division and Deputy Director of the Center for Compact and Efficient Fluid Power. He is an ASME Fellow and has been named a Distinguished University Teaching Professor.

KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 8, 3:15 pm Fowler Hall

Noah Manring (University of Missouri, USA)

Using Nondimensional Analysis to Model, Design, and Test Hydraulic Control Systems

Abstract: This paper presents the merits for modelling and designing hydraulic control systems using nondimensional analysis. It is shown in this paper that nondimensional analysis provides physical insight into the most important features of the control system, facilitating model reduction, providing a basis for machine-design sensitivity analysis, and reducing laboratory experiments. In engineering applications, nondimensional analysis is commonly used for fluid-thermal systems that depend on nondimensional groups such as the Reynold Number, the Mach Number, the Nusselt Number, among others. Even in dynamical systems we use the nondimensional damping ratio to describe the time response of a second order system; however, it is the author's opinion that nondimensional analysis presents a powerful technique for studying hydraulic control systems that should be exploited more fully in our industry. In this paper, the author will present three case studies to show the value of using nondimensional analysis for modelling a hydraulic control system, designing hydraulic machinery, and reducing laboratory experiments. By following these examples, it is believed that efficiency will be improved in bringing products to market, and the quality and performance of our products will be advanced.



Noah Manring

Noah D. Manring is a professor in the John J. Boswell Department of Mechanical and Aerospace Engineering at the University of Missouri.

Manring previously served as dean and Ketcham Professor of the College of Engineering, as well as chair of the Department of Mechanical and Aerospace Engineering and served as chair of the former Department of Electrical and Computer Engineering. On two separate occasions, he served as the college's associate dean of research. He was as associate dean for administration at Princeton University, and as a program manager at Caterpillar's Technical Center in Mossville, Illinois. He holds 15 U.S. patents for innovations in the field of fluid power.

As a professor, he has received research funding from Caterpillar Inc., Festo Corp. and the National Fluid Power Association, as well as from the Department of Education, the National Science Foundation and various private donors. He has additionally done consulting work for several industrial firms, including Moog Inc., FMC Wyoming Corp., Dennison Hydraulics and Parker Hannifin. Manring has published two books, Hydraulic Control Systems, first and second editions, and Fluid Power Pumps and Motors: Analysis, Design and Control. He currently is working on his third book, Opportunity, Genius, and Entrepreneurship: A History of Modern Engineering.

Before joining the MU faculty, Manring worked for eight years in the off-highway mobile equipment industry.

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KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 8, 3:15 pm Fowler Hall

Christian Geis (VDMA, Germany) Research-Industry Collaboration in Europe

Abstract: The industrial competitiveness of Europe's fluid power industry can no longer be taken for granted. Increasing global competition, new technologies and changing geopolitical realities are challenging established strengths and business models. To address these developments, the European fluid power sector has defined four strategic priorities: standardization, digitalization, innovation and cooperation. This keynote will provide an industry perspective on Europe's current situation and highlight how companies, universities and industry organizations are working together to strengthen the sector's long-term competitiveness. Drawing on practical examples from VDMA and CETOP initiatives, the presentation will demonstrate how collaborative efforts in research, digitalization, standardization and public affairs are translating these four priorities into concrete action. It will show how cooperation across the European fluid power community helps strengthen industrial resilience and create the foundation for future growth in a rapidly changing global environment.



Christian Geis

Dr. Christian Geis is Deputy Managing Director of the VDMA Fluid Power Association and Managing Director of the Research Fund for Fluid Power in Germany. He holds a PhD in Mechanical Engineering from the Darmstadt University of Technology and is responsible for strategy, research, innovation, digitalization and education within the German fluid power industry.

Christian actively promotes collaboration between industry, academia and policymakers and represents the sector in national and European initiatives, including CETOP, the European Committee for Oil Hydraulic and Pneumatic Equipment. His work focuses on strengthening the competitiveness of European fluid power through standardization, digitalization, innovation and international cooperation.

KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 9, 8:00 am Fowler Hall

Shawn Horner (Parker Hannifin, USA)

Future Trends in Motion and Control Technology

Abstract: Parker is the global leader in motion and control technologies, providing precision-engineered solutions for a wide variety of mobile, industrial and aerospace markets. This talk will provide an overview of the company and the secular trends driving growth. A specific focus will be on the inter-connected technologies in Parker's portfolio that are enabling the engineering breakthroughs needed in each of these areas.



Shawn Horner

Shawn Horner is currently the Vice President of Technology and Innovation for the Motion Systems Group of Parker Hannifin.

His key responsibilities include leading the Group's R&D efforts globally with a focus on new product development and sustaining engineering. In addition, he provides support to all Motion Systems divisions in the areas of strategy development and M&A.

Shawn has held a variety of roles during his 15 years with Parker, including Business Development Manager for multiple operating groups, Vice President of Corporate Strategy and Digital Initiatives and Vice President of Technology for the Instrumentation Group and the Motion Technology Center.

Prior to Parker, Shawn worked for GE in a variety of roles including engineering, six sigma and product management.

Shawn holds a B.S. degree in Mechanical Engineering and a Master's in Business Administration in Finance from Case Western Reserve University.

In the community Shawn is on the Board of Directors for the Great Lakes Science Center.

KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 9, 8:00 am Fowler Hall

Steffen Haack + Enrique Busquets (Bosch Rexroth, Germany) **AI in Fluid Power Technology**

Abstract: Based on the current state of digitization/ digitalization in hydraulics, potentials for the use of AI in fluid technology processes and products are presented. After clarifying the terminology and classifying the topic, differences between conventional AI and Gen AI are highlighted and current obstacles are discussed. The current AI landscape, the hardware required and the software requirements for using AI are presented. The first main section, "Use AI", presents a number of specific use cases with a focus on process improvements in the areas of engineering and design, training and knowledge management. The second main section, "Build AI", presents a number of product-related use cases at component and system level.



Steffen Haack

Steffen Haack has worked in the fluid power industry for over 20 years and spent another 10 years in electrical automation. Today, he works as CTO of Bosch Rexroth, where his main responsibilities are R&D of the entire company as well as the responsibility for the hydraulics business units. On a voluntary basis, he is Chairman of the Board of the VDMA Fluid Power Association and President of CETOP, the European umbrella organization for fluid power. He also gives lectures on the digitalization of hydraulics at technical universities in different countries.



Enrique Busquets

Dr. Busquets joined Bosch Rexroth in 2016 after earning his doctoral degree in fluid power systems from Purdue University. He currently serves as Vice President of Engineering, Service, and Aftermarket for Bosch Rexroth North America. Dr. Busquets oversees regional product and business development for hydraulic pumps, hydraulic valves, electronics, telematics, software, and electric products, as well as P&L responsibility for the service and aftermarket business in the US, Canada, and Mexico.

KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 9, 8:00 am Fowler Hall

Jeff Herrin (Danfoss, Denmark)

When Technology Leadership Is Not Enough - The Kings of Collaboration

Abstract: Innovation is actually a process, whereby technology, products and systems perfectly solve a customer pain point in a clever way such that the ultimate solution is ideal. We have learned through decades of innovation programs that the core idea or the technology behind the idea is never enough to guarantee a blockbuster solution. There are countless examples where great technology stalls on the entrepreneur's desktop because the full enablers of adoption were not present nor focused on. In this presentation, real-world examples where hydraulic technology adoption is clearly accelerated by add-on capabilities that create a full solution, well beyond just the core technology. Finally, a practical guideline to ensure great technology actually gets fully adopted in the mobile and industrial machinery industry will be shared.



Jeff Herrin

As Senior Vice President of Innovation & Development at Danfoss Power Solutions, Dr. Jeff Herrin and his team partners with our product divisions and external entrepreneurs and tech companies to develop industry-leading technology, solutions, and services. Based in Ames, Iowa, USA, Jeff joined Danfoss in 1998 and has held roles of increasing responsibility within Product and Systems Engineering. Prior to joining Danfoss, Jeff held research positions at NASA Langley Research Center and General Electric Corporate Research from 1993-1998. Jeff has a PhD in mechanical engineering from the University of Illinois at Urbana-Champaign. He has served on the NFPA Board of Directors in the USA for 6 years.

KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 9, 8:00 am Fowler Hall

Dave Norman (Moog, USA)

Fluid Power Earns Its Way on Modern Aircraft

Abstract: The motion-control industry is influenced by macro trends towards more electric, autonomous, and connected systems. We will discuss considerations and options for solving aircraft motion control challenges with the realization Fluid Power remains a powerful, resilient tool for today's modern aircraft.



Dave Norman

Current Role:

David currently serves as the Group Vice President, Engineering & Technology for Moog Inc., Military Aircraft Group

Experiences/Education:

Dave's early career at Moog involved progressively increasing responsibilities in both Product and Development Engineering roles delivering Flight Control Actuation solutions for commercial and military platforms

Dave's middle career at Moog involved Eng Leadership roles for Flight Control and Mission Critical System Solutions for Military Aircraft including F-22, X-47, F-35, and multiple classified platforms.

He has held a series of Engineering and Business leadership roles including Business Unit General Manager, Director of Growth and Innovation, and Vice President of Engineering and Technology.

BSc and MSc in Mechanical Engineering and Control Systems.

Executive Bio:

David Norman is an engineering and technology executive with deep enterprise leadership experience, proven P&L accountability, and a rare blend of corporate and entrepreneurial innovation expertise.

Entrepreneurial Innovation & Venture Creation

- Co-Founded and Built a services business delivering automation solutions to the pharmaceutical manufacturing industry
- Later formed and led an Innovation team within Moog Aircraft Group reporting to the Group President where he developed new capabilities in emerging markets for Moog, reinforcing innovation as a sustained competency—not a one-off experience

Core Competency - hands-on experience creating new businesses from scratch, commercializing technology, and operating in ambiguous, fast-moving environments—skills that are rare and highly transferable in enterprise settings.

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KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 9, 10:45 am Fowler Hall

John Tuntland + Mandi Henderson (CAT, USA)

How Caterpillar Advanced Technology Is Enabling Safer Outcomes and What It Means for Hydraulics

Abstract: With record 2025 revenues of \$67.6 billion and 1.6 million connected assets across approximately 190 countries, Caterpillar is the world's leading manufacturer of construction and mining equipment – and the invisible layer of the tech stack. Backed by \$30 billion in R&D, Caterpillar is redefining jobsite safety through active machine intervention, industrial AI, autonomy, and remote operations – with electrohydraulic systems at the foundation. This presentation will explore how these technologies are enabling safer, more productive outcomes, what that means for hydraulics, and how industry and suppliers can leverage the same enablers to advance safety in their own operations.



John Tuntland

John Tuntland is a senior vice president of Caterpillar Inc., responsible for the Integrated Components Division. In this role, he provides global leadership for the design and manufacturing of components used across the Caterpillar portfolio.

Since joining Caterpillar in 2001, Tuntland has held various roles with increasing responsibility in engineering, commercial and marketing, product management and operations. He has gained extensive international experience through multiple assignments in Asia and global operations leadership. Prior to his current role, John was vice president of the Resource Industries Operations team, which manufactures Caterpillar's prime product mining machines at global facilities specializing in assembly, fabrication, engineering, quality, safety, and supply chain operations.

Tuntland graduated from the University of Illinois with a Bachelor of Science in Agricultural Engineering and earned an MBA from Benedictine University in 2003. He also brings extensive entrepreneurial and leadership experience from outside the organization, including his ownership and operation of Tuntland Farms in northern Illinois.



Mandi Henderson

Mandi Henderson is Vice President of Global Hydraulics at Caterpillar, where she is responsible for the enterprise strategy and governance of the company's \$2 billion hydraulics business. In this role, she leads development and execution of the enterprise component strategy for hydraulics, with a focus on aftermarket growth, make/buy technology development and supply resilience. Mandi began her career as a design engineer at a small agricultural equipment manufacturer before joining Caterpillar as a test engineer in Fuel Systems. Since then, she has held a range of leadership and technical roles across fuel systems product development, category buying, supplier quality, engineering and hydraulics strategy. Her experience includes serving as Supplier Quality Manager for engine components in Europe, based in Peterborough, United Kingdom; leading engineering for Caterpillar-designed valves; overseeing the hydraulic valve portfolio and hydraulics labs; and serving as both a category manager for Resource Industries hydraulics and a hydraulic systems engineering manager. Raised in a small town in Saskatchewan, Canada, Mandi earned a Bachelor of Science in mechanical engineering from Queen's University in Kingston, Ontario, Canada. Outside of work, she enjoys playing hockey.

KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 9, 10:45 am Fowler Hall

Alberto Frulli + Stefano Fiorati (CNH, Italy/USA)

Transforming Off-Highway Machines Through Advanced Fluid Power Technologies

Abstract: The evolution of agricultural machinery toward automation and autonomy is transforming the role of hydraulic systems. Traditionally valued for power density and robustness, hydraulics must evolve into intelligent electro-hydraulic architectures capable of sensing, communication, and real-time control. Advanced fluid power technologies, are turning hydraulics into a key enabler of vehicle intelligence, transforming power transmission systems into scalable automation platforms to support precise motion control, implement coordination, and autonomous operation. This transformation delivers greater precision, efficiency, machine availability, and productivity while helping address skilled labor shortages. At the same time, it drives a talent shift, requiring new competencies that combine hydraulics with electronics, software, controls, sensing, AI, and systems engineering to develop the next generation of autonomous off-highway machines.



Alberto Frulli

Alberto Frulli is the Fluid Power Director at CNH.

He is responsible for defining roadmaps for hydraulic and pneumatic components and systems, and for developing advanced engineering solutions to support future strategies and new product launches across the company's entire portfolio.

He began his career at CNH in 2005 as a Hydraulic Test Engineer. From 2012 to 2017, he managed the European Driveline and Hydraulic Product Validation activities. He then moved to Driveline Product Development, where his most recent role, held until 2025, was Small & Specialty Drivelines Product Development Senior Manager.

He holds a Master's degree in Mechanical Engineering from the University of Modena and Reggio Emilia, Italy, where he has also served as a member of the Industry Advisory Board for the Mechanical and Vehicle Engineering Degree Program.

He is an Adjunct Professor at MUNER (Motorvehicle University of Emilia-Romagna), where he teaches Power Transmission for Off-Highway Vehicles within the Master's Degree Program in Advanced Automotive Engineering - Off-Highway Vehicles.



Stefano Fiorati

Stefano Fiorati is the Powertrain Innovation Director at CNH.

He is responsible for advancing and expanding driveline, hydraulic, electrification and engine technologies across the Company's entire agriculture product portfolio.

Prior to this appointment, Mr. Fiorati was Manager of Tractor Innovation, Zero Emission & Advanced Drivetrain at CNH from 2021-2023 and Tractor Innovation from 2014-2021. In this previous role, he was technical project leader for the New Holland T6.140 Methane Powered tractor prototype and subsequent concepts, presented in 2015 and 2017 respectively and in production since 2021.

Moreover, project related to automation on tractor-baler were under Mr. Fiorati's responsibility like the Agritechnica 2019 awarded "Baler Mode". He is the owner of more than 40 patents.

Mr. Fiorati started his professional career with CNH Industrial in 2011 as Mechanical Design Engineer within the Innovation department.

Stefano Fiorati has a PhD in Mechanics of Machine awarded jointly by the University of Ferrara, Italy, and the Katholieke Universiteit Leuven, Belgium. He has a master's degree in Mechanical Engineering from the University of Ferrara, Italy.

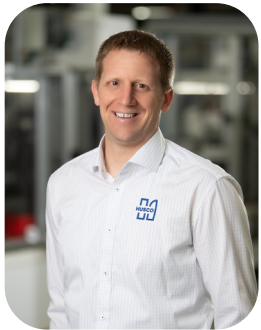
KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 9, 10:45 am Fowler Hall

Corey Quinnell (Husco, USA)

Why the Best Engineering Does Not Always Win

Abstract: The engineers who make the biggest difference are not always the ones who know the most. They are the ones who create the most value—for their teams, their customers, and the world around them. Attendees should leave with a broader definition of engineering success and a renewed perspective on how they can grow—not just as technical experts, but as influential problem-solvers capable of shaping products, organizations, and industries.



