2024 International Maha Fluid Power Conference

West Lafayette, IN, USA

September 3-5, 2024

Final Program

PURDUE UNIVERSITY | Maha Fluid Power Research Center

FOREWORD

Dear Attendees, on behalf of the Organizing Committee, the Maha Fluid Power Research Center (Maha), Purdue University, the Sponsor Organization, it is a great pleasure to present you the Final Program of the 2024 International Maha Fluid Power Conference.

This is third event that Maha organizes at Purdue to network, exchange ideas, and present the recent research trends in fluid power and motion control technologies, and the second event after the creation of the Industry Consortium associated with the Maha Fluid Power Research Center in 2022.

This year's conference has several relevant "first time":

- for the first time the technical program includes presentations from original published papers, along with "presentation only" contributions, you will find instructions to locate the published paper in this document;
- for the first time we have an exhibition area, open to the whole Purdue community and external visitors;
- for the first time we honor the memory of the founder of Maha, the late Prof. Monika Ivantysynova, with a medal that will be given to a Purdue alumni with career achievements related to fluid power and motion control.

The three-day program of the conference will feature 57 technical presentations in two parallel sessions, general keynote lectures from leaders in academia and industry as well as networking event. Additionally, a student recruiting event will take place, thanks to the support of the National Fluid Power Association.

I would like to thank the authors of the papers/presentations, to the session chairs, and the members of the advisory committee for their help in supporting the technical program. A special thank goes to the member companies of the Maha Center for endorsing the event, and to the Industry Advisory Board for providing guidance in the event organization, and for their contribution in the difficult task of selecting the Monika Ivantysynova Medal awardee, among several deserving candidates. I also would like to recognize the Gold, Silver, and Bronze Sponsors, which allowed us to organize an affordable event for students and faculty members. Finally, a special thanks to the key Maha faculty members Dr. L. Shang and Dr. J. Garcia-Bravo, and the Maha staff and students (especially Antonio Esquivel) for their crucial help in organizing all the conference details.

We hope that you will enjoy the conference and leave it with inspirations for new ides, and with enriched professional contacts.

Sincerely,

Andrea Vacca, PhD
Maha Fluid Power Faculty Chair

2024 International Maha Fluid Power Conference

COMMITTEES

SCIENTIFIC COMMITTEE

From Academia:

Torben Ole Andersen, University of Aalborg, Denmark
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Paolo Casoli, University of Parma, Italy
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Bing Xu, Zhejiang University, China
Barbara Zardin, University of Modena and Reggio Emilia, Italy

From Industry:

John Bekker, Bucher Hydraulics
Pierre Bernard, Poclain Hydraulics
Filippo Boiardi, Settima Meccanica
Enrique Busquets, Bosch Rexroth
Germano Franzoni, Parker Hannifin
Matthew Kaldor, Bobcat
Antonio Lettini, Casappa
John Mahrenholz, John Deere
Uli Melchinger, CNH Industrial
Davide Mesturini, Walvoil
Steve Weber, Sun Hydraulics
Catherine Zhuang, Hengli

ORGNIZING COMMITTEE

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

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2024 International Maha Fluid Power Conference

KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 3, 1:15 pm Fowler Hall

Andrea Vacca (Purdue University)

Fluid Power trends towards sustainability

Abstract: By many, fluid power is wrongly considered as a mature technology, limited by an energy efficiency which is too low to cope with the societal needs for sustainable machinery. Technologies able to reduce carbon emissions require efficiencies of the actuation system much higher than common hydraulic control systems. Particularly in mobile applications a high transmission efficiency lowers the energy storage requirements, which is a critical aspects for all technologies based on prime movers that can replace conventional diesel engines, like hydrogen engines or battery electric vehicles. More than ever, these needs have been pushing both industry and academia towards proposing solutions for high-efficient actuation. With emphasis to off-road vehicles, this talk will summarize the most recent progresses towards high efficient solutions that can replace today's systems, but that can retain advantages in terms of cost, robustness and compactness. The presentation will also feature examples including efforts from Purdue and non-Purdue institutions.

Andrea Vacca

Andrea Vacca is the director of the Maha Fluid Power Research Center, the largest academic research center dedicated to fluid power research in the United States. His research focuses on several aspects of hydraulic control technology including new concepts to perform hydraulic actuations, new designs and modeling of positive displacement machines, electrification of fluid power systems, modeling of the properties of hydraulic fluids, reduction of noise emissions from hydraulic components. His research has been funded by the U.S. Department of Energy, the U.S. Department of Agriculture, the National Science Foundation, and several industry partners. Dr. Vacca holds 18 patents/patent applications and he is author of about 200 technical papers, and of the textbook "Hydraulic Fluid Power". He is the Editor in Chief of the International Journal of Fluid Power, one of the directors of the Global Fluid Power Society and a former chair of the Society of Automotive Engineers (SAE) - Fluid Power Division and of the American Society of Mechanical Engineers (ASME) - Fluid Power System and Technology Division.

KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 3, 1:15 pm Fowler Hall

Jürgen Weber (Dresden University of Technology)

From BAUEN4.0 straight to FLUID4.0 - Potentials of Digitization and Communication in Construction Machines and Fluid-Mechatronic

Abstract: The fluid power industry still has some work to do to catch up with the electric drive technology when it comes to digitalization. However, it is already clear that the industry has not missed out on any progress. Both research with projects such as BAUEN4.0 or BaSys4FluidSim and, above all, industry initiatives such as the digitalization working group in the VDMA Fluid Power Association demonstrate the innovative potential of Fluid Power 4.0. In this keynote presentation, the joint path of research and industry in the digitalization of the fluid power industry in Germany will be shown. Starting with digitization mechanisms in mobile applications based on the BAUEN4.0 joint research project and the resulting activities of the Construction Future Lab, technologies, projects and initiatives in other applications will be presented. Finally, the current development trend in the fluid power industry in the areas of interoperability and networked data spaces will be reflected in the current joint research project Fluid 4.0.

Jürgen Weber

Dr.-Ing Jürgen Weber was appointed university professor and chair of Fluid-Mechatronic System Technology at TU Dresden in 2010. Since 2018 he has been the leader of the Institute of Mechatronic Engineering. Professor Weber studied mechanical engineering at TU Dresden, and successfully finished his doctorate in 1991. Until 1997, he was the active senior engineer and the former chair of Hydraulics and Pneumatics. This was followed by an approximately 13-year industrial phase. He was active in various positions at the R&D department of the agricultural and construction machinery manufacturer CNH. Besides his occupation as head of the Department Hydraulics and design manager for mobile and tracked excavators, starting in 2002, he took on responsibility for the hydraulics in construction machinery at CNH worldwide. From 2006 onward, he was the global head of architecture for hydraulic drive and control systems, system integration and advanced development of CNH construction machinery.

KEYNOTE SPEAKERS

TUESDAY, SEPTEMBER 3, 1:15 pm Fowler Hall

William Robertson (California Air Resources Board)

Regional Decarbonization Goals and Off Road Opportunities

Abstract: California and a number of regions are working to demonstrate leadership in Climate Change Mitigation economy wide and on aggressive timelines arriving in the 2030's. Electrification is one of the key enablers of Greenhouse Gas reductions. As light duty vehicles and commercial trucks and buses reduce their impacts, the Off Road sectors become a more significant fraction of remaining emissions. Examples will be discussed of California policies and incentives accelerating Off Road electrification uptake and relatedly aligned programs elsewhere. Beyond the prime mover efficiency advantages available from electrification, these programs benefit incrementally from improved system integration and actuation efficiency. But those improvements can also grow the list of tasks, worksites and missions addressable with a given amount of on-board energy. This two dimensional benefit is a key enabler that accrues from improving the effectiveness of energy use within a piece of equipment while also increasing the equipment's scope of applicability.

William Robertson

Bill Robertson is the California Air Resources Board's Vehicle Program Specialist for Heavy Duty. He advises across the agency on tailpipe and zero emission regulatory programs and incentive programs for technology advancement and equity access. He also leads multistate outreach with jurisdictions seeking to use their Clean Air Act authority to apply California developed tools to meet their local air quality, community exposure and climate mitigation challenges. He has been involved in CARB's successful Low NOx Engine demonstration efforts spanning at least six engine platforms. He has been with CARB for 19 years spending the first decade in CARB's heavy duty emissions dyno facility benchmarking diesel exhaust aftertreatment systems, alternative fuels, and commercial vehicle electrification strategies. He also supported US-EPA Phase 2 GHG standards with hydraulic ePTO testing that has since grown into full flow capable transient loading schemes for emissions testing hydraulic-based Off Road equipment at CARB. He holds a Ph.D. in Physical Chemistry from Yale University and has conducted post doctoral research in aerosol chemistry at University of California, Irvine.

KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 4, 8:30 am Fowler Hall

Berend Bracht (Parker Hannifin)

The Power of Parker

Abstract: The talk will provide a brief overview of Parker Hannifin including all our global businesses, afterwards it will address secular trends in the industry with focus on electrified hydraulics/electrification. Specific application examples will be discussed. A focus will also be given to R&D and Engineering at Parker, living the Parker's purpose statement: "Enabling Engineering Breakthroughs that Lead to a Better Tomorrow".

Berend Bracht

Berend Bracht holds a Master of Science degree in Mechanical Engineering and a Master of Business Administration from the Technical University of Munich (TUM). Berend Bracht is Vice President and President - Motion Systems Group of Parker Hannifin Corporation in Cleveland, OH. He is responsible for all fiscal and strategic aspects of the group's global operations. Mr. Bracht joined Parker in 2018 as Vice President of Operations - Engineered Materials Group where he has been responsible for the global operations of Parker LORD since its acquisition in 2019. Before joining Parker, from 2015 to 2018, Mr. Bracht was President and CEO of Bendix Commercial Vehicle Systems LLC, a leader in the development and manufacture of leading-edge active safety and braking system technologies. Prior to joining Bendix, he had an accomplished 24-year career at Bosch Rexroth, a drive and control technology company, including serving as President and Chief Executive Officer of Bosch Rexroth Americas.

Steffen Haack and Enrique Busquets (Bosch Rexroth)

Improving the productivity and sustainability of industrial and mobile fluid power systems through software and data utilization

Abstract: The relationship between fluid power and data is described both for the industrial and mobile market segments. Not only on the present framework, but most importantly the future state is presented, in order to illustrate the potential for improvements on productivity, efficiency, and sustainability.

Steffen Haack

Steffen Haack holds a doctorate degree in the field of fluid technology, began his career at Bosch in 1996. Since 2001, he has taken on various tasks at Bosch Rexroth, related both to factory automation and hydraulics. From 2015 to 2017, he had already been a member of the board of management. From 2017 to the end of 2021, Haack led the Industrial Hydraulics business unit and rejoined the board of management in January 2021. Since then, he has been responsible for the entire development activities of Bosch Rexroth and the New Business product area. In addition to his professional activities, Haack is chairman of the Fluid Power trade association within the VDMA (German Association of Mechanical and Plant Engineering) and a member of the advisory board of "Deutscher Maschinenbau-Gipfel", the German Mechanical Engineering Summit.

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KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 4, 1:00 pm Fowler Hall

Otto Breitschwerdt and Mandi Henderson (Caterpillar)

Delivering Customer-Driven Technology Solutions

Abstract: With 2023 sales and revenues of $67.1 billion, Caterpillar Inc. is the world's leading manufacturer of construction and mining equipment, off-highway diesel and natural gas engines, industrial gas turbines and diesel-electric locomotives. Caterpillar is leading the industries they serve by providing technologies to help customers build a better, more sustainable world and succeed during the energy transition. Over the past 20 years, Caterpillar has invested over $30 billion in R&D to deliver best-in-class innovation in the areas of automation and autonomy, alternative fuels, connectivity and electrification, harnessing the power and possibilities of connected assets, advanced analytics and machine learning. This presentation will focus on the leading-edge technology solutions Caterpillar offers customers, the value they can provide, and what these technology systems mean for hydraulics.

Otto Breitschwerdt

Otto Breitschwerdt is chief technology officer and a senior vice president of Caterpillar Inc., responsible for the Integrated Components and Solutions (ICS) Division. ICS designs and builds components and systems that are used across the Caterpillar portfolio and also provides technology leadership, engineering, research, validation and manufacturing services to the enterprise. Breitschwerdt joined Caterpillar in 1990 and has served in a variety of positions in sales, marketing, operations, engineering, and supply chain. Prior to this role, he was appointed senior vice president of the Building and Construction Products division (BCP). He served as BCP general manager with global responsibility for manufacturing, designing and marketing the small wheel loader, compact wheel loader, compact track loader, and skid steer loader product lines. Breitschwerdt spent time in various other assignments in the U.S. and Brazil, including the Eastern U.S. region manager, BCP engineering and supply chain director, and Brazil district manager. As the plant manager for the Campo Largo, Brazil facility, he managed the facility's start up, from construction to full production of small wheel loaders and backhoe loaders. Breitschwerdt earned a degree in agricultural engineering from the University of São Paulo in Brazil and is also a graduate of Caterpillar's Executive Leadership Development Program in partnership with Stanford University. In addition to his role as director on the FFA board, he also serves on the Association of Equipment Manufacturers Construction Equipment Sector Board, and the United Way of the Triangle. He has previously served on boards for the Association of Equipment Distributors Foundation and the American Chamber of Commerce in Brazil. Breitschwerdt is a certified executive coach through the Institute for Professional Excellence in Coaching (IPEC) and certified in emotional intelligence through Multi-Health Systems Inc.

Mandi Henderson

Mandi Henderson is Vice President of Global Hydraulics, responsible for enterprise strategy and governance of Caterpillar's $2 billion hydraulics business. She manages development and execution of the hydraulics enterprise component strategy, including aftermarket growth, make/buy, technology development and supply resilience. After a brief stint as a design engineer at a small agricultural equipment manufacturer, Mandi started her Caterpillar career in Fuel Systems as a test engineer, then held roles in fuel systems product development and as a category buyer. She had the opportunity serve as Supplier Quality Manager for Europe engine components, in Peterborough, UK. She returned to the U.S. and then worked as Engineering Manager for Caterpillar-designed valves. The scope of her role eventually grew to include the entire valve portfolio and oversight of hydraulics labs. She has also served as a category manager for Resource Industries hydraulics; and a hydraulic systems engineering manager. Mandi was raised in a small town in Saskatchewan, Canada, and earned a Bachelor of Science in mechanical engineering from Queen's University in Kingston, Ontario, Canada. In her free time, she plays hockey.

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KEYNOTE SPEAKERS

WEDNESDAY, SEPTEMBER 4, 1:00 pm Fowler Hall

Francesca Protano (Case New Holland)

CNH's Tech Journey: Blending AI into human and machine capabilities

Abstract: Want to know how a global leader in agriculture stays ahead of customer needs and industry trends? In this talk Francesca Protano, Head of Tech Strategy and Competence Centers, will provide an overview of the ag tech developments in the areas of AI and Machine learning at global agriculture equipment, technology and services at CNH.

Francesca Protano

Francesca Protano With more than 18 years of international experience, she has held various roles in the R&D, Finance, Marketing, Corporate Development (M&A, Business Development and Strategy) sectors. She was most recently Ventures Managing Director for CNH. She began her professional career at the Fiat Research Center. After graduating in Computer Science, she obtained a Master's degree in Mechatronics and Innovation & Technology Management (Alma Graduate School, Bologna Business School International). Always passionate about technology, today she holds the role of Head of Technology Strategy & Competence Centers in CNH.

Scott Schuh (Doosan Bobcat)

The Future of Fluid Power: Advancements and Emerging Trends

Abstract: In the field of engineering, few systems have stood the test of time like hydraulics. However, with technological advancements and alternative energy innovations, the traditional hydraulic system continues to transform and evolve to further enhance performance, efficiency and reliability. Intelligent hydraulics may be key to staying competitive and powering the machines of tomorrow. Scott Schuh, Chief Technology Officer and Senior Vice President for Doosan Bobcat shares the manufacturer's considerations around both the benefits and trade-offs of differing power sources, smart hydraulics and the needs for future hydraulic systems. Guided by customer demands, jobsite and application requirements, power source capabilities and infrastructure considerations, hear how the company is navigating the future of hydraulics and continuing to drive forward innovative solutions for the machines and jobsites of tomorrow.

Scott Schuh

Scott Schuh graduated in Mechanical Engineering from South Dakota School of Mines followed by receiving a Masters degree in Business Administration from University of South Dakota. He is responsible for product development, product safety and international standards. Joining Doosan Bobcat in 1998, Scott has made significant contributions to our engineering and technology areas, conducting various roles and projects including compact wheel loader, all-wheel-steer loader, embedded software, and hydraulics. He served as an engineering director from 2012 and was promoted to vice president of engineering in North America in 2021.

2024 International Maha Fluid Power Conference

KEYNOTE SPEAKERS

THURSDAY, SEPTEMBER 5, 8:30 am Fowler Hall

Giorgio Rizzoni (Ohio State University)

Prediction of battery remaining useful life using in-vehicle data

Abstract: While electrification presents opportunities for reduced carbon emissions in the commercial vehicle sector, on- and off-highway, electric propulsion in commercial vehicles presents different challenges than the passenger vehicle sector. Understanding the useful life of batteries in electrified propulsion and accessory systems is one such challenge, and this presentation highlights approaches to developing methods to assess health and life of electrochemical battery during its working life.

