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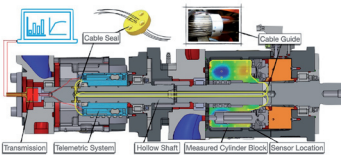
SYMPOSIUM

TUESDAY, 19TH OF MARCH

EFFICIENCY 09:10 - 10:30 a.m.

THERMAL ANALYSIS OF THE CYLINDER BLOCK OF AN AXIAL PISTON PUMP - THE KEY TO MONITORING EFFICIENCY

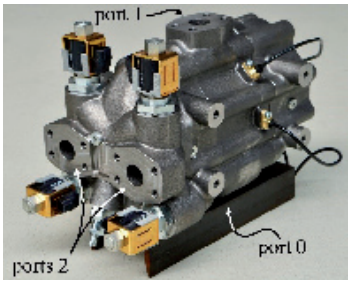
Presenter: Roman Ivantysyn, TUD Dresden University of Technology, Germany



To prepare today's fluid power systems for the future digitalization of the industry, it is necessary to improve the information available regarding the current condition of crucial components of the system. Positive displacement machines, which constitute the core of any hydraulic system, play a vital role in this process. Future smart systems will require more information about the current state of the pump such as power usage and efficiency. Current condition monitoring approaches utilize an array of sensors that need to be sampled at high frequency. The transmission, storage, and post processing of this vast amount of data requires an enormous number of resources, especially if exercised at scale. Previous work conducted at the Institute of Mechatronics Engineering at TU Dresden has demonstrated that measuring the temperature in the lubricating gaps can allow for a deeper insight into the tribological mechanisms in these interfaces. Not only can the gap height, viscous friction and leakage be determined from this information, but also crucial information such as wear level and expected component lifespan can be derived from temperature levels with adequate reference models.
This paper demonstrates that monitoring the thermal condition of the cylinder block is an effective approach to estimate the pump's efficiency. This will be illustrated through both simulation and measurement, in addition to the pioneering measurement of the heat convection coefficient on the cylinder block surface, a critical boundary condition for the simulation.
To measure the temperature of a moving cylinder block, a 160cc axial piston pump was equipped with a telemetric system, which was specially designed and built for this task. Next to the 20 temperature sensors four heat convection coefficient sensors were also carefully placed inside the cylinder block. The resulting measurements did not only validate the simulation but also give a unique insight into the inner workings of a piston pump.

EFFICIENCY DEFINITIONS OF HYDRAULIC TRANSFORMERS AND FIRST TEST RESULTS OF THE FLOATING CUP TRANSFORMER (FCT80)

Presenter: Robin Mommers, INNAS B.V., The Netherlands

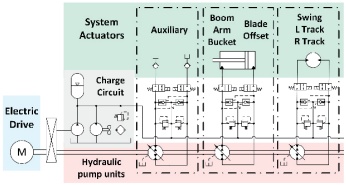


The FCT80 is a new hydraulic transformer, based on the floating cup principle. The transformer has valve plates with three ports, and is controlled by means of setting the rotational position of these valve plates. Contrary to hydraulic pumps and motors, there are no standardised efficiency definitions for this type of integrated transformers. In this paper, general definitions for efficiency and power loss for hydraulic transformers are proposed, which also take the compressibility of the oil into account. This paper also describes and presents the first test results of the overall efficiency of the FCT80.

EFFICIENCY 09:10 - 10:30 a.m.

COMPARISON STUDY OF FULLY INDIVIDUALIZED SYSTEM ARCHITECTURES FOR ELECTRIFIED MINI-EXCAVATORS: DISPLACEMENT CONTROL (DC) VS ELECTRO-HYDRAULIC ACTUATION (EHA)

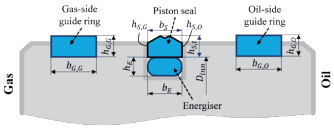
Presenter: Timir Patel, Purdue University, USA



Energy consumption and overall installed power are key parameters for evaluating different technology for the hydraulic actuation system of electrified off-road vehicles. This paper presents a study on these parameters considering the case of all the functions of a 5-ton mini-excavator. The hydraulic system architectures considered for this study are the current commercial solution (load sensing system) and two alternative high-efficiency primary controlled architectures that minimize energy loss: the Displacement Control (DC) system that uses a single electric prime mover and a variable displacement pump for each actuator, and an Electro-Hydraulic Actuator (EHA) system that uses an electric prime mover and a fixed displacement pump for each actuator. For this study, a basic sizing for the two alternative systems is performed based on available commercial components. Both the proposed systems and the conventional LS system are simulated in Simcenter Amesim to determine the energy distribution over a digging duty cycle. The baseline system is also validated based on experimental measurements. The results show a 50% reduction in energy consumption for both the individualized systems, but the overall displacement of the pump units increases by a factor of 3.75. Furthermore, the installed power for the EHA system is 8 times higher than the baseline. Although the study does not suggest a specific architecture for the reference application, the results can assist decision making processes for selecting sub-function primary controlled actuation in future electrified mini-excavators.