Corey Quinnell

Corey Quinnell is the Vice President of Global Engineering at Husco, a leader in hydraulic and electro-hydraulic control systems. With over 20 years of engineering excellence, Quinnell leads international teams to design and implement innovative product architecture across the automotive and off-highway industries. A passionate advocate for education, he was recognized by BizTimes Milwaukee as a Notable Leader in STEM for his extensive work mentoring student co-ops and developing technical engineering curricula. He holds a Master of Engineering Management from the University of Wisconsin-Madison and specializes in fluid power systems, Six Sigma methodologies, and advanced product development.

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GENERAL INFORMATION

PROGRAM FORMAT

Each presenter receives ONLY 20 minutes total, for both presentation and question/answers. Speakers can find their presentation time in the Program Overview. Speakers are advised to meet their session chair at the presentation room and address any presentation questions they might have before the start of the session. During this time, it is also recommended to upload the presentation in the dedicated presentation computer or verify that a personal laptop can be used for the presentation.

PICTURES AND VIDEOTAPING DURING THE CONFERENCES

Conference attendees may NOT take pictures or videos at any presentation without the consent of the author or presenter. An official photographer will be taking pictures during the conferences.

EXPO PROGRAM

The conference Expo will take place on Sept. 9th at the north end of the Memorial Mall, next to the Stewart Center. The Ballrooms of the Purdue Memorial Union (PMU) will be used in case of unfavorable weather conditions. Exhibition hours are 8:00 am to 3:50 pm on Sept. 9th. The Expo will be accessible to everyone, including people not registered to the Maha Conference. Feel free to engage with Purdue students curious about fluid power technology.

ACCESSING PUBLISHER PAPERS and PRESENTATIONS

Technical presentations featuring peer-reviewed papers will have the manuscript accessible by conference participants during the conference. A link / QR code will be provided during the conference. Technical presentation slides will be shared with the conference delegates after the conference, and posted on the Maha center website.

GENERAL INFORMATION

SOCIAL EVENTS

Conference dinners

A cocktail hour (5:30 pm) will precede the conference dinners (6:30 pm). These will occur at the Buchanan Club (Ross-Ade Stadium, 5th floor) on September 8th and at the North Ballroom of the Purdue Memorial Union (PMU) on September 9th. With the exception of some reserved tables, seating is open to maximize network exchanges.

Conference lunches

Lunch boxes will be provided on Sept 9th (12:30 pm) and Sept 10th (12:20 pm) at room 206 of Stewart Center

Maha farewell

A farewell party will occur on Sept 10th at 4:20pm at the Maha Fluid Power Research Center (address: 1500 Kepner Dr., Lafayette, IN). Please contact the conference office in case you need transportation.

INTERNET ACCESS

Wireless internet is available to all attendees via the ATT WIFI hotspot. Please choose ATT Wifi as your internet connection. When you open a browser, you will be automatically connected. You will need to provide your email address and accept terms & conditions. If you have difficulties, please visit the Conference Office

SMOKING POLICY

Smoking is prohibited on the West Lafayette Campus, except in designated smoking areas. All smoking material shall be extinguished and disposed of in an appropriate receptacle at the perimeter of the campus. Designated smoking areas are published in maps around the Purdue campus. The closest smoking area to Stewart Center is located across Sate Street, north of the Agricultural Administration Building.

2026 International Maha Fluid Power Conference

GENERAL INFORMATION

LIMO SERVICE FROM CLOSE AIRPORTS

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Provides service to and from the Indianapolis International Airport (765) 497-3828 or lafayettelimo.com

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PARKING ON CAMPUS

Parking is available in garages on the Purdue campus. There are two gated parking garages which do not require parking permit (daily rate about 10\$/day):

Grant Street Parking garage (120 S Grant St, West Lafayette, IN 47906) <-- most convenient option (5 min walk)

Harrison Street Parking garage (719 Clinic Dr, West Lafayette, IN 47907) <-- 15 min walk

There are other parking garage across campus but that require a "A" parking permit. Among these, good options are the Wood Street Garage or University Street Garage, both under 10 min walk.

Visitors can purchase "A" garage permits or multiple day passes at the Parking facilities office (494-9494) Monday-Friday 7:30-4:30. The price is \$5.00/day and allows parking in any garage EXCEPT Grant Street and Harrison Street garages. Do not park in marked parking spaces or you will be ticketed. We are not able to get your ticket dismissed. For detailed information visit https://purdue.t2hosted.com/cmn/auth_ext.aspx

2026 International Maha Fluid Power Conference

GENERAL INFORMATION

REGISTRATION AND CHECK-IN

Registration will be held on the first floor of Stewart Center in room 109BC from 7:30 am to 1:30 pm on Tuesday, September 8th, and outside Stewart Center 206 from 8:00 am to 10:30 am on Wednesday, September 9th. Both attendees and exhibitors will need to check in at this location.

MAHA INDUSTRY ADVISORY BOARD MEETING

The Maha Industry Advisory Board meeting will take place during lunch on Thursday, September 10, from 12:20 pm to 1:20 pm in Stewart Center 202. Please note that this is a closed-door, invitation-only session. Attendees are welcome to grab their lunch beforehand and bring it to the room. For questions regarding the meeting agenda, please contact the conference chairs.

CONFERENCE AI PORTAL

For the first time, the Maha conference provides an artificial intelligence portal that lets an attendee's preferred assistant read the conference information. Scan a code below and start a chat to learn more about the conference.

Scan either code directly with your phone camera if you use Claude or ChatGPT.

Or scan this code and copy the prompt into another chatbot, such as Gemini or Copilot.

Claude



ChatGPT



2026 International Maha Fluid Power Conference

PROGRAM OF EVENTS

TUESDAY, SEPTEMBER 8

1:00 PM		OPENING AND REMARKS
1:15 PM	STEWART CENTER FOWLER HALL	KEYNOTE LECTURE Session Chair: Jim Van De Ven Jean-Charles Mare (INSA Toulouse, <i>France</i>) Trends in Actuation for Aerospace Jürgen Weber (TU Dresden, <i>Germany</i>) Digitalization in Fluid Power Eric Lanke (NFPA, <i>USA</i>) Future Trends in the U.S. Fluid Power Industry
2:45 PM	WEST FOYER	BREAK
3:15 PM	STEWART CENTER FOWLER HALL	KEYNOTE LECTURE Session Chair: Jürgen Weber Tatiana Minav (Tampere University, <i>Finland</i>) EMA Implementation and Its AI-Based Condition Monitoring/Predictive Maintenance Jim Van De Ven (University of Minnesota, <i>USA</i>) Investigation of Alternative Powertrains for Mobile Machines: Agricultural Sprayer Case Study Noah Manring (University of Missouri, <i>USA</i>) Using Nondimensional Analysis to Model, Design, and Test Hydraulic Control Systems Christian Geis (VDMA, <i>Germany</i>) Research-Industry Collaboration in Europe
5:30 PM	BUCHANAN CLUB	SOCIAL EVENTS
6:30 PM		DINNER

2026 International Maha Fluid Power Conference

PROGRAM OF EVENTS

WEDNESDAY, SEPTEMBER 9

8:00 AM	STEWART CENTER FOWLER HALL	KEYNOTE LECTURE Session Chair: Lizhi Shang Shawn Horner (Parker Hannifin, <i>USA</i>) Future Trends in Motion and Control Technology Steffen Haack + Enrique Busquets (Bosch Rexroth, <i>Germany</i>) AI in Fluid Power Technology Jeff Herrin (Danfoss, <i>Denmark</i>) When Technology Leadership Is Not Enough - The Kings of Collaboration Dave Norman (Moog, <i>USA</i>) Fluid Power Earns Its Way on Modern Aircraft
10:15 AM	WEST FOYER	BREAK
10:45 AM	STEWART CENTER FOWLER HALL	KEYNOTE LECTURE Session Chair: Andrea Vacca John Tuntland + Mandi Henderson (CAT, <i>USA</i>) How Caterpillar Advanced Technology Is Enabling Safer Outcomes and What It Means for Hydraulics Alberto Frulli + Stefano Fiorati (CNH, <i>Italy/USA</i>) Transforming Off-Highway Machines Through Advanced Fluid Power Technologies Corey Quinnell (Husco, <i>USA</i>) Why the Best Engineering Does Not Always Win
12:30 PM	STEWART CENTER 206	LUNCH <i>in parallel with NFPA Student Recruiting Session at Stewart Center 202</i>
1:30 PM	PURDUE MALL	EXPO <i>in parallel with NFPA Student Recruiting Session at Stewart Center 202</i>

2026 International Maha Fluid Power Conference

PROGRAM OF EVENTS

WEDNESDAY, SEPTEMBER 9 (continued)

2:30 PM	STEWART CENTER 278	GEAR AND VANE PUMPS Session Chair: Liselott Ericson Parth Tawarawala (Purdue University, <i>USA</i>) Analysis of Efficiency and Axial Compensation in Continuous-Contact Helical Gear Pumps through Multiphysics Lubrication Modeling and Experimental Validation Carlo Maria Vescovini (Casappa, <i>Italy</i>) Enhanced Multi-Objective Multi-Physics Optimization of Pump Timing Applied to a Dual-Flank Contact Helical Gear Pump Jinglun Qu (Purdue University, <i>USA</i> and Veljan Denison Limited, <i>India</i>) Improvement of Filling Performance of a Balanced Vane Pump through Numerical Analysis and Experimentation Jeff Blaszc (Moog, <i>USA</i>) High Speed Tungsten Carbide Stacked Vane Pump	STEWART CENTER 279	NOVEL TECHNOLOGY IN OFF ROAD VEHICLE Session Chair: Brian Steward Paul Michael (Milwaukee School of Engineering, <i>USA</i>) Influence of Fluid Properties on Hydraulic System Losses in Dynamometer and Excavator Field Testing Xin Tian (CNH, <i>Italy/USA</i>) Off-Road Vehicle Performance & Fluid Power: From Concept Sketch to Hi-Fi and Real-Time Modeling Timir Rajendra Patel (Purdue University, <i>USA</i> and Bobcat, <i>USA</i>) High Efficiency Independent Metering System with Energy Recuperation: The Case of a Mini-Excavator Vignesh Jeganathan (Simerics, <i>USA</i> and Parker Hannifin, <i>USA</i>) Bridging 1D System Modeling and 3D CFD for Hydraulic Slack Adjuster Design: A Decoupled Co-Simulation Approach
3:50 PM	STEWART CENTER 206	BREAK		
4:10 PM	STEWART CENTER 278	PISTON PUMPS AND MOTORS Session Chair: Noah Manring Roman Ivantysyn (TU Dresden, <i>Germany</i>) Ultra Compact High-Speed Axial Piston Pumps for Electrified Mobile Machinery: Optimizing and Testing Tribological Gaps for 10,000 rpm Julien Ntede Florent (University of Bologna, <i>Italy</i> , Purdue University, <i>USA</i> , and Bonfiglioli S.p.A., <i>Italy</i>) Numerical Analysis of the Influence of Ball Joint Clearance on the Elastohydrodynamic Performance of Slipper Interfaces in Axial Piston Motors Karl Stübig (Danfoss, <i>Denmark</i>) Cylinder Block Deformation as Indicator for Cylinder Pressure in Axial Piston Units: A Novel Method Using Strain Gauges Pierre Bernard (Poclain Hydraulics, <i>France</i>) Increasing Tool Productivity by Re-Engineering Radial Pistons Cam-Lobe Motors	STEWART CENTER 279	SUSTAINABLE FLUID POWER Session Chair: Aleksandar Egelja Olivier Reinertz (Institute for Fluid Power Drives and Systems (ifas), RWTH Aachen University, <i>Germany</i>) How Fluid Power Research Can Contribute to a More Sustainable Construction Industry Justin Hernan (Parker Hannifin, <i>USA</i>) Electrification-Enabled Hydraulic Architecture: Improving Efficiency and Total Cost of Ownership Samuele Nizzardo (University of Padova, <i>Italy</i> and Purdue University, <i>USA</i>) Full 3D CFD and FEM Validation of Surrogate-Optimized Hydraulic Manifolds Designed via the M0ThEA Framework Medhat Khalil (Milwaukee School of Engineering, <i>USA</i>) Energy Saving Strategies in Hydraulic-Driven Machine Design
5:30 PM	PMU NORTH BALLROOM	SOCIAL EVENTS		
6:30 PM	PMU NORTH BALLROOM	DINNER		

2026 International Maha Fluid Power Conference

PROGRAM OF EVENTS

THURSDAY, SEPTEMBER 10

8:30 AM	STEWART CENTER 278	DRIVE AND STEER-BY-WIRE Session Chair: Olivier Reinertz Timothy Oppewall (Husco, <i>USA</i>) Steer by Wire Safety: Preserving Steering Under Fault Conditions Through Physics Driven Design Matthias Krug (Thomas Group, <i>Germany</i>) Development of a Demonstrator for a Full Steer-by-Wire Solution Qadeer Ahmed (Ohio State University, <i>USA</i>) Powertrain-Aware Explainable Reinforcement Learning Energy Management in Off-Road Vehicles Barun Acharya (Parker Hannifin, <i>USA</i>) Electrified Traction Architectures for Off-Highway Mobile Equipment: A Decision Framework Lasse Schmidt (Aalborg University, <i>Denmark</i>) Electro-Hydraulic Drive Networks for Next-Generation Working Machines - Design & Results for an Excavator	STEWART CENTER 279	HYDRAULIC COMPONENT TECHNOLOGY Session Chair: Paul Michael Elton Bishop (DigitalHydraulic LLC, <i>USA</i>) Novel Poppet Valve for Digital Hydraulic Transformer Austin Zapata (Purdue University, <i>USA</i>) When Orifice Flow Must Consider Extensional Effects Shanmukh Sarode and Howard Zhang (Parker Hannifin, <i>USA</i>) Sustainability Driven Advanced Hydraulic Pump Designs and Global Fluid Qualification Processes Anders H. Hansen (Aalborg University, <i>Denmark</i>) Experimental Investigation of a Novel Load-Holding Valve Technology Enabling Energy Recovery for Safety-Critical Hydraulic Systems Leonardo Franquillino and Prithvi Nareish Chandiramani (Purdue University, <i>USA</i>) A Novel Hydraulic-Mechanical Linear Actuator Technology for High Efficiency Architectures
10:10 AM	STEWART CENTER 206	BREAK		
10:40 AM	STEWART CENTER 278	SYSTEM DIAGNOSTICS & SIMULATION Session Chair: Lasse Schmidt Stefano Li Veli (University of Sannio, <i>Italy</i> and University of Naples, <i>Italy</i>) Experimental Characterization and Numerical Modelling of an Electric Vehicle Thermal Management System Integrating a Screw-Type ePump Raul Rodriguez (Bosch Rexroth, <i>USA</i> and Ansys/Synopsys, <i>USA</i>) Improving Structural Performance of a High-Pressure Hydraulic Portblock Using Manufacturing-Aware Shape Optimization and Automated Geometry Recovery Brian Steward (Iowa State University, <i>USA</i>) Real-Time Anomaly Detection for J1939-Based Mobile Hydraulic Control Systems Jinhwan Lee (Purdue University, <i>USA</i> and Poclairn Hydraulics, <i>France</i>) A Transient Thermo-Elasto-Hydrodynamic Model for Multi-Lobe Radial Piston Motors Pawan Panwar (Milwaukee School of Engineering, <i>USA</i>) Predictive Maintenance for Hydraulic Pumps through Operating-Point-Aware Deep Learning of Vibration Signals	STEWART CENTER 279	SENSORS AND CONDITION MONITORING Session Chair: Jose Garcia Bravo Massimiliano Ruggeri (STEMS - Institute for Energy and Sustainable Mobility of the CNR, <i>Italy</i> and VIS Hydraulics Srl, <i>Italy</i>) New Sensing Method for Cartridge Valves Daniel Gysling (Corvera, <i>USA</i> and HYDAC, <i>Germany</i>) SONAR-Based Gas Void Fraction Monitoring for Mobile Hydraulic Systems Annalisa Sciancalepore (Sun Hydraulics, <i>USA</i>) Valve-Integrated Position Sensing (VIPS) for Flow Estimation and Monitoring in Electrohydraulic Systems Ishan Suvarna (Purdue University, <i>USA</i> and Bosch Rexroth, <i>USA</i>) Numerical Modeling of Slipper-Swashplate Interface considering Wear and Thermal Effects Kailash Choudhary (Purdue University, <i>USA</i> and Casappa, <i>Italy</i>) Experimental Investigation of Micromotions in Helical External Gear Machines
12:20 PM	STEWART CENTER 206	LUNCH <i>in parallel with Maha Industry Advisory Board Meeting at Stewart Center 202</i>		

