Tampereen teknillinen yliopisto - Tampere University of Technology

ABSTRACTS

The Fourteenth Scandinavian International Conference on Fluid Power, SICFP15

May 20 - 22, 2015

Tampere, Finland

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Department of Intelligent Hydraulics and Automation
Tampere 2015

ISBN 978-952-15-3529-1 (Book of Abstracts)
ISBN 978-952-15-3548-2 (Book of Abstracts, PDF)
ISBN 978-952-15-3530-7 (Proceedings, USB)
ISSN 2342-2726

PREFACE

The first international conference on fluid power in Tampere was held in 1987. That was the start of the series of Scandinavian fluid power conferences. In 1993 the conference was named as Scandinavian International Conference on Fluid Power and it was decided to held the conference every second year alternately in Tampere and Linköping. So we have already almost 30 years' tradition.

The 14th Scandinavian International Conference on Fluid Power conference is organized by Department of Intelligent Hydraulics and Automation (IHA) at Tampere University of Technology (TUT) together with network of Fluid Power Centres in Europe (FPCE).

At this time the conference includes various themes like hybrids, drives, digital hydraulics and pneumatics. Special attention in the program is given for energy efficiency, renewable energy production and energy recovery. They are reflecting well the situation, where environmental issues and energy saving are increasingly important issues.

We received about 125 interesting and high-level abstract proposals. In addition to three invited speakers, about 70 papers were selected for the final programme. This year for the first time in the SICFP conference also peer-review of papers was available for those who asked it and 30 papers passed the evaluation. We appreciate the work what the reviewers have been done. We believe that the conference will give the participants fine opportunities to listen interesting presentations, to exchange opinions and strengthen of old contacts and to establish new ones.

This time the conference proceeding will be published as a printed abstract book and as a USB memory stick and the papers will be publicly available later 2015. We hope that this proceedings will serve you well during the conference but also far in the future as a source of reference.

We would like to express our sincere appreciation to everybody who has contributed to the success of the conference.

Tampere, 8th May, 2015

Kalevi Huhtala
Professor, Conference Chairman

Arto Laamanen
Dr. Tech., Conference Manager

May20–22>2015>TAMPERE FINLAND
SICFP 15
Scandinavian International Conference on Fluid Power

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SICFP15 Exhibitors

Programme

WEDNESDAY, MAY 20

9:15 -	Registration & Coffee
10:00 – 12:00	Opening and Invited Speakers
12:00 - 13:00	**Lunch**
13:00 - 14:30	A1: Drives
	B1: Hydraulic Systems
14:30 - 15:00	**Coffee / Exhibition Area**
15:00 - 16:30	A2: Digital Hydraulics
	B2: Components
19:00 -	**Reception by the City of Tampere, Tampere City Hall**

THURSDAY, MAY 21

9:00 - 10:00	P1: Energy Efficient systems
10:00 - 10:30	**Coffee / Exhibition Area**
10:30 - 12:00	A3: Controls
	B3: Modelling
12:00 - 13:15	**Lunch**
13:15 - 14:45	A4: Pumps
	B4: Valves
14:45 - 15:15	**Coffee / Exhibition Area**
15:15 - 16:45	A5: Robotics
	B5: Energy Efficiency
19:00-	**Gala Dinner, Solo Sokos Hotel Torni Tampere**

FRIDAY, MAY 22

9:00 - 10:00	P2: Reliable Hydraulic Systems
10:00 - 10:30	**Coffee / Exhibition Area**
10:30 - 12:00	A6: Hybrids
	B6: Pneumatics
12:00 - 13:15	**Lunch**
13:15 - 14:45	A7: Fluid Power Systems
	B7: Fluid Storages

19:00 - 22:00 **Cruise & Dinner** (Not included in the basic conference fee)

Peer-reviewed papers are marked with a logo

Wednesday, May 20, 2015, Session A, Small Auditorium	
9:15	**Registration & Coffee**
10:00 - 12:00	**Opening and Invited Speakers** *Session Chair: Kalevi Huhtala, Tampere University of Technology* - Janne Uotila, Sandvik - Ville Kyrki, Aalto University - Bernhard Menz & Karl-Heinz Vogl, Bosch Rexroth
12:00	**Lunch**
13:00 - 14:30	**A1: Drives** *Session Chair: Peter Achten, INNAS* **A Hydraulic Hybrid Wheel Loader with a Novel Power Split Hydraulic Transmission** Feng Wang, Kim Stelson **Comparison Studies of Different Nonlinear State and Disturbance Estimators for a Hydrostatic Transmission** Hao Sun, Harald Aschemann, Robert Prabel **Design Study and Parameter Optimization for a Light-Weight Series Hydraulic Hybrid Vehicle** Katharina Baer, Liselott Ericson, Petter Krus **First Experimental Results of a Hydraulic Hybrid Concept System for a Cut-To-Length Forest Harvester** Kalle Einola, Aleksi Kivi **Gain Scheduling Full State Feedback with D-Implementation for Velocity Tracking of Hydrostatic Drive Transmission** Joni Backas, Reza Ghabcheloo, Kalevi Huhtala
14:30	**Coffee**
15:00 - 16:30	**A2: Digital Hydraulics** *Session Chair: Matti Linjama, Tampere University of Technology* **Development of a Digital Hydraulic Pump for High Torque and Low Speed Applications in Hydrostatic Transmission** Mitsuaki Hayashi, Yuuichi Miura **A Linear Valve Actuated Switched Inertance Hydraulic System** Nathan Peter Sell, David Nigel Johnston, Andrew R. Plummer, Sylwester Kudzma, Min Pan **On Efficiency of Switched Inertance Control for Hydraulic Systems** Anton Sinyakov, Pavel Greshnyakov, Asgat Gimadiev, Victor Sverbilov, Andrew Plummer, Nigel Johnston **Fault Tolerance of Digital Hydraulics in High Dynamic Hydraulic System** Lauri Siivonen, Mikko Huova, Matti Linjama, Heino Försterling, Edgar Stamm, Till Deubel **Energy Saving Using a Multi-Chamber Accumulator: Experimental Results and Proof of Concept** Christian Stauch, Joachim Rudolph

Wednesday, May 20, 2015, Session B, Sopraano	
12:00	**Lunch**
13:00 - 14:30	**B1: Hydraulic Systems** *Session Chair: Jouni Mattila, Tampere University of Technology* **Fuzzy Repetitive Controller for Electro-Hydraulic Periodical Pressure Servo Systems** Zaipeng Man, Fan Ding, Minsheng Deng, Shuo Liu **High Response Overload Protection Valve (HROPV) for Heavy Hydraulics** Juha Lahtinen, Werner Händle **Power Plant Fuel Valve Characteristics Considering Hydrodynamic Force** Asgat Gimadiev, Dmitry Bratchinin, Dmitry Stadnik **Frequency Response Correction of Launch Vehicle Fuel Line** Asgat Gimadiev, Dmitry Stadnik, Pavel Greshnyakov, Marat Gimadiev **Water Hydraulic Check Valve Researches** Franc Majdic
14:30	**Coffee**
15:00 - 16:30	**B2: Components** *Session Chair: Jean-Charles Maré, Institut National des Sciences Appliquées de Toulouse* **Investigation of the main impacts on electrostatic charging in filters** Philipp Cedric Weishaar, Hubertus Murrenhoff **Focus on technical cleanliness in hydraulic manifold system manufacturing** Santtu Pyymäki, Lenna Pitkälä, Jari Rinkinen **Design of a High Speed Single Piston Pump for Piston Pair and Slipper Pair Oil Film Investigation** Liming Lao, Hua Zhou, Anhuan Xie, Ruilong Du **Constant Improvement in Biohydraulics – A Challenge, a Dream or an Impossibility?** Merja Lämsä **Application of Nano-Structured Coatings to the Heat Transfer Surface of Heat Exchangers** Luca Pastorello, Antonino Bonanno

Thursday, May 21, 2015, Session A, Small Auditorium	
9:00 - 10:00	**Energy Efficient systems** *Session Chair: Hubertus Murrenhoff, RWTH Aachen University* **Control of a Semi-Binary Hydraulic Four-Chamber Cylinder** Edwin Heemskerk, Ralf Bonefeld, Henno Buschmann **General Rules for the Design of Efficient Hydrostatic Machines** Peter Achten
10:00	**Coffee**
10:30 - 12:00	**A3: Controls** *Session Chair: Andrew Plummer, University of Bath* **Load Independent Velocity Control on Boom Motion Using Pressure Control Valve** Jesper Kirk Sørensen, Michael Rygaard Hansen, Morten Kjeld Ebbesen **P-Type Iterative Learning Control for two Coupled Hydraulic Cylinders** Robert Prabel, Harald Aschemann **Design of Disturbance Observer of Electro-Hydraulic Loading System for Helicopter Manipulating Booster** Yunhua Li, Zhiqing Sheng, Shaoping Wang **Adaptive Damp Control of Drilling String for Offshore Platform Passive Compensator Under Different Sea Conditions** Zhengzhe Cui, Yinglong Chen, Hua Zhou, Huayong Yang **Hardware-In-The-Loop Electronic Control System for a Universal Test Rig For Hydraulic Servo Cylinders Motion Synchronization and Servo Valves Testing** Taher Mohamed Salah ELDin Fahmy, Saad Abd elfattah Kassem
12:00	**Lunch**
13:15 - 14:45	**A4: Pumps** *Session Chair: Victor Juliano De Negri, Federal University Of Santa Catarina* **Design of a Vane Pump Power Split Transmission for a Highway Vehicle** Biswaranjan Mohanty, Feng Wang, Kim A. Stelson **Modeling and Simulation of Thermal Hydraulic Coupling in Electro-Hydrostatic Modules Involving Fixed-Displacement Vane Pumps** Emanuele Gnesi, Jean-Charles Maré, Jean Luc Bordet **A Novel Concept for a Variable Delivery External Gear Machine** Ram Sudarsan Devendran, Andrea Vacca **Leakage Past Active Contacts in Invoute and Cycloidal Gear Hydrostatic Units** Rathindranath Maiti, Manab Kumar Das, Vineet Sahoo, Krishna Chaitanya Avula, Anukaran Arzare, Vishva Prakash Tolambia, Abhijit Nag **Simulation Analysis of Ring Gear's Micro Motion in Internal Gear Machines** ZHOU Hua, DU Ruilong, YANG Huayong, LV Chenghui
14.45	**Coffee**

15.15 – 16.45	**A5: Robotics** *Session Chair: Marcus Geimer, Karlsruhe Institute of Technology* **Design Overview of the Hydraulic Quadruped Robots HyQ2Max and HyQ2Centaur** Claudio Semini, Jake Goldsmith, Bilal Ur Rehman, Marco Frigerio, Victor Barasuol, Michele Focchi, Darwin G. Caldwell **DEVELOPMENT OF A LIGHTWEIGHT ON-BOARD HYDRAULIC SYSTEM FOR A QUADRUPED ROBOT.** Hamza Khan, Satoshi Kitano, Yifu Gao, Darwin G. Caldwell, Claudio Semini **Vehicle Mass Estimation for Hydraulic Drive System using Longitudinal Motion Model** Miika Ahopelto, Tomi Krogerus, Kalevi Huhtala **NOVEL HAPTIC CONTROLLER FOR NON-ROAD MOBILE MACHINE TELEOPERATION** Jani Erik Heikkinen, Heikki Handroos, Takao Nishiumi **LOW-COST 3D LIDAR FOR THE MAPPING OF AUTONOMOUS MOBILE WORK MACHINE** Antti Kolu, Kimmo Rajapolvi, Mika Hyvönen, Petteri Multanen, Kalevi Huhtala