RUN-IN BEHAVIOUR AND WEAR ON HYDRAULIC PISTON SEALS – EVALUATION OF AN ENDURANCE TEST FOR PISTON ACCUMULATORS

Presenter: Tobias Schulze, TUD Dresden University of Technology, Germany



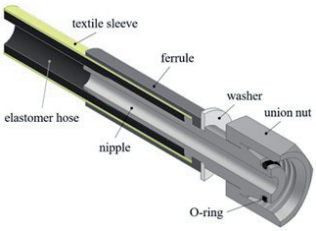
Hydraulic accumulators are essential components in industrial and mobile hydraulic systems, serving various purposes from energy storage to shock absorption and energy recovery. In hydraulic pitch systems of wind turbines, piston accumulators offer significant benefits such as reliability, resilience to centrifugal forces and temperature fluctuations, as well as simple monitoring. Ensuring a proper seal between the gas and oil sides of a piston accumulator and understanding its wear characteristics are crucial for reliable operation of the system. A precise determination of wear often requires the use of measured values.

The current paper presents the results of a 5,000-hour endurance test conducted for piston accumulators under load conditions typical for wind turbine applications and reveals insights into the run-in behaviour and wear process of the seals. During and following the test, parameters such as sealing geometry and surface roughness of inner accumulator tubes were measured. To assess wear volume, Archard's and Fleischer's wear models are discussed. It could be shown that error-free sealing under the current load conditions can be expected for a period of about 20 years.

FUNDAMENTALS 09:10 - 10:30 a.m.

DEVELOPMENT OF A HYDRAULIC ARTIFICIAL MUSCLE WITH HIGH FORCE DENSITY

Presenter: Mathias Niebergall, University of Applied Science Ulm, Germany



The actuation of mechanism like exoskeletons or devices for medical rehabilitation by means of fluid artificial muscles are convincing solutions due to their light weight, exceptional power capacity, remarkable resiliency, and low investment costs. The artificial muscle consist of an inner elastomeric hose surrounded by a textile, braided and reinforced by aramid fibers. The muscle is activated by fluid supply with a radial expansion of the inner pressurized hose accompanied by a corresponding axial contraction. Consequently circumferential stress in the textile reinforcement of the muscle converts into axial contraction force. The focus of this project is the development of high power hydraulic muscles that enable a significant higher pressure level as well as force density than known artificial muscles. Prototypes of new hydraulic artificial muscles have been developed and experimentally evaluated by means of a customized hydraulic test setup. Relating to the initial length of the muscle without fittings, a contraction of 32% has been measured. In this experiment the associated pressure level is 5 MPa. In a second experimental test the force depending on pressure has been measured and a high force density per mass of 60 kN/kg has been calculated.

HYDRAULIC PILE HAMMER SURROGATE MODEL BASED ON PHYSICS-INFORMED NEURAL NETWORK

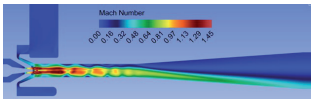
Presenter: YaJun Liu, South China University of Technology, China

The high fidelity digital model of hydraulic pile hammer is able to predict the energy conversion rate of hydraulic system under the specified controller parameters, and guide the matching process of controller parameters and construction conditions. Using neural network to fit the calculation results of simulation software can greatly reduce the calculation cost of prediction process. However, the unexplained feature of neural network output increases the application risk of this method. Based on the classical theory of physics-informed neural network (PINN), a PINN method based on inequalities is proposed in this paper. Based on this method, a physics-informed surrogate model network (PISMN) oriented to the simulation process of hydraulic pile hammer was constructed. It is proved that this method can constrain the output of the surrogate model, improve the stability of the training process, and the median prediction deviation of the prediction results was reduced by 53.0% in the validation set with perturbation.

FUNDAMENTALS 09:10 - 10:30 a.m.

COMPUTATIONAL THERMOFLUID ANALYSIS OF A REFRIGERATION CO2 EJECTOR

Presenter: Roozbeh Mousavi, Hilite Germany GmbH, Germany



The present work is aimed to numerically investigate the thermofluid performance of a Hilite-designed CO2 ejector designed to increase the efficiency of a refrigeration cycle. Using ANSYS-CFX, a homogeneous binary mixture method accompanying the NIST real fluid model, is applied to simulate the fluid flow undergoing a transcritical thermodynamic process. The model is validated using an available experimental measurement. The investigations are done in 3D for a range of the flow control pin strokes considering the pin radial eccentricity.
In addition, a parametric optimization was performed to improve the ejector performance in terms of mass entrainment ratio using ANSYS-OptiSLang. The varying optimization parameters are the parameters defining the ejector geometry in an axial-symmetric form.
The investigations imply a complex interaction between the transcritical real fluid behaviour, shock waves structure and near-wall turbulence, all affecting the ejector performance.