2026 International Maha Fluid Power Conference

PROGRAM OF EVENTS

THURSDAY, SEPTEMBER 10 (continued)

1:20 PM	STEWART CENTER 278	ELECTRIFICATION, DIGITALIZATION & SYSTEM DESIGN Session Chair: Tatiana Minav Germano Franzoni (Parker Hannifin, <i>USA</i>) Hydraulic Innovation in the Real World: Why Some Technologies Thrive, Many Stall, and What Comes Next Liselott Ericson (Linköping University, <i>Sweden</i>) Electrification of Mobile Machines - Exploiting Increased Degrees of Freedom in System Design Anthony Khoraych (Advanced Test and Automation Inc., <i>Canada</i>) From Simulation to Decision-Grade Evidence: Automated Pump Validation for Electrified and Severe-Duty Systems Christian Bock (Bosch Rexroth, <i>USA</i>) Rexroth's Component Digitalization Strategy: How Software Is Redefining Hydraulics Scott D. Sudhoff (Purdue University, <i>USA</i>) Understanding and Mitigating Common Mode Current in Electrified Systems Elena Menegatti (Purdue University, <i>USA</i>) Advances in H2 Engine-Powered Off-Road Vehicles through Integrated Hydraulic System Design and Control	STEWART CENTER 279	SIMULATION TECHNOLOGY Session Chair: Harish Manne Francesco Corradin (Walvoil, <i>Italy</i>) Model Based Design Applied to the Software Development of a Fully Digitalised Hydraulic Circuit - Smart Miniexcavator Case Study Naoki Hirose (IHI Corporation, <i>Japan</i> and Kyushu Institute of Technology, <i>Japan</i>) Unsteady CFD Analysis of Alternating Flow Patterns in a Restrictive Orifice of a Pressure Regulator Valve Priyanka Viswanath (Simerics, <i>USA</i> and Parker Hannifin, <i>USA</i>) 1D System Modeling and 3D CFD Co-Simulation Methodology for Analyzing Transient Behavior in Hydraulic Valves Romain Nicolas (Siemens, <i>France</i>) Excavator Closed-Loop Simulator: From Fuel to Soil Kai Ping Qwah (Purdue University, <i>USA</i> and Thomas Group, <i>Germany</i>) Modeling of Rotor Deformation Effects in Gerotor Pumps for High Pressure Applications Zihao Xu (Purdue University, <i>USA</i>) Experimental Characterization and Control-Oriented Modelling of Proportional Valves for Multi-Common Pressure Rail Systems
3:20 PM	STEWART CENTER 278	CLOSURE AND AWARD		
3:35 PM	-	TRAVEL TO MAHA		
4:20 PM	MAHA LAB	LAB TOUR AND SOCIAL EVENT		

2026 International Maha Fluid Power Conference

RECRUITING EVENT

WEDNESDAY, SEPTEMBER 9

Our goal is to provide a space for companies and students to casually interact with each other, and for both students and recruiters to be professionally matched to each other. The event is sponsored by the National Fluid Power Association.



This event aims to increase students' awareness of the fluid power industry by engaging with companies and exploring careers in our industry.

The event will take place from 12:00 to 2:30 pm in STEW 202. Students may pre-register by submitting their resumes. Participating companies may set up before 11:00 am and join at no additional cost. For more information, please contact Prof. J. Garcia-Bravo.

2026 International Maha Fluid Power Conference

AWARDS

MONIKA IVANTYSYNNOVA MEDAL



Monika Ivantysynova Medal Award recognizes individuals with early association with Purdue who have distinguished themselves for career achievements in fluid power and related industries. The award is dedicated to Prof. Monika Ivantysynova, one of the most accomplished individuals in fluid power and the founder of the Maha Fluid Power Research Center.

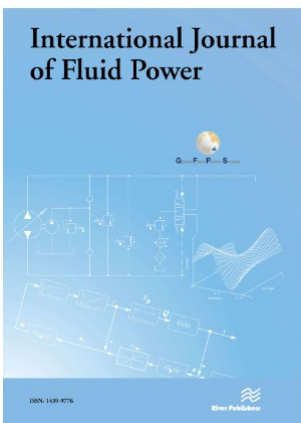
The awardee (up to two awards) will be announced at the 2026 International Maha Fluid Power Conference during the gala dinner on September 9th.

BEST PAPER AND BEST PRESENTATION AWARDS

Best Paper and Best Presentation Awards are sponsored by River Publishers and the Global Fluid Power Society (www.gfpsweb.org). One award will be given to the best peer-reviewed paper presented during the conference, and up to two awards will be given to the best technical presentations. The winners will be selected by committees of experts. These awards will be announced during the closure event of the 2026 International Maha Fluid Power Conference.



JOURNAL PUBLICATIONS

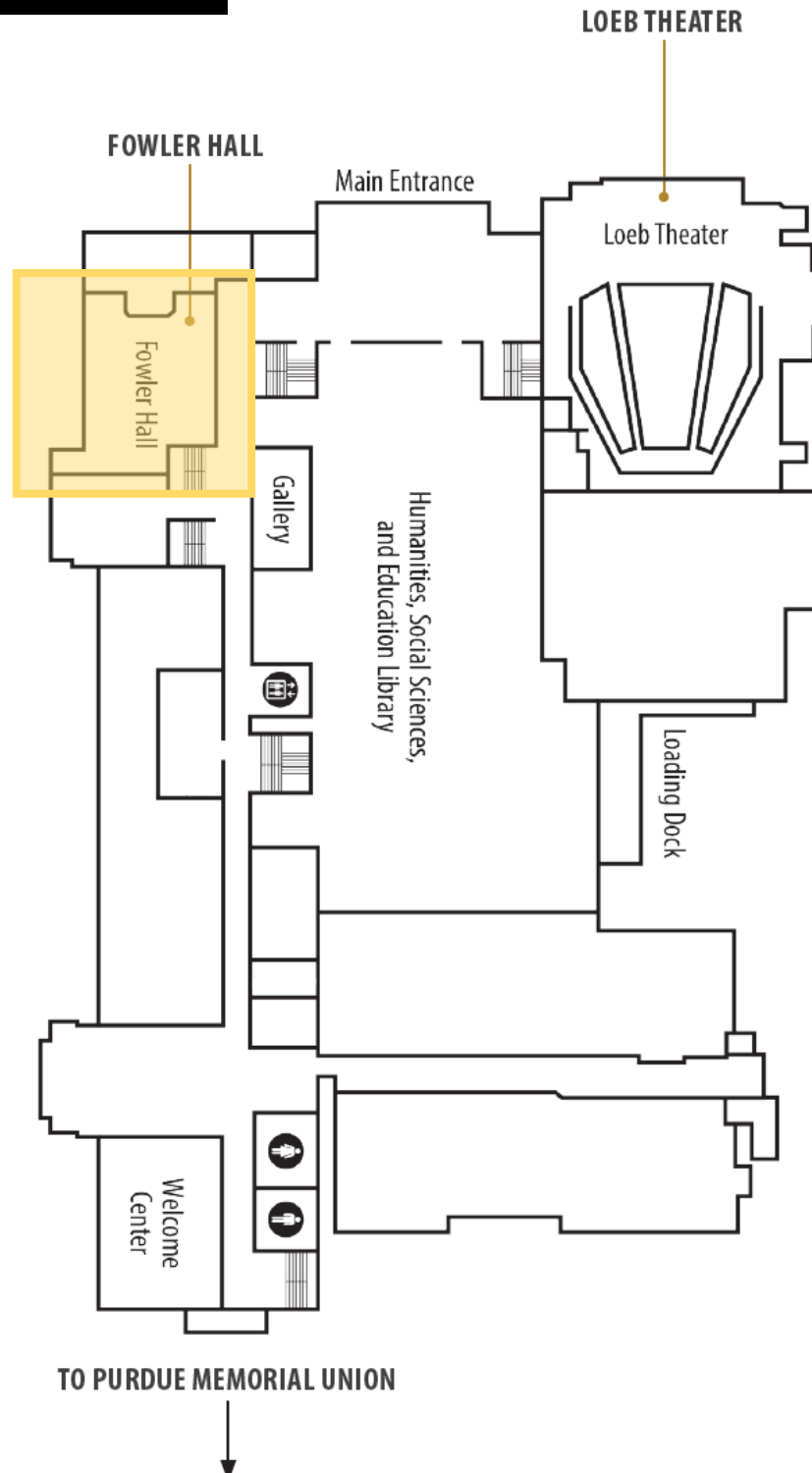


A subset of papers (up to 8) presented during the conference will be selected for subsequent publication on the International Journal of Fluid Power (journals.riverpublishers.com/index.php/IJFP/index). These papers will be selected based on the reviewers' scores obtained prior the conference. The authors of the selected papers will be contacted by the conference organizers for coordinating the publication on the journal.