Thursday, May 21, 2015, Session B, Small Sopraano	
9:00 - 10:00	
10:00	**Coffee**
10:30 - 12:00	**B3: Modelling** *Session Chair: Andrea Vacca, Maha Fluid Power Research Center* **Modelling Study of an Optimum Electric Motor for Directly Driven Hydraulic Pump Emulator in Real-Time HIL-Simulation** Jani Heikkinen, Tatiana Minav, Heikki Handroos, Juan Tapia, Werner Jara **Modelling of a Secondary Controlled Six-Wheel Pendulum Arm Forwarder** Liselott Ericson, Alessandro Dell'amico, Petter Krus **Anomaly Detection and Diagnostics of a Wheel Loader Using Dynamic Mathematical Model and Joint Probability Distributions** Tomi Krogerus, Mika Hyvönen, Joni Backas, Kalevi Huhtala **Improved Exact Solution for FSI Four-Equation Model of Liquid-Filled Pipes** Yuanzhi Xu, Zongxia Jiao, Shuai Wu, Yaoxing Shang **Influence of Clearance on the Superfluous Torque in the Electro-Hydraulic Dynamic Loading System** Liejiang Wei, Wenguang Liu, Jing Zhang, Bin Ma
12:00	**Lunch**
13:15 - 14:45	**B4: Valves** *Session Chair: Heikki Handroos, Lappeenranta University of Technology* **The Use of Inherent Sensor Effects in Hydraulic Valves - A Simple Instrumentality Approach with Magnetic Hysteresis** Nils Steker, Hubertus Murrenhoff **On-Line Estimation of Dead-Zones in the Pilot Stage of Proportional Control Valves with Main-Stage Electrical Position Feedback** Qi Su, Bing Xu, Junhui Zhang **System Model of a Directional Control Valve for Control Applications** Artemi Makarow, Jan Braun, Christoph Krimpmann, Torsten Bertram, Georg Schoppel, Ingo Glowatzky **The Use of Logic Valve in Construction of Hydraulic Subplate Mounted Four-Port Directional Control Valves** Edward Lisowski, Janusz Rajda, Elżbieta Rajda **Development of High Performance - High Flow Hydraulic Directional Control Valves** Mohamed Ahmed Elgamil, Moataz Magdi Amin, Saad Abdelfattah Kassem
14.45	**Coffee**

15.15 – 16.45	**B5: Energy Efficiency** *Session Chair: Huayong Yang, Zhejiang University* **The Concept of Secondary Controlled Hydraulic Motors Applied to the Propulsion System of a Railway Machine** Damiano Padovani, Monika Ivantysynova **Investigation and Improvement of the Energy Efficiency of Hydraulic Deep Drawing Presses** Harald Lohse, Jürgen Weber, Sebastian Neumann, Werner Händle, Dirk Klug **Analysis of a hydrostatic transmission system for horizontal axis wind turbines** Eduardo Augusto Flesch, Henrique Raduenz, Victor Juliano De Negri **New ISO25119 Compliant 6-Indipendent Wheels Electro-Hydraulic Steering System for Agricultural Machine** Massimiliano Ruggeri, Andrea Cervesato **Efficiency of Direct Driven Hydraulic Setup in Arctic Conditions** Tatiana Minav, Panu Sainio, Matti Pietola

Friday, May 22, 2015, Session A, Small Auditorium	
9:00 - 10:00	**Reliable Hydraulic Systems** *Session Chair: Monika Ivantysynova, Purdue University* **Modular Software Design of Safety Related Systems for Mobile Machinery – Reliability, Testability and Simulation** Cornelia Weltzien, Erik Lautner **Digital Hydraulics on Rails – Pilot Project of Improving Reliability on Railway Rolling Stock by Utilizing Digital Valve System** Helmut Fischer, Arto Laamanen, Anssi Iso-Heiko, Oliver Schäfer, Matti Karvonen, Otso Karhu, Kalevi Huhtala, Veli-Pekka Pulkkinen, Ali Huttunen
10:00	**Coffee**
10:30 - 12:00	**A6: Hybrids** *Session Chair: Kim Stelson, University of Minnesota* **Hybrid Load Sensing – Displacement Controlled Architecture for Excavators** Ken Sugimura, Hubertus Murrenhoff **Hybrid Pump Drive** Seppo Tikkanen, Henrik Tommila **Comparative study of fuel reduction methods for hybrid excavators** Qian Zhu, Qingfeng Wang **Hydraulic hybrid actuator - theoretical aspects and solution alternatives** Matti Linjama, Mikko Huova, Matti Pietola, Jyri Juhala, Kalevi Huhtala **Improving Energy Efficiency of a Reach Stacker Using a Potential Energy Recovery System** Thomas Schaep, Wilfrid Marquis-Favre, Eric Bideaux, Eric Noppe, Pierre Rodot, Jean-Christophe Bernigaud, Vincent Langlois
12:00	**Lunch**
13:15 - 14:45	**A7: Fluid Power Systems** *Session Chair: Seppo Tikkanen, Tampere University of Technology* **Research on Pulsation Demand of Pump Used in Electro-Hydrostatic Actuator** Yaoxing Shang, Xiaoshu Zhang, Zongxia Jiao, Shaoping Wang, Liang Yan **Review of hydraulic technologies in wind turbines** Le Tu, Wei Li, Yonggang Lin, Hongwei Liu **Research on the Stiffness of the Hydraulic Transformer Controlled System** Chongfeng Di, Wei Wu, Jibin Hu, Shihua Yuan **Dynamics of Volume Controlled Mechanical Ventilation System** Yan Shi, Jinglong NIU, Maolin CAI, Weiqing XU

Friday, May 22, 2015, Session B, Sopraano	
9:00 - 10:00	
10:00	**Coffee**
10:30 - 12:00	**B6: Pneumatics** *Session Chair: Songjing Li, Harbin institute of technology* **Development of A Parallel Valve Control for A Hot Gas Bulge Test** Johannes Storz **Development of Experimental Equipment for the Analysis of Flowmeter Characteristics in Conditions of Gas Pulsating Flow** Asgat Gimadiev, Ilyas Kashapov, Marat Gimadiev **Energy Efficiency Comparisons of Pneumatic Systems: Effects In After Treatment: Theory and Verification with Time Series Measurements** Jyrki Parkkinen **Design And Fabrication of An Electromagnetic Microvalve for Pneumatic Control of Microfluidic Systems** Xuling Liu, Songjing Li **Simplified Fluid Transmission Line Model for Pneumatic Control Applications** David Rager, Rüdiger Neumann, Hubertus Murrenhoff
12:00	**Lunch**
13:15 - 14:45	**B7: Fluid Storages** *Session Chair: Matti Pietola, Aalto University* **Optimal Paired In-Line Bladder-Style Suppressors for Broadband Noise Control** Elliott Gruber, Kenneth Cunefare **An Approach to Optimize the Design of Hydraulic Reservoirs** Alexander Wohlers **Second Order Dynamic Accumulators, the Features, the Applications and the Feasibility** Mohamed Ahmed Elgamil, Ahmed Rabie Abdelbaki, Chahinaz Abdelrahman Saleh

TITLE:	**A Hydraulic Hybrid Wheel Loader with a Novel Power Split Hydraulic Transmission**
PRESENTING AUTHOR:	Stelson, Kim, *University of Minnesota, United States of America*

A novel power split hydraulic transmission has been applied to the drivetrain of a hydraulic hybrid wheel loader in this paper. Unlike a typical power split hydraulic transmission consisting of planetary gear set and hydrostatic units, the new transmission consists of a vane pump based hydrostatic transmission (vHST) and a variable displacement motor. The vHST functions like a conventional hydrostatic transmission (HST) but has a different form. It uses a double-acting vane pump with a floating ring. By coupling the floating ring to an output shaft, the vane pump becomes a hydraulic transmission. The vHST combines the pumping and motoring functions in one unit, making it much simpler than a conventional HST. By feeding the vHST control flow to a variable displacement motor coupled to the vHST output shaft, a hydraulic power split transmission is created. In this paper, a hydraulic hybrid wheel loader with this new power split hydraulic transmission is designed. A dynamic simulation model is built to help the system parameter selection and to verify the system performance. Simulation results have demonstrated the feasibility of applying this new transmission to a hydraulic hybrid wheel loader.

TITLE:	**Comparison Studies of Different Nonlinear State and Disturbance Estimators for a Hydrostatic Transmission**
PRESENTING AUTHOR:	Prabel, Robert, *University of Rostock, Germany*

In this paper, different state and disturbance estimation techniques are investigated for tracking control of a hydrostatic transmission, which is commercially used in working machines. A nonlinear control-oriented model of a hydrostatic transmission is derived, in which the system disturbances – the leakage volume flow and a resulting disturbance torque – are modelled as lumped parameters. The implemented optimal control structure according to [1] requires a feedback of all the system states and disturbances. Therefore, the controller is extended with state and disturbance estimators providing estimates of the unknown disturbances as well as the unmeasurable system states – the normalised tilt angles of the pump and motor. In this contribution, a nonlinear reduced-order observer, an Extended Kalman Filter as well as an Sigma-Point Kalman Filter are designed and implemented. Validation as well as comparison among these estimation techniques are performed by both simulations and experiments.

TITLE:	**Design Study and Parameter Optimization for a Light-weight Series Hydraulic Hybrid Vehicle**
PRESENTING AUTHOR:	Baer, Katharina, *Division of Fluid and Mechatronic Systems, Linköping University, Linköping, Sweden*

Hydraulic hybrid drives are one potential way of improving the fuel efficiency of vehicles, including the possibility of recuperating braking energy in a hydraulic accumulator. The high power density of fluid power is mainly advantageous for heavy vehicles, or duty cycles characterized with frequent braking and acceleration. For smaller vehicles, hydraulic hybrid drives are thus most interesting under urban and suburban driving conditions. Amongst the existing architectures, the series hydraulic hybrid offers the advantage of operating the internal combustion engine independently of the vehicle speed, at the cost of a less efficient transmission path than a purely mechanical one. Previously, a series hydraulics hybrid light-duty vehicle was modelled in the transmission-line modelling (TLM)-based simulation software Hopsan from the division of Fluid and Mechatronic Systems (Flumes) at Linköping University. This paper studies through simulation-based optimization how the fuel-optimal vehicle design is affected by various mixes of urban and suburban driving requirements. Both the system's hardware and the parameters of a basic control strategy are considered. The results show quite similar designs for most performance requirements combinations, and can be the base for further studies addressing additional requirements, conditions and objectives.

TITLE:	**First Experimental Results of a Hydraulic Hybrid Concept System for a Cut-to-length Forest Harvester**
PRESENTING AUTHOR:	Einola, Kalle, *Ponsse Plc, Finland*

A cut-to-length (CTL) forest harvester is used for felling, delimbing and cross-cutting trees into the dimensions and assortments required by the forest industry. Hydraulically actuated primary functions of the studied machine, such as the cross-cutting and feeding of the tree stem, are commonly known to create a highly fluctuating load for the diesel engine. In order to manage these power demands, a hydraulic hybrid concept system is implemented into a full-scale experimental machine to discover the initial functionality and to collect experimental results. This paper covers only the very first tests related to the harvester head feed function. A detailed hydraulic hybrid system configuration is presented and discussed. In conclusion, the tested system can be said to operate as planned; however, measurements show that the dynamics of a standard over-center, closed-circuit pump that is normally used in hydrostatic drive transmissions is insufficient to meet the demands of the work cycle. A direct bypass valve between the energy storage and the work hydraulics is introduced to the system in order to overcome the somewhat slow pump response. Significant hybrid power was demonstrated in a longer work cycle using pump–motor control only, but in the actual work cycle this power was clearly lower than 50 kW. The dynamical behaviour of the system is discussed further and future work, such as studies about possible ways to improve the dynamics of the pump, is proposed.


PONSSE

TITLE: 	**Gain Scheduling Full State Feedback with D-implementation for Velocity Tracking of Hydrostatic Drive Transmission**
PRESENTING AUTHOR:	Backas, Joni, *Tampere University of Technology, Finland*

This paper presents a gain-scheduling based velocity controller for hydrostatic drive transmissions (HSD). We design our controller based a model of the system which captures most of the nonlinear effects and parameter variation. Therefore, we can obtain much better performance compared to existing linear controllers. Our control strategy is based on full state feedback whose gains are scheduled on measured states which are speed and volume pressures, and estimated hydraulic flow. To implement a standard state feedback, we would need to calculate operating points of all the states at all time. However, due to modelling uncertainty (specially unknown frictions) pressure equilibrium calculation will be very inaccurate. We will employ D implementation methodology to remedy this problem.

For the proof of concept, we show the efficacy of the controller using a validated simulator of a wheel loader with real machine parameters. The experiments are performed both on flat terrain and slope. The results demonstrate that the performance of velocity tracking is high and controllability of the machine is maintained in every situation.

TITLE:	**Fuzzy Repetitive Controller for Electro-hydraulic Periodical Pressure Servo Systems**
PRESENTING AUTHOR:	Man, Zaipeng, *State key Laboratary of Fluid Power Transmission and Control, Zhejiang University, Hangzhou, China*

In recent years, hydraulic transmission systems are widely used in construction and agricultural machinery owing to their high power density, high compactness, and flexible control. In the operation of hydraulic systems, hydraulic impulse pressure, also known as water hammer wave, may arise. To guarantee the reliability and performance of hydraulic systems, it is of vital importance to do impulse testing for hydraulic components.

In this paper, a hydraulic impulse testing system based on pressure-boost cylinder is designed, the output pressure of which can be as high as 42MPa. The pressure-boost cylinder is designed to work in a differential mode, which is under the control of a three-way servo valve. Mathematical model of the system is built, and indicates that it is difficult to obtain satisfactory control effect by traditional PID control method. A fuzzy repetitive controller is designed and applied to the system. Both simulation and experiment results show that the fuzzy repetitive control system can achieve a better performance than traditional PID control system, with the trace error reduced by nearly 50%. In addition, common pressure waveforms including sine-waves and peak-waves can be produced by the system, which can satisfy the demand of most of existing hydraulic impulse testing equipment.