REMAINING USEFUL LIFE ESTIMATION FOR RUBBER O-RING UNDER STORAGE CONDITIONS CONSIDERING DEPENDENT PERFORMANCE INDICATORS

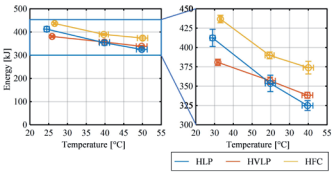
Presenter: Chao Zhang, Beihang University, China

Rubber O-ring seals have been extensively used in various types of hydraulic actuators. If rubber O-ring seals are exposed to a heat environment during storage, it will result in material aging and mechanical properties change. Therefore, it is necessary to obtain an accurate reliability model for rubber O-ring under storage conditions. This paper develops a bivariate-dependent remaining useful life prediction model based on inverse Gaussian (IG) process and Frank Copula. The nonlinear explainable IG process considering unit-to-unit variability is utilized to describe the degradation process of two performance indicators, namely as compression set and compressive stress relaxation. The time scale function in IG process model is determined by material aging model. The Frank Copula is employed to capture the dependent relationship between these indicators. The two-stage parameter estimation method is adopted to estimate parameters in IG process and copula, separately. Bayesian and Expectation-Maximum algorithm are jointly utilized to update parameters in IG process degradation model under exponential family distribution framework. Maximum likelihood estimation is used to update parameter in Frank Copula. To validate the proposed method, aging degradation tests for O-ring seals are conducted. The results demonstrate that the proposed real-time parameter updating method also improves the accuracy of online RUL assessments.

WATER HYDRAULICS 09:10 - 10:30 a.m.

HOLISTIC EFFICIENCY MEASUREMENTS OF A MOBILE WORKING MACHINE: COMPARISON OF CONVENTIONAL MINERAL OILS AND A SUSTAINABLE WATER-BASED FLUID

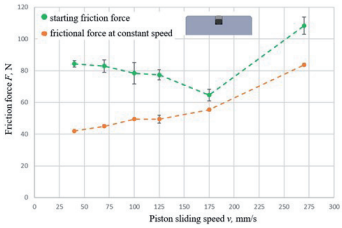
Presenter: Sebastian Deuster, RWTH Aachen University , Germany



The selection of pressure fluids plays an important role in hydraulic systems' efficiency. Depending on physical properties, especially the viscosity, different volumetric and hydraulic-mechanical losses occur in the system. This paper investigates the influence of hydraulic fluids with different physical properties on a crawler excavator's energy efficiency. For this purpose, the overall efficiency of the excavator is examined for different mineral oils and an alternative water-based fluid with deviating viscosity classes and indexes. The study results show that reducing the energy demand over a wide temperature range by lowering the viscosity grade or increasing the viscosity index is not generally feasible. To reduce losses by adapting the hydraulic fluid in a hydraulic system further physical and chemical properties such as pressure viscosity behaviour as well as the density must be considered.

TRIBOLOGICAL PROPERTIES OF HYDRAULIC CYLINDER PISTON SEALINGS IN WATER AND OIL HYDRAULICS

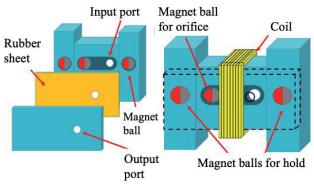
Presenter: Franc Majdič, University of Ljubljana, Slovenia



Hydraulics is indispensable in everyday life because of its ability to work with large forces. Hydraulic cylinders are an important hydraulic element and contain different types of seals. This work presents an investigation of the influence of three different shapes and materials of piston seals in a hydraulic cylinder on the friction force. The friction was tested in two hydraulic fluids, water and mineral oil, at six different piston rod travel speeds on a test rig prepared for this purpose. It was found that the proportion of the friction force in mineral oil is between 60 % and 85 % of the friction force generated by the same piston seal in water. However, a long-term test carried out on a test rig provided data on the leakage of the piston seal before the start of the long-term test, after 50 km of travel, and after 100 km of travel of the piston rod at full load.

DEVELOPMENT OF DIGITAL TYPE TAP-WATER DRIVE FLOW CONTROL VALVE

Presenter: Hiroki Atogami, Okayama University of Science, Japan

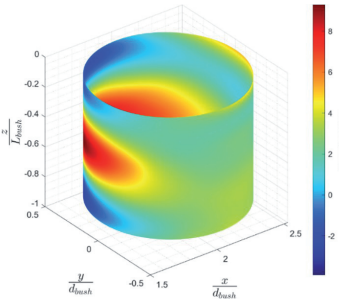


This study concerned with development of digital type tap-water drive flow control valve for water hydraulic systems. In this study we developed a novel type of valve which can generate 10 steps of output flow rate. In addition, a back pressure supply mechanism is applied to the developed valve to assist torque of a stepping motor driving a rotary disk in the valve. The improved valve with the back pressure supply mechanism is compared with conventional digital valve units using typical On/Off valves. As a result, it was confirmed that the size was reduced by 30% and the mass was reduced by 70%.