STEWART CENTER MAP

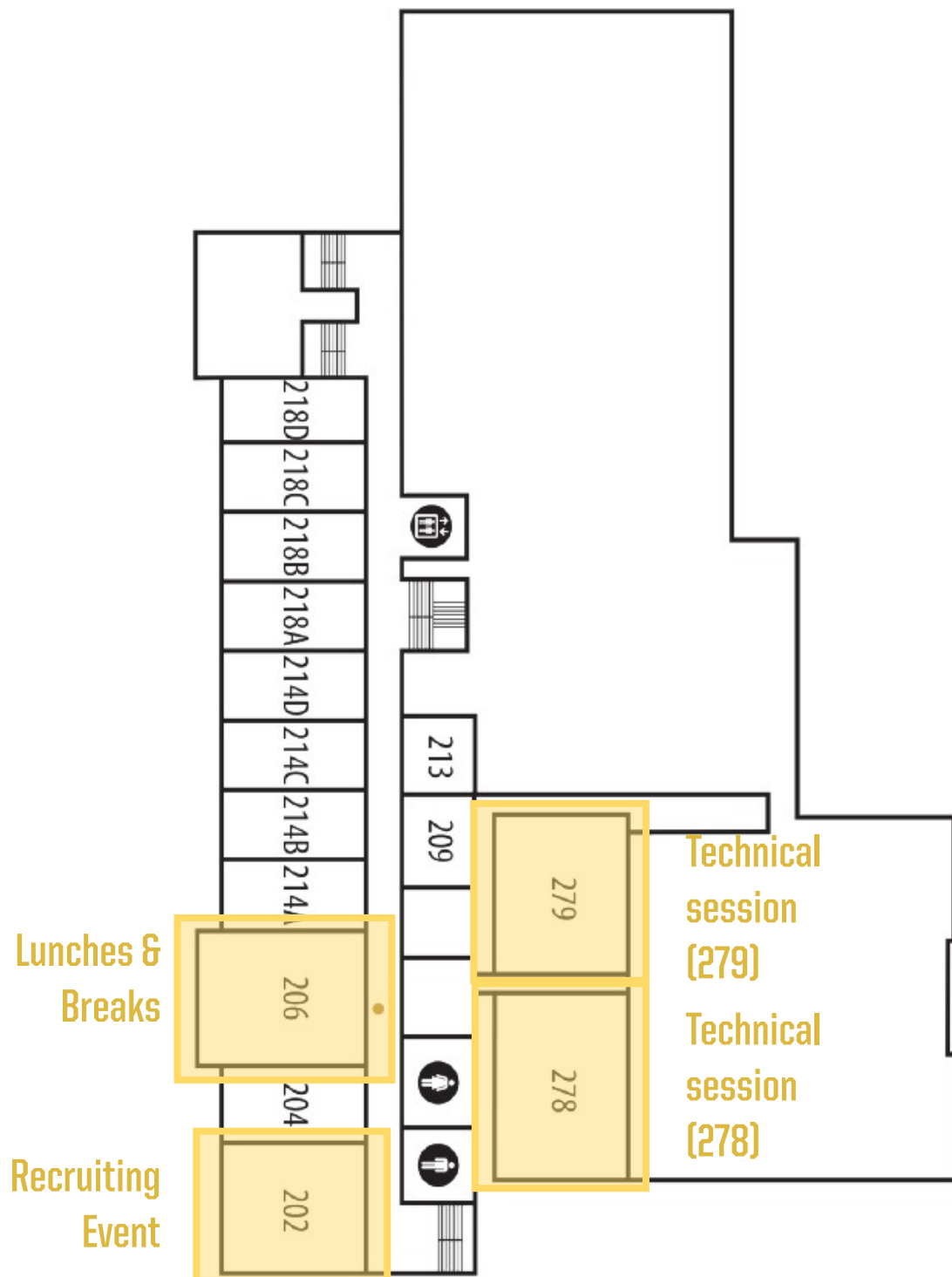
GROUND FLOOR

Plenary sessions
and keynotes



STEWART CENTER MAP

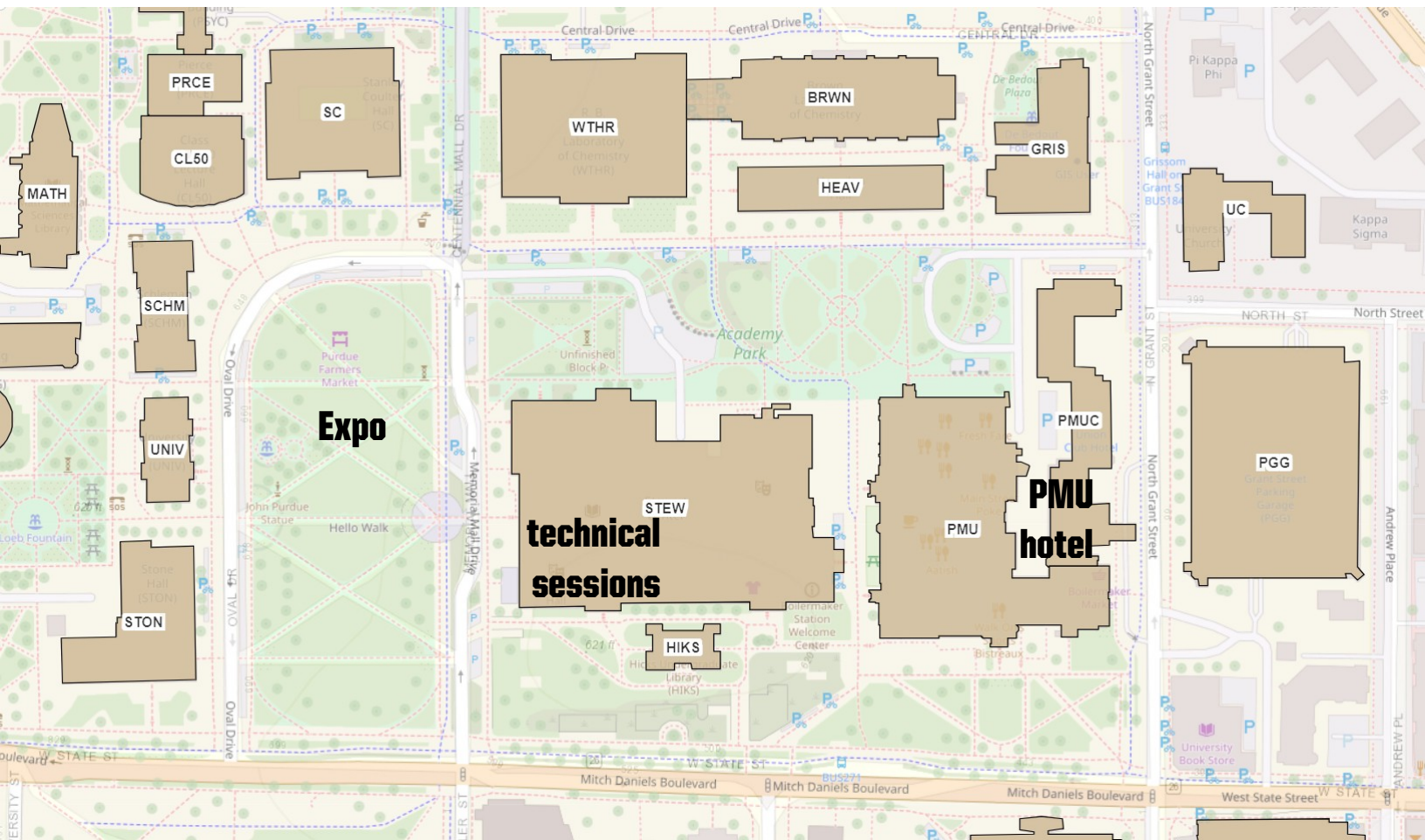
SECOND FLOOR



2026 International Maha Fluid Power Conference

EXPOSITION

LOCATION



HOURS

Assembly: September 8th, 1:00 pm to 5:30 pm

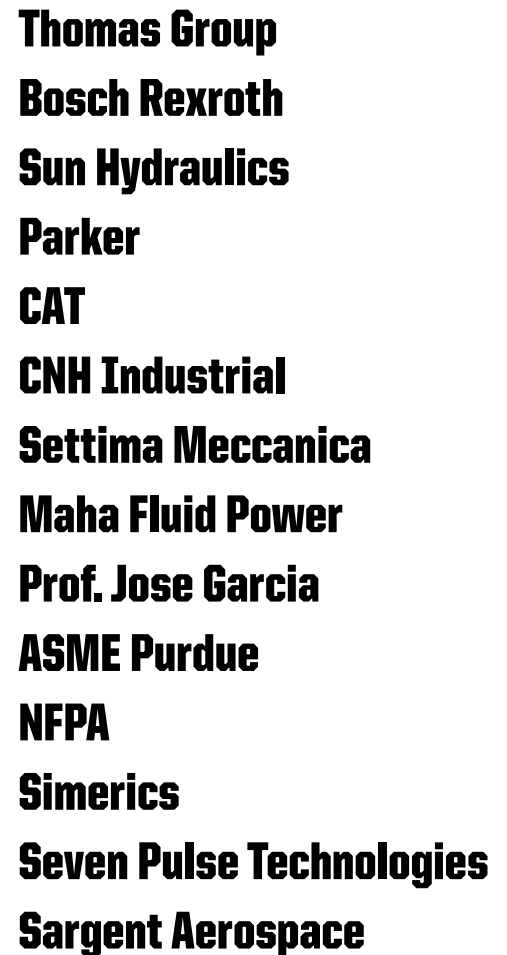
Exhibition: September 9th, 8:00 am to 3:50 pm

Dismantling: September 9th, 4:10 pm to 5:30 pm

The Expo will be accessible to everyone, including people not registered to the Maha Conference.

EXPOSITION

LIST OF EXHIBITORS



2026 International Maha Fluid Power Conference

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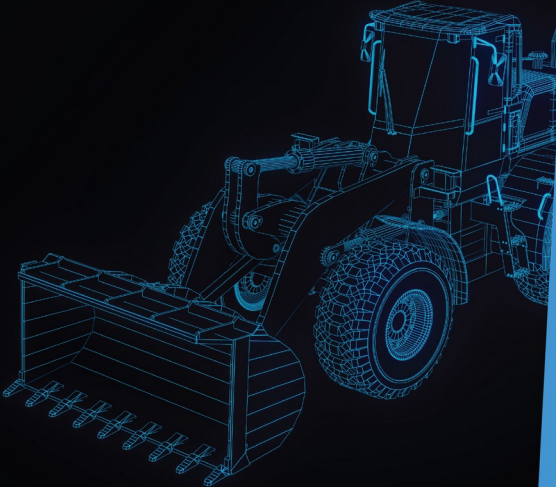


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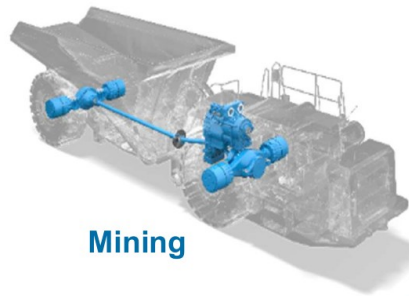


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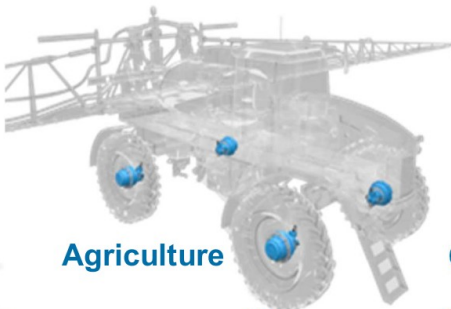


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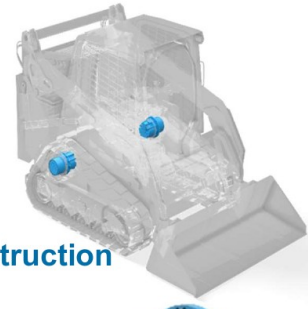
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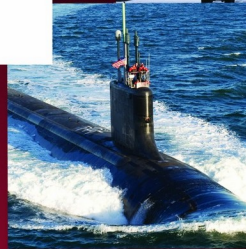
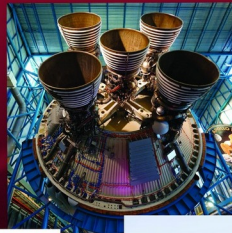
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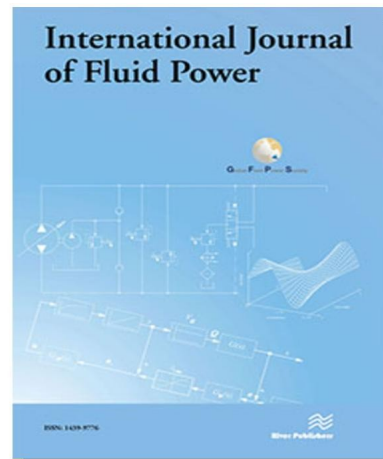
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PRESENTATION ABSTRACTS

GEAR AND VANE PUMPS

Wed Sep 9, 2:30 PM, Stewart Center 278

Title: Analysis of Efficiency and Axial Compensation in Continuous-Contact Helical Gear Pumps through Multiphysics Lubrication Modeling and Experimental Validation

Authors: Parth Tawarawala, Harsh Kulkarni, Dinghao Pan, Andrea Vacca (Maha Fluid Power Research Center, Purdue University, USA)

Abstract: This work presents a multi-physics, strongly coupled numerical model for the study of continuous-contact helical gear pumps (CCHGP), specifically focusing on the numerical analysis of their axial compensation and the prediction of volumetric and hydromechanical efficiencies. The proposed work involves a multi-domain multi-physics modeling approach that combines lumped-parameter modeling of the fluid domain and body dynamics, with consideration of all degrees of freedom and range of motion of the floating bodies, and a CFD-based numerical model for the lubricating interfaces of the continuous-contact helical gear pump, built using an in-house C++-based framework, Multics. The paper shows that the model predicts the pump efficiency trends and outlet pressure ripple in good agreement with experimental measurements on a reference unit, while considerably improving upon state-of-the-art models, and reports a breakdown of the major loss sources in the pump. The paper also demonstrates model capabilities in predicting gear micro-motions and dynamics. The complete model can be used to perform predictive numerical simulations of existing designs or to optimize them to improve performance.

Title: Enhanced multi-objective multi-physics optimization of pump timing applied to a dual-flank contact helical gear pump

Authors: Carlo Maria Vescovini, Manuel Rigosi (Casappa S.p.A., Italy)

Abstract: Growing demand for hydraulic pumps combining reduced noise emissions with high efficiency and robust performance led to the development of solutions like double contact and continuous contact external gear pumps or the use of pre-compression volume in piston pumps. Casappa responded to this trend introducing X technology, dual-flank helical gear pumps featuring high helix angles and further innovative solutions. To fully exploit the performance potential of these machines in real applications, a targeted optimization of internal geometrical features that directly influence pressure build-up and flow pulsations is required. Particular attention is currently given not only to the conventional aspects of pump performances enhancement, but also to the impact on sound quality from the end-user perspective, which is highly influenced by the transmission of pressure pulsations through the machine structure and hydraulic system.

This work presents a numerical study aimed at improving the acoustic and hydraulic performance of the Casappa X technology pump through the optimization of anti-noise discharge grooves integrated into the bearing blocks. Delivery pressure ripple and internal pressure peaks generated during the meshing process are recognized as major contributors to vibration and noise emission. Objective of the study is to define an optimized but easy-to-manufacture discharge groove geometry capable of reducing delivery pressure ripple and sudden internal pressure peaks buildup while maintaining high volumetric efficiency.

PRESENTATION ABSTRACTS

(continued) Enhanced multi-objective multi-physics optimization of pump timing applied to a dual-flank contact helical gear pump

A multi-objective optimization workflow was adopted to support this activity, integrating parametric geometry generation, automated design screening, and pump simulation in different working conditions. The state-of-the-art workflow, developed by Casappa in previous research programs, was significantly enhanced for this specific application, with a focus on robustness, computational efficiency, and convergence capability, and was applied for the first time to the more challenging case of X technology helical gears. The workflow, implemented in modeFRONTIER environment, is coupled with the helical version of Hygesim lumped-parameter model, again developed and tuned within the collaboration programme between MAHA and Casappa. Sixteen geometric design variables were considered, describing the suction and delivery discharge grooves of each bearing block. The optimization problem was formulated in order to minimize different pressure ripple characteristics as well as pump internal forces, while enforcing constraints on volumetric efficiency and gear contact continuity to ensure proper meshing conditions.

The optimization was carried out using the MOGA-II genetic algorithm, evaluating approximately 1500 candidate designs across four representative pump operating conditions. Furthermore, a preliminary geometric and kinematic screening stage was introduced to exclude non-feasible designs prior to the simulation phase, improving computational efficiency and robustness. Convergence analysis demonstrated a stable evolution of the objective functions and confirmed the critical role of discharge groove geometry.

From the Pareto-optimal solution set, one design was selected based on its robustness, geometric consistency between top and bottom bearing blocks, and favourable trade-off between objective functions. Numerical results indicate an average reduction close to 20% in pressure ripple, and nearly 40% in the oscillation of a set of internal forces, without noticeable degradation of volumetric efficiency.

Based on these results, prototyped thrust plates featuring the optimized discharge grooves were manufactured and experimental tests are underway in the Casappa laboratory. The experimental activities are conceived with the primary objective of qualifying the actual performance of the new components. Furthermore, validating the numerical predictions and assessing the reliability of the modeling and optimization framework is of major importance to extend the procedure to different displacement range pumps and to the next generation of Casappa products.

As a future step, components featuring the new optimized geometry will be on-field tested on an electrified excavator, to gather data under real operating conditions and real environment.

PRESENTATION ABSTRACTS

Title: Improvement of Filling Performance of a Balanced Vane Pump through Numerical Analysis and Experimentation

Authors: Jinglun Qu, Andrea Vacca (Purdue University, USA); Sri Krishna Uppaluri (Veljan Denison Limited, India)

Abstract: This paper presents a methodology for designing and optimizing the fluid supply flow path of a balanced twin-lip vane pump, supported by experimental validation. Cavitation in the suction port, caused by insufficient fluid supply to the displacement chamber, is a leading cause of pump failure due to the severe damage it inflicts on critical components. This paper includes the further development of a previously established numerical model to consider the complex supply path of the casing. The methodology utilizes preliminary Computational Fluid Dynamics (CFD) simulations to characterize the hydraulic resistance of the upstream orifices and chambers. The baseline model was validated against existing experimental results to confirm its fidelity. The updated extended model successfully captures the localized cavitation effects occurring within the casing, leading to proposed geometry updates. By characterizing the new design using CFD, the model demonstrates significantly improved supply flow capabilities. Further updates of the cam-ring orifice were conducted, and simulation results predict the substantially improved performance of the pump at maximum operating speeds, which is experimentally validated in this study.

Title: High Speed Tungsten Carbide Stacked Vane Pump

Authors: Jeff Blaszc (Staff Project Engineer) and Joseph Giangreco-Marotta (Staff Design Engineer), Moog

Abstract: This work presents the development and experimental evaluation of a stacked, multi-stage, high-speed vane pump constructed from tungsten carbide for contamination-sensitive systems. Over 130 tests have been conducted on multiple hardware iterations using both oil and water as working fluids. The study investigated a range of undervane configurations, flow geometries, vane tip geometries and port configurations. The design intentionally avoided features used in traditional vane pumps to mitigate contamination risks.

The pump architecture allows multiple stages to be stacked, enabling pressure outputs to be summed to achieve the target performance. Testing was performed at speeds up to 5000 RPM, with volumetric efficiencies exceeding 95% across the operating range. The system delivers total flow rates greater than 110 GPM with an inlet charge pressure of 400 PSI (typical for the application).

Material selection was evaluated with an academic partnership and included a tribological study of various ceramics and cermets. Tungsten Carbide was chosen for its wear resistance, mechanical properties and manufacturing options. The results demonstrate that the stacked configuration can produce high-pressure, high-efficiency pumping offering a robust solution for contamination-sensitive applications.

PRESENTATION ABSTRACTS

NOVEL TECHNOLOGY IN OFF ROAD VEHICLE

Wed Sep 9, 2:30 PM, Stewart Center 279

Title: Influence of Fluid Properties on Hydraulic System Losses in Dynamometer and Excavator Field Testing

Authors: Paul Michael, Director, Fluid Power Institute (Milwaukee School of Engineering, USA)

Abstract: This study examines the impact of fluid viscosity, viscosity index, polymer shear, and traction coefficient in fluid power systems using the ASTM D7721 standard practice for determining the effect of fluid selection on hydraulic system performance. Six fully formulated fluids spanning two viscosity grades and three viscosity index levels were evaluated in a laboratory dynamometer and two excavators from different manufacturers. In the dynamometer test, combining low viscosity with high viscosity index produced higher flow losses but reduced friction under low- and high-speed conditions. In the excavator test, combining low viscosity with high viscosity index reduced the cycle time for river stone truck loading operations. Analysis of the hydraulic circuits helped explain differences in the dynamometer and excavator responses to changes in fluid properties. These findings provide insight into how hydraulic fluid optimization can enhance machine productivity.

Title: Off-Road Vehicle Performance & Fluid Power: From Concept Sketch to Hi-Fi and Real-Time Modeling

Authors: Xin Tian, PhD, System Modeling Engineer (CNH Industrial, USA)

Abstract: Off-road vehicles increasingly require efficient, reliable, and highly integrated hydraulic, mechanical, and control systems. This presentation demonstrates how high-fidelity system simulation can support the development and validation of these complex systems, from component and subsystem models to full-vehicle performance analysis.

A modular simulation approach is presented through case studies covering hydraulic performance, energy-efficiency optimization, electrification, and real-time simulation. Advanced applications including virtual manufacturing quality analysis, and digital-twin-based testing.

These applications illustrate how simulation can extend across the product development lifecycle, enabling faster design iteration, reduced physical testing, improved system performance, and more effective integration of new technologies in off-road vehicles.