Physics-based, control-oriented models enable the design of algorithms for and State of Health (SOH) and Remaining Useful Life (RUL) estimation in the next generation of li-ion batteries for electric vehicles. However, the practical aspects of estimating health and forecasting remaining life (RUL) of in-use batteries is a problem that also requires data analytics techniques to manage large and diverse sets of real-world data that is projected onto a suitable feature space to permit SOH and RUL assessment for individual vehicles based on specific usage patterns, and geographic and climate conditions. This talk presents an overview of a data reduction and feature engineering process based on an extensive data set and aimed at reducing a large data set to essential features to be used in machine learning algorithms to estimate EV battery RUL during the actual life of the vehicle.

Giorgio Rizzoni

Giorgio Rizzoni, the Ford Motor Company Chair in Electromechanical Systems, is a Professor of Mechanical & Aerospace Engineering (MAE) and Electrical & Computer Engineering (ECE) at The Ohio State University. He has served in his current role as Director of Ohio State's Center for Automotive Research since 1999. Professor Rizzoni is a Fellow of IEEE (2004), SAE (2005) and ASME (2022). He received his BS, MS and PhD in Electrical & Computer Engineering from the University of Michigan.

Rizzoni has advised more than 46 PhD and 112 MS students in his career and was recognized by the MAE Department with the Distinguished Graduate Faculty award in April of 2016. He is also the recipient of three Excellent in Undergraduate Teaching awards in the MAE department, of the College of Engineering Stanley and Peter and Clara Scott Awards for Excellence in Engineering Education. He has led inter alia three Department of Education (DOE) Graduate Automotive Technology Education Centers of Excellence, the participation of Ohio State in two DOE US-China Clean Energy Research Centers and multiple Ohio Third Frontier programs. He is currently leading the ARPA-E NEXTCAR program, with the aim of advancing energy efficiency in connected and automated vehicles, and OSU's Advanced Air Mobility efforts.

2024 International Maha Fluid Power Conference

KEYNOTE SPEAKERS

THURSDAY, SEPTEMBER 5, 8:30 am Fowler Hall

Lizhi Shang (Purdue University)

Lubricating Interface Model – Its Current Application and Future Development

Abstract: Sustainable fluid power systems rely on high-performance lubricating interfaces in their hydrostatic pumps and motors. The design improvement of these interfaces is crucial for expanding the operating envelope of hydrostatic machines, improving energy efficiency, and enhancing compatibility with sustainable fluids and materials. However, advancing such critical designs is challenged by a limited understanding of their complex physics and the lack for experienced designers. The Maha Fluid Power Research Center has been at the forefront of developing lubricating interface simulation tools to address these challenges. These tools offer highly accurate performance predictions and comprehensive analyses of fluid-structure interaction phenomena.

This talk will highlight recent successful cases where lubricating interface simulations have aided pump and motor design. For the first time, we will also discuss recent changes in simulation development philosophy at Maha and their outcomes. The presentation will provide an outlook on the future development of this tool, incorporating more precise considerations of material properties, surface properties, and fluid properties. Additionally, we will explore new opportunities in lubricating interface simulation arising from emerging AI technologies.

Lizhi Shang

Dr. Shang's research interests focus on designing and modeling hydrostatic pumps and motors, hydrodynamic pumps and turbines, fluid power systems, and advanced computational and experimental tribological analysis. His research aims to improve energy efficiency, reliability, and controllability of fluid power systems by conducting interdisciplinary research on both component and system level. The research also emphasizes to explore and expand fluid power's use and fluid power technology in new applications. Dr. Shang joined Maha fluid power research center in 2020 as an assistant professor. He graduated as a Ph.D. student in 2018. His Ph.D. advisor is the late professor and Maha founder Dr. Monika Ivantysynova.

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. 3rd and Sept.4th at the Memorial Mall, in front of the Stewart Center.
The Ballrooms of the Purdue Memorial Union (PMU) will be used in case of unfavorable weather conditions.
Expo time is 1 pm – 5 pm on Sept 3rd and 8 am – 5 pm on Sept 4th.
The official opening of the Expo for the conference delegates is 3:00pm on Sept. 3rd, during the first coffee break.
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 (5:00 pm) will precede the conference dinners (6:00 pm). This will occur at the North Ballroom of the Purdue Memorial Union (PMU) on September 3rd and September 4th. With the exception of some reserved tables, seating is open to maximize network exchanges.

Conference lunches

Lunch boxes will be provided on Sept 4th (12:00 pm) and Sept 5th (12:30 pm) at room 206 of Stewart Center

Maha farewell

A farewell party will occur on Sept 5th at 4:00pm 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.

GENERAL INFORMATION

LIMO SERVICE FROM CLOSE AIRPORTS

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

REINDEER
Shuttle service to and from the Indianapolis International Airport (765) 637-5124 or reindeershuttle.com

OTHER TRANSPORTATION SERVICES

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Riehle Plaza Big Four Depot, 200 North 2nd Street (800) 872-7245

GREYHOUND BUS
Riehle Plaza Big Four Depot, 200 North 2nd Street (765) 742-8836 or (800) 231-2222

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

2024 International Maha Fluid Power Conference

PROGRAM OF EVENTS

TUESDAY, SEPTEMBER 3

Time	Location	Event	Location	Event
1:00 PM	FOWLER HALL	**OPENING AND REMARKS**		
1:15 PM	FOWLER HALL	**KEYNOTE LECTURE** **Andrea Vacca** (Purdue University) - Fluid Power trends towards sustainability **William Robertson** (California Air Resources Board) -Regional Decarbonization Goals & Off Road Opportunities **Jürgen Weber** (Dresden University of Technology) - From BAUEN4.0 straight to FLUID4.0 - Potentials of Digitisation and Communication in Construction Machines and Fluid-Mechatronic		
3:00 PM	STEWART CENTER 206	**COFFEE BREAK**		
3:45 PM	STEWART CENTER 214	**SESSION A HYDRAULIC PUMPS & MOTORS I** Session Chair: Jurgen Weber **Ajinkya Pawar** (Purdue University) Multi Domain Thermal Modeling of an External Gear Pump: Component Temperature Prediction and Effect on Efficiencies **Manuel Rigosi** (Casappa) Innovative Gear Pump for Electrified Machines **Jordan Pascale** (Danfoss) Centralized Pressure Control and Displacement Quantization With Digital Displacement Pumps **Thomas Heeger** (Linkoping University) Challenges for Multi-Quadrant Hydraulic Piston Machines **Pierre Bernard** (Poclain Hydraulics) Improving Transmission Efficiency via a Novel Radial Piston Cam Lobe Motor Architecture	STEWART CENTER 218	**SESSION B VEHICLE ELECTRIFICATION I** Session Chair: Brian Steward **Shaoyang Qu** (Bosch Rexroth) Electrification of a Compact Skid-steer Loader – Redesign of the Hydraulic Functions **Michael Terzo** (Xirro) Hyper-efficient Hydraulics of the Future – Platform Specific Architecture for Hybrid and Electrified Machines **Barun Acharya** (Parker Hannifin) Technical, Regulatory, and Safety Challenges in Designing an Electric Power Take-off for Electric or Hybrid Work Trucks **Brent Warr, Greg Morris** (Shell Glolbal Solutions) Hydraulic Machinery Electrification Accelerated Through Shell Dielectric Battery Thermal Fluid **Xingyi Xu** (Hengli) Opportunities and Challenges of Off-road Vehicle Electrification in China - Perspective of a Hydraulic Components Supplier
5:30 PM	STEWART CENTER 206	**BREAK**		
6:00 PM	PMU NORTH	**DINNER**		

PURDUE UNIVERSITY | Maha Fluid Power Research Center

2024 International Maha Fluid Power Conference

PROGRAM OF EVENTS

WEDNESDAY, SEPTEMBER 4

Time	Location	Event	Location	Event
8:30 AM	FOWLER HALL	**KEYNOTE LECTURE** **Berend Bracht** (Parker Hannifin) - The Power of Parker **Steffen Haack & Enrique Busquets** (Bosch Rexroth) - Improving the productivity and sustainability of industrial and mobile fluid power systems through software and data utilization		
10:00 AM	STEWART CENTER 206	**COFFEE BREAK**		
10:30 AM	STEWART CENTER 214	**SESSION C ENERGY AND EFFICIENCY** Session Chair: Saad Akhtara **Antonio Esquivel** (Purdue University) On the hydraulic wind turbine: energy-water nexus and power generation response under turbulent structures in the scale of the turbine's rotor **Nathaniel Fulbright** (Danfoss) Efficiency Improvements in a Servoless Swash Plate Pump: Experimental and Simulation Results **Andrea Polito** (Walvoil) Study and Experimental Application of an Energy Recovery System **Georg Herborg Enevoldsen** (Danfoss A/S) Water as a Battery	STEWART CENTER 218	**SESSION D NOISE VIBRATION AND HARSHNESS** Session Chair: Massimo Rundo **Michael Lenz** (Dresden University of Technology) Design Strategy for Noise Reducing Particle Dampers on Hydraulic Pumps **Dazhuang He** (Purdue University) Simultaneous Transfer Path Analysis of Axial Piston Pump Lumped Parameter Model Results **Bipin G Kashid and Howard Zhang** (Parker Hannifin) Enhancing System Performance in Subsea and Off-highway Applications: A High-fidelity, Transient Dynamic CFD Analysis Approach **Sujan Dhar** (Simerics) A 3D CFD and Computational Acoustics Simulation Methodology for Noise Mitigation Prediction in Gerotor Pumps
12:00 PM	STEWART CENTER 206	**LUNCH**		
1:00 PM	FOWLER HALL	**KEYNOTE LECTURE** **Otto Breitschwerdt & Mandi Henderson** (Caterpillar) - Delivering Customer-Driven Technology Solutions **Francesca Protano** (Case New Holland) - CNH's Tech Journey: Blending AI into human & machine capabilities **Scott Schuh** (Doosan Bobcat) - The Future of Fluid Power: Advancements and Emerging Trends		

PURDUE UNIVERSITY | Maha Fluid Power Research Center

PROGRAM OF EVENTS

WEDNESDAY, SEPTEMBER 4 (continued)

Time	Location	Event	Location	Event
2:30 PM	STEWART CENTER 206	COFFEE BREAK		
3:00 PM	STEWART CENTER 214	**SESSION E OFF-ROAD VEHICLE TECHNOLOGY I** Session Chair: Jose Garcia **Brian Steward** (Iowa State University) Chassis Dynamometer Testing of Hydrostatic Transmission in an Agricultural Vehicle **Xiaofan Guo** (Bosch Rexroth) Electronified Open Circuit Drive Concept for Compact Loaders **Shubham Ashta** (Purdue University) Robust Multivariate Air Handling Control for an Electrified Off-Road Diesel Powertrain **Andrew Krajnik** (HYDAC) Energy Mapping for Machine Electrification	STEWART CENTER 218	**SESSION F SYSTEM DESIGN & ARCHITECTURES** Session Chair: Christian Geis **Germano Franzoni** (Parker Hannifin) Creating Customer Value Through Development of Innovative System Control Concepts **Zihao Xu** (Purdue University) Simulation-Based Investigation to Multi-Common Pressure Rail Systems with Three Pressure Rails and Three-Chamber Cylinders **Elena Menegatti** (Purdue University) Design and Development of a Hydrogen Engine Powered Excavator for Zero-Emissions Off-Road Vehicles Technology Advancement **Timir Rajendra Patel** (Purdue University) An analysis of energy efficient hydraulic actuation architectures for mini-excavators
4:30 PM	STEWART CENTER 214	**SESSION G COMPONENTS** Session Chair: Jim Van de Ven **Wieslaw Fiebig** (Wroclaw University of Technology) Reduction of Dynamic Loads in Piston Compressors Through the Use of Mechanical Resonance **Mario Morselli** (Stem) A Novel Device for Oil Deaeration **Paul Michael** (Milwaukee School of Engineering) Tribological Studies of Hydraulic Cylinder Piston and Rod Seals	STEWART CENTER 218	**SESSION H SPECIAL FLUID POWER APPLICATION** Session Chair: Eric Lanke **Ali Naderi** (Purdue University) Application of Water Hydraulics of Pulse Reverse Osmosis Process **Farid Breidi** (Purdue University) Fluid Power Training and Education in the Digital Era: a Case Study of a Virtual Reality Lab **David Warsinger** (Purdue University) Fluid Power R&D Needs for Next-Generation Desalination
5:30 PM	PMU NORTH	DINNER		

2024 International Maha Fluid Power Conference

PROGRAM OF EVENTS

THURSDAY, SEPTEMBER 5

Time	Location	Event	Location	Event
8:30 AM	STEWART CENTER 214	**GENERAL LECTURE** **Giorgio Rizzoni** (Ohio State University) - Prediction of battery remaining useful life using in-vehicle data **Lizhi Shang** (Purdue University) - Lubricating Interface Model–Its Current Application and Future Development		
9:30 AM	STEWART CENTER 214	**SESSION I SENSORS AND MEASUREMENTS** Session Chair: Wieslaw Fiebig **Anthony Khoraych** (Advanced Test and Automation Inc.) Innovating Aeration Measurement for Enhanced Vehicle Lubrication Systems **Antonio Masia** (Purdue University) Power Loss in Piston/cylinder and Slipper/swashplate Interface at Extreme Low-speed Operating Condition **Massimiliano Ruggeri** (Imamoter CNR) Innovative Hyper-thin Sensor for Cartridge Valves Diagnostics and Predictive Diagnosis	STEWART CENTER 218	**SESSION J HYDRAULIC PUMPS AND MOTORS II** Session Chair: Pual Michael **Jinhwan Lee** (Purdue University) An Elastohydrodynamic Lubrication (EHL) Model for Radial Piston Motor **Roman Ivantysyn** (Dresden University of Technology) Comprehensive Transient Thermal Modeling of Axial Piston Pumps: Insights From Displacement Chamber Pressure, Temperature and Heat Convection **Matthias Krug, Zubin Mistry** (Thomas Magnete, Purdue University) Experimental and Numerical Analysis of Internal Micromotions in Gerotor Units: Exploring Contact Mechanics and Lubrication Interfaces
10:30 AM	STEWART CENTER 206	**COFFEE BREAK**		
11:00 AM	STEWART CENTER 214	**SESSION K CONDITION MONITORING & SAFETY** Session Chair: Massimiliano Ruggeri **Svenja Horn** (Dresden University of Technology) Causal Condition Monitoring for Axial Piston Pumps: Prediction of Different Faults Under Variable Operating Conditions **Daniel Gysling** (CorVera) SONAR-based Real-time, Gas Void Fraction Monitoring Systems for Mobile Hydraulic Systems **Marvin Durango** (Purdue University) Transforming Excavator Operation: Fusing Teleoperation, Digital Twin, and Fluid Power System for Optimal Performance and Safety Conditions **Stig Kildegaard Andersen** (Danfoss A/S) Piston harmonic analysis -fatigue crack study	STEWART CENTER 218	**SESSION L VEHICLE ELECTRIFICATION II** Session Chair: Giorgio Rizzoni **Woongkul Lee** (Purdue University) High Power Density Integrated Electric Drives for Transportation Electrification **Rene Chacon** (Dassault Systemes) Advancing Reliability in Electro-hydraulic Actuators Through a Model-based Systems Engineering Approach With 1D and 3D Simulation Tools **Weijin Qiu** (John Deere) Facilitating the Development of a Novel Battery-hybrid Wheel Loader Exploiting Hardware-in-the-loop Technique **Christian Haas** (RWTH Aachen University) Optimization-based System Synthesis for Electrified Mobile

2024 International Maha Fluid Power Conference

PROGRAM OF EVENTS

THURSDAY, SEPTEMBER 5

12:30 PM — STEWART CENTER 206

LUNCH

1:30 PM

STEWART CENTER 214

SESSION M DIGITALIZATION

Session Chair: Farid Breidi

Haotian Han (Purdue University)
Numerical Investigation of Lubrication film cavitation

Dinghao Pan (Purdue University)
Analysis of the Incomplete Filling of a Positive Displacement Pump Due to Undissolved Gas Involving Experiments and Simulations

Arlie Nuetzel (Siemens)
Early Architecture Design Exploration of Electrified Heavy Equipment

Christian Geis (VDMA)
Digitalization & Sustainability: The Key to the Future of Fluid Power

Israa Azzam (Purdue University)
Synchronized Digital Reality Remote Environments for Seamless Control of Fluid Power Manipulators

STEWART CENTER 218

SESSION N OFF-ROAD VEHICLE TECHNOLOGY II

Session Chair: William Robertson

Sumaiyyah Nizam (Bosch Rexroth)
Kinematic Position Control in Compact Track Loaders

Jose Garcia-Bravo (Purdue University)
What Happened to Hydraulic Hybrids?