TITLE:	**High Response Overload Protection Valve (hropv) for Heavy Hydraulics**
PRESENTING AUTHOR:	Lahtinen, Juha, *Valmet Technologies Oy, Finland*

The paper web speed in paper machine can be 1800 m/min (30 mm/millisecond). In paper web breaks several layers of paper can go through the high loaded nip that can include soft covered rolls. Rolls and belts will damage if nip is not unloaded before the coming pressure peak. Similar quick unloading requirements; relieving load within few milliseconds, exist also in many other application areas of heavy hydraulics. In 2007 Metso Paper discussed with Moog GmbH (Finland and Germany) to get quick electrical on-off valve that will react on pressure rise velocity, the start of acceleration. Moog considered the challenge and after some time gave suggestion to develop cartridge valve based on pure hydraulic elements instead of electrical components. For Metso point of view, the simple technology could fulfill the requirements of robust system with high reliability. During 2007 a working solution for valve was invented by Moog GmbH. Work was divided and Metso Paper was responsible for test environment, pilot unit, measuring system and control cover hydraulic circuit. The test unit, impact test device, was built around a pendulum where the mass weight and falling height were adjustable. The target set point for pressure rise velocity was 10000 bar/s and target for 100 % step response was 2 ms. The HROPV fulfilled the dynamic requirements and results were much better compared to results with accumulator. On the other hand, the set value adjustability was poor and the repeatability of function was not best possible and needed future work.


HYDAC

TITLE:	**Power Plant Fuel Valve Characteristics Considering Hydrodynamic Force**
PRESENTING AUTHOR:	Stadnik, Dmitry, *Samara State Aerospace University, Russian Federation*

The work presents a mathematical model of power plant differential valve with exact regulation of fuel consumption rate during starting and stopping time. The throttle characteristics and hydrodynamic force affecting the valve head from the side of liquid flow have been calculated with the ANSYS software package. The valve mathematical model has been implemented with the help of the MATLAB/Simulink software package. Transient processes in the valve appearing at its opening and closing have been calculated, influence of hydrodynamic force and design parameters on the transient process quality has been studied.

TITLE:	**Frequency Response Correction of Launch Vehicle Fuel Line**
PRESENTING AUTHOR:	Greshnyakov, Pavel, *Samara State Aerospace University, Russian Federation*

Design engineers of liquid multistage launch vehicles (LV) always take into account the probability of longitudinal instability called Pogo-effect. One of the traditional measures to provide LV longitudinal stability is the frequency response correction of fuel lines with the use of dampening units. Notwithstanding the developed design solutions to provide LV longitudinal stability, the open literature gives little attention to calculation methods for correcting devices and to the analysis of frequency response of fuel lines with a dampener.

The report presents a mathematical model developed on the basis of the energy equation for gas and liquid cavities of the dampener, and of the equations of continuity and equilibrium of movable parts. This mathematical model allows estimating the influence of different design parameters on its dynamic properties. In particular, frequency dependent acoustic admittance of the dampener has been obtained with the use of MatLab/Simulink software package. Frequency response of the fuel-supplying mainline with a connected dampener clearly demonstrating the reduction of fuel line natural frequency has also been obtained. The method of frequency response calculation and parameter selection for a LV longitudinal stability dampener has been proposed herein.

TITLE:	**Water Hydraulic Check Valve Researches**
PRESENTING AUTHOR:	Majdic, Franc, *Faculty of Mechanical Engineering, University of Ljubljana, Slovenia*

Care for clean and healthy environment should be increasing on daily basis. Different kind of hydraulic fluids are used nowadays. Majority of them are harmful. Use of tap water as hydraulic pressure medium is one of possible solution. The work is based on development and researches of check valve for water hydraulic. The first part of the paper includes background and overview of standard check valves on market. The second part is based on the design and development of a new check valve. On presented check valve we carried out numerical calculations and measurements of pressure drop for two types of hydraulic fluid – tap water and mineral hydraulic oil. There were also performed strength calculations for critical parts of the check valve. In the last part of the work, the comparison and analysis of experimental results of pressure drop between the two different fluids in the check valve are presented.

DAY 1, WEDNESDAY MAY 20, 2015 CONFERENCE PROGRAMME
Session A2, Small Auditorium, 15.00-16.30

TITLE:	**Development of a Digital Hydraulic Pump for High Torque and Low Speed Applications in Hydrostatic Transmission**
PRESENTING AUTHOR:	Hayashi, Mitsuaki, *IHI corp., Japan*

For the hydraulic drivetrain In the several renewable energy (e.g. wind, wave or tidal) applications, a kind of radial piston pump generating large torque at a low speed with flow distributor by ON/OFF valve control is introduced and its experiment has been done. General double acting cylinders are applied for the mechanism of pumping, and then the structure of this pump is simple and easy to extend for various specifications. Distribution of flow from the pumping cylinders is controlled by the ON/OFF valves, and it is possible to realize variable displacement function. To avoid flow leak and resistance on the ON/OFF controlled valve, a spool type valve with seal at the spool land is applied, so reduction of the valve operating force is compatible with non-leak characteristic. It is driven by an electric servo motor so that the valve operation is performed to exact timing. The pump that consists of these components mentioned above was built as an experiment, and the experiment which evaluates its characteristic was conducted. Its specification of hydraulic output power is 50kw by 5-cylinders, rated pressure is 20MPa and max flow-rate is 150liter/min. Finally, the pumping and variable displacement functions depending on the ON/OFF valve controls were confirmed, and the response and efficiencies in several operating conditions were estimated.

TITLE:	**A Linear Valve Actuated Switched Inertance Hydraulic System**
PRESENTING AUTHOR:	Sell, Nathan Peter, *University of Bath, United Kingdom*

A Switched Inertance Hydraulic System (SIHS) makes use of a switching element, a hydraulic capacitance and an inertance in order to achieve theoretically lossless control of hydraulic flow and pressure. This paper reports on experimental results of a SIHS which is set up to control pressure and makes use of a novel linear valve as its switching element. The control and dynamic performance of this valve are characterised before presenting experimental results of the flow booster circuit. It was found that the SIHS worked as expected at a limited range of switching widths and frequency before a failure within the instrumentation precluded experimentation on a wider range of conditions.

TITLE:	**On Efficiency of Switched Inertance Control for Hydraulic Systems**
PRESENTING AUTHOR:	Sinyakov, Anton, *Samara State Aerospace University, Russia*

In hydraulic drives, throttling valves are usually used for flow and pressure control. The disadvantage of this control method is poor efficiency - typically 50% of the input energy is dissipated into heat, especially at low loads. The use of switching valves controlled by pulse-width modulation (PWM) is an efficient alternative to analog components. In combination with an inertance tube the switching valve forms a switched inertance device (SID) which can be used as a flow or pressure booster. The switching valve is a critical component of the SID. It must be fast, have low resistance and low leakage. Although research on fast switching valves has been conducted intensively over the last decade, the performance of commercially available valves is not good enough for digital hydraulics. To use valves available on the market one needs to match the valve performance to the switching requirement. The paper presents research results in the application of typical servo valves for switching control of flow in a flow booster configuration. Sizing of the hydraulic system is carried out with the objective to reach the highest possible efficiency. Mathematical modeling and simulation are performed to reveal the impact of the SID variables (duty cycle and phase delay between high and low pressure valves openings) on the system dynamics. The simulation results show that the energy efficiency of the system under switching control is higher by 10-15 % as compared to the throttle control. The mathematical model and results of the simulation are verified by experimental study.

TITLE:	**Fault Tolerance of Digital Hydraulics in High Dynamic Hydraulic System**
PRESENTING AUTHOR:	Siivonen, Lauri, *Tamlink Ltd, Finland*

Digital valve system has some unique features concerning fault tolerance. The system is able to continue operation despite a valve fault with small degradation in performance. The increased level of fault tolerance does not require any additional components and is completely software-based. Static analysis, simulations and experimental measurements show that although operation can be continued despite of a single valve fault, the tracking accuracy may suffer and the amount of needed switchings may increase. Accurate and fast fault detection and identification is very important part of fault tolerance in such system. Also the controller must be designed properly so that maximum performance can be achieved even if a valve is acting faulty.

TITLE: 	**Energy Saving Using a Multi-chamber Accumulator: Experimental Results and Proof of Concept**
PRESENTING AUTHOR:	Stauch, Christian, *Center of Mechatronics and Automation Technologies ZeMA gGmbH, Germany*

Energy storage and energy recovery are subjects of major importance in mobile hydraulic systems. The implementation of hydraulic storage solutions seems natural but often such solutions fail to meet the requirements due to restrictions such as limited pressure ranges. A possible solution to overcome these restrictions is the multi-chamber piston-type accumulator. In contrast to conventional hydro-pneumatic accumulators, the multi-chamber accumulator has several fluid chambers in parallel which can be pressurised separately. This paper is concerned with the experimental investigation of the energy recovery potential of the multi-chamber accumulator. An experimental set up involving a four-chamber accumulator and a forklift mast is presented. Investigations for a simple lifting and lowering cycle yield energy savings up to 45% and a reduction of the peak supply flow rate by 56% dependent on the operating mode.

DAY 1, WEDNESDAY MAY 20, 2015 CONFERENCE PROGRAMME
Session B2, Sopraano, 15.00-16.30

TITLE:	**Investigation of the Main Impacts on Electrostatic Charging in Filters**
PRESENTING AUTHOR:	Weishaar, Philipp Cedric, *Institute for Fluid Power Drives and Controls, Germany*

Currently hydraulic fluids with a reduced ash and zinc concentration are deployed to a greater extend. Unfortunately these fluids exhibit a low electric conductivity. When these fluids pass through filters they become electrostatically charged. This in turn can lead to discharges, which are capable of destroying the filter and facilitate the oxidation of the fluid. These effects pose a threat to the functionality of the entire system. In order to face these potential problems it is mandatory to gain a better understanding of the underlying mechanisms and the contributing factors. In this paper an initial model for electrostatic charging is proposed. Subsequently the existing experimental setup and some required modifications are presented before the experimental results of a selection of filter material samples are given. This investigation includes the impact of the pressure, temperature, flow rate as well as the housing's ground as influencing factors. Using these results, general observations regarding the main contributing factors of electrostatic charging are derived. In addition to these observations a qualitative explanation of some of the identified tendencies is made.

TITLE:	**Focus on Technical Cleanliness in Hydraulic Manifold System Manufacturing**
PRESENTING AUTHOR:	Pyymäki, Santtu, *Parker Hannifin Manufacturing Finland Oy, Finland*

ISO 16232 (2007) standard for technical cleanliness was created based on needs from automotive industry in Europe. It has not been used so far widely in hydraulics manufacturing where various cleanliness standards are used to analyze and monitor hydraulic fluid cleanliness. Parker Hannifin is global leader in motion and control technologies. Parker Hannifin's Hydraulic Controls Division Europe is developing and manufacturing hydraulic manifold systems and special valves for focused Marine, Oil&Gas and Heavy Mobile applications in Business Unit Lokomec (later PH Lokomec) located in Tampere, Finland. Products are mainly customer specific and developed in close co-operation with customers.

PH Lokomec joined a multi-company project named KompuNW (1.1.2011 – 30.4.2013) focusing on technical cleanliness. Tampere University of Technology's Department of Intelligent Hydraulics and Automation was the research party in the project. During this project PH Lokomec developed knowledge and understanding about technical cleanliness and started to shape a vision for itself about technical cleanliness in future. Several process changes were introduced during the project and PH Lokomec decided to include technical cleanliness as one of the key areas to focus in future operational developments. Lean philosophy is a key part of Parker Hannifin's strategy to continuously pursue operational excellence. PH Lokomec has identified a strong link between several key Lean tools and technical cleanliness. PH Lokomec is continuously developing manufacturing processes to improve technical cleanliness.

TITLE:	**Design of a High Speed Single Piston Pump for Piston Pair and Slipper Pair Oil Film Investigation**
PRESENTING AUTHOR:	Lao, Liming, *Zhejiang University, China*

Measurement of oil film characteristics in friction pairs is an effective method to understand the friction behaviour and energy behaviour of the hydraulic piston pump. In this paper, a single piston pump with high rotary speed for piston/cylinder pair and slipper swash-plate pair oil film investigation is presented. The design problem of flow distributor and flow pulsation attenuation is discussed. A separate flow distributor is designed to make piston chamber connect either suction port or discharge port synchronously. The effect of oil elasticity on distributor's leakage is analyzed and a lag angle is applied to distributor for less leakage. The pulsation attenuation effect with accumulator is analyzed using linearization method. Finally the whole single piston pump system is modeled in AMEsim software. The simulation results shows the single piston pump achieve pulsation amplitude less than 9.4% of average flow-rate and volume efficiency higher than 56.3%.