PRESENTATION ABSTRACTS

Title: High Efficiency Independent Metering System with Energy Recuperation: The Case of a Mini-Excavator

Authors: Timir Rajendra Patel, Andrea Vacca, and Charlie Young (Purdue University, USA and Bobcat, USA)

Abstract: Traditional centralized fluid power architectures in earthmoving machinery exhibit substantial energy dissipation due to load mismatch across simultaneously operating actuators and an inability to recover gravitational potential energy from overrunning loads. To resolve these fundamental inefficiencies, this presentation presents a load-sensing (LS) based independent metering (IM) hydraulic layout integrated with a dynamic energy recovery circuit, which has been theoretically validated and physically implemented on a 5-ton excavator prototype. The proposed architecture leverages a decoupled proportional valve network to actively manipulate individual actuator chamber pressures. This highly adaptable configuration reduces throttling by redirecting flow from overrunning actuators into a hydraulic accumulator to store energy. A recirculation system then feeds this stored energy back into the main supply line by directing the accumulator flow to the supply system. To feed this stored energy back into the main supply line, multiple recirculation architectures were investigated, including routing the accumulator flow to the pump inlet, through an auxiliary hydrostatic unit, or bypassing the pump entirely to directly supply the valve system. Initial numerical simulations of a 90-degree trenching cycle, paired with standard test rig validation, verified the underlying valve control logic and pressure transients. These simulations indicated a 42% reduction in throttling losses relative to the baseline architecture, yielding an absolute hydraulic efficiency improvement of approximately 12%. Building on these results, the system was fully integrated into a 5-ton excavator prototype powered by a diesel engine. Field testing of the prototype yielded a 13.7% reduction in the engine shaft energy consumption while performing a simplified form of the digging cycle. Additional testing of the prototype during standard extension and retraction actuations validated the system functioning and performance. This presentation will cover the proposed system's design and working principle, simulation framework, prototype implementation challenges, and the future optimization-based control schemas required to maximize energy recovery potential in commercial machinery.

PRESENTATION ABSTRACTS

Title: Bridging 1D System Modeling and 3D CFD for Hydraulic Slack Adjuster Design: A Decoupled Co-Simulation Approach

Authors: Vignesh Jeganathan, Chris Imholte, Andrew Kleitsch, Ashutosh Pandey, Bipin Kashid (Simerics, USA and Parker Hannifin, USA)

Abstract: The design of safety-critical hydraulic braking subsystems, such as slack adjusters, necessitates the accurate prediction of complex transient interactions between multi-body kinematics and high-fidelity fluid dynamics. While traditional one-dimensional (1D) lumped-parameter models offer systemlevel insights, they fail to resolve localized phenomena like cavitation, flow separation, and transient pressure spikes. Conversely, fully coupled 3D computational fluid dynamics (CFD) is often computationally prohibitive for extensive design-space exploration. This paper proposes a technically robust, decoupled 1D-3D co-simulation methodology that leverages the strengths of both modeling paradigms to optimize hydraulic performance and reliability. In the proposed framework, a 1D system model is utilized to perform a comprehensive parametric study across a wide range of operating pressures and accumulator configurations, identifying critical transients and near-failure edge cases. These 1D-derived results are then mapped as time-dependent boundary conditions to a high-fidelity 3D CFD model within the Simerics MP environment. A novel contribution of this work is the implementation of a tailored modeling strategy for multi-body fluid-structure interaction (FSI), where contact formulations and damping factors—guided by 1D kinematic data—are used to stabilize the simulation of rapid cylinder collisions.

PRESENTATION ABSTRACTS

PISTON PUMPS AND MOTORS

Wed Sep 9, 4:10 PM, Stewart Center 278

Title: Ultra Compact High-Speed Axial Piston Pumps for Electrified Mobile Machinery: Optimizing and Testing Tribological Gaps for 10,000 rpm

Authors: Roman Ivantysyn, Jürgen Weber (Institute of Mechatronic Engineering, Technische Universität Dresden, Germany)

Abstract: High-speed electric drives are being adopted in mobile machinery, with automotive e-motors commonly operating up to 10,000 rpm and beyond. To exploit this speed range in electrohydraulic powertrains, hydrostatic units must be qualified and redesigned for ultra-high rotational speed, where tribological limits are often the limiting factor, when boosting the inlet pressure. In the present work, a wobble-plate type axial piston pump platform was selected due to advantage of mass independence in the rotating kit. This rotating kit can be operated at 61.1 cm³/rev (fixed 12° wobble angle) or 94.6 cm³/rev (18°). The baseline pump is rated at 2,400 rpm in open-circuit operation, where the self-priming speed limit was confirmed by measurements as the primary limit. To isolate the tribological speed limit, the inlet was pressurized and a temperature and particle monitoring instrumentation was implemented. Temperatures were monitored at bearings, piston-cylinder gap, and slipper leakage locations. Together with online particle monitoring these metrics were used as an early warning indicator. With this methodology, stable overspeed operation up to 4,000 rpm was achieved at various pressures. At 3,800 rpm and 300 bar, a rapid thermal rise at the slipper interface and increased particle activity indicated imminent failure, and the test was terminated intentionally before catastrophic damage occurred. Post-test inspection confirmed that the pump remained intact, enabling failure mode analysis without obscured failure chains. The paper presents the test methodology, the sensor-based stop criteria, and a simulation-guided redesign workflow for high-speed operation. Improvements of the slipper design are demonstrated by simulation and measurement, followed by a thermally adaptive, mesostructured slipper concept targeted at 10,000 rpm. In parallel, the requirements for a next-generation high-speed test rig are derived to enable testing at approximately 360 kW (61.1 cm³/rev, 10,000 rpm, 350 bar), which would upgrade this mobile pump to a power density of 17 kW/kg, outperforming all existing pumps on the market.

PRESENTATION ABSTRACTS

Title: Numerical Analysis of the Influence of Ball-Joint Clearance on the Elastohydrodynamic Performance of Slipper Interfaces in Axial Piston Motors

Authors: Julien Ntede Florent, Ishan Suvarna, Lizhi Shang (Maha Fluid Power Research Center, Purdue University, USA); Andrea De Pascale, Davide Moro (University of Bologna, Italy); Alberto Gatti (Bonfiglioli Riduttori S.p.A., Italy)

Abstract: The tribological behavior of the slipper-swashplate interface is a primary factor limiting the operational lifespan and power density of swashplate axial piston motors. Under high hydraulic loading, the assumption of rigid body motion becomes invalid because elastic deformations within the slipper assembly substantially modify the geometry of the lubricating film. This study examines the typically overlooked influence of non-conformal contact mechanics in the piston-ball/slipper-socket joint and its role in driving deformation of the sealing land. Hertzian contact theory was employed to characterize the pressure distribution across the ball-socket interface, and a series of finite element simulations were conducted in ANSYS to quantify the effects of varying joint clearances. The results demonstrate that increasing the clearance significantly reduces the effective contact area, thereby generating localized stress concentrations. These stress concentrations impose a more concentrated mechanical load on the slipper body, inducing significant elastic warping and geometric nonlinearity across the sealing land interface.

The resulting increase in local contact pressures not only amplifies structural distortion but also may promote higher frictional losses within the ball-socket joint, as higher normal loads between relatively moving surfaces intensify boundary and mixed lubrication conditions. This effect contributes to greater energy dissipation and accelerated wear, further affecting the overall tribological performance of the assembly.

To evaluate the influence of structural deformation on the interface's load-carrying capacity, a hypothetical contact region was defined to simulate the mechanical interaction within the ball-socket joint. This was achieved by isolating the slipper and performing a parametric study in which the contact angle, measured radially from the central axis, was systematically varied. For each discrete angular increment, the specific pressure distribution required to equilibrate the piston's axial force was numerically determined and applied as the primary boundary condition. A comparative analysis shows that a clearance of 15 μm , corresponding to a contact angle of 60°, minimizes sealing land distortion. The resulting deformation field was then incorporated into the MULTICS Multiphysics framework to evaluate its influence on the load capacity of the slipper-swashplate interface.

PRESENTATION ABSTRACTS

Title: Cylinder Block Deformation as Indicator for Cylinder Pressure in Axial Piston Units: A Novel Method Using Strain Gauges

Authors: Karl Stübig, Luca Löding, Frank Geuer, Lars Leonhard, Matthias Liermann, Sumeru Srinivasamurthy, Carsten Fiebing, Robert Rahmfeld (Danfoss Power Solutions GmbH & Co. OHG, Germany)

Abstract: Cylinder bore pressure prediction is the foundation for designing timing notches in valve plates of axial piston units. The timing notches in a valve plate affect not only efficiency of the axial piston unit, but also its controllability and NVH characteristics. It is state of the art to use cylinder bore pressure measurement for verification of simulation results. With a telemetry system, the bore pressure data can be retrieved from the rotating unit to a stationary data acquisition system. This data can be used for comparison with simulation results, to support the optimization of different timing designs of the valve plate and operating conditions. The feasibility of integrating a pressure sensor into the rotating kit of a production unit depends on space constraints between housing and kit and is further complicated by routing of wires through the shaft to the telemetry unit. As the units become smaller, it is increasingly difficult, if not impossible, to fit the pressure sensor and cables securely. This paper investigates a novel approach to use a strain gauge applied to the outside of the cylinder block as an indication of the pressure inside the cylinder block. This approach addresses a major obstacle to the experimental investigation of smaller size displacement units, since the strain gauge is mounted flat on the surface of the block in an area, where most deformation is to be expected. Measurement results show the correlation of the strain gauge signal in comparison with a conventional pressure measurement. The signal is affected by additional parameters, such as shaft speed and angle, line delta pressure, and temperature.

Title: Increasing tool productivity by re-engineering radial pistons cam-lobe motors

Authors: Pierre Bernard (Poclain Hydraulics, France)

Abstract: Radial pistons cam-lobe motors are renowned for their versatility and robustness, which makes them an ideal solution for powering productivity focused applications such as rock cutter heads, coal mining machines, or drilling equipment. As it stands, the motors used on these applications are mostly identical to motors employed in hydrostatic transmissions for propelling vehicles, a kind of application for which the usage profile is very different. This poses the question of the productivity improvements that could be achieved by designing a radial pistons cam-lobe motor specifically for such power-intense applications.

This study describes a radial pistons cam-lobe motor design engineered to maximise tool productivity, and availability throughout the machine's lifespan. The example of a harvester head for processing trees is taken as a benchmark application to demonstrate performance improvements. After describing this particularly harsh application, a representative reference usage cycle, and productivity metrics are proposed. A radial pistons cam-lobe motor design optimised to allow productivity improvements on the tree harvester head is then introduced, and a simulation model of the harvester head installed on its base machine detailed. In a comparative simulation study, the upgraded motor is substituted for the reference component on the harvesting-head and both models are simulated over the previously introduced reference usage profile. In conclusion, the respective performances and the demonstrated productivity gains are discussed.

PRESENTATION ABSTRACTS

SUSTAINABLE FLUID POWER

Wed Sep 9, 4:10 PM, Stewart Center 279

Title: How Fluid Power Research Can Contribute to a More Sustainable Construction Industry

Authors: Olivier Reinertz, Christian Bertram, Katharina Schmitz (Institute for Fluid Power Drives and Systems (ifas), RWTH Aachen University, Germany)

Abstract: The construction industry is facing severe challenges in near future. The reasons are widespread. First, the growing earth population leads to a continuously rising demand for infrastructure, living and industrial space, forcing the construction industry to raise productivity. On the other hand, the building and construction sector is responsible for approx. 34 % of the global anthropogenic CO₂ emissions, while this share will grow further with enhanced construction activity. Significant parts of these emissions result from the production of building materials. Cement production alone generates approx. 6 % of the global emissions, due to its enormous used quantities and high temperature requirements in production. Paradigm changes in raw material selection, building designs, and material use are therefore unavoidable. Additionally, the drive systems of mobile construction machines contribute to the sector's emissions. While construction principles need to change, the requirement for earth moving and mining and thus for more efficient and emission-free working machines persists. Finally, construction is a labor-intensive branch, facing severe problems with recruitment due to the shrinking number of young people in many industrialized countries and the direct concurrence with more attractive, less physically demanding jobs.

The paper shows how fluid power can contribute to an ecologically and socially more sustainable construction industry by means of several examples from current research at ifas and beyond. Herein, both dimensions of sustainability are simultaneously optimized by automation of construction processes, e.g. by means of partly automated mobile machines with additional intelligence, to allow real time surveillance of the building progress, fluid power enabled automated prefabrication of lightweight assemblies, which require less concrete and labor on site, and enhanced switching schemes and fluid selection for mobile hydraulics to ensure increased energetic efficiencies.

PRESENTATION ABSTRACTS

Title: Electrification-Enabled Hydraulic Architecture: Improving Efficiency and Total Cost of Ownership

Authors: Justin Hernan (Parker Hannifin, Hydraulic Pump and Motor Division)

Abstract: Hydraulics have long been foundational to productive machines, and electrification is now enabling new electro-hydraulic architectures that improve duty-cycle efficiency and controllability without giving up the unrivaled power density and robustness hydraulics provide. Electrification is enabling hydraulics to be packaged and controlled differently – favoring duty-cycle-optimized, on demand operation, integrated diagnostics, and hybrid partitioning of machine functions – so electrified platforms can capture efficiency gains, reduce total cost of ownership all without sacrificing system performance.

This presentation focuses on architectural changes enabled by electrification. Topics include variable speed electro-hydraulic power systems, on-demand pressure and flow, and centralized versus decentralized concepts. A duty-cycle-based comparison framework is used to quantify efficiency and performance tradeoffs including standby losses, operating point shifting with variable speed capability, and thermal and noise behaviors. Duty-cycle and laboratory-based testing are used to evaluate system architectures over representative operating cycles to guide parameter and component selection.

Anticipated results include: (1) quantified duty-cycle impacts showing where electrification-enabled hydraulic architectures reduce energy consumption without compromising system performance. (2) A practical selection framework clarifying where traditional hydraulics remains the best solution, and where hybrid electro-hydraulic architectures can ease battery and drivetrain demands and help reduce overall emissions.

Title: Full 3D CFD and FEM Validation of Surrogate-Optimized Hydraulic Manifolds Designed via the MOfEA Framework

Authors: Samuele Nizzardo, Alberto Benato (University of Padova, Italy); Andrea Vacca (Maha Fluid Power Research Center, Purdue University, USA)

Abstract: Despite their high power density and robust performance in aerospace and mobile applications, traditional hydraulic actuation systems are increasingly scrutinized for their energy consumption and operational efficiency. In this context, optimization of the hydraulic manifold architecture plays a key role. The internal routing of these components strongly affects both steady-state flow losses and overall structural mass, making manifold layout a critical factor in improving fluid-dynamic performance and the efficiency of next-generation hydraulic systems. This paper presents the CFD and structural validation of a fully automated design algorithm for the generation of optimized internal flow topologies in additively manufactured hydraulic manifolds (MOfEA, Manifold design Optimization through Theta* path finder and Evolutionary Algorithms). The proposed framework implements a self-executing sizing methodology that estimates pressure drops using an adapted Ito correlation and determines the minimum safe wall thickness through Lamé equations. Compared with conventional design workflows, which typically require time-consuming manual iterations, the proposed approach significantly reduces design time (less than 25 minutes for a complex real-world application) while enabling a systematic exploration of highly efficient manifold configurations. To validate the algorithm, a reference optimized manifold geometry was analyzed. Assuming the same material, the CFD results show that the optimized topology reduces pressure losses by more than 84% compared to a conventional cross-drilled baseline.

PRESENTATION ABSTRACTS

(continued) Full 3D CFD and FEM Validation of Surrogate-Optimized Hydraulic Manifolds Designed via the MOTHEA Framework

At the same time, finite element structural analysis shows that despite a 93.1% reduction in weight, the optimized manifold satisfies structural integrity requirements under operating pressure. Although the present mass evaluation does not include valve-thread connections or support structures, the results demonstrate the reliability of the proposed algorithm in generating feasible ultra-lightweight manifolds with markedly reduced parasitic losses.