Jacob Lengacher (Purdue University)
Implement-only Implementation of a Multi Pressure Rail System to an Agricultural Planter

Zifan Liu (Bosch Rexroth)
Design and Demonstration of a Battery-powered Electric Compact Skid-steer Loader

Saad Akhtara (National Renewable Energy Laboratory)
A Deep Reinforcement Learning Framework to Develop Supervisory Controller of a Novel Multi-pressure Rail Tractor-planter Hydraulic System

3:00 PM — STEWART CENTER 214

CLOSURE & AWARD

3:15 PM — -

TRAVEL TO MAHA

4:00 PM — MAHA LAB (KEPNER)

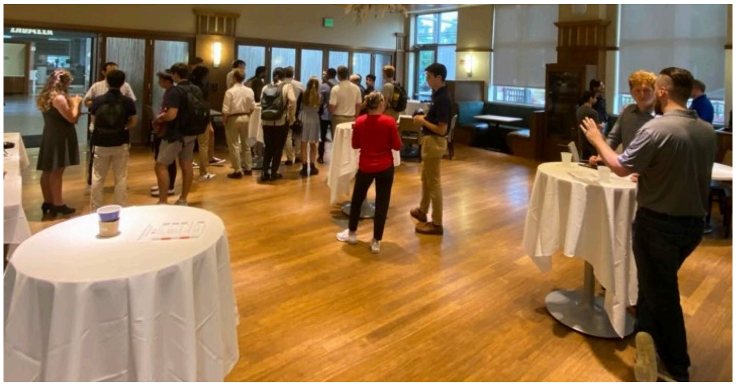
LAB TOUR & SOCIAL EVENT

2024 International Maha Fluid Power Conference

RECRUITING EVENT

WEDNESDAY, SEPTEMBER 4

Thanks to the sponsoring of the National Fluid Power Association, during the conference it will be possible to promote careers in fluid power by providing a space for companies and students to casually interact with each other, and for both students and recruiters to be professionally matched together.



This event will take place between 4 and 6 pm in rooms 278 and 279 at the conference venue. This is an opportunity for industry to engage with Purdue Engineering and Technology students at large as well as student presenters from other institutions attending the conference.

These students can pre-register before the event by submitting their resume (see QR code below), which will be made available to all companies participating to the recruiting event. The student recruiting event is an additional event occurring concurrently with the technical conference program and the Industry Expo. If participating in this event you may setup your table as soon as 3 pm. This Student Recruitment Event is open to companies participating as exhibitors, registered conference participants, Maha industry members or conference sponsors, at no additional cost. Interested recruiting companies will have access to a separate space for conducting individual interviews on Thursday.
Please contact Prof. J. Garcia-Bravo in case you need additional information, or if you need to verify additional space availability.

If you are a student interested in signing up for the recruiting event, and willing to be contacted by one of the participating companies, please use this QR code to upload your information.

2024 International Maha Fluid Power Conference

AWARDS

MONIKA IVANTYSYNOVA MEDAL

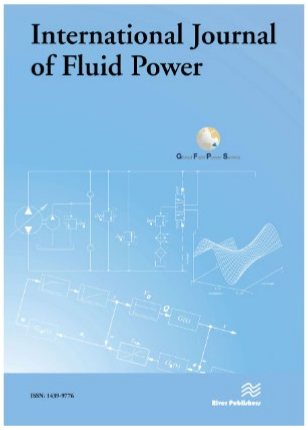
The Monika Ivantysynova award recognizes individuals with early association with Purdue (as student, post doc, visiting researcher, junior faculty) that have distinguished themselves for career achievements in fluid power and related industry. The award is dedicated to Prof. Monika Ivantysynova, one of the most accomplished individuals ever existed in fluid power, and founder of the Maha Fluid Power Research Center. The award consists of an engraved bronze medal dedicated to Monika Ivantysynova, and it is given every two years, in in occasion of the Maha Fluid Power Conference at Purdue University.

The first awardee (up to two awards) will be announced at the 2024 International Maha Fluid Power Conference during the dinner of September 4th.

BEST PAPER AWARD

A best paper award sponsored by the Global Fluid Power Society (www.gfpsweb.org) will be given to the best paper presented during the conference. The winner of the award will be selected based on both the reviewers' scores obtained prior the conference as well as the scores of selected judges assigned during the presentation. The best paper award will be announced at the 2024 International Maha Fluid Power Conference, during the dinner of September 4th.

JOURNAL PUBLICATIONS



A subset of papers (up to 7) 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.

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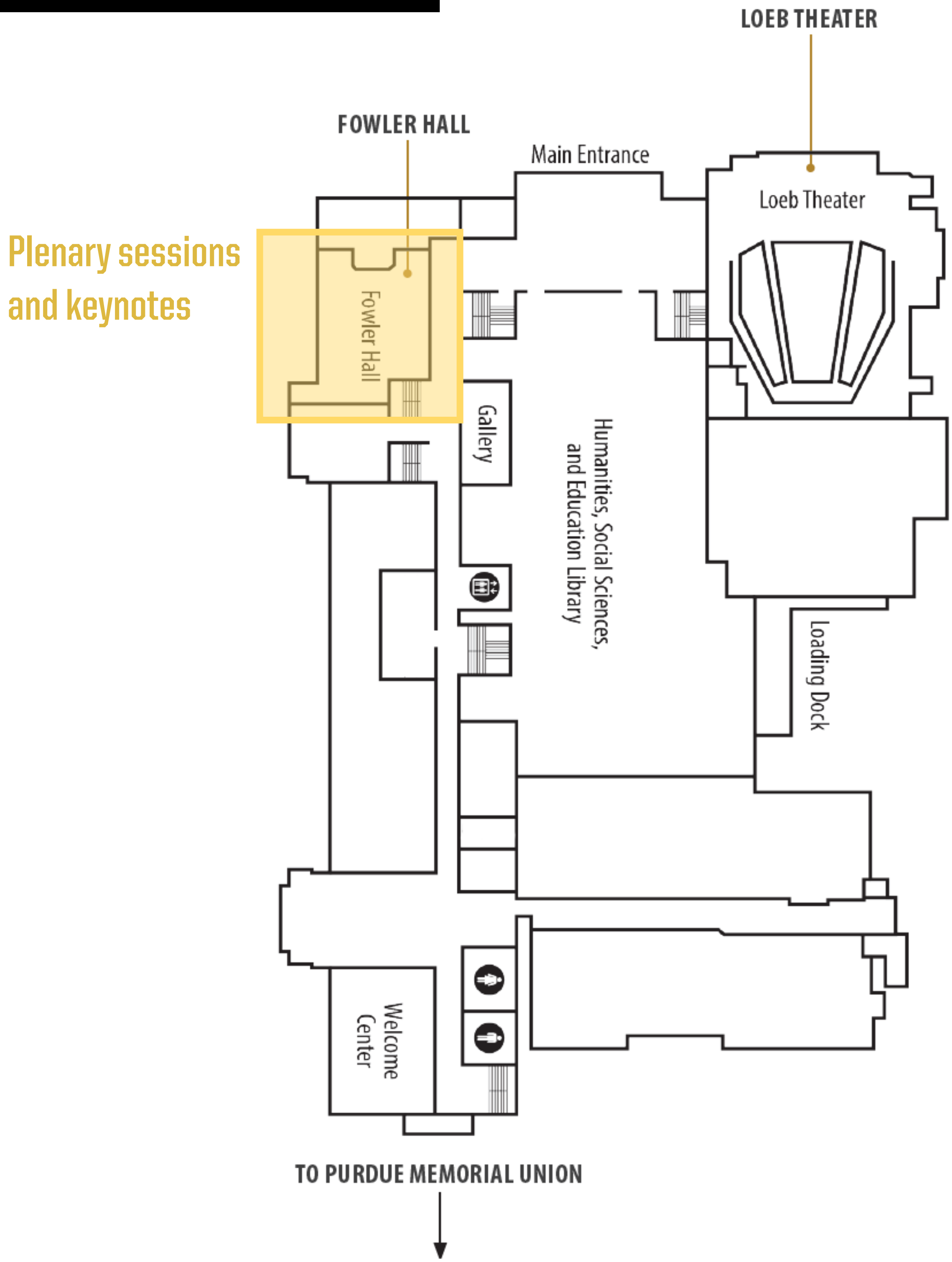
2024 International Maha Fluid Power Conference

STEWART CENTER MAP

GROUND FLOOR



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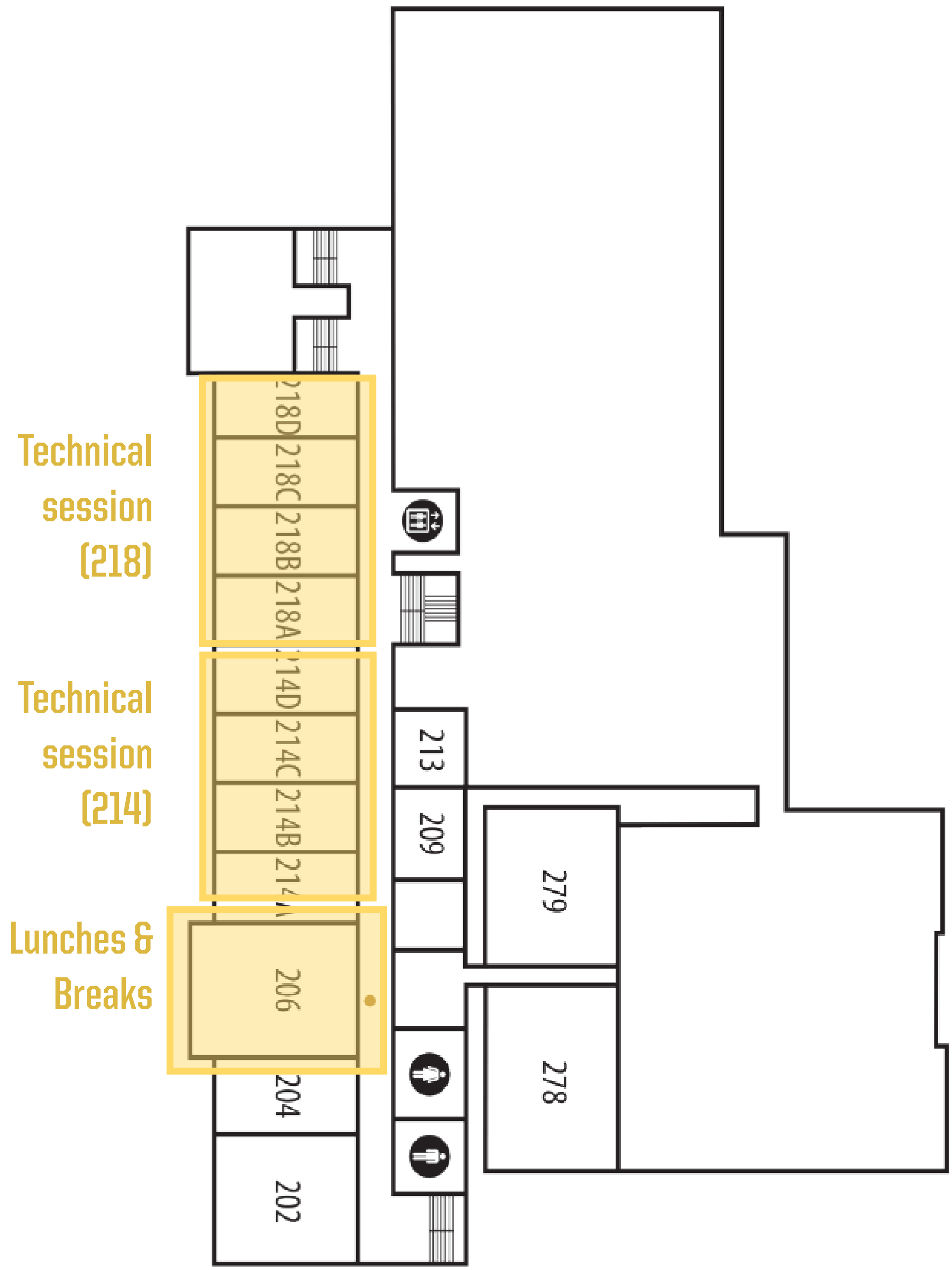
STEWART CENTER MAP

SECOND FLOOR



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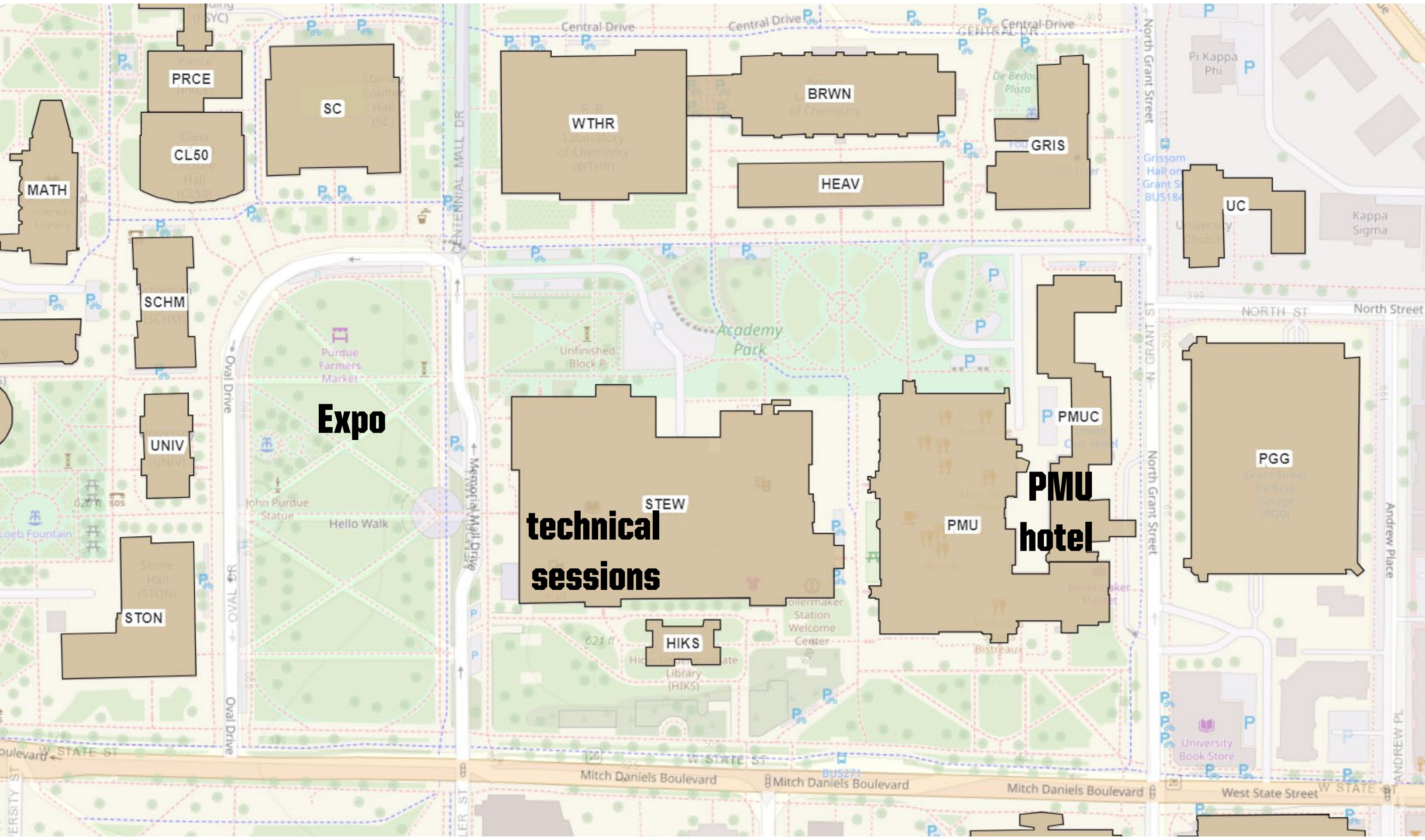
2024 International Maha Fluid Power Conference

EXPOSITION

LOCATION



HOURS

September 3rd : 1 pm - 5 pm

September 4th : 8 am - 5 pm

The official opening of the Expo for the conference delegates is 3:00pm on Sept. 3rd, during the first coffee break.