TITLE:	**Constant Improvement in Biohydraulics – a Challenge, a Dream Or an Impossibility?**
PRESENTING AUTHOR:	Lämsä, Merja, *TerraFin Oy, Finland*

Biohydraulic fluids´ modern development has been ongoing now over three decades. For traditional hydraulic fluids, based on mineral oils, it took over 40 years to be as good as they are today! So we are getting closer for that period also for biohydraulic fluids. Is there still something that can be done? Some properties, which still can be forbettered? Some technical aspects, which can be as brilliant as within traditional fluids?

Mother Nature gave us raw materials for biolubricants, natural esters, which are the best and if we add there a little bit of knowledge and chemistry, where will we end up?

Oxidation stability, cold stability properties, life time, anticorrosion properties, low friction and wear, good water and air separation, hydrolytic stability - the list is pretty long, what we have been able to forbetter during the years and even in the last 2-3 years!

What is also essentially important: Today we have standarlised methods with what we can measure all the possible chemical, physical, technical, environmental, healthy properties of bio hydraulic fluids. And give realiable facts from the testing.

Biohydraulics compete today with their technical performance and as an "extra value" customers get the environmental and healthy acceptance.

In this paper there are shown the latest test results in biohydraulics, the development steps happened in R&D during the years, comparison to the international biohydraulic fluids and environmental standards.

JOHN DEERE

TITLE:	**Application of Nano-structured Coatings to the Heat Transfer Surface of Heat Exchangers**
PRESENTING AUTHOR:	Pastorello, Luca, *Imamoter C.N.R., Italy*

Traditionally, the attempts to improve the heat exchangers performances focused on the increasing of the heat transfer surface according to the need to keep the overall dimensions and the pressure drops restrained and the heat transfer efficiency high. Now that the relationship between surface width, geometrical efficiency and dimensions is reaching its maximum limits, the attention begins to move on the increase of the heat transfer coefficient. Under this condition, the proposal of the usage of nano-structured coatings is to induce the property of super-hydrophobicity to the surfaces in contact with the fluids involved in the heat transfer. This property is able to produce an increasing of the heat transfer coefficient and a decrease of the power losses caused by friction. The technology developed is based on the principle which in nature is known as “Lotus effect” to obtain a super-hydrophobic surface. The application of this technology to real products with measurable targets will open the doors to an entire new generation of products to be applied in fluid power systems of mobile machinery where the efficiency and dimensions constraints are in many cases critical. The paper is aimed to determine the thermal and fluid-dynamic performances of heat exchangers with super-hydrophobic surfaces. A comparison between the nano-coated heat exchanger and the “traditional” one will be showed in order to evaluate the given improvement in terms of: heat transfer coefficient, pressure drop reduction, industrial feasibility.

DAY 2, THURSDAY MAY 21, 2015 CONFERENCE PROGRAMME
Session P1, Small Auditorium, 9.00-10.00

TITLE:	**Control of a Semi-binary Hydraulic Four-chamber Cylinder**
PRESENTING AUTHOR:	Heemskerk, Edwin, *Bosch Rexroth AG, Germany*

In the past years there have been several publications about digital fluid power including multi-chamber cylinders. Multi-chamber cylinders are typically controlled by switching valves that connect the cylinder chambers to one of the supply pressures (often revered to as digital cylinder). This configuration allows for significant reduction in energy consumption and has the potential to recover energy from the load. However the number of discrete force levels that can be produced by this concept is limited. The target of this study was to improve the force resolution to achieve accurate control of the cylinder. For this, one of the chambers is no longer connected to the supply pressures by a switching valve but with a proportional valve. Control strategies for pressure, force and position control were developed and successfully implemented on a test bench at Bosch Rexroth. The laboratory measurements showed that compared to the digital cylinder with the new approach the controllability of the load/cylinder (speed and force resolution) can be improved without losing much of its energy efficiency.

TITLE:	**General Rules for the Design of Efficient Hydrostatic Machines**
PRESENTING AUTHOR:	Achten, Peter, *INNAS BV, Netherlands*

Current pumps and motors have already passed their expiration date. Especially the manufacturing costs and the energy efficiency don't meet up to today's market demands. New pumps and motors should already have replaced the current inadequate designs, if only the industry would have developed such alternative solutions. This paper not only calls for such an innovation, it also outlines the guidelines for efficient, heavy-duty hydrostatic principles:

• Avoid lateral loads in sliding interfaces;
• Avoid high bearing loads;
• Avoid piston rings;
• Avoid wide seal lands;
• Avoid high velocities in sliding interfaces;
• Avoid the risk for cavitation;
• Avoid large dead volumes;
• Avoid complicated tolerance chains and kinematic conflicts;
• Reduce the barrel spring force;
• Reduce the losses of the displacement control in variable displacement pumps and motors.

The company who succeeds in such an innovation has the opportunity to strengthen its own market position, but more importantly, will also be able to open entirely new markets for hydraulic applications.


Rexroth
Bosch Group

DAY 2, THURSDAY MAY 21, 2015 CONFERENCE PROGRAMME
Session A3, Small Auditorium, 10.30-12.00

TITLE:	**Load Independent Velocity Control on Boom Motion Using Pressure Control Valve**
PRESENTING AUTHOR:	Sørensen, Jesper Kirk, *University of Agder, Norway*

This paper presents a novel scheme for closed loop speed control of a pressure control valve with attention to the load dependency of both the dead band and the metering-in flow. The control strategy is designed with

the use of a minimum of sensors. The only required sensors are position sensor on the cylinders. The performance of the proposed controller is being evaluated both with and without the additional use of pressure transducers. The control scheme is implemented experimentally on a cylinder actuated knuckle boom of a commercial vehicle loader crane.

TITLE:	**P-type Iterative Learning Control for Two Coupled Hydraulic Cylinders**
PRESENTING AUTHOR:	Prabel, Robert, *University of Rostock, Germany*

In this contribution, a proportional ILC algorithm (P-ILC) in combination with a cascaded backstepping control structure is applied to two coupled hydraulic cylinders. The P-ILC is a model-free algorithm, which adjusts the desired trajectory for the backstepping control structure. The adjustment of the desired trajectory for the actual trial is calculated in such a way that the trajectory is corrected (updated) by evaluating the tracking error of the previous trial. A cascaded backstepping control is implemented as an underlying control approach, where the updated desired trajectory from the P-ILC serves as input. The outer loop of the backstepping control is designed for the mechanical subsystem, where the difference pressures in both hydraulic cylinders serves as control inputs for the inner control loops. These control loops are responsible for the difference pressures of the hydraulic cylinders, with the hydraulic volume flow through the chambers of the cylinders as control inputs. The proposed control algorithm is finally validated at a dedicated test rig.


SANDVIK

TITLE:	**Design of Disturbance Observer of Electro-hydraulic Loading System for Helicopter Manipulating Booster**
PRESENTING AUTHOR:	Li, Yunhua, *School of Automation Science and Electric Engineering, Beihang University, China*

Addressing on the working characteristics of helicopter manipulate booster under high-frequency aero-dynamic load with dynamic load superimposed on large static load, this paper has developed an electro-hydraulic loading system to simulate the load with sinusoidal dynamic load superimposed on large static load. The mathematical model of the electro-hydraulic loading system is firstly established. Double loop cascade composition control strategy is applied in loading system controller design. The inner-loop controller is expected to make the actual plant track a nominal model approximately; the outer-loop controller is expected to realize the desired force tracking performance. The disturbance observer based approach is adopted in inner-loop controller design to suppress the surplus force and other interferences, also to enhance system robustness to parameter perturbations and uncertainties. The low pass filter Q(s) is designed by H∞ mixed sensitivity optimization method. The simulation results indicate that, with designed Q(s), surplus force is suppressed effectively, meanwhile system robustness is guaranteed.

TITLE:	**Adaptive Damp Control of Drilling String for Offshore Platform Passive Compensator Under Different Sea Conditions**
PRESENTING AUTHOR:	Cui, Zhengzhe, *Zhejiang University, China*

The passive heave compensator is widely used in offshore drilling platform nowadays. The traditional passive compensation system is designed in one sea condition and the performance of it decreases when the sea wave become severe. This paper find out a new conception to use the compensation system adaptively by changing the damp ratio between drilling string and drilling fluid. To achieve the goal, the influencing factors of the damp ratio have been studied, and the square relationship between damp ratio and velocity of the fluid has been given. Nonlinear and linear model have been built to analyze the performance of compensation system, and the feasibility of damp control by changing the fluid velocity adaptively has been proved from them. By using the compensation ratio as the control target, the new system has a better performance for the vibrate caused by the sea wave remain stable when sea condition changes.

TITLE:	**Hardware-in-the-loop Electronic Control System for a Universal Test Rig for Hydraulic Servo Cylinders Motion Synchronization and Servo Valves Testing.**
PRESENTING AUTHOR:	Fahmy, Taher Mohamed Salah ELDin, *Alezz Aldekheila Alexandria Steel Co. (EZDK), Egypt*

This paper presents the details of a universal hydraulic test rig, with an eye on the rig electronic control system, developed for testing the motion synchronization of two loaded unconnected hydraulic servo cylinders and for testing servo valves of different sizes and brands. The rig has been designed so as to allow also testing the performance of two servo cylinders at the same time. Results of testing the motion synchronization of two servo cylinders are presented. Measurements for the no load flow and blocked load internal leakage at different input signals for malfunctioning and repaired servo valves of different types are also presented. The rig has been used as an off-line simulator to verify the quality of repair and the assurance of coincidence of the hydraulic and electronic null positions of the repaired servo valves. The presented results confirm the fidelity and fertility of the rig.

DAY 2, THURSDAY MAY 21, 2015 CONFERENCE PROGRAMME
Session B3, Sopraano, 10.30-12.00

TITLE:	**Modelling Study of an Optimum Electric Motor for Directly Driven Hydraulic Pump Emulator in Real-time Hil-simulation**
PRESENTING AUTHOR:	Minav, Tatiana, *Aalto University, Finland*
Hardware-in-the-loop (HIL) setups are used in research, since it allows fast, accurate and easily repeatable testing of hybrid topologies of non-road mobile machinery under realistic conditions. In a previous study, it was shown that a virtual model of a hydraulic machine in a HIL setup can be used for testing by emulating a directly driven hydraulic pump with an electric motor. As the used setup did not fulfil requirements, criterion for choosing a new electric motor was suggested. Therefore, in this research an attempt to model and simulate the optimum electric motor for directly driven hydraulic pump emulation was made. Set of initial solution motor parameters to fulfil a minimum settling time of Ts =0.001 seconds for emulator motor torque response are used in a Simulink model.	

TITLE:	**Modelling of a Secondary Controlled Six-wheel Pendulum Arm Forwarder**
PRESENTING AUTHOR:	Ericson, Liselott, *Linköping University, Sweden*
One of the major concerns in the forest industry is the impact on the soil caused by the forest machines during harvesting, where damage can have a negative impact on growth at replanting for example. Another concern is the working environment of the operator. Both these issues have a negative impact on productivity. A new six-wheel pendulum arm forwarder is being developed within a collaborative research project. The new forwarder aims to reduce soil damage by means of an even pressure distribution and smooth torque control. This paper presents the first step in the development of the driveline, where a secondary control approach is chosen for its ability to control the motion of each wheel individually. Simulation models of both vehicle and driveline have been constructed developed, partly for the development of the control strategy, and partly for evaluation. A speed control concept and a torque control concept have both been evaluated for different scenarios with regard to their ability to reduce wheel slip. Results have shown that a velocity control approach is more sensitive to kinematic model accuracy while wheel slip is handled automatically. A torque control approach is more robust towards model accuracy while the reduction of slip is dependent on an accurate model.	


SIEMENS

TITLE:	**Anomaly Detection and Diagnostics of a Wheel Loader Using Dynamic Mathematical Model and Joint Probability Distributions**
PRESENTING AUTHOR:	Krogerus, Tomi, *Tampere University of Technology, Finland*

In this paper, we present anomaly detection and diagnostics for articulated frame steered hydraulic wheel loader. The presented methodology is based on the analysis and comparison of the responses of a dynamic mathematical model and a real wheel loader using a joint probability distribution of correlation coefficients of multiple variables. The behaviour of an undamaged machine is modelled by probability density functions of the correlation coefficients using histograms and test how well the future behaviour fits the model. First, the time series data of multiple variables are segmented into segments of the same length. Correlation coefficients are then calculated for each segment and the distributions of the correlation coefficients are estimated by computing probability density functions using histograms. Finally, the joint probabilities that the correlations in the data segments of the time series data are observed are calculated using the already computed histograms. The diagnostics is based on the combination of static threshold and threshold based on mean value of joint probabilities. The dynamic mathematical model of the wheel loader is presented with verification results. A jammed flushing valve of the hydrostatic transmission was used as an anomaly to study the changes in the joint probability values. Finally, the efficiency of the presented method is presented with good results regarding detection of anomalies and diagnostics of the wheel loader.