Title: Energy Saving Strategies in Hydraulic-Driven Machine Design

Authors: Dr. Medhat Khalil, PHD, CFPHS, CFPAL, Program Director of Fluid Power Education (Milwaukee School of Engineering, Milwaukee, WI, USA)

Abstract: Hydraulic control systems serve almost all industries around the globe, on the ground, in the water, and in the air. Hydraulic-driven machines are extensively and widely used worldwide, whether for stationery or mobile applications, and whether for civil or military applications. Hence, every fraction of energy saving and efficiency improvement has a significant impact on the amount of carbon emission that can be cut. This presentation discusses a roadmap of energy saving as applied to hydraulic-driven machines. The road map shows in brief various architectural, constructional, and operational strategies for energy saving in hydraulic driven machines on both the component and the system level. However, for space limitations the presentation discusses only few selected topics from the presented road map.

PRESENTATION ABSTRACTS

DRIVE AND STEER-BY-WIRE

Thu Sep 10, 8:30 AM, Stewart Center 278

Title: Steer-by-Wire Safety: Preserving Steering Under Fault Conditions Through Physics-Driven Design

Authors: Timothy Oppenwall, Federico Zappaterra, Ben Holter (Husco)

Abstract: Off-highway machinery is undergoing a rapid transition toward digitally controlled, software-defined vehicles, driven by increasing demands for automation, operator assistance, and adaptable machine behavior. Steering systems are a central enabler of this transformation. Steer-by-Wire (SbW) architectures replace or supplement the mechanical steering linkage with electronic sensing, control, and actuation, allowing steering feel, response, and functionality to be shaped in software. However, adoption of SbW in off-highway machines, particularly those intended for limited on-road travel, has been constrained by safety concerns and the high cost and complexity of conventional redundancy-based designs. This presentation addresses how safe, practical SbW can be achieved without extensive duplication of electronic controllers and power supplies.

The presentation begins by examining the current state of SbW technology and the conventional safety approach, in which fault tolerance is achieved primarily through layered electronic redundancy. While effective, this approach imposes significant penalties in system packaging, validation effort, and lifecycle cost, especially for machines operating in harsh environments. These constraints are contrasted with the practical needs of off-highway OEMs who require robustness, serviceability, and scalability across multiple platforms with stringent economic pressure.

The presentation then describes the methods used to develop and validate an alternative SbW architecture that meets functional safety and regulatory requirements. Applicable steering, machinery, and safety standards, including ISO 5010 for steering performance, ISO 10998 for road travel on agricultural machinery, and ISO 13849-1 and ISO 13849-2 for functional safety, are reviewed and interpreted in the context of SbW. These standards are used as design inputs to define system architecture, diagnostic coverage, fault detection thresholds, and acceptable behavior during faults. Model-based systems engineering methods and safety analyses are employed to demonstrate system compliance.

Key technical elements of GenSteer, Husco's SbW system solution, are presented in detail, focusing on how fail-functional steering behavior can be achieved through system-level physics and design rather than fully replicated electronic paths. In the GenSteer architecture, the operator's input energy is leveraged as a means of electrical backup, allowing continued steering controllability during certain electrical fault conditions without reliance on a second power source. Hardware-in-the-loop simulations and bench testing are used to validate steering performance, haptic feedback fidelity, self-centering behavior, and diagnostic response under normal and degraded operating conditions. These simulation activities are complemented by vehicle-level evaluations that assess controllability, steering feel consistency, and transitions between nominal and fault states.

PRESENTATION ABSTRACTS

(continued) Steer-by-Wire Safety: Preserving Steering Under Fault Conditions Through Physics-Driven Design

The results include demonstrated alignment with international standards, quantified reductions in electronic complexity compared with conventional SbW safety architectures, and evidence steering performance can be maintained in both nominal operation and fault scenarios. The presentation will show how diagnostic strategies and fail-functional characteristics preserve predictable vehicle steering response, rather than defaulting to system shutdown or excessive redundancy. Integration considerations are also addressed, illustrating how the SbW system can be incorporated into existing off-highway platforms while minimizing changes to vehicle packaging, power distribution, and validation processes.

Overall, this presentation is intended for engineers and technical leaders who design, integrate, or evaluate steering systems and are seeking realistic pathways toward next-generation machine control. By emphasizing standards-based design, validated safety engineering methods, and system-level physical principles, the presentation demonstrates how software-defined steering can be practically implemented in off-highway machinery in a way that balances safety, performance, and economic viability.

Title: Development of a demonstrator for a full steer-by-wire solution

Authors: Matthias Krug (Thomas GmbH)

Abstract: With the following presentation the results of the development of a demonstrator for full steer-by-wire solutions shall be presented. Steer-by-wire solutions are increasingly relevant due to trends like electrification (e.g. CO₂ reduction, efficiency), automation and assistance (e.g. productivity, safety), and connectivity (e.g. fleet management, predictive maintenance). However, the use cases are not only relevant for automotive applications but also for applications with focus on forestry and agricultural machinery, construction equipment and material handling as well as municipal vehicles, tail lifts, and attachments.

As functional safety in steer-by-wire systems is essential, special focus lies on the redundancy within the developed system, i.e. the system must maintain steering performance (e.g. forces, response, duration of steering in failure mode comparable to normal operation) even in the event of a single fault.

The presentation will first discuss the development of the system, with focus on requirements such as operational requirements but also normative requirements. The required performance level will be presented discussing potential failures and malfunctions throughout the system including all components. Based on all analysed faults a final steer-by-wire system which was developed to exclude the potential failures will be outlined.

The remainder of the presentation discusses the simulations of the final system and displays the built demonstrator. Comprehensive experiments are carried out to analyse the performance of the demonstrator including the system reaction on manipulated malfunctions.

PRESENTATION ABSTRACTS

Title: Powertrain-Aware Explainable Reinforcement Learning Energy Management in Off-Road Vehicles

Authors: Hend Abououf, Athar Hanif, Sidra G. Bhatti, Qadeer Ahmed, Scott A. Shearer (The Ohio State University, USA); Nitish Chandramouli, Jon A. Dickson (Cummins Inc., USA)

Abstract: The presentation will introduce and evaluate a series-hybrid range-extender powertrain architecture for high-power off-highway vehicles, addressing key challenges in electrification. This architecture offers precise control of engine operating points but introduces multiple energy conversions that can lead to significant power losses. An effective energy management strategy (EMS) is essential to overcome the losses while minimizing fuel consumption, maintaining battery state of charge (SOC), and ensuring high engine efficiency. However, the highly variable, stochastic, and uncertain operating conditions typical of off-highway applications limit the effectiveness of threshold-rule-based control strategies and reduce the optimality of model-based optimal control strategies. To address these challenges, an explainable, interpretable reinforcement-learning-based EMS that adapts to high-variance environments, handles uncertainty, and generalizes to unseen operating conditions will be discussed. A powertrain constraints-aware, explainable, and interpretable Double Deep Q-Network (XI-DDQN) controller is developed, trained on actual experimental duty cycles, and evaluated on unseen actual real-world scenarios to assess its adaptability and generalization. The proposed EMS is benchmarked against dynamic programming (DP) and compared to a rule-based controller. The results, based on the validated model, demonstrate that the proposed XI-DDQN successfully captures the optimal control behavior of DP while maintaining robust adaptability across uncertain and generalized operating conditions. The XI-DDQN-based EMS achieves up to a 23% reduction in fuel consumption compared with a conventional powertrain and delivers an average 11.3% reduction relative to the rule-based strategy under unseen operating conditions. These findings highlight the effectiveness of the proposed approach in achieving fuel-efficient, robust, and interpretable energy management for next-generation hybrid off-highway machinery.

Title: Electrified Traction Architectures for Off-Highway Mobile Equipment: A Decision Framework

Authors: Barun Acharya, System Application Engineering Manager (Parker Hannifin Corporation)

Abstract: As mobile equipment manufacturers transition from diesel-mechanical to electric powertrains, selecting the right traction architecture is not straightforward. The same electric motor technology can be paired with very different power transmission approaches, and each combination brings trade-offs that depend heavily on the application.

This paper examines three traction system architectures for battery-electric off-highway machines: eHydrostatic, eHydraulic Gearbox, and Electromechanical. The eHydrostatic approach pairs a PMAC motor with a variable displacement hydrostatic transmission. The eHydraulic Gearbox is a novel concept that replaces variable displacement components with fixed units driven by a PMAC servomotor, creating a different set of system-level trade-offs. The Electromechanical option removes hydraulics entirely, coupling an electric motor directly to a mechanical gearbox.

For each architecture, we evaluate key parameters including speed-torque operating range, system efficiency, packaging, regenerative braking capability, failure mode behavior, and field serviceability. We show that each topology has distinct advantages depending on application requirements, and that the right choice depends on the specific duty cycle and operating conditions of the target machine.

PRESENTATION ABSTRACTS

(continued) Electrified Traction Architectures for Off-Highway Mobile Equipment: A Decision Framework

The paper proposes a practical selection methodology to help engineers identify the most suitable traction architecture early in the system design phase.

Title: Electro-Hydraulic Drive Networks for Next-Generation Working Machines - Design & Results for an Excavator

Authors: Lasse Schmidt (AAU Energy, Aalborg University, Denmark)

Abstract: Energy efficiency in hydraulic working machines has been a research priority for decades, driven by fuel-cost pressures and the push toward electrification. Yet despite continuous component evolution, system-level design principles have remained fundamentally unchanged - still reliant on "control-by-brake" strategies that manage power through throttle losses. Advances such as independent metering, static load compensation, and multi-pump architectures reduce consumption incrementally, but do not escape this paradigm. Electro-hydraulic actuators (EHAs) eliminate principal losses, yet their high cost, oversized components, excessive cost levels, and the need to meet non-concurrent peak force and speed demands limit practical adoption in the market.

A further challenge compounds the problem: highly efficient systems exhibit dramatically reduced damping, degrading control performance and, in extreme cases, rendering machines unproductive or even not useful. Meaningful progress therefore demands a disruptive rethinking - one that addresses efficiency, controllability, and cost simultaneously from first principles.

Electro-Hydraulic Drive Networks (EDNs) represent such a departure. By employing only variable-speed displacement machines on a common DC bus connected to strategically selected actuator chambers - and enabling chamber short-circuits across actuators - EDNs achieve electro-hydraulic power split. The result: very high energy efficiency, smaller components, and reduced installed power compared to EHAs. This architecture-centric approach, however, vastly expands the design space; a three-actuator system yields over 36,000 unique functional architectures, while a six-actuator system exceeds 9 trillion - each with its own optimal control structure.

This presentation details the design of an EDN for the implement system of a 15-tonne wheeled excavator (boom, arm, and bucket cylinders). Addressing architecture synthesis, control-structure development, and experimental validation. Results demonstrate stable, well-behaved control and energy-consumption reductions of nearly 80 % versus the original ICE-powered system - and nearly 50 % versus a straightforward battery-electric conversion of that same baseline.

EDNs offer a compelling path toward energy efficient, high-performance hydraulic machinery - one that challenges the industry to move beyond incremental gains and embrace systemic innovation.

PRESENTATION ABSTRACTS

HYDRAULIC COMPONENT TECHNOLOGY

Thu Sep 10, 8:30 AM, Stewart Center 279

Title: Novel Poppet Valve for Digital Hydraulic Transformer

Authors: Elton Bishop (DigitalHydraulic LLC, USA)

Abstract: Need for an efficient and robust hydraulic transformer for secondary controlled drives is well established. The 4-bit, linear-acting Digital Hydraulic Transformer (DHT) approach has given promising results, but in development of more advanced functionality, valves failed due to high demands. No valve was found that met requirements, so effort was undertaken to design a valve, specifically for DHT, from first principles, that shifts reliably in extreme conditions. This novel poppet valve is conceived, manufactured, tested and evaluated as potential DHT Bit-1 valve. Apparatus is set up to establish p-Q curve, and to measure Cv and leakage. As well, apparatus is set up to explore critical flow and response at critical flow but found to be inadequate for the flows and pressure spikes involved. Valve p-Q curve and leakage are applied to existing DHT model and impact on performance is examined, including efficiencies and End Of Stroke strategies.

Title: When Orifice Flow Must Consider Extensional Effects

Authors: Austin Zapata, Andrea Vacca (Purdue University, USA)

Abstract: Orifice flows are a fundamental building block of hydraulic pumps and systems, but the complex physics within them is often simplified in frequently-used relationships for ease-of-use. When polymer melts which exhibit strong non-Newtonian behaviors are used, though, these phenomena become dominant and have significant effects on the flow behavior, leading to inaccuracies if the orifice equation is used. Typical orifice relationships often consider only the effect of flow regime, which is captured by the Reynolds number. The ratio of extensional to shearing flow, often called the Trouton ratio, must be considered in some specialized cases. This study will develop an orifice model which accounts for extensional effects of the fluid by a relationship between dimensionless parameters: the Euler number, the Reynolds number, and the Trouton ratio. The use cases of this expression are then detailed. The model is developed using experimental data of pressure drop and flow for six different fluids across which there are a total of 282 data points. The model's coefficient of correlation is shown to be 0.9990, demonstrating the high accuracy of this model across a wide range of Reynolds numbers.

PRESENTATION ABSTRACTS

Title: Sustainability driven Advanced Hydraulic Pump Designs and Global Fluid Qualification processes

Authors: Shanmukh Sarode, Howard Zhang, Patrick D. Fischer (Parker Hannifin, USA)

Abstract: Electrification of mobile machinery is reshaping requirements for hydraulic systems, driving a need for higher operating speeds, increased power density, reduced noise emissions, and improved sustainability. Concurrently, regulatory and market trends are accelerating the transition toward cleaner hydraulic fluids and improved operational efficiencies. This paper presents Parker Hannifin's latest developments in hydraulic pump technologies – piston, gear, bent axis, and vane, that are engineered specifically for state-of-the-art applications.

For gear pumps, a 'simple by design' architecture is introduced that retains straight-tooth designs while exploiting advanced manufacturing methods to safely enable substantially higher shaft speeds at competitive cost. For bent axis pumps, an integrated ripple chamber is demonstrated that effectively reduces flow ripple, achieving multi-decibel system noise reduction. In parallel, valve plate and suction channel refinements significantly increase self-priming speeds, with gains up to 17% depending on pump displacement. The next-generation vane pump incorporates advanced tribological coatings to support higher operating pressures while delivering exceptional self-priming capability suitable for demanding electrified mobile duty cycles. Virtual and physical validation campaigns are used to qualify these concepts against application-relevant performance and durability criteria. The paper further outlines an ePump integration strategy that leverages these pumps within multiple levels of modularity.

In parallel with hardware advances, hydraulic fluids are undergoing rapid evolution in base stocks, additive packages, and physical properties to improve efficiency, durability, and environmental performance. Parker Hannifin has implemented an enhanced, globally aligned fluid qualification process that systematically evaluates a wide range of fluids across major pump platforms and application profiles. This updated process reflects the latest pump designs and fluid chemistries and was developed through internal global collaboration and external engagement with fluid and additive suppliers, research institutions, and OEM customers. The resulting framework ensures robust, application-relevant validation of pump-fluid combinations for next-generation electrified mobile machinery, supporting a more sustainable hydraulics product landscape.

PRESENTATION ABSTRACTS

Title: Experimental Investigation of a Novel Load-Holding Valve Technology Enabling Energy Recovery for Safety-Critical Hydraulic Systems

Authors: Anders H. Hansen and Per Johansen (AAU Energy, Aalborg University, Denmark)

Abstract: This presentation reports an experimental study of a novel load holding technology that addresses the conflicting requirements of energy efficiency, motion quality, and safety compliance. The proposed concept preserves the safety principles defined by e.g. ISO 8643 and EN 13852-1 while enabling recovery of potential energy during load lowering and reducing reliance on dissipative throttling without compromising load stability.

Experimental studies are performed on a dedicated hydraulic test bench representing a single-rod cylinder drive with external loading. Repeatable tests are conducted over varying loads, lowering speeds, and pressure levels, with a conventional load holding solution used as reference. The experiments emphasize operating conditions representative of safe load control, including controlled lowering under load and behavior following failure.