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

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2024 International Maha Fluid Power Conference

EXPOSITION

LOCATION

LIST OF EXHIBITORS

- Thomas - Magnete
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- Parker
- Bosch Rexroth
- CAT
- Maha Fluid Power
- CNH
- Poclain
- Settima Meccanica
- Sun Hydraulics
- C3D Materials
- CorVera
- Bucher
- NFPA
- Fluid Power Club
- Simerics
- Dr. Yan Gu's tent

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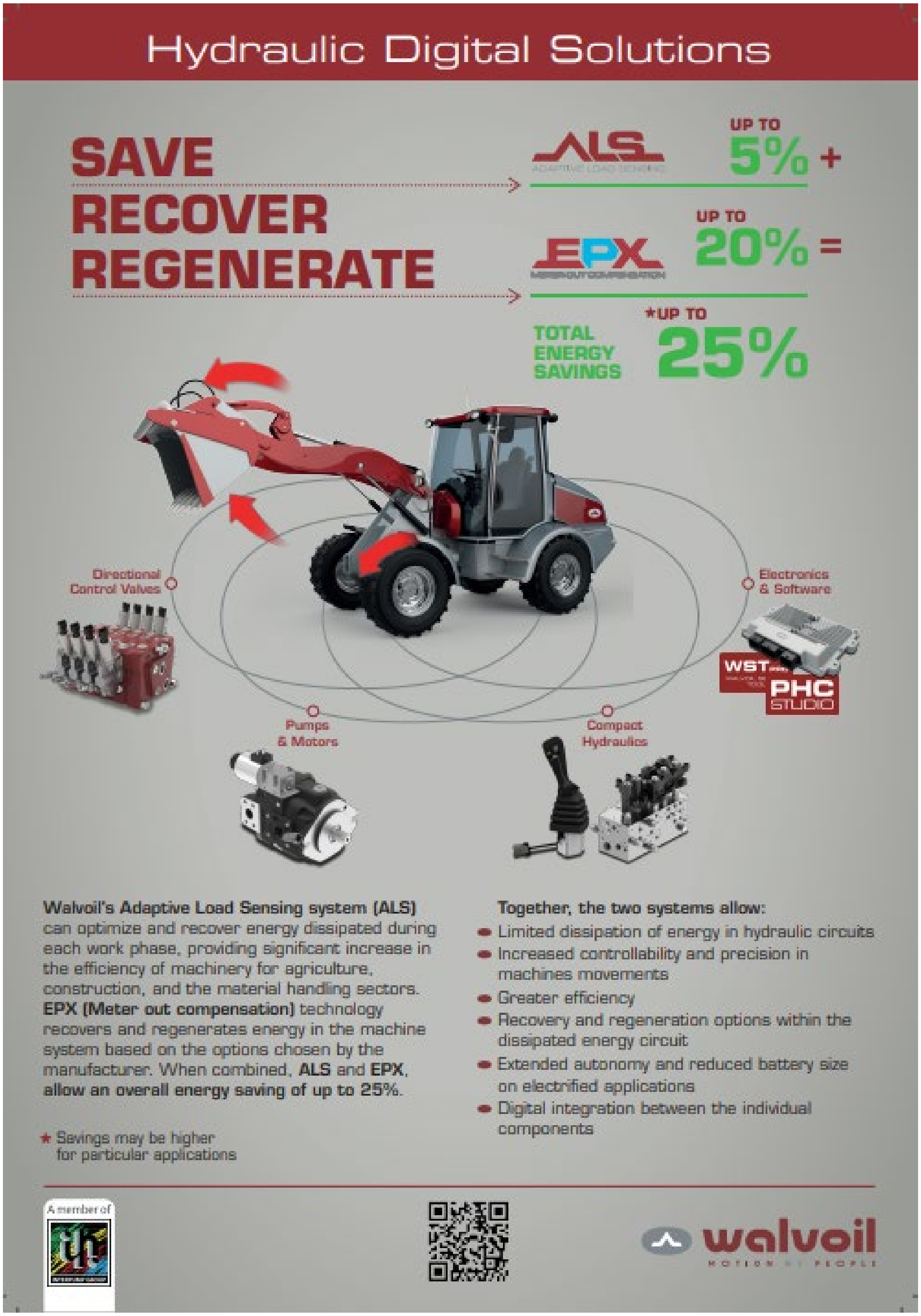

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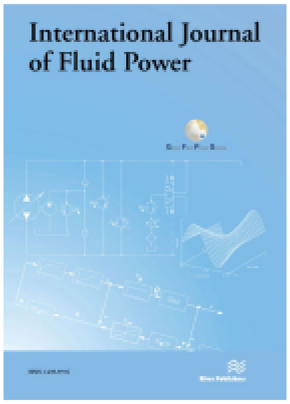

Session A: Hydraulic Pumps and Motors I

Title: Multi Domain Thermal Modeling of an External Gear Pump: Component Temperature Prediction and Effect on Efficiencies

Authors: Ajinkya Pawar, Andrea Vacca, Manuel Rigosi (Purdue University)

Abstract: The frictional losses at lubricating interfaces in an external gear pump as well as other mechanical losses at boundary layers when the working fluid flows through different grooves and channels result in heat generation. The temperature of the working fluid can significantly rise, especially in journal bearing and lateral gap lubricating films due to energy dissipation. Important fluid properties, such as viscosity and bulk modulus, which affect the lubricating interface performance significantly, have strong dependence of temperature. The energy is also dissipated to moving solid components, which can potentially cause adverse effects on lubricating interface performance. Thus, thermal effects affect the overall EGM performance and simulation models must consider these effects in order to design lubricating interfaces to minimize power losses and improve machine performance. Current work presents a multi domain simulation model of an EGP encompassing fluid domain, solid domain and lubricating interface domain of operation. The thermal modeling is done across the EGP tooth space volumes, lubricating films and all solid components including gears, lateral bushings and the housing. The effect of modeling thermal effects on efficiency prediction is shown. The frictional losses and leakages at lubricating interfaces are predicted with higher accuracy. Finally, an effort is being made towards validation of the component temperature prediction by measuring operating temperature of the lateral bushings and the housing of a helical gear pump and validating the proposed model.

Title: Innovative Gear Pump for Electrified Machines

Authors: Manuel Rigosi (Casappa)

Abstract: This paper presents a new type of external gear pump, capable of significantly improve the performance mix of current most widespread gear pump technologies for mobile machines, while maintaining the same wide-range applicability.

This innovative gear pump proposal should address the main common needs of electrified mobile equipment, in broad markets like building and construction, material handling, agriculture and on-highway vehicles.

The enormous push towards the frenetic development of fully electrified machines has led the OEMs to pursue a straight forward strategy, that is to keep unchanged all possible subsystems of the machine, like the hydraulic circuit architecture and components, and to concentrate on the core challenge: the complete replacement of the power source, with all the paradigm shifts linked to it like the deep redesign of the thermal management system and the electric circuit, in a way that is vaguely price approachable.

During this first electrification projects it emerged that hydraulic pumps have clearly become the main source of acoustic annoyance and that current components efficiency is strongly limiting the machines working day autonomy.

2030s-2040s electrified mobile equipment will have layouts, circuital solutions, component dimensioning and couplings probably far from the current ones, but nowadays it seems evident that OEMs can not rely on disruptive hydraulic products, like for example hydraulic pumps capable to properly work at twice the traditional rotational speeds to better exploit the potential of electric motors.

(continued) Up to now, pump manufacturers can recommend top level efficiency pumps or top silent ones, but highly "polarized" in the proposal. Also, most of these solutions are limited in their applicability due to the limitations of their casing material.

In this paper, taking inspiration and pushing some design concepts from Hydraulics and Transmissions industries beyond, a brand new external gear pump is presented. The introduction of high-helix gears working at zero backlash, with a specific re-designed profile, shows to unleash improvements both in terms of efficiency and noise. The adoption of a smart balancing system, composed of a set of micro-grooves laser-marked on the interal surface of gears lateral balancing plate, proves to properly bear over time the considerable axial force generated by the helical driver gear, without any limitation for multiple section pump configurations. Additionally, a self-lubricating feature for the tooth tip – gear seat coupling is introduced in order to guarantee the full reliability of this product, with cast iron casing, for heavy duty cycles.

In the first part of the paper the innovative package of technical solutions is introduced. Later, their beneficial effects on pump functioning and performances, both from a theoretical and practical point of view, is deeply described. In the last part of the paper, experimental results confirm that the new pump has an average efficiency 6 % higher compared to the current state-of-the-art one, while at the same time its average sound pressure level is 3 dB(A) lower.

Title: Centralized Pressure Control and Displacement Quantization With Digital Displacement Pumps

Authors: Jordan Pascale, Chris Williamson, Jim Hennen, Paul Rindahl (Danfoss)

Abstract: Danfoss Power Solutions has developed a centralized pressure control solution for multi-pump hydraulic power units in the industrial market. This system architecture has been developed around the use of the Digital Displacement Pump (DDP) which is highly efficient over a wide range of operating conditions and has typically shown a >30% decrease in electrical input energy over similar systems using axial piston pumps. MTS Systems expanded this centralized control to work in a harmonized fashion with other pumping technologies housed within unique motor-pump modules; some containing DDP and others containing conventional axial piston pumps. This arrangement provided several benefits and empirically demonstrated the DDP module efficiency over the axial piston pump module in supplying fluid power to dynamic downstream force and motion systems that replicate real-world automotive drive files and test track profiles. Special consideration was required when implementing DDP in a system with multiple pumps' (maximum of 6) outlet flow combined in parallel. Allowing each individual pump controller to operate in pressure control mode caused compounding complexity in tuning, and noisy, unstable flow pulsations. As a solution, a centralized pressure control scheme was implemented in which a system level microcontroller evaluated user inputs, pressure signals from a transducer, executed logic, and output displacement commands to each pump controller as required to meet the system demand. What makes this control scheme unique is that in a multi-pump system, one pump has a continuously variable displacement fraction with any value from 0 to 100%. The other pump displacements were controlled in a quantized manner with stepped values of displacement (for example: 0%, 25%, 75%, 100%). Hose resonant frequencies were also avoided in this manner. Testing and implementation of this control scheme has proven to be effective in reducing system tuning complexity and undesirable flow pulsations in the system. Measured results for energy savings and noise/vibration reduction are presented in the paper.

PRESENTATION ABSTRACTS

Title: Challenges for Multi-Quadrant Hydraulic Piston Machines

Authors: Thomas Heeger (Linkoping University)

Abstract: In the USA, off-road vehicles are responsible for 8 % of the energy consumption of the transportation sector resp. 2.3% of the total energy consumption in 2016 [Davis2022, Lynch2017]. In Sweden, their relevance is even higher, with construction machinery, such as excavators and wheel loaders, being responsible for 6 % of Sweden's total carbon dioxide equivalents in 2023 [SEPA2023]. The motion system of these machines usually relies heavily on hydraulics, and thus a large part of the used energy passes through a hydraulic pump. In conventional systems, this pump is driven by a combustion engine. Thus, there is no energy recuperation, and typically, one pump supplies several actuators, and therefore sharing losses occur. This results in a low hydraulic system efficiency, which has been estimated to be around 21 % in 2012 [Love2012], even though standard fluid power components often have peak efficiencies above 90 % [Dubbel2018].

To increase system efficiency, new architectures are explored, often including electric drives and energy recuperation. Therefore, the hydraulic machines need to work both as pumps, converting mechanical power into hydraulic power, and as motors, converting hydraulic power back into mechanical power. However, the availability of machines that can operate in all desired modes is limited, as multi-quadrant operation comes with performance penalties. This presentation discusses challenges for multi-quadrant operation of hydraulic piston machines, with a particular focus on commutation, i.e., the transition between high- and low-pressure level for each chamber. Furthermore, other important aspects for pump/motor operation such as hydrostatic compensation ratios, design of inlet channels, low-speed capability, and flow control through speed or displacement control are discussed. The presentation shows that the design of multi-quadrant machines is challenging, and this has to be considered when choosing the system architecture. [Heeger2024].

Title: Improving Transmission Efficiency via a Novel Radial Piston Cam Lobe Motor Architecture

Authors: Pierre Bernard, Vincent Langlois, Maxime Maurer (Poclain Hydraulics)

Abstract: This paper presents the energy efficiency optimization of a closed loop hydrostatic transmission, using the example of a heavy tandem roller compactor application. An innovative concept of radial piston cam lobe motor is proposed, which allows a paradigm shift in hydrostatic transmissions sizing, essentially moving away from breakout torque as the entry point to sizing and refocusing the transmission sweet spot on its most used conditions. After giving a brief overview of the application and its usage profile, a description of a standard system and components currently in use on this type of machine will be provided. This standard transmission will be used as a reference case for the energy efficiency study. Then, the novel radial piston cam lobe motor architecture will be introduced, and its main characteristics highlighted. In combined theoretical and experimental studies, this upgraded motor and its optimized transmission will be substituted for the reference machine transmission, and the energy efficiency evolution will be evaluated. The final part of this paper will discuss the agreement of simulation and experimental results, and comment upon the energy efficiency gains obtained with the proposed transmission.

Session B: Vehicle Electrification I

Title: Electrification of a Compact Skid-steer Loader – Redesign of the Hydraulic Functions

Authors: Shaoyang Qu, Zifan Liu, Rafael Cardoso, Enrique Busquets (Bosch Rexroth)

Abstract: Compact skid-steer loaders are among the most popular machinery in the North American market. With increased customer interest and pushing regulations of electric vehicle, there has been a growing trend towards electrification in this sector, driven by the potential for efficiency improvements, sustainable production, and emissions reduction. However, realizing the full benefits of electrification requires addressing various challenges related to component sizing, packaging, and system control. This study is based on the full electrification of a 5-ton compact tracked loader with 67kW rate power, involving the removal of the diesel engine system and hydraulic ground drive. It also consists of a rechargeable energy storage system, thermal management, dedicated re-design of the implement functionality and auxiliary system. The primary focus of this paper is on the challenges associated with electrifying the hydraulic implement functions. A novel e-load sensing system is proposed, featuring energy regeneration capabilities. This system is designed to seamlessly integrate into the electrified powertrain, reducing components and conserving space in the compact machine. The dedicated hydraulic system mainly consists of the electronified open-center pump (eOC-P) and load sensing pre-compensated valve (RM-MPP) sourced from Rexroth. The compensator for the boom function is re-designed to remain static, allowing a bidirectional path for regeneration during the boom lowering phase. The eOC-P offers pressure control, flow control, displacement control, and torque control modes, achieved by replacing the traditional mechanical load sensing feedback with sensor signals. By employing a combined strategy involving the eOC-P and valve control, the re-engineered system adapts its operational modes to suit both single and multiple user conditions, aiming to achieve optimal energy performance. In single-user scenario, such as to raise and lower boom, displacement control of the pump can be utilized to minimize throttling losses with fully opened valve. With multiple users like boom and bucket functions, the compensator for the bucket function regulates the flow rate in its path. Meanwhile, the pump supplies the total required flow, with the excess flow directed to the boom function. This mode is particularly effective when the load pressure of the boom surpasses that of the bucket, representing the common operational scenario for compact skid steer loaders. A lumped-parameter simulation model is developed in Amesim environment, with baseline measurements as the inputs to evaluate the system performance. The results from the system simulation indicate that the suggested system has the potential to achieve a remarkable 55% energy savings in a single boom raising and lowering cycle when compared to conventional load sensing systems. Furthermore, approximately 20% of the energy expended can be recovered and stored in the electric storage equipment. In conclusion, the full electrification of compact skid-steer loaders offers significant benefits in terms of efficiency and emissions reduction. However, to unlock its potential, challenges related to component sizing, packaging, thermal management a hydraulic system redesign must be effectively addressed. This research underscores the innovative design of hydraulic functions with electric drive, offering valuable insights that contribute to the progression of electrification in the construction equipment industry.

PRESENTATION ABSTRACTS

Title: Hyper-efficient Hydraulics of the Future – Platform Specific Architecture for Hybrid and Electrified Machines

Authors: Michael Terzo (Xirro)

Abstract: Despite significant and worldwide efforts to electrify and hybridize off-highway vehicles, the industry has had limited commercial success stories to point to. With extreme duty cycles and diverse applications, there has been no clear path to unlocking electrification. In this presentation, Mr. Terzo will present his almost two decades of experience on why this may be and how it might be altered in the future. A technical discussion detailing how power-on-demand hydraulics, when purpose built into a platform specific system can provide the cost, performance, and energy advantages that will tip the scale towards electrification. Join us for a highly technical, no-holds barred presentation that cuts through the industry noise and presents a future you can get excited about.

Title: Technical, Regulatory, and Safety Challenges in Designing an Electric Power Take-off for Electric or Hybrid Work Trucks

Authors: Barun Acharya (Parker Hannifin)

Abstract: This presentation delves into the multifaceted challenges associated with designing an electric Power Take-Off (ePTO) system for electric or hybrid work trucks. The integration of ePTO technology into these vehicles demands a thorough consideration of technical, regulatory, and safety factors. Technical challenges involve optimizing power delivery, efficiency, and reliability while satisfying the diverse operational or duty cycle requirements of work trucks. The presentation will discuss various modular and integrated design solutions, along with the integration of new and existing hydraulic system architecture controls within the ePTO. Regulatory considerations encompass compliance with evolving standards and safety regulations, including cybersecurity requirements and functional safety standards governing electric vehicle components. Safety concerns entail mitigating risks associated with high-voltage systems, ensuring operator and bystander safety during ePTO operation, and implementing fail-safe mechanisms. The presentation examines these challenges and proposes solutions to facilitate the successful deployment of ePTO systems in electric or hybrid work trucks, thereby advancing sustainable transportation solutions.

Title: Hydraulic Machinery Electrification Accelerated Through Shell Dielectric Battery Thermal Fluid

Authors: Brent Warr, Greg Morris (Shell Global Solutions)

Abstract: The off-highway equipment and especially Hydraulic Machinery has seen a surge of electrification development as of late. The high-power demands of off-highway equipment will require more robust thermal management. Over the last 10 years Shell Global Solutions has developed new types of direct contact immersive dielectric based thermal fluids to address the challenge of thermal management for batteries & power electronics. These Gas to Liquid (GTL) based fluids protect battery cells from overheating under ultrafast charging and high demand operating conditions. The thermodynamic properties, dielectric strength, auto ignition temperature and economical cost present them as ideal fluids for direct contact immersive thermal management of batteries and power electronics. Direct contact immersive thermal management promote decreased charge times and increased output power. Additionally, battery longevity, durability and safety are enhanced thereby improving holistic system performance, while reducing total cost of ownership.