WATER HYDRAULICS 09:10 - 10:30 a.m.

NUMERICAL MODEL OF PISTON/CYLINDER INTERFACE WITH CONSIDERATION OF TURBULENCE EFFECT FOR WATER HYDRAULICS

Presenter: Haotian Han, Purdue University, USA



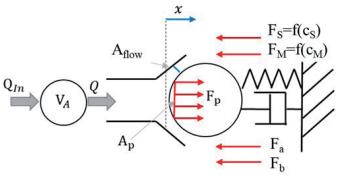
Axial piston machines find their use over a wide range of the power spectrum owing to their superior reliability, efficiency, and power density. They are also a key component in applications like reverse osmosis and firefighting wherein the working fluid is water. Utilizing low viscous fluid, such as water, as a working fluid poses challenges in designing the critical lubricating interfaces of the piston pumps. Specifically, low viscosity makes it difficult for the lubricating interfaces to provide sufficient bearing and sealing functions in challenging operating conditions. In order to maintain the lubricating interface performance in water hydraulic piston pumps, costly materials, and tight manufacturing tolerances are often utilized. To improve the efficiency and cost-effectiveness of these pumps, accurate numerical simulation tools that consider the fluid and structure interaction are needed to provide valuable insights into these lubricating interfaces. Although the Reynolds equation is a reliable method for determining the fluid pressure distribution in an oil-based piston pump, it assumes a laminar flow which may not be applicable to water piston machines. For example, in an inclined piston/cylinder interface of a water hydraulic pump, there may be regions in the film wherein the large gap height combined with the low viscosity of water induce turbulence effects. If the traditional Reynolds equation is used in such a scenario, it is likely to overestimate the leakage flow through the interface as it does not account for turbulence. Therefore, it is important to incorporate the effect of turbulence in the diffusive terms of the Reynolds equation to accurately describe the Poiseuille flow with high Reynolds numbers. The challenge is further compounded by the micromotion and deformation of the solid body, resulting in the unevenness of the gap height in the lubricating film. Therefore, the consideration of turbulence can only be applied regionally in such cases. The current study proposes a fluid-structure interaction model with the consideration of the localized turbulent effects. This modeling approach is applied to the piston/cylinder interface of an axial piston machine that uses water as the working fluid. The approach stems from the modification of the Poiseuille term to incorporate a function of the Reynolds number. The fluid dynamics considering the turbulence effect was validated against the solution of the Navier Stokes equation using commercial CFD software. The modified Reynold equation was implemented in an axial piston pump EHL model coupled with the multi-body dynamics. The simulation results from the novel pump model were compared to a measurement and the accuracy of the proposed model was found largely improved from the traditional laminar solution. The calculated flow rate was found to be 54.6% lower with the additional consideration of the turbulence effect in the studied case.

VALVES

10:55 a.m. - 12:15 p.m.

CHARACTERISTIC AND OSCILLATION TENDENCY STUDY FOR DIFFERENT SEAT GEOMETRIES OF THE PILOT STAGE OF A TWO-STAGED PRESSURE CONTROL VALVE

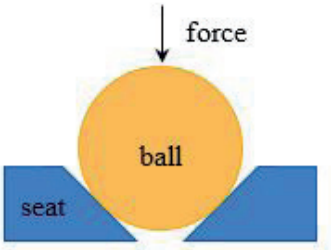
Presenter: Martin Kloetzer, Rausch & Pausch, Germany



Two-staged pressure control valves are used in various applications. The usage in semi-active shock absorbers leads to several advantages compared to orifice controlled proportional valves. However, the high dynamic operation and limited assembly space as well as an oscillation tendency requires a detailed understanding and precise layout of the valve, especially the pilot stage. This paper presents a research study of different seat geometries of the pilot stage of a two-staged pressure control valve concerning function parameters and oscillation tendency.
The pilot stage operates as a pressure relief valve with the function to achieve a specific pressure at the pilot seat. The relevant equations to describe the function is the balance of forces combined with the equations of the individual factors (e.g. flow-force). The derivation and determination is done analytically. Just a few parameters, e.g. hydraulic resistance characteristic, will be determined by numerical CFD-simulations and measurements. The relevant description is the pressure-flow-stroke-characteristic (p-Q-x). In general, the study is verified by comparison with measurements and 1D-system simulation.
For pilot stage valves as well as pressure relief valves, there are different possible geometries for the seat and the sealing edge (e.g. ball or cone poppet seat). The various geometries have different advantages and disadvantages regarding performance, stroke dependency, dynamic behaviour as well as component complexity and robustness. This paper demonstrates the impact on different poppet seat geometries regarding the listed factors above. This provides the following benefits: First, simple overview and comparison of various poppet valve concepts regarding basic function. Secondly, a detailed influence analyses of specific design parameters. Additionally, this study can easily be used or extended by the user due to the analytical approach. Finally, this study shows and explains the fundamental functionality and dependencies. This increases the knowledge and application opportunities by helping to design poppet valves.