The results demonstrate reduced throttling losses and increased energy recovery while preserving smooth motion, load stability, and compliance with safety-related functional requirements. In this context, the study highlights how hydraulic load holding, an essential safety function in mobile and offshore machinery with cylinder drives as mandated by standards such as ISO 8643 for off-highway equipment and EN 13852-1 for offshore cranes can be realized without relying exclusively on dissipative throttling-based control. By moving beyond conventional load holding valves that stabilize motion at the cost of lost potential energy, the proposed approach illustrates a pathway toward safer and more energy-efficient hydraulic systems that enable controlled load lowering while retaining compliance with established safety standards.

Title: A Novel Hydraulic-Mechanical Linear Actuator Technology for high Efficiency Architectures

Authors: Leonardo Franquilino; Prithvi Chandiramani; Andrea Vacca; Lizhi Shang. (Maha Fluid Power Research Center, Purdue University, USA)

Abstract: While hydraulic systems offer unmatched power density for linear actuation, their energy efficiency is fundamentally limited by throttling losses, pump conversion inefficiencies, and the inability to recover overrunning energy. Additionally, because supply systems must be sized for infrequent peak demands, their installed capacity significantly exceeds average duty-cycle requirements. To address these limitations, this work introduces a novel Hydro-Mechanical Actuator (HMA) and its associated architecture, combining hydraulic and mechanical actuation technologies. The HMA features a hydraulic motor driving a linear screw mechanism coupled to the actuator rod, all housed within a cylinder barrel that can be pressurized to generate an assisting pushing force. This design enables a hydraulic hybrid architecture based on pressure-supply secondary control concept, improving transmission efficiency and facilitating supply system downsizing. For proof of concept, the front attachment of a track-loader is evaluated under realistic drive-cycle conditions. A comprehensive design procedure is presented to size the actuator components to meet operating requirements. Furthermore, a sequential optimization framework is proposed to maximize efficiency and system downsizing. The main findings demonstrate that HMA maintains a packaging envelope comparable to conventional hydraulic cylinders while achieving significant performance improvements over a baseline solution. Specifically, net system efficiency increases from 10% to 51%, the supply system's maximum power requirement is reduced from 33 kW to 7.8 kW, and supply pump displacement is reduced from 45 cc/rev to 10 cc/rev.

PRESENTATION ABSTRACTS

SYSTEM DIAGNOSTICS & SIMULATION

Thu Sep 10, 10:40 AM, Stewart Center 278

Title: Experimental Characterization and Numerical Modelling of an Electric Vehicle Thermal Management System Integrating a Screw-Type e-Pump

Authors: Stefano Li Veli, Emma Frosina (University of Sannio, Italy); Luca Romagnuolo, Valerio Di Cosmo, Adolfo Senatore (University of Naples Federico II, Italy)

Abstract: Nowadays, the adoption of electric and hybrid-electric propulsion systems has become a common solution for the stringent decarbonization requirements. These technologies require advanced thermal management solutions capable of ensuring effective cooling of critical components while limiting energy consumption. Although centrifugal pumps are commonly used in cooling circuits, their performance can be affected by variable pressure losses and changing operating conditions, reducing flow-control accuracy. This work presents the experimental characterization, numerical modelling, and validation of a thermal management system for a high-performance electric vehicle, integrating a prototype screwtype positive-displacement e-pump. Tests were carried out on a dedicated test rig to hydraulically characterize the main circuit's components, including the electric motor and inverter, under different pump speeds and flow-rate distributions imposed by a needle-valve adjustment. The collected data were used to calibrate and validate a lumped-parameter model developed in Simcenter AMESim. The model accurately reproduced the measured pressure losses and the flow distribution across the different circuit branches, confirming the reliability of the numerical approach.

Title: Improving Structural Performance of a High-Pressure Hydraulic Portblock Using Manufacturing-Aware Shape Optimization and Automated Geometry Recovery

Authors: Raul Rodriguez, Jeemon Kurian, Rafael Cardoso (Bosch Rexroth); Sebastian Stahn (Ansys/Synopsys)

Abstract: The continued demand for higher-performing hydraulic systems places increasing structural demands on critical pump components. In high-pressure axial piston pumps, the portblock serves as a key functional element responsible for directing hydraulic fluid through a complex network of internal passages. Due to the interaction of geometric transitions, casting constraints, and pressure loading, localized stress concentrations can develop at critical passage intersections within the component. Identifying practical design changes that reduce these stress concentrations is often challenging because modifications must be implemented while preserving external interfaces, packaging requirements, and manufacturing feasibility. Traditional design iterations based on manual geometry refinement can require significant engineering effort while exploring only a limited portion of the available design space.

This presentation describes a simulation-driven development workflow jointly applied by Bosch Rexroth and Ansys to improve the structural performance of a hydraulic portblock design used within a production pump platform. The primary objective was to reduce stress concentrations in critical regions of the component while maintaining the existing product envelope, preserving functional interfaces, and respecting manufacturing requirements associated with high-pressure ductile iron castings.

PRESENTATION ABSTRACTS

(continued) Improving Structural Performance of a High-Pressure Hydraulic Portblock Using Manufacturing-Aware Shape Optimization and Automated Geometry Recovery

The workflow combines finite element analysis (FEA), gradient-based shape optimization, manufacturing-aware optimization controls, and automated geometry reconstruction. A baseline structural assessment was first performed to identify critical stress concentrations associated with the internal fluid passage geometry under representative design operating pressure loading conditions. The resulting stress field served as the input for a shape optimization process focused on the internal flow passage boundaries. Unlike topology optimization approaches that generate entirely new concepts, shape optimization was selected because it enables targeted improvement of an existing mature design while maintaining protected boundaries, interfaces, and functional requirements.

To maintain manufacturing feasibility, the optimization process was guided by casting-aware constraints. Directional morphing controls were used to limit geometry movement to permissible regions, while dimensional bandwidth controls were applied to maintain practical wall thickness distributions. These constraints allowed the optimization to explore structural improvements while remaining consistent with established manufacturing requirements. The resulting geometry reduced local stress concentrations around critical fluid passage transitions while preserving protected interfaces and manufacturing constraints.

A key element of the workflow is an automated geometry recovery process ("Back2CAD"). Converting optimized mesh-based geometries into CAD models suitable for engineering development remains a significant practical challenge in industrial applications. The automated reconstruction process generates a CAD-compatible solid representation of the optimized geometry, significantly reducing the manual effort traditionally associated with geometry recreation and providing a highly refined starting point that engineering teams can rapidly finalize and evaluate for production feasibility.

Evaluation of the reconstructed optimized design demonstrated an approximately 35% reduction in maximum principal stress within the critical region of interest while maintaining the prescribed design constraints. The complete optimization process was executed in an automated overnight run comprising approximately 90 optimization iterations. This case study demonstrates how high-performance computing, manufacturing-aware shape optimization, and automated geometry recovery can be integrated into a practical engineering workflow for accelerating structural design improvements in hydraulic components.

Title: Real-Time Anomaly Detection for J1939-Based Mobile Hydraulic Control Systems

Authors: Andrew Pfeiffer, Brian Steward, Manimaran Govindarasu, Souradeep Bhattacharya, Ranuka Kanakanamalage (Iowa State University, USA)

Abstract: As off-highway vehicles (OHV) become increasingly interconnected for remote control and telematics, the cybersecurity attack surface grows. The controller area network (CAN) communication systems dominating mobile hydraulics are highly vulnerable to manipulation. Specifically, the SAE J1939 message protocol, commonly used in OHVs, has a well-known message structure that facilitates attacks. To address these challenges, this study introduces a machine learning-based anomaly detection system (ADS) tailored for J1939-based CAN networks. Three distinct attack vectors—Spoofing, Denial of Service (DoS), and Fuzzing—were simulated to evaluate real-time detection performance on a physical hydraulic testbed. Furthermore, the ADS framework was extended to detect operational fault conditions, demonstrating success in identifying the onset of hydraulic cavitation.

PRESENTATION ABSTRACTS

Title: A Transient Thermo-Elasto-Hydrodynamic Model for Multi-Lobe Radial Piston Motors

Authors: Jinhwan Lee, Lizhi Shang, Pierre Bernard (Purdue University, USA and Poclairn Hydraulics, France)

Abstract: This study presents the computationally efficient transient thermal elastohydrodynamic lubrication model for a multi-lobe radial piston motor. The periodic boundary condition and time-domain segmentation for a coupled thermal system of equations enable a 500 times faster simulation than a direct full-domain simulation. The accuracy of the developed model was validated against transient temperature measurements over the operating time scale. The predicted temperature evolution closely follows the experimental trend, with a maximum deviation of 2.3 °C observed at the end of the cycle. The steady-state results suggest a large temperature rise in solid parts and lubricating films. At 350 bar and for 80 rpm, the temperature rises are 22.8 °C for the roller-bushing and 88.1 °C for the piston-cylinder interface. Due to a significant decrease in viscosity, the tribological performance of the piston lubricating interfaces degrades. The roller-bushing interface demonstrated partial rupture of the lubricating film, and the piston-cylinder interface showed 30% higher contact force and area during the first half of the piston upstroke than in the isothermal simulation. Overall, the developed method can be applied to any type of hydrostatic machines such as axial piston pumps and gear pumps while providing system-level transient thermal analysis under varying operating conditions.

Title: Predictive Maintenance for Hydraulic Pumps through Operating-Point-Aware Deep Learning of Vibration Signals

Authors: Pawan Panwar (Milwaukee School of Engineering, USA)

Abstract: Catastrophic pump failures cause costly downtime and collateral machine damage. This work shows that a single non-invasive triaxial accelerometer sampled at 2 kHz can recover the complete operating state of a bent-axis piston pump, including speed, pressure, flow, volumetric efficiency, and remaining useful life (RUL). The proposed approach was validated on a bent-axis piston pump subjected to 17 accelerated wear stages, induced via ISO dust injections. The dataset comprised 877 five-second recordings across 500 to 1700 rpm and 2000 to 5000 psi at 80 °C. A compact 1D convolutional neural network (CNN) trained on raw vibration signals. CNN achieved $R^2 > 95\%$ for all targets. Single axis models matched kinematic accuracy but underperformed on wear sensitive targets, highlighting the importance of cross-axis correlations in capturing degradation signatures. This work delivers a robust, adaptable condition monitoring strategy that uses noninvasive real time vibration analytics to forecast pump failure.

PRESENTATION ABSTRACTS

SENSORS AND CONDITION MONITORING

Thu Sep 10, 10:40 AM, Stewart Center 279

Title: New Sensing Method for Cartridge Valves

Authors: Massimiliano Ruggeri (CNR - STIMS, Italy); Sara Baldoni, Chiara Gialluca, Christopher Rosi (VIS Hydraulics S.r.l., Italy); Matteo Ferri, Luca Belsito (CNR - ISMN, Italy)

Abstract: Trends in hydraulic system design tend to avoid proportional valves because of energy losses intrinsic to their operation. Yet valves are fundamental in many applications and often are used in functional safety critical applications. Current systems require increasing precision in controls and actuations, as well as higher safety performance levels in both components and systems. Both of these requirements involve sensors to make the component and systems fully observable and controllable. It is particularly difficult to implement sensors integrated directly in cartridge valves. However, sensors installed directly inside the valves would allow direct observation of their behaviour. This would provide highly valuable diagnostic information from functional safety perspective and would be crucial for precise control of valve operation. The paper presents a new sensor integration method for cartridge valves, which allows a direct observation of their functionality and enables a precise tuning of the valve in low flow metering condition, as well as the direct control of valve safe position. The applied sensor is a miniaturized MEMS sensor whose usage is the consequence of a mechanical-electronic valve co-design approach. The valve design, the sensor and its readout electronics, as well as the tests are presented, with a discussion of the possible usage of the assembly and a more general idea for new design of both proportional and status valves.

Title: SONAR-Based Gas Void Fraction Monitoring for Mobile Hydraulic Systems

Authors: Daniel Gysling (CorVera, LLC, South Glastonbury, CT, USA) and Brian Schreiber (HYDAC, Bethlehem, PA, USA)

Abstract: Entrained gas in fluid power systems is a contaminant that can 1) damage critical components, 2) reduce efficiency and precision and 3) reduce the life of hydraulic fluids and other critical components in hydraulic systems. Monitoring entrained gas levels and mitigating their effects is particularly challenging for mobile hydraulic systems in which optimizing reservoir size, power consumption, and reliability are key aspects of optimizing overall system performance.

This paper describes work validating the application of HYDRx™ SONAR-based gas void fraction measurement on a fluid power test bench. SONAR-based gas void fraction measurement technology utilizes SONAR-based beam-forming technology to determine the speed at which naturally-occurring, low-frequency, sound propagates within aerated hydraulic fluids by interpreting the output of a pair of sensors installed at two locations along the length of a hydraulic line. The measured sound speed is then interpreted in terms of the gas void fraction of the hydraulic fluid.

The presentation describes three embodiments of SONAR-based Gas Void Fraction measurements, each of which is tailored to address differing requirements within the fluid power industry. These include 1) port-pressure sensors installed into existing process lines to provide real-time, in-situ gas void fraction, 2) strain-based, clamp-on sensors installed on existing process lines also providing real-time, in-situ gas void fraction measurement, and 3) a continuous sample-based architecture that measures the gas void fraction within a sample of hydraulic fluid that is extracted and returned to the hydraulic system under test.

PRESENTATION ABSTRACTS

(continued) SONAR-Based Gas Void Fraction Monitoring for Mobile Hydraulic Systems

Data is provided for each of the three implementations applied on HYDAC's Fluid Power Test bench in Bethlehem, PA, USA. In each of these tests, the hydraulic fluid within the fluid power test bench is aerated prior to entering a hydraulic reservoir. The gas void fraction is measured within the aerated hydraulic fluid exiting a hydraulic reservoir, thereby simulating real-world conditions associated with gas void fraction carrying-under from a reservoir and entering the inlet of hydraulic pump.

HYDRXTM technology draws from over 25 years of experience of applying SONAR-based gas void fraction measurements in wide range of industrial applications including downhole oil and gas well applications, pulp and paper slurries, mining slurries and food and beverage applications. This work builds-off previously published work that demonstrated the utility and accuracy of this approach for measuring aeration in fluid power system by direct comparison with independent references and analytical modeling.

Title: Valve-Integrated Position Sensing (VIPS) for Flow Estimation and Monitoring in Electrohydraulic Systems

Authors: Annalisa Sciancalepore, Application Engineer (Sun Hydraulics)

Abstract: The increasing demand for smarter and more efficient hydraulic systems is driving the need for compact, cost-effective sensing solutions that can be seamlessly integrated into existing components. This work introduces a Valve-Integrated Position Sensor (VIPS) applied to a flow meter cartridge valve. VIPS is a compact device based on a novel sensing technology, installed at the rear of the valve to measure spool displacement and enable real-time estimation of hydraulic flow.

When integrated with a flow control valve within a control loop, the VIPS-enabled flow meter cartridge provides a practical and reliable flow-related feedback signal, leading to improved control accuracy, stability, and overall system responsiveness.

By embedding sensing functionality directly at the valve level, VIPS enables a new class of "self-sensing" hydraulic components capable of delivering valuable operational and diagnostic information. This approach enhances system efficiency and supports advanced condition monitoring strategies. In particular, variations in estimated flow, when combined with additional system-level information, can be leveraged to identify wear, contamination, or performance degradation, enabling early detection and proactive maintenance. As fluid power systems continue to evolve toward electrification and tighter integration with electronic control architectures, solutions such as VIPS help bridge the gap between hydraulics and electronics. Overall, this work demonstrates how a simple, scalable sensing approach can enhance system awareness, improve control performance, and support the development of more connected, efficient, and reliable hydraulic machines.