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(continued) Traditional air and water glycol thermal management systems have deficiencies that can be addressed with immersion cooling technology. The air-cooled batteries and power electronics cover most of the battery's surface area, however cooling efficiency is not optimal. The heat capacity of air is not well suited to remove the amount of heat generated. Alternatively, water glycol has a very high heat capacity but cannot come in direct contact with the cells due to the fluid's conductivity. Therefore, these fluids are limited to indirect contact through cooling plates and fins that are in contact with the cells. Battery packs that utilize cooling channels between the cells still only contact about 11% of the cell's surface area. The low surface area and conductive thermal resistance severely limits the thermal management of the battery Today's best fast charging technology, with water glycol cooling plates only reach 2C (30- minutes) charge rates. A demonstration using a battery pack cooled by Shell thermal fluid shows 4C (15 minute) ultra-fast charge capability reducing charge time to 12 minutes from 0 to 80%. The cells temperatures were monitored and shown to increase less than 25°C during the charge event. Similarly, the same battery could be discharged in the same amount of time in similar conditions. This would be useful in extreme power demands, such as using an external battery as a power bank charged at level 2 power due to grid limitations. That external battery can then be used to ultra-fast charge equipment on site. CFD modelling of traditional cooling methods show large temperature gradients across the battery cells. The same models show immersive cooling with thermal fluids maintains a uniform temperature across the cell. This leads to less degradation in the cells and allows for higher charge and discharge currents without compromising the battery's integrity. Experiments done by Idaho National Labs are presented to demonstrate the effects of temperature on battery capacity over time. Furthering demonstrating the potential to increase battery longevity with improved immersive thermal management. The battery nail puncture test is conducted to assess the thermal fluid effects on the battery in a crash event. Results show the initial energy release from a cell puncture causing a short, but normally where adjacent cells would heat up and vent, an energy absorption occurs. This prevents thermal runaway and propagation resulting in one of the safest thermal management system options. Similar results are shown for the heating wire test. It is concluded that GTL based thermal fluids are currently the most practical mass manufactured solution to the increased performance, longevity, and safety of current battery systems.

Title: Opportunities and Challenges of Off-road Vehicle Electrification in China - Perspective of a Hydraulic Components Supplier

Authors: Xingyi Xu (Hengli)

Abstract: Driven by China's Carbon-Neutral Strategy, electrification of road vehicles, i.e. passenger cars, buses and light trucks, has achieved remarkable results in China. Currently, electrification of off- road vehicles, e.g. mining, construction, and agricultural equipment, is gaining more and more attention and has entered the fast track of technology development. In this presentation, we will first introduce the status of off-road vehicle electrification development in China. Then, we will describe the opportunities this electrification development would bring to the off-road vehicle industry. Further, we will analyze, from the perspective of a traditional hydraulic components supplier, the technological and commercial challenges associated with the electrification. Finally, we will present Hengli's approach to these challenges.

Session C: Energy And Efficiency

Title: On the hydraulic wind turbine: energy-water nexus and power generation response under turbulent structures in the scale of the turbine's rotor

Authors: Helber Antonio Esquivel-Puentes, Jose Garcia-Bravo, David Warsinger, Luciano Castillo, Andrea Vacca (Purdue University), Leonardo P. Chamorro (University of Illinois at Urbana-Champaign)

Abstract: Current electricity generation using non-renewable energy sources represents 40% of the global CO2 emissions, alongside the 4 million tons of CO2/year generated by desalination plants. The need to accelerate the energy transition to decarbonize two basic needs as are electricity and freshwater generation boosts the development of functional alternatives. Previous studies have shown the numerous advantages of using hydrostatic transmission to transmit the power harvested by wind turbines as an alternative to the current mechanical drive train. The aim of this study is to experimentally prove the feasibility and the convenience of using wind energy to simultaneously generate electricity and produce freshwater by means of an integrated hydraulic powertrain. The cyber-physical system integrates four main subsystems: the prime mover, which is an electric motor simulating the rotor of the wind turbine, the hydrostatic transmission, the electric generator with its load, and the reverse osmosis system. The power quality reaches competitive outputs since the hydrostatic transmission has a damping effect on the fluctuations induced by the turbulent structures of the incident boundary layer with wind speed fluctuations up to 5%. The hydrostatic transmission reaches an overall efficiency of 79% under the input used and salinities tested. The specific energy consumption obtained by testing the range of feed salinities from 5 g/L to 40 g/L is in the range of 1.6 kWh/m3 to 6.8 kWh/m3 without an energy recovery device, respectively. The specific energy consumption is reduced by the use of the energy recovery device from 11% to 41%. With the proposed system architecture, a reduction in energy consumption and cost for desalination and energy generation systems is achieved. Additionally, achieving net-zero CO2 emissions during freshwater and electricity generation is possible using the proposed combined system employing fluid power. To test the concept under real conditions, a hydraulic wind turbine prototype was tested under real atmospheric conditions. The wind speed analyzed corresponds to an atmospheric boundary layer quasi-neutrally stratified during the period under study. The mean incoming wind flow at hub-height during the period studied was 7.11 ms-1. The Reynolds number during the period use to analyze the response of the wind turbine is estimate at ReD=1.48×106. The damping effect given by the intrinsically features of the wind turbine worked accurately during most of the sampling time having an evident reduction of power fluctuations amplitude around 22% for this particular case.

Title: Efficiency Improvements in a Servoless Swash Plate Pump: Experimental and Simulation Results

Authors: Nathaniel Fulbright, Samuel Hall, Matthew Creswick, Stanislav Smolka, Robert Rahmfeld (Danfoss)

Abstract: Variable displacement axial piston units conventionally use a servo system (consisting of a servo piston and valve) to adjust and control their displacement. In a novel design approach, the traditional servo system is removed, and the displacement is adjusted only by the loads on the swash plate. By employing specialized valve plate porting and control logic, the design allows for the displacement to be controlled without a servo system, improving efficiency and reducing complexity and size, and also introduces the ability to adjust the cross-port area profile of the valve plate. This adaptability significantly reduces cross-port flow and its associated losses, particularly in low-flow, high-pressure conditions, and it enables tunability in efficiency and noise.

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(continued) Previous work has demonstrated the controllability of a servoless swash plate pump. In this work, theorized efficiency improvements are confirmed by experimental data indicating up to an 18% improvement in overall pump efficiency. A 1D simulation modeling approach is presented, detailing the unique considerations that must be considered for a servoless pump. The simulation model produces efficiency improvement predictions that are generally within ±3% of the experimental results and are often within ±2%.

Title: Study and Experimental Application of an Energy Recovery System

Authors: Andrea Polito (Walvoil)

Abstract: Experimental activity for the application of an Energy Recovery System on a 2.2t Compact Full-Electric Loader, arranged for material handling purpose. The system is based on the innovative EPX directional control valve and provides for the possibility of immediate reuse of hydraulic power or its conversion for a battery storage. The two regeneration approaches are compared experimentally and energetically, with particular attention to the criticalities of compact machines. The influence of system parameters is also investigated, and a new adaptive approach is proposed as an additional optimization opportunity.

Title: Water as a Battery

Authors: Georg Herborg Enevoldsen (Danfoss A/S)

Abstract: To be added

Title: Optimal designs of a hydromechanical hybrid transmission by minimizing fuel consumption and damage to human health

Authors:, Nicola Andretta, Antonio Rossetti, Alarico Macor (University of Padua)

Abstract: The hybrid hydromechanical transmission must be sized by fully exploiting its strengths: the energy contribution of the hydraulic source and the possibility of managing the thermal source at the most convenient conditions. Therefore, in this paper we propose a simulation-based optimisation which searches the design parameters values of both transmission and hydraulic source while minimizing the fuel consumption along a typical route. A second objective function involving emissions was also considered. The difficulty of managing numerous chemical species with different dangers has been overcome by summarizing them in a single parameter: the damage to human health. In this way the concept of emission corresponds with the concept of damage to health. A study was carried out on a 12 m class urban bus. The results of this study allow us to evaluate the effects of the hybridization of a hydromechanical transmission and the effects of the engine management criteria, not only on the optimal values of the design parameters, but also on fuel consumption and damage to human health.

Session D: Noise Vibration And Harshness

Title: Design Strategy for Noise Reducing Particle Dampers on Hydraulic Pumps

Authors: Michael Lenz, Ahmed Shorbagy, Svenja Horn and Prof. Jürgen Weber (Dresden University of Technology)

Abstract: Noise stands as a pivotal design criterion for displacement units, since it can limit their operability in a human environment. Especially in the context of evolving trends such as electrification, variable speeds, and the decentralization of hydraulic drives, the noise emissions of the displacement units are increasingly becoming a focal point for both research and manufacturers. Particle damping provides a means of broadband mitigation of structural vibration and associated noise emissions. The approach involves the introduction of cavities filled with particles into the structure of some parts of the displacement units. The oscillation of the surrounding structure induces free movement of the particles, leading to energy dissipation through shocks and friction among the particles and with the surroundings. The key features of the approach are passivity, broad-spectrum effectiveness, simplicity and maintenance-free operation. Furthermore, it is broadly applicable to oscillating structures, making it adaptable regardless of specific pump design. For successful application, the dimensions and internal structure of the damper, the particles and the degree of filling of cavities must be aligned with the expected frequency and amplitude range, and direction of vibration. This requires an in-depth analysis of the dynamics of the pump in operation. This paper outlines the design process for attachable particle damper components for an axial piston pump. These components serve as a first step towards structurally integration of cavities in pump design, allowing the evaluation and refinement of the method's potential for the displacement units under flexible conditions. For practical purposes, attachable dampers also offer the option to retrofit existing designs for enhanced acoustic performance, while leaving the core functionality unaffected. The analysis of vibrations is twofold, comprising an experimental component on the one hand, which encompasses measurements of fluid- structure- and air-borne noise, modal analysis, and operational vibration measurement, and on the other hand a finite element analysis studying the structural vibrations under realistic operational loads. As a result, suitable locations for damper components are identified and the expected vibration characteristics are quantified. Design principles for particle dampers are derived from the literature and adapted to the application in order to achieve a bespoke design for each of the identified locations. Following manufacture, the impact of the damping components on the emitted sound power is evaluated experimentally.

Title: Simultaneous Transfer Path Analysis of Axial Piston Pump Lumped Parameter Model Results

Authors: Dazhuang He, Antonio Masia, Yangfan Liu, Lizhi Shang, Daniel Dyminski (Purdue University)

Abstract: The recent trend in electrifying off-road vehicles has brought to light a critical issue – the noise emission of hydrostatic pumps and motors. In the transition from internal combustion engines (ICE) to electric motors, the previously masked noise from hydraulic pumps and motors has become significant in fluid power systems for off-road applicationsIn present study, a dedicated lumped parameter model (LPM) was developed in Amesim. The numerical model takes into account various factors, including the fluid-dynamic path, unit kinematics, forces and moments acting on the main components. The effects of the main lubricating interfaces were neglected. The LPM simulates the internal forces/moments/ripples that cause noise and vibration of the axial piston pump. The method of simultaneous transfer path analysis (sTPA) is then developed to statistically determine the relation between internal forces/moments/ripples and consequent noise and vibration software, followed by validation through

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(continued) experimental testing on an engine dynamometer at the University of Wisconsin. Results are benchmarked against a non-eBoosted engine, serving as the baseline. With simultaneous excitation information provided by LPM and operational measurement of acoustic/vibration responses, the sTPA is capable to estimate the frequency response functions between the excitations and acoustical/vibrational responses. The frequency response functions are estimated by solving a regularized least-squares problem, and generalized cross validation is used to determine the regularization factor. sTPA also provides the results of path contributions, which characterize the significance of individual transfer paths. A 45cc pump was subjected to testing enabling the collection of data on noise levels, vibrations, and pressure ripple. The unit was tested over a large range of operating conditions. The measurements were then utilized to correlate, analyze, and understand the noise measurements with the pump's internal excitation in terms of forces and moments to target what component contributes the most to the noise emission. The results provided by sTPA highlights the critical path contributions and the main mechanisms that contribute to the noise emission over a range of frequencies. A parameter sensitivity analysis based on sTPA results is conducted, in which the sensitivities of noise and vibration level of the piston pump to multiple design/operation parameters are investigated. In the case study, sTPA reveals that the moment oscillation exerted on the pump house around the axis of the swashplate tilting has the most significant impact on the overall a-weighted noise level. sTPA also suggests that, in a representative operation condition of the case study, there is a potential of reducing the A-weighted noise level by 4.5 dB by shifting the phase of pressure ripple excitation by 93.6 degrees. In conclusion, sTPA is potentially capable of aiding noise and vibration reduction in hydraulic pumps for off-road vehicle applications.

Title: Enhancing System Performance in Subsea and Off-highway Applications: a High-fidelity, Transient Dynamic CFD Analysis Approach

Authors: Vignesh Jeganathan, Rayhan Ahmed , Yawei Chen, Shyam Sundar Pasunurthi, Ashutosh Pandey (Simerics), Emanuele Gnesi, Raju Kalidindi, Bipin G Kashid, Howard Zhang (Parker Hannifin)

Abstract: In hydraulic fluid power engineering, the need for reliability and high efficiency in system components, including valves and pumps, is paramount. This requirement becomes even more critical in tough operational environments, such as off-highway and subsea applications, which require both robust durability and optimal operational efficiency. Computational Fluid Dynamics (CFD) simulations are often used to address these demands and assume a pivotal role during product development. This paper demonstrates the use of CFD simulations as a tool to study the operations of a solenoid valve and a vane pump, which are used in subsea and off-highway applications. Our research employs 3D CFD simulations to examine complex transient dynamic phenomena such as two-piece poppet separation in solenoid valves and vane translation in the vane slots of vane pumps. By modeling these complex transient dynamics, we illustrate how CFD can identify problems that are difficult to test experimentally, and offer valuable insights for enhancing performance.

Title: A 3D CFD and Computational Acoustics Simulation Methodology for Noise Mitigation Prediction in Gerotor Pumps

Authors: Sujan Dhar (Simerics)

Abstract: Positive displacement pumps are key components in automotive and hydraulic fluid systems, often serving as the primary power source and a major source of noise in both on-highway and off-highway vehicles. This study introduces a novel method for predicting noise in positive displacement pumps by combining a

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(continued) Computational Acoustics(CA) approach with a 3D Computational Fluid Dynamics (CFD) approach, both implemented in the Simerics-MP+ software. The CFD simulation includes the detailed transient motion of the rotors (including related mesh motion) and models the intricate cavitation/air release phenomena at varying pump speeds. The acoustic simulation employs a Ffowcs-Williams Hawkings (FW-H) formulation to predict sound generation and propagation based on the detailed flow field predictions from the CFD model. The proposed methodology is demonstrated for two different designs of a gerotor pump. Gerotor pumps are widely utilized in vehicle coolant, lubricating, and other fluid systems for both conventional and electric powertrains. Simulations of the gerotor pump designs were conducted under a wide range of operating conditions, resulting in the prediction of a full range of sound pressure spectra across various sound frequencies. These simulation results are compared with sound pressure measurements, revealing that the simulation approach can effectively predict the relative sound pressure distribution across the frequency spectrum. Notably, the mitigation of sound pressure at specific regions of the frequency-RPM spectrum was accurately captured. This presentation will aim to provide a comprehensive insight into the modeling methodology and will compare the sound pressure spectra obtained from simulations and experiments. The proposed method harnesses the ability to obtain detailed, high-fidelity 3D flow field and cavitation/air release solutions in positive displacement machines and demonstrates excellent potential for predicting noise improvements resulting from pump design changes. Thus, it has the potential to provide valuable insights for designing quieter pumps.

Title: A Numerical Modeling Procedure to Reduce the Noise Emitted by External Gear Pumps

Authors: Emma Frosina, Francesca Pedriellib, Eleonora Carlettib, Pietro Maranib, Luca Romagnuoloa, Adolfo Senatorec (Sannio)

Abstract: External gear pumps offer very good performance at competitive costs, making them widely spread worldwide. On the other hand, these machines are generally characterized by high levels of vibrations and noise emissions. This article presents a numerical methodology based on a lumped parameter approach to optimize both spur and helical gears External Gear Pumps (EGPs). The methodology was implemented in a multi-environment tool, called EgeMATor MP+ developed by the Fluid Power Research Group of the Universities of Naples and Sannio. This tool executes a closed-loop procedure, which starts from the pump drawing. Thanks to several subroutines developed in different interconnected environments, it permits global analysis, and later optimizes, EGPs. A reference pump was optimized acting on the geometry of the pressure relief grooves of the wear plate, with the objectives of reducing flow ripple fluctuations, pressure spikes, and crossflow.

Finally, both reference and optimized pumps were tested in a laboratory of the CNR-STEMS research institute in Ferrara using a specific test rig, which physically isolates the pump from the prime mover. Sound pressure levels were measured in several points around each pump and the results showed an effective reduction of the emitted noise for the optimized design.

Session E: Off-Road Vehicle Technology I

Title: Chassis Dynamometer Testing of Hydrostatic Transmission in an Agricultural Vehicle

Authors: Brian Steward (Iowa State University)

Abstract: The Off-Highway Vehicle Chassis Dynamometer Laboratory at Iowa State University has the capability to test the propulsion systems of agricultural and construction vehicles in the context of the whole vehicle. The chassis dyno absorbs power from a vehicle propulsion system through four independently controlled banks of rollers for each of the four vehicle corners. The facility is designed to test vehicles up to 450 kW per corner, with speeds of up to 80 km/h, and offers independent monitoring and loading of each wheel. In collaboration with Danfoss Power Solutions, an agricultural sprayer associated with the Danfoss Ames Application Development Center, with a hydrostatic transmission, was tested on the chassis dynamometer.[continued] The vehicle underwent both steady-state testing across ranges of speed and tractive force levels. For transient testing, simulations of field conditions were developed using the dyno control software. Simulations include slope ascending and descending, deceleration and acceleration and changes in motion resistance force. This facility enables consistently repeatable test conditions fostering deeper understanding of hydrostatic drivetrains and their performance.