SIMULATION OF GAS LEAKAGE ON BALL SEAT VALVES

Presenter: Felix Fischer, RWTH Aachen, Germany



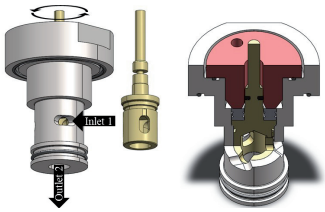
Gas leakage is a critical issue in various industrial applications that utilize ball seat valves. This is especially relevant for hydrogen applications, due to its high reactivity. This paper presents the application of a model for analyzing liquid leakage on ball seat valves applied to gases and the experimental validation of these results. The research objective is to enhance the understanding of the leakage mechanisms and provide valuable insights for improving the design and performance of ball seat valves. The simulation model considers valve geometry, surface roughness, and material properties to predict the leakage behavior accurately. The simulation method is based on the contact mechanics model developed by Persson. It considers the surface roughness via the two-dimensional spectral density. The model is validated experimentally by comparing the simulated leakage rates with experimentally measured values for seats with different surface roughness and anisotropy. This way, the validation shows whether the leakage model can be applied to gases.

VALVES

10:55 a.m. - 12:15 p.m.

DEDICATED DESIGN OF THE FLOW ANGLE OF FREE JETS FOR ROTARY SLIDE VALVES

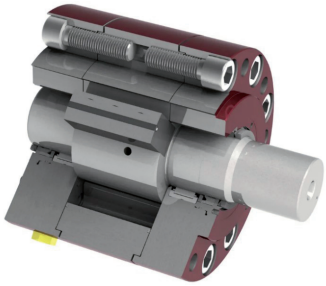
Presenter: Lennard Günther, TUD Dresden University of Technology, Germany



The paper presents a general analytical method for the determination of the flow angel in hydraulic components like valves and pumps. In this paper it will be illustrated by a rotary slide valve. The design of the flow geometry e.g. in valves depends on many influencing parameters. A suitable choice of parameters ensures that target variables such as flow characteristics, flow force, but also other effects such as cavitation and noise generation can be improved. An important parameter is the flow angle of the free jet, which forms in each valve directly downstream of the narrow section of the control edge. The resulting free jet influences the flow force as well as cavitation damage. By a suitable choice of the angle of this free jet, the flow force can be reduced by changing the direction of the outgoing impulse. With regard to cavitation, the impact of the free jet can be shifted and thus the cavitation erosion can be shifted or weakened. However, the flow angle is not always known and the influence of the parameter cannot be fully exploited. In the past, numerous elaborate experimental investigations or simulations have been carried out to improve influencing parameters on corresponding target sizes, as just mentioned. In many cases, the decisive factor is the flow angle of the emerging free jet.
This paper deals with the investigation of the flow angle of free jets as well as the technical application on the basis of rotary slide valves. In the first section, geometric factors influencing the flow angle are discussed, as well as the transferability of the results under varying operating conditions (laminar and turbulent). Using a generic minimal model, the behavior of the flow angle with respect to geometric influence factors and operating conditions is investigated by means of CFD. The results are adapted to the real application, a rotary slide valve. Direct adjustment of the flow angle results in a significant improvement in the resistance torque caused by the flow force. It becomes clear how efficient the adjustment of the flow angle can be if the basis of the formation of the free jet is known. Due to the derivation of the relationship with the help of an abstracted minimal model, the knowledge gained can be used in many ways and can also be transferred to other applications in the field of fluid technology. Optimization processes are more efficiently without using elaborated models e.g. driven by CFD.

DEVELOPMENT AND TESTS OF A HYDRAULIC SWIVEL DRIVE WITH HYDROSTATIC BEARINGS

Presenter: Lutz Müller, TUD Dresden University of Technology, Germany



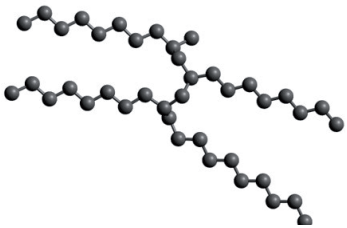
Hydraulic swivel drives from SÜDHYDRAULIK by Homrich Maschinenbau GmbH are widely used for different applications. Especially for oscillating movements with high frequencies and for integration of functions as thrust bearings, the axial load bearing capacity of the drives had to be improved. To achieve this goal, a hydrostatic thrust bearing was designed for the high load series swivel drive SP 15 D. In a first attempt, the design was focused on achieving the highest possible load at operating pressure of the swivel drive with an acceptable leakage flow. The analytic calculations were executed according to common literature, but supplemented with FEM simulations and test data to consider elastic deformations. The test of the prototype showed a good agreement with the calculation results.

TRIBOLOGY

10:55 a.m. - 12:15 p.m.