PRESENTATION ABSTRACTS

Title: Numerical Modeling of Slipper-Swashplate Interface considering Wear and Thermal Effects

Authors: Ishan Suvarna, Lizhi Shang (Purdue University, USA and Bosch Rexroth, USA)

Abstract: Predicting performance of pump designs under real-life operating conditions is a difficult task to achieve. Minor interface design features can have major effects on pump efficiency, reliability and noise generation, increasing the complexity of modeling pump behavior. Furthermore, understanding how a given design will function under real operator cycles often requires physical endurance testing, increasing cost and time requirements for the product development process. To mitigate this issues, "digital twins" can allow detailed modeling of a physical pump under the actual operator cycles. Continuous data integration would allow the

Title: Experimental Investigation of Micromotions in Helical External Gear Machines

Authors: Kailash Choudhary, Ajinkya Pawar, Andrea Vacca (Maha Fluid Power Research Center, Purdue University, USA); Sabrina Di Domenico, Manuel Rigosi (R&D Department, Casappa S.p.A., Italy)

Abstract: This paper presents an experimental investigation into the gear micro-motions and structural compliance effects in external gear machines (EGMs). While traditional models often prioritize rigid-body kinematics, this study highlights the critical necessity of considering multi-regional elastic deformations to accurately interpret internal gap heights. A commercial helical gear-type EGP was used as the reference machine, equipped with a novel experimental setup designed to measure the gear micromotions using calibrated eddy-current sensors. Experiments were conducted at multiple shaft rotational speeds, with discharge pressures ranging from 10 bar to 250 bar at a constant fluid temperature of 50 °C. The results demonstrate that while journal bearing interface gap height stabilizes nearly at 50 bar, significant gear micromotions continue to be captured as pressure scales to 250 bar. This behavior is successfully attributed to the effects of structural responses from expansion of housing, compression of bushing, and deformation of multi-layer soft liners situated between gear and bushing, forming journal bearing interface. The study concludes that these elastic deformations are significant enough to be captured by high-precision sensors and must be accounted for in the design and modeling of high-pressure fluid power components to ensure reliable performance predictions.

PRESENTATION ABSTRACTS

ELECTRIFICATION, DIGITALIZATION & SYSTEM DESIGN

Thu Sep 10, 1:20 PM, Stewart Center 278

Title: Hydraulic Innovation in the Real World: Why Some Technologies Thrive, Many Stall, and What Comes Next

Authors: Germano Franzoni, Principal Systems Engineer (Parker Hannifin, USA)

Abstract: Over the past three decades, hydraulic system development has seen recurring waves of innovation aimed at improving efficiency, controllability, and total cost of ownership. Many concepts have been introduced with strong technical promise—hydraulic hybrids, pump-controlled actuation, independent metering, and various forms of energy recovery for overrunning loads—yet broad market adoption has often been limited. At the same time, a smaller set of solutions has achieved durable success, such as electrohydraulic steering, while several emerging architectures remain “open verdict,” including distributed power, electrohydraulic actuation, multi-rail pressure systems, and multi-chamber cylinders.

This presentation offers a practitioner’s review of these technology cycles through the lens of customer equipment development and field experience. Rather than focusing solely on theoretical benefits, it examines the practical reasons technologies succeed or stall: duty-cycle mismatch, efficiency gains that disappear in real operation, control complexity, calibration burden, packaging constraints, reliability and contamination sensitivity, functional safety requirements, serviceability, and the economic realities of machine platforms and supply chains. The talk will highlight representative examples, distilling patterns that repeatedly surface when new hydraulic architectures move from prototypes to production.

The session concludes with a forward-looking perspective on where fluid power is most likely to evolve in the coming years, including the role of electronics and software, electrification-driven boundary conditions, and the increasing importance of data-driven commissioning and diagnostics. Attendees will leave with a structured way to evaluate “next big” hydraulic concepts and a set of grounded expectations for what will—and will not—scale across real machines and real customers.

Title: Electrification of Mobile Machines - Exploiting Increased Degrees of Freedom in System Design

Authors: Liselott Ericson (Linköping University, Sweden)

Abstract: Electrification of mobile machines is often viewed primarily as replacing the internal combustion engine with an electric motor. However, electrification also introduces new degrees of freedom that can fundamentally change how the complete machine and its subsystems are designed. Multiple electric machines, variable-speed operation, and new hydraulic architectures create opportunities for improved efficiency, controllability, and system integration.

This presentation discusses how these increased degrees of freedom can be exploited in the design of future mobile machines, with a particular focus on electro-hydraulic systems. Examples from research will illustrate different approaches, including variable-speed pump operation, multi-pump systems, and integrated electro-hydraulic energy converters.

PRESENTATION ABSTRACTS

(continued) Electrification of Mobile Machines - Exploiting Increased Degrees of Freedom in System Design

At the same time, the increased degrees of freedom result in a much larger design space. Finding the best combination of system architecture, component sizing, and control therefore becomes an optimisation problem. System-level modelling and optimisation are important tools for exploiting this additional design freedom and identifying efficient solutions for future electrified mobile machines.

Title: From Simulation to Decision-Grade Evidence: Automated Pump Validation for Electrified and Severe-Duty Systems

Authors: Anthony Khoraych (Advanced Test and Automation Inc., Canada)

Abstract: The presentation would focus on practical lessons from physical pump and fluid-system validation, including model correlation, performance and durability testing, automated test execution, and the use of diagnostic measurements to better understand aeration and unstable system behaviour.

Title: Rexroth's Component Digitalization Strategy: How Software is Redefining Hydraulics

Authors: Christian Bock, Kendal Beaty, Rafael Cardoso (Bosch Rexroth US)

Abstract: Hydraulic systems have grown in capability and complexity to address growing system requirements and pain points across the industry. Pressure, flow, and power control capabilities come at an increased monetary cost in terms of physical system and hardware complexity. Through the fusing of electronic sensor data and software systems, the additional hardware complexity that was previously required can be removed or minimized. This presentation outlines how the implementation of software-centered systems can bring about physical space and cost savings, enhanced controllability and flexibility, and reduction in our environmental impact.

Multiple physical configurations are required to cover specialized scenarios, creating a balancing act between functional offerings and cost effectiveness. Additional hardware components enable hydraulic systems to fulfil specialized requirements which results in increased physical complexity. A single hydraulic pump now becomes a family of options; each tailored to specific use cases.

Using software-centered systems physical components are made digital, using model-based controls to interface with existing hardware. Hardware is automatically calibrated and data filtered to account for tolerances and improve accuracy. Interchangeability of components becomes easier, as the reactions of the hardware can be digitally tuned to the application type. The physical hydraulics become an adjustable system to account for a use cases requirements and operational needs. This presentation will showcase Rexroth's latest progress in integrating software with hydraulic components for open and closed-circuit systems. We will demonstrate how we are both enhancing current components with software and creating new hydraulic devices designed specifically for electronic control.

PRESENTATION ABSTRACTS

Title: Understanding and Mitigating Common Mode Current in Electrified Systems

Authors: Scott D. Sudhoff (Purdue University, USA)

Abstract: The fast edge rates of modern power semiconductors coupled with unavoidable parasitic capacitances results in common mode currents. These currents flow through the ground conductors and structure of a vehicle rather than through the intended power conductors. The fields produced by common mode currents fall off very slowly with distance and can lead to interference and control system failure. Common mode voltages can build up and pit bearings in machinery leading to mechanical failure. In this presentation, the nature, causes, and mitigation of common mode voltages and currents are discussed.

Title: Advances in H₂ Engine-Powered Off-Road Vehicles through Integrated Hydraulic System Design and Control

Authors: Elena Menegatti, Doni Thomas, Greg Shaver, Andrea Vacca (Purdue University, USA)

Abstract: Hydrogen engines offer a promising pathway for reducing carbon emissions in off-road vehicles while largely retaining the established architecture, components, and manufacturing processes of conventional internal combustion engines. However, operating H₂ engines under ultra-lean conditions to suppress knock and reduce engine-out NO_x emissions introduces significant challenges in transient operation. This work investigates a Multi-Pressure Rail (MPR) hydraulic architecture as an enabling technology for ultra-lean H₂ engine operation in a medium-to-large-sized excavator. The proposed system uses multiple pressure levels to reduce throttling losses and decouple actuator power demand from the engine, enabling down-speeding toward higher break thermal efficiency regions, reducing fuel consumption and hydrogen storage requirements. By controlling the pump displacement and distributing hydraulic power across the pressure rails, the MPR architecture lowers the torque demand, allowing the H₂ engine to maintain stable operation in ultra-lean conditions. The proposed approach is evaluated through high-fidelity co-simulation of the engine, hydraulic actuation system, and system controller. Results demonstrate that the MPR architecture significantly improves engine transient response during demanding excavator cycles that cannot be sustained with conventional load sensing hydraulics. The results highlight the potential of coordinated hydraulic system design and engine control to enable H₂ engines for off-road applications.

PRESENTATION ABSTRACTS

SIMULATION TECHNOLOGY

Thu Sep 10, 1:20 PM, Stewart Center 279

Title: Model Based Design applied to the Software development of a fully digitalised hydraulic circuit - Smart Miniexcavator case study

Authors: Francesco Corradin (Walvoil S.p.A.)

Abstract: A Model Based Design (MBD) approach is presented for the software development of a fully digitalised hydraulic circuit, using a Smart Miniexcavator as a case study. The digital twin of the machine is built in Amesim, where both the 3D multibody excavator model and the hydraulic model are developed and integrated. Through co-simulation with Simulink, the control logic – covering electronic pump management strategies and overall system logics – is designed and validated in a fully virtual environment. This approach significantly reduces the need for physical prototyping and on-machine test hours, resulting in a faster, more robust and fully traceable software development process.

Title: Unsteady CFD Analysis of Alternating Flow Patterns in a Restrictive Orifice of a Pressure Regulator Valve

Authors: Naoki Hirose, Seiei Masuda, Yasushi Matsunaga (IHI Corporation, Japan); Fumio Shimizu, Kazuhiro Tanaka, Takeshi Yamaguchi (Kyushu Institute of Technology, Japan)

Abstract: The damping force generated by the damping orifice installed in a pressure-regulating valve is regarded as a key factor governing the overall stability and dynamic response of the valve. However, this damping force varies in a complex manner depending on the local flow field around the orifice, the amplitude of the volumetric flow rate, and the excitation frequency, and its fundamental mechanisms have not yet been fully clarified. To elucidate these mechanisms, three-dimensional unsteady CFD analyses were performed for the flow around the damping orifice within a pressure-regulating valve system, and the resulting flow patterns were examined in detail. The analyses revealed that, under unidirectional-flow conditions, a highly unsteady vortical structure is formed in which starting and stopping vortices are generated and subsequently collapse, whereas under alternating-flow conditions, distinctly different flow fields appear on the upstream and downstream sides of the orifice. This paper reports on these characteristic flow-field structures.

PRESENTATION ABSTRACTS

Title: 1D System Modeling and 3D CFD Co-Simulation Methodology for Analyzing Transient Behavior in Hydraulic Valves

Authors: Priyanka Viswanath, Ashutosh Pandey (Simerics Inc., USA); Nathan Rosenbaum, Chris Imholte, Bipin Kashid (Parker Hannifin, USA)

Abstract: Hydraulic valves are key components in fluid power systems and are required to operate reliably over wide pressure, flow, and temperature ranges, often under fast-changing load conditions. As hydraulic systems become more compact, complex interactions between valves and the surrounding sub-system can lead to undesirable phenomena such as noise and dynamic instabilities. These effects can degrade system performance, damage components, and negatively impact operator experience. Identifying the root cause of such behavior is challenging and frequently relies on repeated prototyping and extended testing, increasing development time and delaying product launch. This paper presents a decoupled cosimulation methodology for modeling transient flow behavior and instabilities in hydraulic valves. The approach combines one-dimensional (1D) sub-system modeling with three-dimensional (3D) Computational Fluid Dynamics (CFD) analysis using Simerics-MP+. The 1D models establish the operating envelope and are validated against test data to define the boundary conditions for high-fidelity 3D CFD simulations. Targeted CFD analysis enables the identification of operational deviations, cavitation, jets, flow separation and ensuing vortices, which are critical in identifying local instabilities. These detailed insights are difficult to obtain through 1D analysis or to capture experimentally. By maintaining a decoupled framework, the methodology ensures computational efficiency while preserving realistic system behavior. The results demonstrate reduced prototyping cycles and accelerated valve development, providing a practical and scalable approach for resolving complex dynamic issues in modern hydraulic valve designs.

Title: Excavator closed-loop simulator: From fuel to soil

Authors: Romain Nicolas (Siemens)

Abstract: This presentation is about demonstrating a closed-loop excavator simulator where soil resistance, machine dynamics, hydraulic power & fuel consumption interact in one co-simulation loop, so we can explore the real trade-offs and move toward multi-objective optimization and verification: productivity, fuel consumption, and durability, together. A step-by-step approach is presented where Simcenter Motionsolve, Simcenter Amesim and Simcenter EDEM are demoed all together.

PRESENTATION ABSTRACTS

Title: Modeling of Rotor Deformation Effects in Gerotor Pumps for High Pressure Applications

Authors: Kai Ping Qwah, Andrea Vacca, Matthias Krug (Purdue University, USA and Thomas Group, Germany)

Abstract: Gerotor pumps are widely utilized as positive displacement units in low-to-medium pressure applications, such as automotive engine oil and fuel systems. Modern technological demands require higher operating pressures, for which Gerotors remain a strong candidate. While advanced simulation models can accelerate progress in Gerotor design, modeling a pump for high-pressure applications necessitates accounting for rotor deformation effects, which are often overlooked in conventional rigid-body models. Current methodologies, including 3D CFD, lumped parameter (LP), coupled LP-lubricating interface models, and deformable lateral compensation mechanisms, fail to capture the exact rotor deformation effects that influence the lubricating interface, TSV pressurization, and internal leakage behaviors.

To address this gap, this paper presents a multi-domain numerical model that integrates rotor deformation effects into the simulation of a lateral compensation Gerotor pump's operation. Utilizing a fully-coupled LP-CFD-FEM framework, this approach is implemented via the proprietary MULTICS multi-physics simulation tool. The model incorporates an FEM polygonal ring formulation that calculates the structural deformation, capturing the displacement of each tooth and the resulting alteration of the tooth tip gap height. This model forms a comprehensive coupling with LP and Reynolds solvers to evaluate the tooth tip flow loss and the lateral film leakages, respectively.

The proposed model provides detailed estimations of lateral film behaviors, including tilting and lateral gap heights, TSV pressurization, and the overall volumetric efficiency of the pump. Comparative analysis against experimental results reveals a close match in both lateral film behavior and volumetric efficiency, emphasizing the critical role of rotor deformation. Results demonstrate a predicted volumetric efficiency of approximately 72% when rotor deformation effects are considered, closely aligning with experimental data, compared to an over-predicted 83% when these effects are neglected. This work highlights the critical importance of rotor deformation considerations in high-pressure applications, advancing the state of the art in gerotor pump modeling and simulation.

PRESENTATION ABSTRACTS

Title: Experimental Characterization and Control-Oriented Modelling of Proportional Valves for Multi-Common Pressure Rail Systems

Authors: Zihao Xu, Andrea Vacca (Purdue University, USA)

Abstract: Multi-common pressure rail (MPR) systems are emerging as a high-efficiency architecture for multi-actuator machines because they reduce throttling losses and enable energy recuperation. Recent studies, including prior work from this lab, identify pressure rails combined with multi-chamber cylinders as a particularly promising configuration, which is now approaching commercial deployment. However, accurate motion control remains a major challenge. All control actions are ultimately realized by proportional valves, whose dynamics are often insufficiently modelled and rarely validated by measurements.

This work experimentally characterizes and models the proportional valves of a test rig built around a three-chamber cylinder and its valve control manifolds. A trapped-volume step test is introduced to obtain the rail-to-rail valve response without a flowmeter, using chamber-pressure measurements with the cylinder fixed at end stroke. Based on these measurements, a two-stage cascade model comprising solenoid-current and valve-opening dynamics is proposed. Model parameters are identified through forward simulation in the pressure domain, avoiding the noise amplification associated with differentiating measured pressure. The identified parameters explain the observed dead time and the valve-to-valve variation, and are now used for the design and pre-verification of the cylinder controller on the test rig. The remaining steps toward validation on the prototype machine are also discussed.