Title: Electronified Open Circuit Drive Concept for Compact Loaders

Authors: Xiaofan Guo, Shaoyang Qu, Rafael Cardoso, Enrique Busquets (Bosch Rexroth)

Abstract: Compact loaders hold a prominent position in the North American machinery market, with their drive function typically relying on closed-circuit hydrostatic transmission as a mature solution. This study introduces an innovative concept termed Electronified Open Circuit Drive (eOC-D), which comprises three open-circuit units. This design incorporates one pump to drive two motors, offering stepless speed control for the hydrostatic transmission. In contrast, the traditional hydrostatic transmission utilizes two closed-circuit pumps and two drive motors, commonly incorporating fixed-displacement or step-speed control, such as 2-speed configurations. This innovative eOC-D concept is derived from the electronified open-circuit (eOC) unit by Rexroth, recognized for its capability in pressure and displacement control, as well as various working modes. With four-quadrant capabilities in terms of displacement and speed, the eOC unit can smoothly transition from negative to position displacement, functioning as both a pump and a motor. Consequently, the eOC-D concept enhances drive performance through advanced electronic control of pressure, flow, torque, and power. This is facilitated by a newly developed software platform designed for the RC controller from Rexroth. In addition, the eOC-D approach leads to a significant reduction in component costs when compared to the closed-circuit architecture. Only one drive pump is required instead of two, a single relief valve serves the open circuit instead of four, and the necessity for a charge pump is eliminated. Furthermore, the design enables the potential for energy regeneration during braking conditions, making use of the four-quadrant capability inherent in the EOC units. In this study, a simulation model is

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[continued] developed in the Simulink environment utilizing the lumped-parameter method. The chosen reference vehicle is a 67kW power-rated compact loader, specifically the Caterpillar T259D. Through simulations, the eOC-D system is optimally sized considering an optimal combination of pump, motor, and gearbox. The performance of energy efficiency and dynamic response is evaluated from simulation. Taking the power consumption of the charge pump, the eOC-D system demonstrates higher efficiencies and faster response compared to the baseline The efficiency improvement ranges from 5% to 10%, while the response time sees a reduction of over 50%. In conclusion, the open circuit drive design presents significant benefits for compact loaders, including cost reduction and enhanced controllability. Through comprehensive simulations encompassing various duty cycles and operating conditions, the feasibility of the concept is convincingly demonstrated, validating its potential for successful implementation across a diverse range of applications and contexts. The integration of the eOC-D concept holds the promise of transforming the drive systems of compact loaders, paving the way for more efficient and cost-effective solutions in the construction equipment industry.

Title: Robust Multivariate Air Handling Control for an Electrified Off-Road Diesel Powertrain

Authors: Shubham Ashta, Nicholas Vang, Weijin Qiu, Chisom Emegoakor, Sree Harsha Rayasam, Tyler Swedes, Jacob Mazanec, Giraldo Luis, Bryan Frushour, Gregory Shaver, Sage Kokjohn, Jaal Ghandhi and David Rothamer (Purdue University)

Abstract: This conference paper delves into the advantages of employing an electrified intake boosting system in a 4.5L John Deere diesel engine.

The electrified intake system (eBooster) strategically activates solely during transient operations to mitigate drops in the air-to-fuel ratio (AFR) that may result in smoke emissions. To adeptly oversee the electrified air handling system, we introduce a two-degree-of-freedom robust H-infinity single-input single-output (SISO) eBooster controller and a robust model-based H-infinity multiple-input multiple-output (MIMO) controller. These controllers are engineered to regulate the desired AFR, engine speed, and diluent air ratio (DAR) through the control of air handling actuators (exhaust throttle and EGR valve) and fueling strategies. The robust SISO controller is crafted utilizing a linear plant model derived through system identification, while the robust MIMO controller is developed based on a physics-based mean value engine model meticulously calibrated to accurately replicate high-fidelity engine simulation software. Both controllers are subjected to simulation using high-fidelity engine simulation. While both the SISO and MIMO controllers exhibit improvements in AFR, DAR, and engine speed recovery during load transients, the robust MIMO controller outperforms them, showcasing superior overall engine performance. This superiority is attributed to its nuanced understanding of the coupling between each actuator input and the model output. Operating in tandem with the electrified intake boosting system, the MIMO controller brings about significant enhancements. The engine not only recovers to a steady state 70% faster than the baseline but also mitigates engine speed droop by 45%. Consequently, the engine's ability to accommodate load torque sees an increase, underscoring the benefits of an electrified air handling system governed by a robust MIMO controller.

Title: Energy Mapping for Machine Electrification

Authors: Andrew Krajnik (HYDAC)

Abstract: There is a growing trend toward Electrification in mobile markets today. This represents a significant learning curve for most OEM's as they work to understand new technologies (e-motors and batteries), and how to optimize them for a given application. Energy Mapping is a technique that can help them understand the power and energy consumption of an existing machine. This gives us the information we need to select appropriate motors to replace consumers in the machine, and also the determine the battery energy needed for the application.

Session F: System Design & Architectures

Title: Creating Customer Value Through Development of Innovative System Control Concepts

Authors: Germano Franzoni (Parker Hannifin)

Abstract: The design of the "next generation" of hydraulic systems can follow different paths, defining the specific trends in each application or industry. For example, some applications are focused on efficiency improvements, others on investigation of alternative power sources, others on noise reduction, etc. In certain cases, the most interesting and most valuable developments can be achieved through the development of innovative control concepts. Controls of hydraulic systems is usually the topic of one or more sessions at every academic Fluid Power conference where the focus is mostly technical or theoretical. This presentation is instead focused on the industry perspective, giving some real-life examples, and taking into considerations not only the technical challenges, but also other factors such as the feasibility piece and the necessary collaboration between the component supplier and OEM (i.e. final customer).

On the technical side, the control of hydraulic systems should be developed creating an accurate model of the system which interacts with a model of the machine. When facing this challenge, to achieve the best solution to the problem, a collaboration needs to be established between the supplier and the OEM. The first one can bring to the table the expertise about the components' operation and create high-fidelity system models, the second one instead brings to the table the expertise about the machine operation, the desired outcome of the controls and all the operating situations in which the control can be operated.

Once the best solution is developed, there is also another important piece that needs to be addressed: ownership of the controls. The partnership between the component supplier and the OEM needs to continue throughout the life of the machine, when improvement, upgrades are released. In this presentation, the approach of the GMS team at Parker Hannifin will be presented: this is based on creating a long-lasting collaboration between Parker and its customers, with distinct goals as well as defined roles and responsibilities.

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Some examples of control systems which are currently in production will be presented:

1) Control architecture for a variable piston pump with energy recovery capability
2) Control for a E-LS system based on fixed displacement pump, variable speed PMAC motor and Inverter
3) Control for a steer-by-wire system
4) Coordinated motion control for a forestry machine

For every example, the technical solution will be described as well as the collaboration piece will be mentioned and described.

Title: Simulation-Based Investigation to Multi-Common Pressure Rail Systems with Three Pressure Rails and Three-Chamber Cylinders

Authors: Zihao Xu, Andrea Vacca (Purdue University) , Jan Nilsson (Wipro Engineering)

Abstract: Among the various architectures proposed to increase the efficiency of hydraulic systems in excavators, multi-common pressure rail (MPR) systems offer considerable advantages, particularly when multiple actuators operate frequently under overrunning load conditions. These systems can also benefit from decoupling the primary units and the actuators as well as the capability to make use to multi-chamber cylinders. By comparing all the MPR systems for excavators, the systems with three pressure rails and three-chamber cylinders seem to be a better choice, balancing the increased efficiency and increased installation cost. For a more detailed investigation to the efficiency gains and controllability of the system, a full simulation model that includes the engine, hydraulic system, machine dynamics, and optimized actuator controllers is developed for a mid-size excavator. Additionally, the operating point of the internal combustion engine (ICE) is adjusted along with the pump displacement controller, ensuring the ICE operates in a high-efficiency region with reduced partial loading. A case study on a 22-ton excavator was conducted using the developed simulation model and controllers. Simulation results, based on typical truck loading and grading utilization cycles, demonstrate a potential fuel consumption reduction of up to 36% compared to the reference.

Title: Design and Development of a Hydrogen Engine Powered Excavator for Zero-Emissions Off-Road Vehicles Technology Advancement

Authors: Elena Menegatti, Andrea Vacca, Gregory Shaver (Purdue University)

Abstract: In light of the urgency to tackle the climate emergency, governmental initiatives to achieve carbon neutrality by 2050 are leading to increasing demand for zero emissions solutions for off-road vehicles. Hydrogen engines offer a cost-effective and robust technology, leveraging existing knowledge of internal combustion engines, and provide an ideal solution for machines that operate in remote areas where recharging stations are not easily available, such as construction machines. Advancing towards a zero-carbon technology is not solely about emissions reduction, but it's also about improvements in the overall machine architecture and performance, through a comprehensive analysis of its operational requirements and demands. Additionally, this technology imposes new challenges due to hydrogen engines' slower transient response compared to their diesel counterparts.

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(continued) Construction machinery is characterized by high and rapidly changing loads, and current actuation systems impose harsh transients on the prime mover, increasing the risk of stalling an engine with slower transient behavior. To tackle these challenges, the fluid power architecture must be optimally designed to ensure compatibility with hydrogen combustion engines. Taking the reference case of a 24 ton. excavator, a model of the machine is developed and simulated in MATLAB/Simulink to enable its operation with a hydrogen engine of same displacement as the baseline diesel, proving the feasibility of this technology. Simulations on duty cycle are conducted to predict fuel consumption and CO2 emissions, perform a comparison with the load sensing baseline machine, and evaluate efficiency gains. The findings aim to demonstrate the viability of hydrogen engines as a zero-emission solution for construction equipment.

Title: An analysis of energy efficient hydraulic actuation architectures for mini-excavators

Authors: Timir Rajendra Patel, Isha Bayad, Andrea Vacca [Purdue University], Charlie Young [Bobcat]

Abstract: The rising demand for battery operated off-road vehicles gives a great push towards high energy efficient actuation architectures that with reduced energy consumption and maximize battery up-time. With excavators occupying a large market share in the construction equipment industry, this presentation shows a study on high efficiency hydraulic architectures replacing the conventional compensated load-sensing (LS) system on an electrified 49 hp 5-ton mini-excavator. The reference cycle that is used is the traditional 90º digging cycle considering only the planar functions, i.e., boom, arm and bucket. The first electrified solution being considered is the Multi-common Pressure Rail (MPR) architecture that has shown promising efficiency improvements in the past literature, by offering load decoupled pump operation, reduced throttling losses and energy recuperation capability. The flow control strategy for the MPR system is based on a state-based valve controller with only pressure feedback. This system is compared with known individualized architectures in terms of energy consumption and installed pump capacity. The systems are simulated in Simcenter Amesim to determine the energy distribution over the reference cycle and a basic sizing study is performed using commercial components. The results for the MPR system with two constant pressure rails show a 30% prime mover shaft energy consumption reduction compared to a 50% reduction using the individualized systems.

Session G: Components

Title: Reduction of Dynamic Loads in Piston Compressors Through the Use of Mechanical Resonance

Authors: Wieslaw Fiebig and Willy Prastiyo (Wroclaw University of Technology)

Abstract: In reciprocating compressors that use the slider-crank mechanism, the input torque experiences significant fluctuations due to the inertial forces of the reciprocating components. In this paper, a technique for improving the dynamics of reciprocating compressors is presented using the phenomenon of mechanical resonance. The study involves a comparative analysis using multibody dynamics simulations (MBD), and experimental investigation comparisons are performed in two main operation setups: 1. piston without an additional coil spring element; and 2. piston with an additional coil spring element.

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[continued] System performance is analysed by examining the forces in joints, inertia torque, and estimated power demand of both main sets of components in various scenarios of simulation considering different configurations of friction, pressure load, reciprocating mass, and spring stiffness. The MBD model is prepared and simulated in MSC ADAMS. torque amplThe findings of this study confirm that the resonance setup offers a significant advantage, exhibiting significantly lower inertia itude compared to the conventional setup, primarily attributed to the compensation of inertia forces by spring forces.

Not only by the use of steel spring, in case of the work of a compressor system, resonance can also be attained by the process of air compression. The stiffness of the air spring in the cylinder itself can be harnessed to achieve resonance. In this case, the influence of pressure on the natural frequency of the system is taken into account. To simulate the dynamics of fluid, an equivalent multidomain system of the model is made in Simcenter Amesim. Simulation results indicate that an increase in equivalent spring stiffness (air spring plus steel spring) leads to higher power efficiency. All rotating joints of the set-up with spring at resonance exhibit lower peak and RMS value of force on joints. Finally, experimental verification of the slider-crank mechanism at resonance demonstrates behaviour equivalent to the simulations. On the basis of the analysis, it can be concluded that controlled mechanical resonance can effectively reduce inertia load fluctuations in reciprocating compressors. This proposed method holds potential application, particularly in industrial cross-head compressors in which the share of inertial forces is greater and the forces occurring in the crank- slider mechanism determine the wear and durability of individual elements.

Title: A Novel Device for Oil Deaeration

Authors: Mario Morselli (Stem)

Abstract: The presence of free air is a common problem for many machines, expecially for the ones that use the same fluid for the power transmission and the hydraulic network. The free air actually cannot be seen as a sole problem, but a it causes a series of problems, because it affects pump or motors efficency and mechanical reliability, noise, oil endurance, oil temperature, the needs for heat exchange and the very way of working of the hydraulic devices like valves, distributors and all the hydraulic services. The devices currently used to limit this problem have several limitations including pressure drop or the long time required to perform theyr effect. An innovative approach : a dynamic hydraulic machine to be fitted in line that provides an efficient air separation in “true time” toghether with an useful prevalence of the fluid towards for pump inlet and for the separated air delivery. The effectivness of the device is related to the bubbles dimensions on one side and the fluid viscosity on the other side: an overview on the simulations performed and the test validation. The use of this device shows a very positive balance between the energy used and the energy saved.

Title: Tribological Studies of Hydraulic Cylinder Piston and Rod Seals

Authors: Paul Michael (Milwaukee School of Engineering)

Abstract: Rod seals serve a critical role in the reliability and controllability of hydraulic cylinders. Seal failure can lead to environmental contamination and friction-related control instabilities. A test rig was developed to measure friction at the rod-seal interface. The effects of varying rod surface profile, sliding speed, and pressure were experimentally studied. The impact of these factors on seal friction was complex. Boundary, hydrodynamic, elastohydrodynamic and stick-slip lubrication regimes were observed. Surface profile and fluid chemistry play a major role. Results are interpreted within the context of basic lubrication principles to identify the key surface parameters for controlling rod-seal friction and stick-slip.

Session H: Special Fluid Power Applications

Title: Application of Water Hydraulics of Pulse Reverse Osmosis Process

Authors: Ali Naderi (Purdue University)

Abstract: Reverse osmosis is the most efficient method of purifying and recycling contaminated water. However, reverse osmosis is a process that requires high pressure systems, and somewhat involved flushing cycles of the membranes used to separate clean water from brackish water. There is a need for a streamlined process for the filtration of water, so the process is more continuous and efficient. Current trends in urban and vertical farming rely heavily on clean water for the production and sustainability of freshly produced foods grown indoors. An energy efficient and streamlined approach for recycling water in indoor farms will improve the sustainability of vertical farms by reducing water consumption and water contamination. This project is focused on the design, prototyping and testing of a Pulse Flow Reverse Osmosis test bench for the application of recirculating water in a vertical farming prototype. The system will be tested by examining a variety of properties such as water pressure, temperature, flow, and light intensity. The goals of this project are centered around studying the feasibility of implementation of a novel and efficient reverse osmosis system for water purification and recycling to be used in indoor hydroponic systems.

Title: Fluid Power Training and Education in the Digital Era: a Case Study of a Virtual Reality Lab

Authors: Farid Breidi (Purdue University)

Abstract: This research presents a case study on the effectiveness of Virtual Reality (VR) as an educational and training tool by comparing the learning experiences and outcomes between a VR-based fluid power lab and a traditional hands-on lab. A VR simulation was developed, which allowed students to interact with virtual models of basic fluid power components, such as gear pumps, pneumatic cylinders, and pressure relief valves. Quantitative and qualitative data were collected through surveys that assessed students' task load, overall experience, and perceptions after completing the physical and VR labs. The results revealed that while the VR lab did not offer the tactile realism of a physical lab, it provided unique advantages, such as enhanced visualization of internal components, the ability to explore exploded views, and innovative interaction with equipment. Additionally, the VR lab's multimedia resources and self-directed nature were seen as significant benefits. However, some students encountered challenges with technical glitches, unintuitive controls, and physical discomfort. Despite these drawbacks, the study demonstrates VR's potential to enhance fluid power education by offering an immersive, scalable alternative to traditional labs, which can help address space and equipment limitations while better preparing students for industry roles.