TRIBOLOGICAL DESIGN BY MOLECULAR DYNAMICS SIMULATION - THE INFLUENCE OF POLAR ADDITIVES ON WALL SLIP AND BULK SHEAR

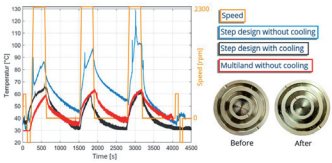
Presenter: Seyedmajid Mehrnia, Technical University of Darmstadt, Germany



This study employed Molecular Dynamics (MD) simulations to examine the tribological impact of polyalkylmethacrylate (PAMA), a polar lubricant additive known for its role as a Viscosity Index (VI) improver, when combined with the non-polar lubricant polyalphaolefin (PAO) 6. Examining the solid-lubricant interface in a confined liquid between iron surfaces with a Couette flow, the research delves into molecular interactions, emphasizing mechanisms governing wall slip for both non-polar and polar molecules. Notably, for non-polar molecules, a singularity in slip length is observed with a molecular-scale gap height resulting in an infinite slip length. However, the addition of polar additives eliminates slip, leading to increased friction. Furthermore, in terms of bulk shear, the introduction of polar additives reduces shear thinning as temperature increases. This dual observation highlights the substantial impact of polar additives on both wall slip behavior and bulk shear properties in the lubricant system.

TRIBOLOGICAL PROPERTIES OF DIFFERENT SLIPPER DESIGNS OF AN AXIAL PISTON PUMP

Presenter: Svenja Horn, TUD Dresden University of Technology, Germany



New application areas such as compact drives and displacement control using variable electric motors require that hydrostatic machines exhibit good performance also at very low relative speeds without being damaged during critical mixed friction conditions. While some pumps currently address this issue using leaded metals in their sliding bearings, European regulations (Reach Regulation) mandate the transition to lead-free materials in the near future. To address these challenges, this paper investigates about surface structures that offer the ability to selectively modify the pressure field within the fluid gap, generating additional hydrodynamic pressure. In this research project, various slipper surface structures of an axial piston pump were developed through extensive simulation studies and tested on a pump test-rig as well as on a dedicated hydrostatic tribometer.

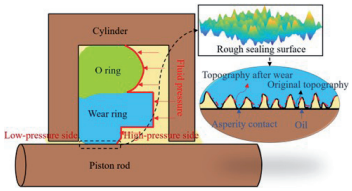
This paper outlines the development, construction, and optimization of a novel hydrostatic tribometer capable of adjusting speed, pressure, acceleration and temperature. Multiple measurements were conducted with different slipper geometries. The results encompass torque, temperature and wear measurements. They are presented along with a comprehensive analysis and validation of the findings in comparison to simulation and pump test results. In this study the tribometer revealed specific constraints not detected in pump bench tests, underscoring the imperative nature of such examinations.

TRIBOLOGY

10:55 a.m. - 12:15 p.m.

NUMERICAL STUDY ON ABRASIVE WEAR OF RECIPROCATING SEALS UNDER MIXED LUBRICATION CONDITIONS

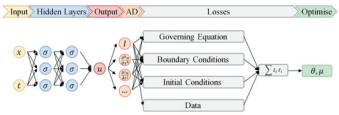
Presenter: Jiehao Wang, Tongji University, China



The reciprocating seals of the actuator are under mixed lubrication conditions, where rough peak contact and oil film lubrication coexist. The seal wear during operation has a severe impact on its sealing performance. The actual wear phenomena usually include many forms, such as abrasive wear, adhesive wear, etc. The classical Archard model based on adhesive wear theory is commonly used for seal wear analysis, while research on abrasive wear is still rare. This study establishes a three-body micro-contact model of the piston rod, abrasive and wear ring based on fractal theory and finite element simulation to analyze the contact characteristics of abrasives in the sealing separation. The influence of fractal surface parameters, abrasive size, shape, and material hardness on abrasive motion, contact, and friction stress are investigated. Next, the percolation channel model of the sealing surface is established to investigate the mechanism of topography characteristics on the leakage after wear. The calculation model and method for reciprocating seal leakage can be obtained based on percolation theory. This model and theoretical analysis aim to clarify the wear failure life assessment, full life cycle management, and anti-degradation design of reciprocating seals.