TITLE:	**Improved Exact Solution for Fsi Four-equation Model of Liquid-filled Pipes**
PRESENTING AUTHOR:	Xu, Yuanzhi, *School of Automation Science and Electrical Engineering, Beihang University, Beijing, China*

The four-equation model consists of two equations for the fluid and the other two for the pipe, describing the axial vibration of liquid-pipes. Fluid-structure interaction (FSI) is significantly considered in this model, typically solved with the method of characteristics (MOC) which introduces the numerical error inevitably. When friction and damping effects are neglected, the model can be solved with an exact solution without interpolations. The only weakness of this solution is high time cost due to its recursion approach. An improved method based on this exact solution is proposed in this paper, using the time interpolation rather than recursive method, to speed the calculation. The present solution improves the efficiency dramatically while retains the level of accuracy.

TITLE:	**Influence of Clearance on the Superfluous Torque in the Electro-hydraulic Dynamic Loading System**
PRESENTING AUTHOR:	Wei, LieJiang, *LanZhou University Of Technology, China*

The superfluous torque existed in the electro-hydraulic dynamic loading system would make the torque loading precision down and reduce the bandwidth of the loading system, the engineering practical experience shows that: the clearance in the mechanical connections of loading system transmission chain makes superfluous torque more complex and difficult to compensate, and torque loading precision even worse. Aiming at these problems, with the method of power bond graph, the electro-hydraulic dynamic loading system mathematical model including clearance nonlinearity is established, which abstracts from the dynamic loading process of semi physical simulation experiment in a large scale wind turbine's variable pitch-controlled system. When the value of the clearances are 0, 0.1, 0.2, 0.4, 0.8 and 0.9 mm respectively, the results of simulation with 20-sim software show that: when the position system (the bearing object of electro-hydraulic load simulator) is in starting and reversing, the clearance has the strengthening effect on superfluous torque; with the value of clearance increasing from 0 mm to 0.8 mm, the superfluous torque peak rises from 3.7 Nm to 164.2 Nm, and the torque loading precision changes from 1.85% to 82.1%; when the clearance reaches up to 0.9 mm, the phenomenon of limit cycle oscillations would occur in the loading system, and the system cannot work steadily at present.

TITLE:	**Design of a Vane Pump Power Split Transmission for a Highway Vehicle**
PRESENTING AUTHOR:	Stelson, Kim A., *University of Minnesota, United States of America*

The demand for low emissions and better fuel economy requires increased vehicle drive system efficiency. A Vane Pump Power Split Transmission (VPPST) can fulfill this need. A VPPST functions much like a conventional power split hydro mechanical transmission (HMT) but without the planetary gear. It consists of a Vane Power Split Unit (VPSU) and a variable displacement hydraulic motor. The VPSU is a double acting vane pump with a floating ring. The Input shaft of the VPSU is directly coupled to the engine and the output shaft, fixed to the floating ring, is connected to the drive train. The control flow of the VPSU is fed to a variable-displacement motor mounted on the VPSU output shaft. Unlike an HMT, where the transmission ratio can be adjusted by changing the displacement of the pump or motor, or both, in a VPPST, the transmission ratio is adjusted by controlling the displacement of the motor thus affecting the pressure of the control port of the VPSU. The resulting infinitely variable transmission allows for optimum engine operation by decoupling the engine speed from the drive speed. When the control flow is zero, the input and output shafts lock up at the same rotational speed. The transmission also has an integral clutch that allows de-clutching the engine from the drive train by retracting the vanes of the VPSU. In this paper, the design of a VPPST sized for a Class 1 pickup truck is demonstrated.

TITLE:	**Modeling and Simulation of Thermal Hydraulic Coupling in Electro-hydrostatic Modules Involving Fixed-displacement Vane Pumps**
PRESENTING AUTHOR:	Gnesi, Emanuele, *Parker Hannifin Manufacturing France S.A.S., France*

The thermal-hydraulic model of an electro-hydrostatic module involving a variable speed, fixed-displacement, internal-drain vane pump is developed at system level for analysis and for support of preliminary sizing. A generic model structure is proposed for the pump energy losses that are made dependent on velocity, pressure and temperature. Leakage and friction models are implemented accordingly. Model structure and implementation are proposed giving preference to re-using standard submodels of the AMESim software library and to balance model complexity and realism. Then, the proposed approach is deployed for simulating the temperature rise during static injection in moulding machines that are powered and controlled via an electro-hydrostatic module. In this particular phase, the pump operates at extremely low delivery flow, inducing a rapid temperature rise that may directly impact service life. For validation, a very penalizing approach is used which runs the model in open loop in response to motor electromagnetic torque, ambient temperature and hydraulic load resistance. Conclusions are drawn concerning the model accuracy and the mains issues encountered, regarding model structure, knowledge models and parameters preliminary determination.


PONSSE

TITLE:	**A Novel Concept for a Variable Delivery External Gear Machine**
PRESENTING AUTHOR:	Vacca, Andrea, *Maha Fluid Power Research Center, Purdue University, United States of America*

This paper presents a design analysis of a novel concept of variable delivery flow external gear machine (EGM) previously introduced by the authors. This innovative design encompasses all the well-known advantages of traditional EGMs, but also introduces a cost effective solution for varying the amount of fluid displaced per unit revolution of the shaft. The paper summarizes the main features of the design, which is essentially based on a unique implementation of a variable timing concept for the connections of the tooth space volumes with the inlet/outlet ports. To permit high range of flow regulation, this new design utilizes asymmetric profiles for the teeth. Previously, the authors tested the new design on an existing pump, utilizing the same casing and designing new internal parts (gears and lateral bushings) suitable for the implementation of the new concept. With this concept tests, a potential for flow variation in the range 100% - 68% with high level of energy efficiency comparable to other variable displacement pumps was shown. The design utilized, however, was characterized by design constraints on the gear profiles given by the requirement of utilizing an existing casing. In the present study, a parametric study for the proposed variable delivery flow unit is performed to understand its full potentials. Results shows that assuming the involute profile for both the cost and drive side of the gears, the range of flow variation tends to increase with the number of teeth per gear, and a 62% flow variation can be achievable with a 30 teeth profile.

TITLE:	**Leakage Past Active Contacts in Invoute and Cycloidal Gear Hydrostatic Units**
PRESENTING AUTHOR:	Maiti, Rathindranath, *Indian Institute of Technology, Kharagpur, India*

Patterns of leakage flow through the ‘active’ contact, which separates a high pressure zone or chamber (HPZ) from its adjacent low pressure zone or chamber (LPZ), in gear hydrostatic (HST) units, are analyzed using CFD method in Ansys Fluent ® environment. Two type HST units- one is the common involute external toothed gear unit and the other is the form closed ‘epitrochoid (cycloid class) generated gear’- namely GEROTOR and ORBIT units, are considered for analyses. An earlier photo imaging evidences, by another research group, exhibiting not only the leakage but other relevant phenomenon such as possibility of cavitation, back flow etc. has evoked the present CFD analyses for theoretical backup of the experimental results. Essentially pressure buildups are also considered. Rigorous analyses were carried out for estimating the geometric shape of leakage paths, which involved gear geometry, kinematic, contact deformations etc. CFD results have good agreement with the earlier experimental results and confirm the usefulness in predicting the leakage phenomenon at the transition contact zones of considered HST units.


Rexroth
Bosch Group

TITLE:	**Simulation Analysis of Ring Gear's Micro Motion in Internal Gear Machines**
PRESENTING AUTHOR:	Ruilong, DU, *ZhejiangUniversity, China*

This paper presents a new modeling approach for studying the oil film characteristics between the ring gear and the case in internal gear machines. In traditional research, the assembly relationship of ring gear and case bore was considered as an ideal cylindrical pair, and the micro motion of ring gear and its influence on oil film height and pressure had not been discussed yet. However, wedge oil film between the ring gear and the case is actually formed due to the pressure acting on ring gear teeth while Internal Gear Machines are running, causing micro motion of the ring gear. The model presented mainly consists of two parts namely the gears meshing model that deals with the unbalanced force and the oil film model that deals with the supporting force. The gears meshing process is numerically modeled based on the characteristics of the involute, after which unbalanced force precisely integrated. The oil film pressure field is analyzed based on the lubrication theory of the oil film under different oil film height field, after which the supporting force is precisely integrated. The supporting force is important for balancing the unbalanced force, being responsible for functions of sealing and lubricating. Consequently, the simulation model is implemented with MATLAB and running in co-simulation to obtain the resultant force of the ring gear, which should stay at its minimum value to achieve of the goal of minimizing shear stress and preventing excessive wear. Finally, the dynamic characteristics of the ring gear’s micro motion and pressure distribution are analyzed.

TITLE:	**The Use of Inherent Sensor Effects in Hydraulic Valves - a Simple Instrumentality Approach with Magnetic Hysteresis**
PRESENTING AUTHOR:	Steker, Nils, *Robert Bosch GmbH, Germany*

Key aspects such as machine safety, error detection and operator comfort in the sector of mobile machines become more and more important. Because of the increasing complexity of the machine and more extensive specifications triggered by cost pressure and competitors, new technologies are required permanently.

This article deals with the aspect of the inherent sensor function in magnetic actuators, which are used in hydraulic valves. The attempt is to generate information about the state of the solenoid actuator out of the electrical quantities current and voltage. It is known that a change in the air gap respectively the position of the armature will vary the magnetic resistances for the flux in the magnetic circuit. This is accompanied by a change in the inductance. The resulting current in the winding depends on this inductance. Thus, there exists a relationship between the electrical parameters and the position of the armature. In case the position of the armature is known, the position of the spool can be concluded at least for a directly controlled hydraulic valve.

This paper presents a way of position detection with simple instrumentality and with high system restrictions. It investigates how to make the most of this effect without additional hardware compared to contemporary systems. Furthermore the influence of magnetic hysteresis is detected by test bench measurements.

TITLE:	**On-line Estimation of Dead-zones in the Pilot Stage of Proportional Control Valves with Main-stage Electrical Position Feedback**
PRESENTING AUTHOR:	Su, Qi, *Zhejiang University, China*

The two-stage proportional directional valves with main stage electrical position feedback are widely used in large-flow applications for motion control or velocity control. The pilot stage is specially designed with two kinds of dead-zones. However, these dead-zones are usually poorly known, increase with wear and tear and change from valve to valve in mass production because of their small sizes. This paper presents a useful method to estimate the dead-zones. With the help of main stage displacement sensor and the current sensor, we use four current parameters to represent the break points of the dead-zones. With these accurate dead-zones, the asymmetry and unknown dead-zones can be compensated for a single valve in mass production more precisely. What's more, the measuring process can be done in a short time without shutting down the plant systems. Thus the dead-zones valves can be calibrated online when the tracking performance is degraded. Based on the dead-zone parameters estimated by this method and the dual rate cascade control, a digital valve controller is designed. The comparative experimental results show that this method is effective to estimate the asymmetry and unknown dead-zones. This dead-zone detection also can be applied to other electro-hydraulic proportional valve controlled position control systems with unknown dead-zones.

TITLE:	**System Model of a Directional Control Valve for Control Applications**
PRESENTING AUTHOR:	Makarow, Artemi, *TU Dortmund University, Germany*

Hydraulic directional control valves are highly integrated mechatronic systems employing different areas of expertise such as mechanics, electrical engineering, fluid mechanics and control theory. During operation of such a hydraulic valve, strong nonlinear effects occur in all individual components. Hence, for the precise positioning of the valve piston a complex closed loop controller with a large number of coupled parameters is used. A systematic modeling leads to knowledge of the internal processes which can be used for the development of new and efficient control strategies. The aim of this work is the modeling of all valve components which have an influence on the optimization of the valve controller. Modeling from a control engineering point of view is only feasible if the model accuracy is adequate while the required simulation time is acceptably short, to allow extensive testing and potentially enable real-time control applications. In respect of this requirements, model classes with lumped parameters are suitable. Existing models usually deal exclusively with individual subsystems and often use models which have very high computational load. This paper describes the systematic upgrading of familiar static models with lumped parameters for electromagnets with a dynamic component. A new identification process is developed that yields a sufficient model accuracy starting from a small number of measurable signals. The simulation quality is validated on unseen data and is compared with the simulation performance of a data-based approach.