Title: Fluid Power R&D Needs for Next-Generation Desalination

Authors: David Warsinger (Purdue University)

Abstract: Advances in desalination, especially the leading technology, reverse osmosis, are key to addressing sustainability challenges. However, substantial hydraulic limitations are hindering adoption of the most efficient and fouling-resistant variants of reverse osmosis. What unites the family of emerging configurations is time-varying conditions and the need for new specialty

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[continued] Equipment. Batch Reverse Osmosis can achieve the highest efficiency desalination by following the osmotic pressure curve over time, recirculating the concentrate stream until it is sufficiently desalinated for discharge. It thus requires a high-pressure pump, with discharge pressure of 27-70 bar, that maintains its efficiency while cycling across that pressure range every few minutes. To do so, the most efficient and suitable option today is positive displacement pumps. More crucially, batch Reverse Osmosis needs a circulation boost pump that provides a fraction of one Bar boost to those varied conditions: current options have dismal efficiency as the sealants needed to support the inlet ports against the back pressure increase the frictional loss. This pump can be eliminated by using a pressure exchanger to recover the brine pressure, but that also has large losses since the pressure drop is high. Specialty fast-acting valves may be needed for these batch processes. Reverse osmosis processes can also reach higher salinities by using a less salty stream on the normally pure side of the membrane, dubbed osmotically assisted reverse osmosis (OARO). Such a process may require specialty pumps with high inlet pressures, which can be reduced with a batch approach. A simpler alternative for high salinities uses membranes with low salt rejection, which sacrifices some energy efficiency. Beyond pumps, commercializing these processes requires special materials. The corrosive salts necessitate options such as duplex or 316-grade stainless steel. Some components that manage to use alternate materials, like fiberglass membrane pressure vessels or sensors, may need upgraded versions for newer extreme pressure variants. Membranes themselves need improvement to reach even higher pressures, include better spacers for enhanced mixing, and become compatible with OARO by having counterflow channels or low-salt rejection materials.

Session I: Sensors and Measurements

Title: Innovating Aeration Measurement for Enhanced Vehicle Lubrication Systems

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

Abstract: The quest for optimizing vehicle hydraulic performance and reliability places a spotlight on the critical role of lubrication systems. Traditional methodologies fall short in accurately gauging aeration levels within lubricants, a factor paramount to ensuring operational efficiency and longevity of system components. This presentation introduces a pioneering approach to aeration measurement, focusing on active flow regulation to dynamically undissolve aeration to a reference pressure. By addressing the inherent challenges of varying flow and pressure conditions that alter the state of aeration, our solution maintains constant pressure and flow, enabling precise measurement of total undissolvable gas at critical system points. Through improved data correlation and a new generation of testing methods tailored for realworld applications, this research aims to elevate aeration measurement to a fundamental routine akin to checking pressure and temperature. The vision is clear: to advance a safer world in transportation by pioneering and integrating sophisticated aeration measurement techniques into our projects. Join us in redefining the standards of lubrication systems, paving the way for more reliable and efficient vehicles.

Title: Power Loss in Piston/cylinder and Slipper/swashplate Interface at Extreme Low-speed Operating Condition

Authors: Antonio Masia, Lizhi Shang (Purdue University)

Abstract: In this paper, the performance of swashplate-type axial piston pumps and motors' tribological interfaces, specifically the piston/cylinder, and slipper/swashplate, are investigated under low-speed and high-pressure conditions

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(continue) and two different temperatures. The study aims to identify frictional torque loss and external leakage from these interfaces under medium pressure (ranging from 50 [bar] to 125 [bar]) at extremely low speeds (ranging from 0 [rpm] to 250 [rpm]), and two temperature (30 [ºC] and 40 [ºC]) for the operating fluid. The study uses a specially designed test chamber and a customized piston pump rotary group to measure frictional torque loss and external leakage. The design of the test chamber, rotary group, test procedure, and sensor specifications are also discussed. The result identifies the operating speed where hydrostatic pumps and motors need to be considered to win the start-up torque which highly affects the performances of the units in the low speeds operating condition.

Title: Innovative Hyper-thin Sensor for Cartridge Valves Diagnostics and Predictive Diagnosis

Authors: Massimiliano Ruggeri (STEMS-CNR), Francesco Maita, Luca Maiolo (IMM-CNR), Mattia Ferri (E.S.T.E), Christopher Rosi, Sara Baldoni (VIS Hydraulics)

Abstract: Functional Safety asks for diagnose-ability of systems and components in order to make the systems fully observable and to check for faults to be recovered in real time to avoid dangerous consequences of the faults themselves. At the same time, new technologies offer new materials and new production processes, which allow the creation of new sensors to meet the requirements of the functional safety certification procedures. Diagnostics and predictive diagnosis are not only related to functional safety, but rather to quality and function availability, which represent two very important aspects of quality products. Finally cartridge valves are widely used in many hydraulic systems, both in mobile and in industrial applications, and the follow up of this research could be of wide interest in the fluid power community. Cartridge valves are often part of systems that must meet functional safety requirements. The pressure measurement on the line is not sufficient to guarantee the safety and correct functioning of a valve but, above all, pressure measurement it does not contain information on the state of health of the valve and its state with respect to the average life and the distance from a dangerous failure. The paper deals with describing some type of failures of cartridge valves and describes how an innovative hyper-thin sensor is able to detect such failures before they occur, also with a reasonable warning of the moment of failure. This distance between the moment of time in which the sensor is able to detect an anomalous condition of the valve and the moment of time of failure is measured in number of cycles or in and has been tested on a bench at the headquarters of the VIS Hydraulics Company on a series of valves. The paper describes the sensor, its characteristics, including the thickness (8 microns) and the manufacturing method, and discusses the problems of installing the sensor itself on the valve body, in the area where the valve coil is also installed. The article also describes the necessary modifications to the body of the coil, to the space necessary for housing the sensor and the variation of the electromagnetic characteristics of the field generated by the modified coil with an increased gap between valve body and coil, evaluating the acceptability of the new solution.

In fact, the sensor is a hyper-thin strain gauge that completely envelops the valve body, so as to be able to detect any variation in the shape of the valve body at any point on the body itself. In this way the sensor is able to detect any type of breakage in the body due to fatigue or excessive pressure or any other cause. It will be also discussed the temperature compensation for the sensor and how itself is an important part of the detection process. Finally, the paper presents the real tests at test bench and describes the future scenarios considering the usage of this class of sensors.

Session J: Hydraulic Pumps And Motors II

Title: An Elastohydrodynamic Lubrication (EHL) Model for Radial Piston Motor

Authors: Jinhwan Lee, Lizhi Shang (Purdue University)

Abstract: This study presents an Elastohydrodynamic Lubrication (EHL) simulation model developed for a multi-lobe radial piston motor (RPM) and its experimental validation. Those type of RPMs were commonly used under high torque and low speed conditions. Therefore, the severe wear and excessive power loss due to high load challenges its lubricating interfaces design. However, understanding these lubrication interfaces has been limited by difficulties in experimental measurement under high pressure in small gaps and the complexity of the multi-physics involved. To address these challenges, the proposed model solves a density-based Reynolds equation to predict tribological behaviors of fluid films around a piston with the consideration of multi-body motions and elastic deformations. The simulation results indicate that the lubrication regimes and contact pressure strongly rely on the chamber pressure and motor rotational speed. Viscous friction was a primary cause of the power loss for fluid film between the roller and piston, but the solid contact occurs between piston and cylinder bore especially during high load condition. This paper presents the simulation, the governing equation, the numerical solver, the force balance calculation and the fluid and structure interactive scheme. The paper also reports the comparison between the simulated power loss and contact area against the experimental measurement

Title: Comprehensive Transient Thermal Modeling of Axial Piston Pumps: Insights From Displacement Chamber Pressure, Temperature and Heat Convection

Authors: Roman Ivantysyn, Juergen Weber (Dresden University of Technology)

Abstract: Preparing today's fluid power systems for the industry's impending digitization requires enhancing the quality of information about the current condition of key system components. Positive displacement machines, vital to any hydraulic system, are central in this endeavor. The evolution towards intelligent systems demands a more detailed understanding of the pump's current state, including its power usage and efficiency metrics. Current condition monitoring methods predominantly rely on pressure or acceleration sensors, which necessitate high-frequency sampling and frequency analysis. Managing this substantial data—its transmission, storage, and analysis—demands considerable resources, particularly at larger scales. Prior research at the Institute of Mechatronics Engineering at TU Dresden has demonstrated that temperature measurements in lubricating gaps, taken at lower frequencies, yield profound insights into the tribological processes at these interfaces. Such measurements not only reveal gap height, viscous friction, and leakage but also provide essential information on component wear, efficiency and predicted lifespan, assuming the use of appropriate reference models.

This approach has been further advanced by monitoring steady state component surface temperatures that are accessible without the modification of the parts. This paper demonstrates the successful linkage of steady-state efficiency with the extrapolated steady-state temperature of the cylinder block surface, derived from transient state analyses. Using the empirical data, it was possible to extrapolate brief transient data sequences to steady state conditions otherwise only to be reached within 20-30 min. Utilizing a novel transient pressure – temperature correlation in the displacement chamber, a model was developed elucidating the impact of circulating oil on component heating and cooling. This model enables a physical representation of the transient thermal behavior, predicting how fluid conditions affect the steady-state temperatures of components in the rotating kit.

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[continue] This approach allows for an in-depth understanding of heat transfer mechanisms within the pump, especially in relation to its efficiency. This is achieved without reliance on empirical data, enabling the scalability of this approach across multiple pump types. This innovation represents a substantial advancement in predictive accuracy, particularly when integrated with advanced gap simulations like Caspar FSTI. By combining transient and steady-state thermal predictions, it creates a comprehensive and robust tool for the diagnosis, design, and optimization of pump performance.

The findings not only enhance the theoretical understanding of axial piston pumps but also pave the way for practical applications in predictive maintenance and system optimization, heralding a new era in hydraulic system analysis and design.

Title: Experimental and Numerical Analysis of Internal Micromotions in Gerotor Units: Exploring Contact Mechanics and Lubrication Interfaces

Authors: Matthias Krug, Zubin Mistry, Andrea Vacca (Thomas Magnete, Purdue University)

Abstract: This presentation introduces a numerical method to evaluate the performance and micromotions of rotors in a Gerotor unit, supported by extensive experimental validation. An experimental test setup was specifically developed to measure the micromotions of the outer rotor, along with basic torque and outlet flow measurements. This was validated with a simulation model capable of performing fluid dynamic analysis using a lumped-parameter approach to determine pressures within defined control volumes. Fluid dynamics are solved concurrently with the planar motion of the inner and outer rotors using Newton's laws of motion. This motion solution is integrated with the analysis of the lubricating interfaces around the rotors, based on the Reynolds equation. Contact dynamics and elastohydrodynamic relations are applied at multiple contact points between the rotors. The comparison of experimental data to simulation results shows a good match, with accuracies of 0.9% for volumetric prediction, 2% for hydromechanical prediction, and 2.5% for radial motion prediction. The proposed methodology provides detailed insights into rotor behavior and can be used to enhance current designs and evaluate new concepts.

Session K: Condition Monitoring & Safety

Title: Causal Condition Monitoring for Axial Piston Pumps: Prediction of Different Faults Under Variable Operating Conditions

Authors: Svenja Horn, Ahmed Shorbagy, Michael Lenz, Simon Knoll, Moritz Winter, Juergen Weber (Dresden University of Technology)

Abstract: The existing maintenance guidelines require the replacement of components at regular intervals in order to avoid spontaneous failure. This ensures the overall reliability, but causes high costs for the manufacture, replacement and disposal of potentially still healthy components. Predictive maintenance concepts aim to mitigate these drawbacks through presenting needs-tailored maintenance strategies. Previous work has primarily focused on the clear detectability of various failures. However, the methods and analyses developed so far are custom-fitted for specific pumps, systems and sensors lacking the deep insight into the causality and transferability of the identified characteristics and minimal requirements for the amount, quality and type of sensors. This paper explains in detail how targeted and realistic artificial wear is applied to the valve plate, the slipper and the slipper-piston joint of an axial piston pump. A comprehensive analysis involving a wide range of over 100 measured operating points is analyzed. The data array contains multiple measurements of the same operating conditions to guarantee reproduction of the operating conditions and trends. The data was sampled using both high-frequency and low-frequency sensors. The analytical evaluation of the measurement data highlights the impact of the worn pump parts on efficiencies, discharge flow rate, temperatures, accelerations and others. Various machine-learning models are developed to determine wear-specific, transferable and scalable features for a holistic recording of the component's condition. The pre-processing of the data, i.e. extraction, reduction and normalization of the features, is carried out using signal analysis methods based on systematic, transparent and logical processes. In addition, varying the number of sensors and features allows the computation of the classification rate based on the sensors utilized. The objective is to determine an optimum set of features and a minimum measurement equipment configuration for high classification rates. Beyond pure wear detection, the load collectives that contribute to wear are derived, enabling the pump to be optimized for operating points with high wear. This approach provides the groundwork for the next decisive step: by employing the established linkage of causal relationships between wear and load history developed within the scope of this work, it is possible to determine the remaining service life in the application.

Title: SONAR-based Real-time, Gas Void Fraction Monitoring Systems for Mobile Hydraulic Systems

Authors: Daniel Gysling (CorVera)

Abstract: The presence of entrained in hydraulic systems acts 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 reservoir size, power consumption and reliability are paramount and operating conditions are highly variable. The presentation introduces CorVera's $HYDR_X$™ Gas Void Fraction Monitoring system as a simple, practical and accurate way to measure gas void fraction in hydraulic systems. $HYDR_X$™ utilizes a convenient and flexible system architecture allowing real-time gas void fraction monitoring on a distributed basis within mobile hydraulic systems.

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[continued] The presentation describes how HYDR$_X$™ technology utilizes first-principle, SONAR-based, beam-forming technology to determine the speed at which naturally-occurring, low-frequency, sound is propagating within of aerated hydraulic fluids by interpreting the output of a pair of acoustic pressure sensors installed at two location on a hydraulic line. The measured sound speed is then interpreted in terms of the gas void fraction of the hydraulic fluid. HYDR$_X$™ 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. The presentation will describe recent testing at Purdue's Maha Fluid Power Research Center in which HYDR$_X$™ was evaluated on a Fluid Power Test bench. HYDR$_X$™ was installed on a hydraulic line supplying the inlet to a hydraulic pump. Entrained air was introduced by two methods: 1) throttling the hydraulic fluid upstream of the HYDR$_X$™ system causing gas-breakout from the hydraulic fluid, and 2) introducing air by allowing air entrainment into the low-pressure inlet line. A comparison of HYDR$_X$™ results with available reference will be presented for this and other laboratory-based demonstrations of SONAR-based gas void fraction monitoring systems.

Title: Transforming Excavator Operation: Fusing Teleoperation, Digital Twin, and Fluid Power System for Optimal Performance and Safety Conditions

Authors: Marvin Durango, Jose A. Solorio, Gina C. Baquero, Andres Rincon, Jose Gracia-Bravo (Purdue University)

Abstract: The goal of this project is to explore the application of fluid power system control, merging the benefits of mixed reality technology for Fluid power system applications to provide users with an interactive and immersive experience. Emphasizing operation and training is crucial for construction, agriculture and other heavy equipment. Teleoperation serves as an alternative to mitigate exposure to hazardous environments. However, isolating operators from the machine leads to a slow learning curve and non-natural control. Moreover, the literature also suggests the scale models can be used to provide proper training before handling real machines. Virtual reality modules allow training by interacting with digital representations of the equipment. Head-mounted devices, and other hardware - joysticks and sensors -contribute to a robust training module. The primary objective is to implement a sensor-based control in real-world and virtual environments, while simultaneously utilizing sensors to gather real-time data as a means to close the control loop and improve machine operations. All of this to control a fluid power system with the Hololens2, therefore, enabling users to manipulate components via a computational model simulated on a game engine software. This project features a physical system in representing a scaled down pneumatic excavator. The excavator serves as the output of the mixed reality control system. Bridging the gap between teleoperation, digital twins, and fluid power systems has not been done in the past. This approach aims to not only provide a safe method for controlling a fluid power system but also enable real-time visualization of measured variables. The virtual excavator experience can serve as a training tool, allowing users to familiarize themselves in a safe and controlled environment. Additionally, this integration has the potential to improve efficiency in fluid power system control. The successful activation of the system's solenoids by the virtual controls is verified ensuring accurate tracking of variables by sensors and displaying real-time graphics on the Head Mounted Device demonstrating stability and reliability of its performance. Visual Studio 2022, and Windows 11 SDK are the other tools were implemented for achieving this integrated system.

PRESENTATION ABSTRACTS

Title: Piston Harmonic Analysis - a Fatigue Crack Study

Authors: Stig Kildegaard Andersen (Danfoss A/S)

Abstract: To be added

Session L: Vehicle Electrification I

Title: High Power Density Integrated Electric Drives for Transportation Electrification

Authors: Woongkul Lee (Purdue University)

Abstract: In this talk, I will first discuss innovative inverter and electric machine topologies for maximizing the energy conversion efficiency and power density with less resource use, ultimately enabling electrification among a broad range of transportation systems such as heavy-duty vehicle and aircraft. I will also present various electric motor and power electronics integration strategies to achieve high power density with reduced electromagnetic interference noise and power losses.