FAST COMPUTATION OF LUBRICATED CONTACTS: A PHYSICS-INFORMED DEEP LEARNING APPROACH

Presenter: Faras Brumand-Poor, RWTH Aachen, Germany



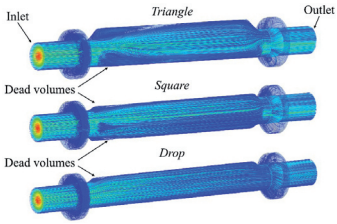
The frictional behavior of pneumatic seals determines functionality in various fluid power switching applications. Understanding the complex relationship between friction and component properties is challenging. Experimental descriptions are often infeasible due to time and cost constraints. Therefore, an elastohydrodynamic lubrication (EHL) simulation model, the ifas-DDS, was implemented to calculate the friction in translational pneumatic seals. While the EHL simulation provides an accurate solution to the underlying partial differential equations, it is computationally expensive. An approach to obtain an accelerated solution is the use of neural networks (NN). However, their main disadvantage is that they do not necessarily embed the physical mechanism underlying a particular dataset. In recent years, a new form of NN has emerged, the physics-informed neural network (PINN), which is imposed with physical laws, increasing the algorithm's accuracy. This approach offers several possibilities, e.g., extrapolation and more robust training. In this paper, a variation of the Reynolds equation, implemented in the ifas-DDS, is solved with a PINN. The complete hydrodynamic PINN (HD-PINN) framework is presented and compared to the ifas-DDS afterward. The results show the possibility of the HD-PINN framework for modeling the EHL with high speed, less to no accuracy loss, and minimal tuning effort.

MATERIALS

10:55 a.m. - 12:15 p.m.

ADDITIVE MANUFACTURING OF HYDRAULIC COMPONENTS – PRESSURE LOSS COMPARISON OF DIFFERENT SELF-SUPPORTING CHANNEL GEOMETRIES

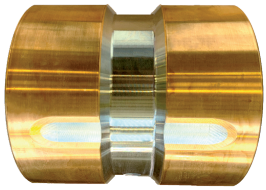
Presenter: Zita Tappeiner, RWTH Aachen University, Germany



Additive manufacturing (AM) and in particular laser powder bed fusion (LPBF) are increasingly being used as manufacturing technology in hydraulics for flow optimization, function integration and weight reduction. These advantages can especially be exploited in hydraulic manifolds. Conventional manifold intersections are created by crossing two vertical bores. The turbulence resulting from the sharp edges and the deflection leads to undesired flow losses. These can be avoided with the design freedom of LPBF, which allows flow optimization in hydraulic channels. However, the development of new channel geometries is limited by design guidelines. Starting from a straight, round channel geometry, this paper presents the steps to design self-supporting channel geometries for horizontal build up. Therefore, different cross-sectional shapes are tested, and critical design details are explained. In addition, this paper examines the influence of post-processing methods on AM components. A comparison of the different geometries is shown with a CFD simulation as well as FEM simulation for strength investigation. For experimental investigation and simulation validation, selected test specimens were printed and post-processed. With a new designed test rig, the pressure losses of the different geometries and post-processing methods were measured and a comparison with the simulative results is shown. Overall, this paper provides an overview of the necessary steps in the design of hydraulic AM components for flow optimization.

BRONZE CLADDING FOR BIMETAL PARTS PRODUCED BY LASER DEPOSITION BRAZING

Presenter: Hannes Freisse, Kugler Bimetal SA, Switzerland

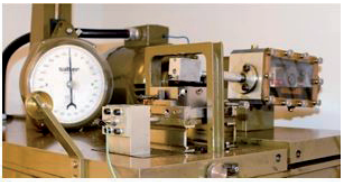


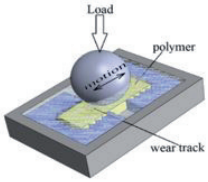
Bronze has emerged as a highly functional material for various tribological applications, owing to its diverse alloys that offer adaptable material properties for a wide range of loads. Bronze can be used as a solid material or applied as a functional layer in bi-metal components, offering a combination of the superior mechanical properties of the steel base body with the excellent tribological properties of the bronze alloy. Conventionally, bi-metal bearings are casted, a labour-intensive and material-inefficient process. Laser deposition brazing offers a potential solution to these disadvantages. However, it faces the challenge of ensuring sufficiently high layer bonding strength between the steel base body and the bronze alloy layer. This paper presents the production of bi-metal bearings through laser deposition brazing and material analysis, focusing on the development of a reliable process that ensures high-quality bonding between the steel and bronze layers.

MATERIALS 10:55 a.m. - 12:15 p.m.

ON POLYOXYMETHYLENE COMPOSITE FOR SUSTAINABLE HYDRAULIC VALVES

Presenter: Ana Trajkovski, University of Ljubljana, Slovenia





The aim of this study was to investigate the tribological properties of polyoxymethylene reinforced with carbon fibres which has proven to give comparable results to high performance polyetheretherketone, regardless their price difference. The results obtained in glycerol-water mixture were compared with the results of tests using conventional hydraulic oil and demineralised water as lubricant. The tests were performed at room and elevated temperature, as expected in hydraulic applications.
The results showed very low coefficient of friction and specific wear rate in glycerol-water mixture, comparable to the values measured in standard hydraulic oil (COF ~ 0.027 - 0.033, specific wear rate ~ 10-7 mm^3/Nm), and lower than measured in water (COF ~ 0.14, specific wear rate ~ 10-6 mm^3/Nm), at room temperature. At elevated temperature, coefficient of friction slightly increased in hydraulic oil and glycerol-water mixture, but decreased in water, and values become comparable for all lubricants. Specific wear rate significantly increased in hydraulic oil and glycerol-water mixture at elevated temperature, and became comparable to the specific wear rate measured in water. Based on results, both polyoxymethylene composite and glycerol-water mixture can be good alternative for standard hydraulic oil and steel tribo-pairs, leading towards excellent tribological properties.