TITLE:	**The Use of Logic Valve in Construction of Hydraulic Subplate Mounted Four-port Directional Control Valves**
PRESENTING AUTHOR:	Rajda, Janusz, *Cracow University of Technology & Ponar Wadowice SA, Poland*

In this work Cracow University of Technology and Ponar Wadowice investigate the possibility of building four-port valves, in which replacement of the spool by hermetically sealed logic elements would be possible. New innovative pilot operated four-port directional control valve has been developed. It provides total seal for each flow path and in a system can be used interchangeably with a conventional valve. The paper presents the CFD analysis and bench experimental results for the valve. The results show that it is possible to build a logic type hydraulic directional control valve keeping ISO 4401 (CETOP, DIN) connection standard. As it is clear from the research, the solution has good dynamic performance, achieves flow curves similar to the standard hydraulic directional valve, and in some cases even better. In addition, advantage of the valve made up of logic valves is easy change of configuration of the internal connections, which is not possible in the case of standard spool valves. The new type of directional valve allows to perform additional functions in hydraulic system.

TITLE:	**Development of High Performance - High Flow Hydraulic Directional Control Valves**
PRESENTING AUTHOR:	Elgamil, Mohamed Ahmed, *Cairo University, Egypt*

Fast switching hydraulic directional control valves (DCVs) are the key components for digital hydraulics and for applying modern techniques such as PWM in on/off hydraulic drive and control systems. The speed of response and the openings of the currently available pilot operated DCVs limit the use of these modern control techniques to hydraulic systems with relatively low flow rates. Valve speed of response, even for valves designed for this specific purpose, restricts the maximum switching frequency and duty time modulation. To achieve valve fast switching response and high flow capacity, some new configurations for two stage spool valves are proposed. In this paper one of these configurations is presented and its performance is investigated. In this type two 3-way DCVs, each driven by a piezoelectric actuator, are used for piloting the valve spring-centred main spool. The main spool side areas subjected to pilot pressure are chosen to consume small pilot flow and provide enough pilot pressure force for stroking the main spool at high speed. Usage of a two land main spool, which has a decentring static flow force during a part of its stroke, as well as a four land spool which always has static centring flow force are studied. The governing equations are derived and the response is numerically simulated for valves equivalent to servo valves size NG16 available in industry. The results of simulations show the high speed of response and high flow rate of the proposed valve.

DAY 2, THURSDAY MAY 21, 2015 CONFERENCE PROGRAMME
Session A5, Small Auditorium, 15.15-16.45

TITLE:	**Design Overview of the Hydraulic Quadruped Robots HyQ2Max and HyQ2Centaur**
PRESENTING AUTHOR:	Semini, Claudio, *Istituto Italiano di Tecnologia (IIT), Italy*

Legged robots have not yet demonstrated the desired versatility and higher mobility that would justify their more complicated design with respect to wheeled or tracked vehicles. To make these robots ready for real world applications -- for example as assistants to humans in dangerous areas -- important challenges must be solved first, such as dynamic locomotion over rough terrain, dynamic balancing after disturbances, structural robustness to falls, self-righting (to get back up on the feet after falling), active or passive compliance in the legs, state estimation, perception and optional dexterous manipulation. In this paper we will focus on the robustness, self-righting and manipulation aspects. We will give an overview of the design of two new hydraulic robots: HyQ2Max, an improved, robust version of our hydraulic quadruped HyQ, and HyQ2Centaur, a centaur-style robot that combines the HyQ2Max locomotion platform with a pair of new hydraulic manipulator arms. We will focus on the self-righting ability of the quadruped robot and present the results of rigid-body dynamics simulations. Next, we will focus on the mechanical design concept of the new compact hydraulic arms and discuss the hydraulic actuation system. To the authors' best knowledge this is the first time the design of a fully hydraulically actuated centaur robot is presented.

TITLE:	**Development of a Lightweight On-board Hydraulic System for a Quadruped Robot.**
PRESENTING AUTHOR:	Semini, Claudio, *Istituto Italiano di Tecnologia (IIT), Italy*

This paper presents the development of an on-board power pack for a highly dynamic and lightweight hydraulic quadruped robot called MiniHyQ. It is a torque-controlled quadruped robot able to walk over rough terrain, jump and run. The compact power pack is designed to fit inside MiniHyQ's torso section. The hydraulic power source is provided by an on-board miniature gear pump which is driven by a high torque brushless motor. The selection of each appropriate component of power pack is discussed in detail. A step-by-step procedure is proposed which demonstrates how to design of the power pack for a quadruped robot in order to obtain the desired performance. A centralized compact and lightweight manifold design is also presented which works at 20 MPa operating pressure.

TITLE:	**Vehicle Mass Estimation for Hydraulic Drive System Using Longitudinal Motion Model**
PRESENTING AUTHOR:	Ahopelto, Miika, *Tampere University of Technology, Finland*

The real-time mass estimation of the vehicle is applied for the machine with the hydraulic drive system. The mass estimation is based on the longitudinal drive model comprising the model of hydraulic drive transmission. The resistance forces of the longitudinal motion such as the air drag, rolling resistance and friction of the drive system are modelled. The actual mass of the vehicle is deduced from the measured hydraulic torque and from the force causing the acceleration. As the aerodynamic drag, rolling resistance, road grade load and transmission losses have a significant share from the total drive torque, the effects of these forces are taken account. Further, the estimated mass data is classified by recognising operation conditions where the mass estimation is accurate. After a short acceleration-deceleration period, the measured signals provide enough data for estimating the mass of the vehicle. The experimental tests are run with a middle-size wheel loader and with a typical work cycle resulting ±5% accuracy from the real mass. Furthermore, the proposed model and recognition of the operation conditions are applicable to estimate also other vehicle parameters such as friction force or road grade.

TITLE:	**Novel Haptic Controller for Non-road Mobile Machine Teleoperation**
PRESENTING AUTHOR:	Handroos, Heikki, *Lappeenranta University of Technology, Finland*

There are multiple commercially available haptic devices, but very few are specifically designed for the purpose of tele operation of non-road mobile machinery (NRMM). This paper presents a novel haptic controller for the tele operation of NRMM. The manipulability and workspace of an earlier designed haptic controller was analysed with Matlab and Robotic Toolbox. Results of this analysis suggests the direction of further development of the controller.

TITLE:	**Low-cost 3D Lidar for the Mapping of Autonomous Mobile Work Machine**
PRESENTING AUTHOR:	Kolu, Antti, *Tampere University of Technology, Finland*

Autonomous mobile work machines need the capability of sensing and mapping the surrounding area.Machines can utilize several sensors such as laser scanners and cameras for this purpose. The challenge in their use is the relatively high price compared to the value of mobile work machines, and the sensitivity of sensors to harsh operating conditions. This paper presents a low-cost 3D LIDAR for the sensing and mapping of autonomous work machine, which is based on 2D laser scanner and electric motor drive that rotates the scanner. The 2D laser scanner provides range and intensity values from the measured plane and the controller of electric motor provides the rotation angle and rotation speed of the scanner. By combining these values together with navigation data of the machine, 3D point cloud of the surrounding area can be created. This paper presents the development of hardware and control system for the rotating of the 2D laser scanner. Their integration to autonomous mobile work machine and example of mapping results are also presented.

TITLE:	**The Concept of Secondary Controlled Hydraulic Motors Applied to the Propulsion System of a Railway Machine**
PRESENTING AUTHOR:	Padovani, Damiano, *Purdue University, United States of America*

A hydraulic propulsion system is a convenient choice for the railway construction and maintenance machines because of their large mass and repetitive working cycles with frequent stops. The common approach in industry uses valve-controlled layouts that have high fuel consumption and are often difficult to control effectively. These architectures introduce unnecessary energy dissipations and energy recovery during braking is problematic to implement thus friction brakes are utilized. In this regard, the present paper proposes an architecture with secondary controlled hydraulic motors capable of improving the global efficiency of the system via regenerative braking while ensuring precise stopping. Since the limited adhesion is a crucial topic in railway applications, the system under investigation is simulated using a high-fidelity model of the hydraulics combined with a detailed modeling of the wheel/rail interface in order to carefully evaluate the slip coefficients of the wheels. In conclusion, this work shows that secondary control is a feasible solution for railway machinery.

TITLE:	**Investigation and Improvement of the Energy Efficiency of Hydraulic Deep Drawing Presses**
PRESENTING AUTHOR:	Lohse, Harald, *TU Dresden, Institute of Fluid Power, Germany*

The importance of the energetic properties of hydraulic deep drawing presses is constantly growing because of the rather high installed power, rising energy costs and recent activities of legislation and standardization. However, only little research has been done in this direction in the past. Consequently, the systematic technical improvement has been very difficult. This unsatisfying situation has been the motivation for doing research in this field. The article presents exemplarily the activities for a modern single-action test machine with a nominal slide force of 2500 kN. The first step was the experimental analysis of the energy efficiency, followed by simulation studies using a comprehensive model with lumped parameters. Additionally, the simulation was utilized for virtual testing of modified hydraulic drive structures. The final step was the implementation of selected measures for the slide drive and for the die cushion drive in a test machine. After the setup phase, the new drive system worked well and brought a maximum reduction of the machine's consumption of electric energy of about 30 % for the regarded forming tasks and user settings. Apart from this, the experimental results showed that the utilized simulation methodology can predict the real energetic properties with high accuracy.

TITLE:	**Analysis of a Hydrostatic Transmission System for Horizontal Axis Wind Turbines**
PRESENTING AUTHOR:	De Negri, Victor Juliano, *Federal University of Santa Catarina, Brazil*

The paper presents a conception and analysis of a hydrostatic transmission for a horizontal axis wind turbine. This alternative design, when compared to either a gearbox or direct transmission, presents a promising solution for the transfer of the extracted power from the wind to the electric generator and for the regulation of the rotor speed. It also results on the decoupling of the rotor speed from the generator speed. The variation of the rotor speed allows for the maximization of the wind energy capture. On the other hand, it keeps the generator operating with synchronous speed in relation to the electrical grid. In this context, a dynamic model in AMESim of the hydrostatic transmission was developed, whose purpose is to control the rotor speed while maintaining constant generator speed. This control task is carried out by a variable displacement motor where the displacement is determined by one of two classic PID controllers, switching according to wind and rotor speed. The model also represents the interaction between the wind and rotor as well as the connection of the generator with the electrical grid. Considering a 150 kW wind turbine, the system response is studied for wind speed step inputs and for turbulent wind profiles. The input and output power and the output electric frequency are analyzed as well as the rotor and generator torques. The adopted solution for the transmission and control system proved to be effective regarding the proposed objectives.

TITLE:	**New Iso25119 Compliant 6-indipendent Wheels Electro-hydraulic Steering System for Agricultural Machine**
PRESENTING AUTHOR:	Ruggeri, Massimiliano, *IMAMOTER-CNR, Italy*

Performance requests and machine automation, in conjunction with new regulations for agricultural and earthmoving and construction machines, represent today the most difficult challenge for machine designers and researchers. Machine control systems complexity and compliance with safety regulation is one of the most complex problems to be solved in new machines design.

The paper describes a steering system design and testing, installed in on a big 6 wheels agricultural self-propelled machine, that must comply with new regulations in terms of functional safety. The vehicle steering is driven by an electro-hydraulic system totally controlled using by wire electronics; this architecture requires a too high functional safety performance level. In fact the safety analysis of the system lead to a performance level required whose compliance is a too challenging task, due to the required quality of the software and to the cost a fully redundant hardware, on both electronic and hydraulic side. A thorough analysis on steering function and system characteristics was performed, in order to reduce the overall risk of the steering function, considering that a pure hydraulic solution is not possible due to the leakages in the steering systems that can change the parallelism of corresponding wheels in the two sides of the machine.

The paper explains the solution, the hazard analysis results and the approach to “risk reduction by electro-hydraulic design” that allowed a better solution, offering the same functionality thanks to a minimal risk approach.

TITLE:	**Efficiency of Direct Driven Hydraulic Setup in Arctic Conditions**
PRESENTING AUTHOR:	Minav, Tatiana, *Aalto University, Finland*

This paper focuses on investigation of directly driven hydraulic setup (DDH) for non-road mobile machinery (NRMM) application in arctic conditions. The control of the system is implemented directly with a servo motor drive without conventional hydraulic control valves. Speed of the double-acting cylinder is determined by in-coming oil flow from the pump, out-coming flow to the hydraulic motor and angular speed of the electric motor. Efficiency measurements of DDH setup performed in different operating conditions (speed, payload, duty cycle) and environmental conditions (temperature, humidity). Influence of temperature on results is studied in range of +20 to -10 °C. Thermal images across the pump and electrical machine demonstrate relative efficiency of the components. Change in fluid temperature (delta T) across the pump indicates volumetric/friction loss within the pump and demonstrates its behavior during cold start-up. Sankey diagrams shows reduced pumping and system efficiency as heat generation results in energy consumption and heat load within the system during lifting.