Title: Advancing Reliability in Electro-hydraulic Actuators Through a Model-based Systems Engineering Approach With 1D and 3D Simulation Tools

Authors: Rene Chacon (Dassault Systemes)

Abstract: This presentation covers a holistic approach to enhancing the reliability of electro-hydraulic actuators by integrating advanced 1D and 3D simulation tools within a Model-Based Systems Engineering (MBSE) framework. Emphasizing conceptual design, optimization, and Finite Element Analysis (FEA), our research showcases the effectiveness of combining simulation tools and systems engineering principles for superior performance and reliability. The presentation explores the streamlined use of 1D simulation tools in system electrification, elucidating their role in ensuring optimal functionality and facilitating comprehensive understanding of condition monitoring, noise, and vibration analysis within the MBSE framework, thus identifying potential issues before physical prototyping.

PRESENTATION ABSTRACTS

Title: Facilitating the Development of a Novel Battery-hybrid Wheel Loader Exploiting Hardware-in-the-loop Technique

Authors: Weijin Qiu, Shubham Ashta, Gregory M. Shaver, Scott Johnson, Bryan C. Frushour (John Deere)

Abstract: Stricter emissions regulations have placed unprecedented pressure on off-road OEM companies to reduce the fuel consumption of their products. This has led to the adoption of powertrain electrification as a viable solution. The increased complexity associated with powertrain electrification necessitates a more reliable and efficient testing approach to assess the control performance of off-road vehicles with electrified powertrains. In this study, a real-time hardware-in-the-loop (HIL) simulation platform was developed for validating a novel heuristics-based vehicle power management (VPM) strategy to be implemented on a novel heavy-duty offroad wheel loader featuring battery-hybrid powertrain configuration. The platform incorporates a vehicle power management strategy for power distribution, component-level controllers to oversee actuator functions, and physics-based models of powertrain components to mimic vehicle performance. This HIL simulation platform enables the safe and efficient testing and validation of a controller board comprising the VPM strategy and a DC/DC converter control system. Results from simulations conducted on the HIL platform demonstrate that the studied battery hybrid wheel loader can achieve over 10% fuel savings.

Title: Optimization-based System Synthesis for Electrified Mobile

Authors: Christian Haas (RWTH Aachen University)

Abstract: The electrification of mobile machinery is leading to the development of new drive solutions. In addition to the replacement of the combustion engine by electric drive components, the mechanical and hydraulic drive components and the system layout can also be redesigned. The electrification of machinery allows for the development of more efficient systems and the reduction of costs on the battery side. This opens up a wide range of possibilities and degrees of freedom in the development process. The selection of a suitable drive concept is therefore a challenge. In conventional development processes, potential drive concepts are often examined with the help of system simulations and/or prototype tests. The suitability of the drive system for the application is only evaluated after a thorough investigation and a mostly iterative design process. The entire process involves a great deal of effort and ties up resources. Consequently, a large number of different system combinations cannot be evaluated economically using conventional methods. This article therefore presents an approach for improving the design process. The methodology enables the automated evaluation of drive systems. In order to achieve this, possible system layouts are modelled in the form of reduced models, as shown in Figure 1, an optimization space with possible system topologies is set up and suitable system topologies are selected by means of optimization.

Session M: Digitalization

Title: Numerical Investigation of Lubrication Film Cavitation

Authors: Haotian Han, Lizhi Shang, Georg Herborg (Danfoss High Pressure Pumps), Stig Kildegaard Andersen (Danfoss High Pressure Pumps)

Abstract: Cavitation in hydraulic systems presents a significant challenge, often leading to severe damage to mechanical components and impacting the longevity and reliability of machines. This phenomenon occurs not only in fluid chambers and ports but also in lubricating interfaces. Although cavitation effects have been considered in system-level or computational fluid dynamic (CFD) simulations, there has not been an investigation into cavitation effects within lubricating interfaces that takes into account fluid-structure interaction (FSI), such as body micro-motion and material deformation.

This study develops a robust FSI model incorporating elasto-hydrodynamic lubrication (EHL) effects to simulate an axial piston machine. The numerical predictions, including the location and intensity of cavitation in the lubrication film, are validated against experimental data. The results demonstrate the capability of the proposed model to reliably predict cavitation behavior, offering valuable insights for the design and optimization of hydraulic machinery in high-stress environments.

Title: Analysis of the Incomplete Filling of a Positive Displacement Pump Due to Undissolved Gas Involving Experiments and Simulations

Authors: Dinghao Pan, Andrea Vacca, Dan Gysling (Purdue University)

Abstract: The analysis of the incomplete filling behavior of positive displacement machines requires considerations of the undissolved air (i.e. aeration) often associated with uncertainties in the evaluation of the air content within the working fluid and its dependencies with the suction pressure.

This study contributes to this topic by presenting an experimental analysis as well as modeling considerations based on an experimental set-up designed by the authors that measures the filling characteristics of an internal gear pump under induced gaseous cavitation. Measurements considered in the study include the pump flow rate vs. shaft speed, as well as the undissolved gas content at the inlet via an innovative solution by CorVera. Experimental results show that with the same pump inlet pressure, low-speed operations present more tendency for incomplete filling, as compared to higher-speed conditions. This is due to the transient behavior of the air release process in the line connecting the reservoir to the pump, an effect often neglected in similar analyses. This observation is supported by the measured undissolved gas content, which decreases from 7% (at 500 rpm) to 1.5% at 1500 rpm, while the inlet pressure is maintained at 0.3 bar absolute. The measured air release was compared with analytical models, including the equilibrium model and the first-order dynamic model, where a good match was observed between the measurements and the first-order model results produced with an 8 s time constant for fluid with 6 % total air. The incomplete filling behavior was further examined with a lumped parameter-based simulation model based on the equilibrium fluid model, showing that the total air content at the inlet condition greatly affects the accurate prediction of the pump's incomplete filling. A significant consistency was also found between the measured undissolved air content and the air content values that best predicted the incomplete filling phenomenon.

PRESENTATION ABSTRACTS

Title: Early Architecture Design Exploration of Electrified Heavy Equipment

Authors: Arlie Nuetzel (Siemens)

Abstract: To accelerate electrification transition, heavy equipment manufacturers need to consider multiple architectures early in the design process. An innovative methodology have been developed, combining system simulation, optimal control methods, and reinforcement learning, to simulate and evaluate hundreds of architectures. Driven by a patented artificial intelligence technology, including a state-of-the-art machine learning and scientific computing stack, the software generates a wide range of system architectures from a formal model description. The methodology will be exposed on various examples of off-highway machines

Title: Digitalization & Sustainability: The Key to the Future of Fluid Power

Authors: Christian Geis (VDMA)

Abstract: In principle, the digitization of products and digitalization in general enable new business models, such as predictive maintenance, and offer many opportunities for monitoring and controlling of systems. In a world where the focus is increasingly shifting towards sustainability, emissions, efficiency and circular economy, digitalization also helps to optimize solutions and meet reporting obligations (e.g. in the EU). The presentation will introduce a European-funded major research project focusing on digital twins ("asset administration shell") and use cases on system and sustainability aspects. The Fluid 4.0 project and the expected results will help to lead fluid power into the future and keep it competitive.

Title: Synchronized Digital Reality Remote Environments for Seamless Control of Fluid Power Manipulators

Authors: : Israa Azzam, Farid Breidi (Purdue University)

Abstract: This work proposes using Digital Reality (DR) technologies to design a synchronized remote environment that enhances the human-machine interface for Fluid Power Manipulator Control. The DR remote environment aims to reduce operational costs and time while ensuring the safety and security of human operators by extending operators' seamless access and control over their fluid power manipulator from a distance. The collaborative aspect of this environment enables real-time feedback, allowing multiple remote operators to communicate and interact in a synchronized digital space with a degree of control over the fluid power system. Additionally, the digital remote environment's features and capabilities provide operators with a secure setting to perform tasks off-site, away from the complex dynamics of the physical environment. Two DR environments—Virtual Reality (VR) and Mixed Reality (MR)—were investigated and tested in various aspects, including design, implementation, accessibility, user comfort, and other functionalities. The findings from these evaluations lead to the selection, design, and development of the optimal synchronized remote environment. After development, control synthesis algorithms will be designed and integrated into the system to ensure accuracy during task execution.

Session N: Off-Road Vehicle Technology I

Title: Kinematic Position Control in Compact Track Loaders

Authors: Sumaiyyah Nizam (Bosch Rexroth)

Abstract: In recent years, due to the increased affordability of digital devices, especially sensors and control units, an increasing trend has been observed in automated functions in Mobile machines. This shift towards automation is not just a trend but a necessity as experienced operator labor is becoming scarce and productivity targets are set higher. Hence, automating complex working functions in construction machinery brings higher productivity while ensuring safety and easy operability. This work presents an innovative approach to design a Kinematic Positioning system in Compact Track Loaders. It utilizes inertial sensors with accelerometers and gyroscopes to compute precise angles for the loader arm, bucket, and Chassis. To ensure utmost precision a post-computation angle correction is performed by plausibility implementation between measured movement and valve actuation. Additionally, the Madgwick quaternion filter approach is applied to the accelerometer readings to help reduce errors induced by driving and steering conditions. With the determined angles, the Kinematic Position Control for the system is derived from a Quintic planner. This unique feature ensures proper synchronization between moving links while considering different machine geometries, which sets the proposed solution apart from others in the market. Gain scaling is then performed based on the movement rate of the associated links to ensure robust control and optimized performance. Three primary assistance functions are currently being offered with the help of this approach, namely, Return to Position, Work Tool Position, and Electronic Self Levelling, further enhancing the system's versatility and usability. Work Tool position allows the operator to memorize any bucket angle within the full range of motion. This memorized angle can be with respect to the Chassis or the previous link. The operator can thus return the bucket to a memorized position by a pre-determined action. This feature allows fast and consistent operations for low groundwork applications like trenching and grading. Return to position extends this feature and enables the operator to return the loader and bucket to memorized positions automatically. The operator can use it for multiple applications, such as material handling and truck loading. For these applications, if the bucket and boom movement are not synchronized, it can lead to dumping of material and loss of performance. Current solutions in the market for compact track loaders offer the possibility of returning the links to a preset dig position. The proposed solution provides the flexibility to memorize any position of the links along with synchronization between the loader and bucket. Electronic Self Levelling is a key feature of our system, offering a significant improvement over its current hydraulic alternative. By introducing an operable range for the function, we enable the continuous use of self-levelling in all boom operation scenarios, a capability that the hydraulic alternative lacks. This feature also allows the operator to manually override it with bucket operation, providing flexibility and control. Auto resume of the function with a new target bucket angle is also supported after a manual override, ensuring seamless operation, and enhancing the system's user-friendliness. Therefore, the combination of inertial sensors with Madgwick quaternion filter and post-computation angle correction aligned with control algorithms designed for the specific target application has proven to significantly increase performance, safety and operability as demonstrated by this work. Return to Position, Work Tool Position and Electronic Self Levelling are some of the core functions that can be used based off this solution. This solution also opens the door for other semi-automated features to be incorporated in the future.

Title: What Happened to Hydraulic Hybrids?

Authors: Jose Garcia-Bravo (Purdue University)

Abstract: Hydraulic hybrids have been studied since the '70s of the last century. However, it is now, with a move towards electrification and independence from fossil fuels in automotive, when various topologies of hydraulic hybrids have a real opportunity to stand out for their improved efficiency and potential advantages over purely electric drivetrains. This paper sums the origins and developments of hydraulic hybrid powertrains and reviews the most recent investigations conducted on electric-hydraulic architectures. Hydraulic systems can improve EVs benefits, especially in terms of energy efficiency, battery life cycle and motor downsizing. For this reason, electric-hydraulic vehicles have the potential to enter the automotive industry if they overcome optimization control and accumulator and battery sizing challenges. This paper discusses the results of an investigation where 130+ in person interviews were carried out to survey the trucking industry, construction and utility vehicle industries. The work focused on looking into market trends, customer perception and technical barriers that have significantly slowed down the proliferation of hydraulic hybrid transmissions in these and other related mobile sectors

Title: Implement-only Implementation of a Multi Pressure Rail System to an Agricultural Planter

Authors: Jacob Lengacher, Xiaofan Guo, Andrea Vacca (Purdue University), Ryan Jenkins [Case New Holland]

Abstract: Tightening emissions regulations and rising energy costs have driven a desire across many industries for more efficient actuation systems. This is particularly true of the agricultural sector, where a common arrangement is a tractor hydraulically supplying a towed implement hosting multiple actuators.

This arrangement is known for frequently having low energy transmission efficiencies (on the order of 20%), and improvements are challenging as many alternative solutions require modification of both the tractor and the implement. This work addresses the above issue, by proposing an implementation of the Multi-Pressure-Rail (MPR) hydraulic control concept to an agricultural planter chosen as reference implement. The work shows that the proposed solution maintains compatibility with conventional load sensing technology, meaning that a tractor not conceived for MPR can still power an MPR implement and allow for significant savings. This is done by manipulating the load sense network of an unmodified tractor to set system pressures to those required by the MPR system. This paper outlines the working principles of the system, an analytical assessment of the system's saving potential, and finally, a full-scale experimental validation using vehicles in actual planting conditions. The experimental results demonstrate a remarkable 37% reduction in hydraulic power consumption, proving the readiness and the technical relevance of the proposed solution.

PRESENTATION ABSTRACTS

Title: Electrification of a compact skid-steer loader – redesign of the hydraulic functions

Authors: Shaoyang Qu, Zifan Liu, Rafael Cardoso, Enrique Busquets (Bosch Rexroth)

Abstract: Compact skid-steer loaders stand as key players in the North American machinery market. In response to increased customer interest and evolving regulations, a notable shift towards electrification has emerged within this sector. This trend is propelled by the promise of enhanced efficiency and a substantial reduction in emissions, reflecting an important step towards sustainability in the industry. This presentation focuses on the comprehensive electrification of a 5-ton compact tracked loader with a 67kW rate power based on Rexroth's eLION high voltage platform including hardware (electric motor, inverter, onboard charger, DC-DC converter, gearbox and cables) and software. The electrified machine consists of the following sub-systems: battery, thermal management, electric drive, electric-hydraulic implement, charging system, human interface control system and other accessories. These sub-systems operate synergistically to unlock the full potential of electrification, resulting in enhanced system efficiency, elimination of harmful emissions, and reduction in noise pollution. The design process starts with component sizing using Rexroth's in-house sizing tool eFADI based on eLION portfolio for the drive and implement systems. The baseline machine testing provides the data to size the battery pack and thermal systems. The electrification process introduces additional components, notably the battery system and liquid cooling elements, in comparison to the traditional compact loader. Effectively packaging these components within the vehicle frame is a significant challenge, considering the small footprint of the loader machine, the amount of cabling and piping, and proper mounting of all electric components against shock and vibration. To extend the operating hours of the fully electric machine, every possible efficiency gain has been pursued in the scope of system design and control. The traction system eliminates the traditional hydrostatic circuit and applies the electric two-track drive configuration by integrating Rexroth's eGFT gearbox and EMS 700V electric motor. The implement system uses Rexroth's low-noise electronified open-center pump (eOC-P) and modified pre-compensated RM valve to enable energy regeneration and improve hydraulic efficiency. In comparison to the diesel baseline, the electrified prototype shows remarkable energy savings and noise reduction without compromising dynamic performance. To optimize the design of certain sub-systems, lumped-parameter simulation has been employed to determine the optimal system configuration, and key results would be presented. A detailed illustration for each sub-system and integration to the whole electrified vehicle is presented as well.

In conclusion, the comprehensive electrification of compact skid-steer loaders presents noteworthy advantages despite significant engineering challenges associated with component sizing, packaging, and thermal management. Rexroth's eLION platform serves as a viable system solution to electrify every off-highway application in a sustainable manner without any compromise. This study illuminates these challenges, offering valuable insights that contribute to the progress of electrification within the construction equipment industry.

PRESENTATION ABSTRACTS

Title: A Deep Reinforcement Learning Framework to Develop Supervisory Controller of a Novel Multi-pressure Rail Tractor-planter Hydraulic System

Authors: Saad Akhtara, Eric Miller, Andrew Glaws, Ken Kelly (National Renewable Energy Laboratory)

Jacob Lengacher, Yifei Chen, Andrea Vacca [Purdue University]

Abstract: Reinforcement Learning (RL) exemplifies recent Machine Learning (ML) advances that enhance our understanding of complex dynamical systems across disciplines. Unlike conventional supervised ML, which relies on labeled input and output data, RL focuses on optimizing actions through intelligent interaction with dynamic environments to maximize rewards. In this study, we employ Deep Neural Networks to train a Reinforcement Learning framework (DRL) for supervisory control of a Multi-Pressure Rail (MPR) tractor-planter system. The MPR model is developed using two methods: i) Data-driven Reduced Order Modeling and ii) State-Space representation of hydraulic systems. The DRL interacts with the MPR model via three channels: i) observation (angular velocity and operating pressure measurements), ii) reward (power consumption, penalizing simultaneous actuator switches), and iii) action (medium pressure set point and operation mode). The DRL trains an ANN to find optimal control strategies by maximizing rewards from observations. Results show the approach is computationally efficient and effective in predicting optimal control strategies.