DAY 3, FRIDAY MAY 22, 2015 CONFERENCE PROGRAMME
Session P2, Small Auditorium, 9.00-10.00

TITLE:	**Modular Software Design of Safety Related Systems for Mobile Machinery – Reliability, Testability and Simulation**
PRESENTING AUTHOR:	Weltzien, Cornelia, *Hydac System GmbH, Germany*

This paper identifies the challenges during the development of control software for safety critical electro-hydraulic systems which shall be implemented in a wide-range of mobile machinery. The approach is based on a modular software design which provides a maximum of reliability and reusability of software components without reducing the flexibility or functionality of the system.

An inevitable prerequisite in order to provide functional safe software is the application of directives and standards for safety related software development [1], [2], [3], [4]. This paper will mainly focus on ISO 13849 [1] but general conclusions will be drawn extending beyond this specific standard. Due to the fact that safety requirements for software are entirely process related, the testability and documentation of safety related software is of key importance. In order to achieve testable software test features have to be implemented into the software by designing testable function modules, limiting the logic combination between functions, implementing test interfaces and entry points into the code. Therefor the testability of the software has to be defined at the very beginning of the software development process. The focus of this paper will be laid on identifying the safety requirements for software as mandated by the standards for safety related software development. Furthermore it will highlight how the chosen approach of modular software design will help to fulfill these requirements.

TITLE:	**Digital Hydraulics on Rails – Pilot Project of Improving Reliability on Railway Rolling Stock by Utilizing Digital Valve System**
PRESENTING AUTHOR:	Fischer, Helmut, *Bosch Rexroth AG, Germany*

Finnish Railways (VR) is a state-owned railway company in Finland. It has 18 six-carriage high-speed body-tilting Pendolino trains (“Pendolino”) which have been built in years 1995-2006. The Finnish Pendolino train is based on the FIAT Ferroviaria’s ETR 460 model but it is adapted to Finnish environmental conditions. The motivation for the research work was to improve the reliability of the tilting system and to decrease the life cycle costs. The Pendolino’s tilting system and retrofit options were studied by Tampere University of Technology (TUT). The most promising option found was substituting unreliable and costs generating servo valves with a robust Digital Valve System (DVS). In early phase, one tilting module was modified at TUT and the concept level testing was carried out. Functionality was proven and Bosch Rexroth developed and designed a market-proof version of a digital hydraulic tilting system for Pendolino train. New systems were tested on both at stand still depot tests and on rails at normal operation velocities. Since the successful verification tests, two cars with the digital hydraulic tilting system have been in line service for more than two years with excellent reliability. The new DVS based tilting system is now replacing the original system in the entire Finnish Pendolino fleet.


HYDAC

DAY 3, FRIDAY MAY 22, 2015 CONFERENCE PROGRAMME
Session A6, Small Auditorium, 10.30-12.00

TITLE:	**Hybrid Load Sensing – Displacement Controlled Architecture for Excavators**
PRESENTING AUTHOR:	Sugimura, Ken, *IFAS (Fluid Power Drives and Controls), Germany*

Energy saving is very important due to the shortage of energy resources and the need to protect the global environment. Manufacturers of mobile machinery have responded to this need by developing more efficient hydraulic systems. Examples of such improved architectures are displacement controlled or transformer systems, which aim to minimize throttling losses. To further improve efficiency a new hybrid architecture, which combines the advantages of load sensing with displacement control, while at the same time eliminating their inherent disadvantages is proposed. The new hybrid architecture for hydraulic excavators is introduced in detail and the potential for efficiency improvement is shown by using simplified load models and a modelled digging cycle.

TITLE:	**Hybrid Pump Drive**
PRESENTING AUTHOR:	Tikkanen, Seppo, *Tampere University of Technology, Finland*

The number of applications with rotational speed controlled fixed hydraulic pumps is increasing because they offer good controllability and efficiency compared to conventional fixed speed pump drives. Both electric motors and pumps are dimensioned according to maximum power/torque. Consequently, the electric motor is significantly larger than the hydraulic pump. This paper introduces a double pump system with connection to additional hydraulic supply creating a hybrid drive. The power/torque demand can be reduced making it possible to choose a smaller electric motor without sacrificing performance while increasing power density. The connection to two energy sources results in a flexible energy supply and makes it possible to recover either hydraulically or electrically. Simulated results show that the studied circuit enables electric motor size reduction as much as 50% when the bottom of the cylinder is the load side and the second pump is connected to the accumulator or pressure source. This is applicable in applications where the rod side loading is remarkably lower as well as in other applications that have a minor extending load.

JOHN DEERE

TITLE:	**Comparative Study of Fuel Reduction Methods for Hybrid Excavators**
PRESENTING AUTHOR:	Zhu, Qian, *Zhejiang University, China*

This paper presents a simulation study of three fuel reduction methods for hybrid excavators. The configuration of the studied hybrid excavator is a compound type. An optimal control method, dynamic programming, is used in the simulation to reduce the affection of non-optimal control strategy. Comparison of the three methods is first analyzed with the same work load to evaluate the effectiveness of these three methods on the fuel economy. Then a further study of the relationship of the three methods with different work loads and assist motor sizes is analyzed. Simulation results show that the three fuel reduction methods all have pros and cons. The fuel reduction method should be carefully selected for different work loads.

TITLE:	**Hydraulic Hybrid Actuator - Theoretical Aspects and Solution Alternatives**
PRESENTING AUTHOR:	Linjama, Matti, *Tampere University of Technology, Finland*

This paper presents and analyses a hybrid solution, in which the hydraulic energy storage element is integrated to the hydraulic actuator. The approach yields new system layout – distributed hybrid system – in which only mean power is transmitted between actuators and high power peaks are handled locally. Three different implementations are discussed. A multi-actuator excavator load cycle is analysed and dimensioning of components is discussed. Limitations of the approach are also discussed.


SIEMENS

TITLE:	**Improving Energy Efficiency of a Reach Stacker Using a Potential Energy Recovery System**
PRESENTING AUTHOR:	Schaep, Thomas, *INSA Lyon, France & Terex Cranes France*

This paper aims to compare three solutions of potential energy recuperation on a mobile harbour machine designed to stack containers. The current system dissipates the energy during the boom lowering through a flow control valve. The first system uses only a flow control valve to reach the pressure imposed by the accumulator. The second system uses a transformer based configuration directly coupled to the internal combustion engine (ICE). It allows to reuse easily the energy but also to recover it regardless of the pressure difference between the hydraulic circuit and the accumulator. The last system presented is also composed of a pressure transformer which is not attached to the ICE. This layout permits an independent rotation speed of the recuperation devices from the ICE, enabling also to avoid the engine braking. The solutions have been modelled and simulated for different initial and final positions of the container in terms of height and depth. The system without transformer showed an amount of energy recovered lower than 35% because of the limitation of the accumulator volume. The second solution directly coupled to the engine shaft demonstrated better performances. However between 15% and 20% of the recoverable energy is dissipated by the engine braking. The last architecture showed fuel consumption economy of up to 20%. The great advantages of this solution is its independence from the ICE speed and the engine braking but also the possibility to recover energy even when the lifting actuator pressure is low, for instance when an empty container is lowered.

TITLE:	**Development of a Parallel Valve Control for a Hot Gas Bulge Test**
PRESENTING AUTHOR:	Storz, Johannes, *RWTH Aachen University, IFAS, Germany*

During the last years, hot forming of sheet metal parts has become an alternative production process of high strength components. New material concepts, e.g. boron-manganese steels, permitted the application of hot stamping, especially in the automobile industries. A request of knowledge about the thermo-mechanical material properties of these sheet metals at elevated temperatures and high strain rates demands the enhancement of existing test procedures. Since hot tensile tests can only be evaluated until comparable low strains, a hot gas bulge test at elevated temperatures and high strain rates is being developed. Standardized bulge tests use hydraulic oil as forming medium. However, the application of hydraulic oil is not possible at hot stamping conditions i.e. with temperatures up to 950 °C. Furthermore, the forming speed has an increasing influence on the material behaviour at increasing temperatures. Therefore, a new design of a so called hot gas bulge test is being developed, which includes a closed loop control of the forming speed. An analysis of the expected material behaviour leads to possible configurations. A parallel valve concept is chosen to control the bulge test and examined for the use in a gas based bulge test.

TITLE:	**Development of Experimental Equipment for the Analysis of Flowmeter Characteristics in Conditions of Gas Pulsating Flow**
PRESENTING AUTHOR:	Gimadiev, Marat, *Samara State Aerospace University, Russian Federation*

The work presents the results of test stand development for experimental analysis of flowmeter error caused by gas pressure pulsations. Error test is based on comparison of the gas flow measured by the test flowmeter in conditions of pulsating flow and the same gas quantity – by a master flowmeter in the flow without pulsations. To dampen pressure pulsations in a pipeline after the test flowmeter the displacementtype oscillation damper has been used. The work shows theoretical and experimental pressure oscillograms and pressure pulsation spectra in the test stand mainline as well as the pulsation error research results of the orifice flowmeter.

TITLE:	**Energy Efficiency Comparisons of Pneumatic Systems: Effects in After Treatment: Theory and Verification with Time Series Measurements**
PRESENTING AUTHOR:	Parkkinen, Jyrki Juhani, *Aalto University, Finland*

The idea of air circulation for reuse purposes in pneumatic systems has become an important alternative. The CPS (Closed Pneumatic System, patented innovation) has been implemented in some industrial plants in Finland. Author has dealt the subject in detail in his publication [1].

The effect of the after treatment system to the total energy efficiency of the pneumatic system varies considerably in different applications. Especially when a pneumatic system with an adsorption dryer is in use, the proportion of compressed air of the total production needed for degeneration purpose is considerable large (according to various references 15-20%).

In this paper, theoretical calculations for the consumption of energy based on generic models of pressure behavior in different cases (pressure-dependent/independent, 2-point-controlled and inverted control) are presented.

The theory is shown to be in line with actual pneumatic systems by time-series measurements in the industrial plant. These measurements include values for compressed air flow, pressure (bar) and power/energy. In these measurements the measurement data is first collected from the open pneumatic system and then the measurements have been repeated with the closed system.

TITLE:	**Design and Fabrication of an Electromagnetic Microvalve for Pneumatic Control of Microfluidic Systems**
PRESENTING AUTHOR:	Liu, Xuling, *Harbin institute of technology, China*

This work presents the design, fabrication and experiment of an electromagnetic microvalve for pneumatic control of microfluidic chips to miniaturize the whole pneumatic control devices. The microvalve is composed of two parts, a miniature electromagnetic actuator and a valve body. The two parts are fabricated separately and assembled. The valve body are fabricated by a soft lithography process of elastomeric materials (Polydimethylsiloxane, PDMS). Tests showed that the designed microvalve worked at pressures up to 280kPa with the applied voltage of 24V. The fast open response (~ 6.4 ms) and close response (~ 4.0 ms) of the valve was achieved with a leak rate as low as 0.26sccm at 200kPa (N2) pressure. We tested the pertinent dynamic parameters such as flow rate in on/off mode, flow rate of duty cycles and actuated frequencies in pulse width modulation mode (PWM). Our method provides a simple, cheap and small microvalve which avoids the bulky and expensive external pressure control solenoid manifold. This allows it to be easily integrated into portable and disposable devices.

TITLE:	**Simplified Fluid Transmission Line Model for Pneumatic Control Applications**
PRESENTING AUTHOR:	Rager, David, *Festo AG & Co. KG, Germany*

The neglect of transmission lines in pneumatic controller synthesis limits the possible control performance or the length of the connecting tubes. In literature, complex and accurate models have been derived for the description of flow phenomena in tubes, but low-order models for controller design and stability analysis are rare. This paper proposes a second-order modal approximation of the one-dimensional linear resistance compressible model and includes non-linear tube friction. The model was validated in time domain as well as in frequency domain. An application for the model in pressure control was shown and compared to the state of the art.

TITLE:	**Research on Pulsation Demand of Pump Used in Electro-hydrostatic Actuator**
PRESENTING AUTHOR:	Shang, Yaoxing, *Beihang University, China*

Conventional centralized aircraft hydraulic system has very high demands on the flow output pulsation of the engine driven pump (EDP). However, few papers have mentioned the requirements on the high speed pump used in Electro-Hydrostatic Actuator (EHA). The performance of EHA is important in electro-hydraulic servo system. It is known the pump used in an EHA has a huge influence on its performance especially the flow pulsation of the pump lowers EHA performance. Therefore, the focus is to investigate the pulsation demand of the pump according to the performance of EHA. By using AMESim, a common EHA model is established to simulate the working conditions of EHA and the pump unit. In this paper, the working parameters of the pump are adjusted while the system performance characteristics are observed and analysed. And the pulsation demand mentioned can be concluded through reverse analysis. System performance of EHA such as position tracking error, dynamic response, dynamic stiffness and force loop are evaluated in simulations. Meanwhile, the acceptable range of pump flow pulsation is analysed. That is, the pulsation demand is given according to the EHA performance requested.

TITLE:	**Review of Hydraulic Technologies in Wind Turbines**
PRESENTING AUTHOR:	Tu, Le, *The State Key Laboratory of Fluid Power Transmission and Control, Zhejiang University, China*

The reliability of wind turbines is receiving increasing attention as the scale of wind turbines gets larger. In modern wind turbines, hydraulic transmission plays an important role in keeping the turbines operating safely and steadily. The paper analyses the utilization of hydraulic technologies in brake system, pitch control system and power transmission system. In particular, the hydro-mechanical hybrid transmission is presented in detail, which combines the high efficiency of mechanical transmission with power output stability of hydraulic transmission, and becomes a new research trend in wind turbines.

TITLE:	**Research on the Stiffness of the Hydraulic Transformer Controlled System**
PRESENTING AUTHOR:	Di, Chongfeng, *National Key Laboratory of Vehicular Transmission, Beijing Institute of Technology, China*

In the hydraulic transmission control system, there are mainly two kinds of control systems: valve controlled system and pump controlled system. Valve controlled system has large throttling loss and low efficiency. Pump controlled system decreases the energy loss a lot and improves the system efficiency. Besides these two sorts of control systems, as the development of hydraulic common pressure rail, hydraulic transformer controlled system has been developed. Hydraulic transformer can realize system control without throttling loss theoretically.

The paper proposes the mechanical structure of the hydraulic controlled system, which consists of the hydraulic common pressure rail, hydraulic transformer and actuators. Both the hydraulic transformer controlled motor system and the hydraulic transformer controlled cylinder system were investigated simultaneously. Both system models were also built respectively. To realize better system control, the system stiffness equations were developed. The stiffness of pump controlled system was also discussed. An experimental apparatus for hydraulic controlled system was designed and constructed.

The results indicate that the hydraulic transformer cylinder speed is determined by both the oil pressure and the loads. The stiffness of the hydraulic transformer controlled system is smaller than the stiffness of pump controlled system. And the system stiffness changes with the variation of the hydraulic transformer controlled angle. It becomes large with the increase of the hydraulic transformer controlled angle.

TITLE:	**Dynamics of Volume Controlled Mechanical Ventilation System**
PRESENTING AUTHOR:	Shi, Yan, *Beihang University, China*

Dynamics of mechanical ventilation system can be referred in pulmonary diagnostics and treatments. In this paper, to illustrate the influences of key parameters on the dynamics of the volume controlled ventilation system, firstly, a new mathematical model of the ventilation system is proposed. Secondly, the mathematical model is verified through comparison of simulation results and experimental results. At last, the influences of key parameters on the dynamics of the volume controlled ventilation system are carried out. This study can be helpful in respiratory treatment, diagnostics and design of various medical devices or diagnostic systems.

TITLE:	**Optimal Paired In-line Bladder-style Suppressors for Broadband Noise Control**
PRESENTING AUTHOR:	Gruber, Elliott, *Georgia Tech, United States of America*

The dimensions and charge pressures of in-line bladder-style suppressor pairs were optimized to find the configuration with maximum broadband noise control for a range of operating pressures. The dimensions under consideration for both suppressors within a pair are the inner radius of the bladder, the inner radius of the outer shell and the length of the bladder, which are the dimensions that determine the pressurized gas volume within the device. The separation distance between the suppressors was also considered. Prior work optimized the charge pressure of commercially available devices in several configurations: a single suppressor, two similarly-sized suppressors in series, and two dissimilarly-sized suppressors in series. Results of example optimizations show the optimal suppressor pairing does have a large pressurized gas volume; however, the volume is not the largest volume attainable within the bounds on the design variables. The respective dimensions for each suppressor within an optimal pair are dissimilar between the pair. Dissimilar dimensions for each suppressor within the pair yield different frequency-dependent performance for each suppressor; therefore, there is not a shared deficiency that would lead to poor performance in a given frequency range as could be the case with identical devices. This result underscores the importance of optimizing the dimensions of a suppressor pair instead of simply employing two of the largest devices available.

TITLE:	**An Approach to Optimize the Design of Hydraulic Reservoirs**
PRESENTING AUTHOR:	Wohlers, Alexander, *HYDAC FluidCareCenter GmbH, Germany*

Increasing demands regarding performance, safety and environmental compatibility of hydraulic mobile machines in combination with rising cost pressures create a growing need for specialized optimization of hydraulic systems; particularly with regard to hydraulic reservoirs. In addition to the secondary function of cooling down the oil, two main functions of the hydraulic reservoir are oil storage and de-aeration of the hydraulic oil. While designing hydraulic reservoirs regarding oil storage is quite simple, the design regarding de-aeration can be quite difficult. The author presents an approach to a system optimization of hydraulic reservoirs which combines experimental and numerical techniques to resolve some challenges facing hydraulic tank design. Specialized numerical tools are used in order to characterize the de-aeration performance of hydraulic tanks. Further the simulation of heat transfer is used to study the cooling function of hydraulic tank systems with particular attention to plastic tank solutions. To accompany the numerical tools, experimental test rigs have been built up to validate the simulation results and to provide additional insight into the design and optimization of hydraulic tanks which will be presented as well.

TITLE:	**Second Order Dynamic Accumulators, the Features, the Applications and the Feasibility**
PRESENTING AUTHOR:	Elgamil, Mohamed Ahmed, *Cairo University, Egypt*

In this paper, new type of compact hydraulic accumulators is introduced with the capability to store high amount of hydraulic energy and to change its mean working pressure without exchanging effective volume of oil with the system. This new accumulator, called "Dynamic Accumulator", is a sort of a second order dynamic system where the swept volume of the accumulator would depend on the dynamic periodic variation of the working pressure in addition to its dependency on the static variation. Various features of this second order dynamic accumulator which comprises spring-mass system are presented. The proposed accumulator has the advantage of being capable of tuning its natural frequency, change its damping coefficient and control its mass movement online. Thus, the accumulator is suitable for wide range of working pressures and operating conditions. Applications in suppressing the pulsations and suggested locations to attach the accumulators are presented. The usage of this accumulator to drive and control pumping heads of a new under development pump of geometric volume control by small amount of control oil is explained. Feasibility regarding the developed stresses in the accumulator components is proven by finite elements simulation and capability to dynamically suppress the pulsation when integrated with the system is proven analytically.

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SICFP15 ORIENTATION GUIDE

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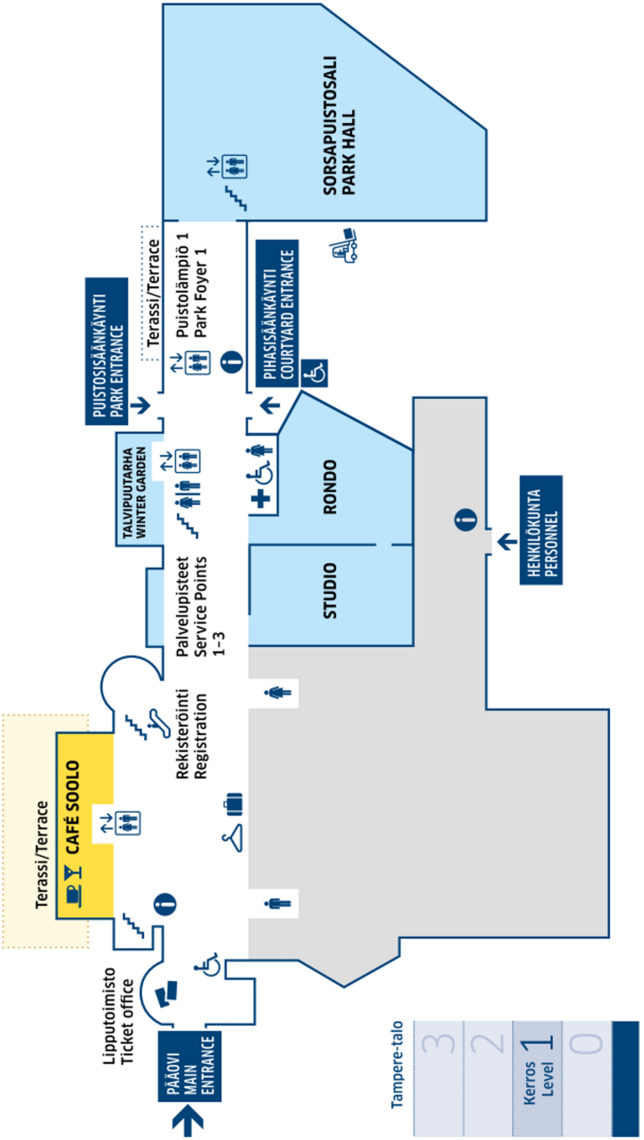

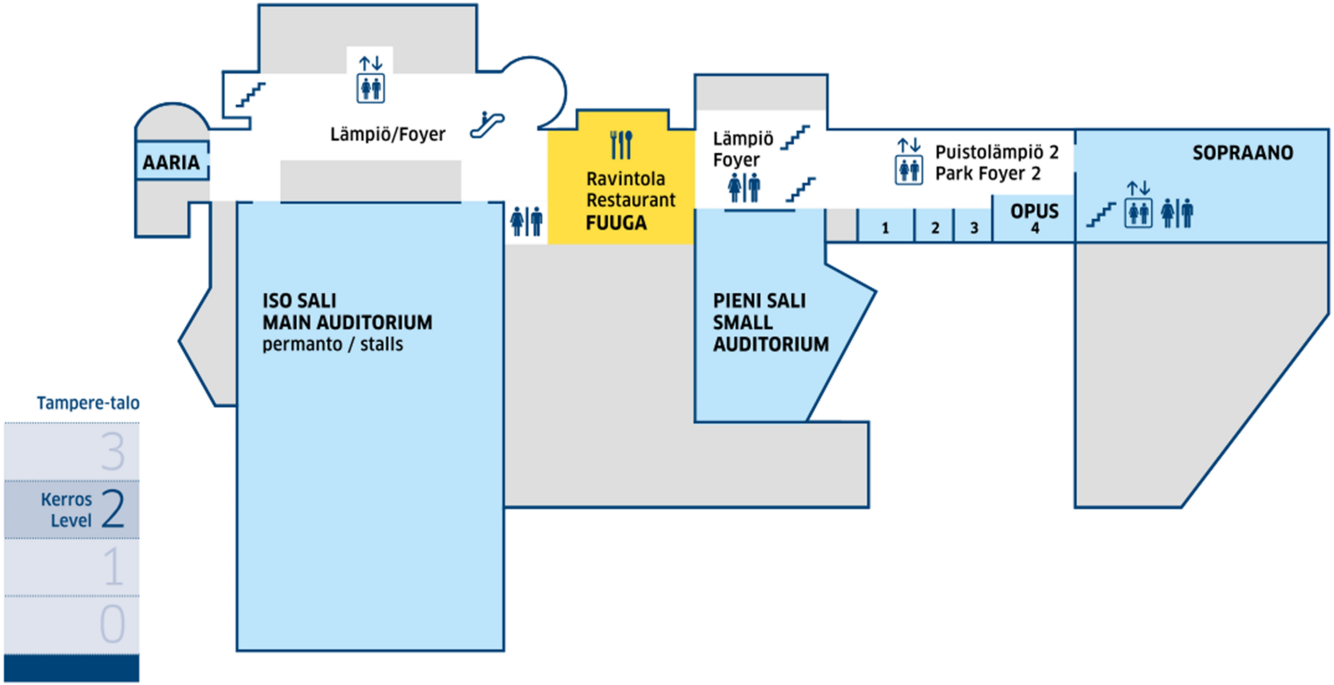
Lämpiö/Foyer
AARIA
Ravintola
Restaurant
FUUGA
Lämpiö
Foyer
Puistolämpiö 2
Park Foyer 2
SOPRAANO
1
2
3
OPUS
4
ISO SALI
MAIN AUDITORIUM
permanto / stalls
PIENI SALI
SMALL
AUDITORIUM
Tampere-talo
3
Kerros
Level
2
1
0

SICFP15 Events & Tampere Orientation Guide

1. **Tampere Hall / Tampere-talo**
    - Get-together 19.5.2015, 19:00 - 21:00
    - Conference 20.5-22.5.2015
2. **Tampere City Hall**
    - Reception by the City of Tampere 20.5.2015 19:00 - 20:30
3. **Solo Sokos Hotel Torni Tampere**
    - Gala Dinner 21.5.2015, 2015, 19:00 -
4. **Laukontori Harbour**
    - Cruise & Dinner 22.5.2015, 19:00 - 22:00