SUSTAINABLE PRODUCTIVITY FOR MACHINING KEY COMPONENTS IN FLUID POWER

Presenter: Tobias Stolz, MAPAL Fabrik für Präzisionswerkzeuge Dr. Kress KG, Germany

The aim of this study was to investigate the tribological properties of polyoxymethylene reinforced with carbon fibres which has proven to give comparable results to high performance polyetheretherketone, regardless their price difference. The results obtained in glycerol-water mixture were compared with the results of tests using conventional hydraulic oil and demineralised water as lubricant. The tests were performed at room and elevated temperature, as expected in hydraulic applications.
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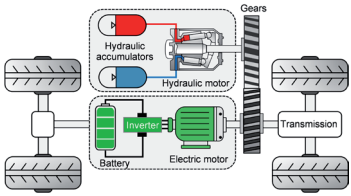
MOBILE APPLICATIONS 1:05 - 2:25 p.m.

METHODOLOGY OF SYSTEM PARAMETER OPTIMIZATION FOR PARALLEL ELECTRIC HYDRAULIC HYBRID MOBILE MACHINE VIA CONVEX PROGRAMMING

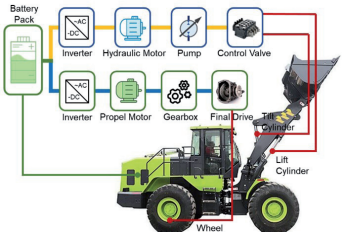
Presenter: Zichang Lin, Zhejiang University, China



Hydraulic hybrid powertrain is widely investigated for its high power density of hydraulic power system. In designing a hybrid vehicle, finding the combined optimality of component sizing and energy management is essential for minimizing vehicle costs and maximizing energy efficiency. Simultaneous optimization framework is an effective and important method due to its computational efficiency and resolution. In this paper a convex programming-based system parameter optimization framework is proposed for hydraulic hybrid vehicle. This technique allows simultaneous optimization of component sizing and energy management by converting it into a convex problem. To illustrate this, the system optimization problem in a parallel electric hydraulic hybrid wheel loader is posed over a fixed loading cycle. The Pareto front of PEHH system parameter optimization problem is obtained. The HM size is the main factor of system performance trade-off between battery aging and energy consumption. PEHH can reduce the battery capacity loss in a loading cycle by 26.4% compared to the pure electric drive with a 13.0% increase of energy consumption. With the same grid number of 7, the CP-based simultaneous method consumes 99% less computing time than DP-based bi-level method and provides the optimal solution with 1.5% less battery capacity loss.

OPTIMAL SPEED TRAJECTORY OF ELECTRIC WHEEL LOADERS AIMING AT EXTENDING BATTERY LIFETIME

Presenter: Haoxiang Zhang, Zhejiang University, China

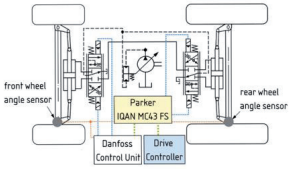


The electrification of wheel loaders is considered a leading trend due to its advantage of zero-carbon emissions. However, the inevitable phenomenon of battery degradation has led to increased battery usage and maintenance costs. This study first extends the battery lifetime by optimizing the speed trajectory based on the typical loading cycle of the wheel loader. The optimal control problem is formulated by systematically modelling the wheel loader's powertrain and using a precise semi-empirical battery aging model. To reduce computational costs, the modified optimal control problem includes a weighted penalty on travel time. A combined algorithm of dynamic programming and Brent's method (DP-BM) is introduced to provide a numerical solution to the optimization problem with a reduced computational burden. Simulation results demonstrate that the optimized trajectory can decrease the average power consumption of the battery and reduce the number of full equivalent cycles, resulting in a 4.48% improvement in the average battery lifetime compared to the typical trajectory. Furthermore, the proposed approach significantly reduces computation time compared to the conventional dynamic programming method, with an average reduction of 95%.

MOBILE APPLICATIONS 1:05 - 2:25 p.m.

CONTROL OF REAR-WHEEL STEERING FOR A FOUR-WHEEL STEERED AGRICULTURAL STANDARD TRACTOR

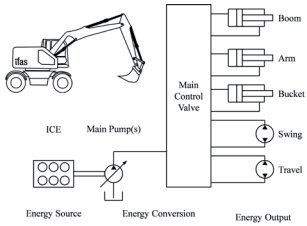
Presenter: Ruben Hefele, Technische Universität München, Germany



Steering is crucial for automation in agriculture. Four-wheel steered tractors are better suited for highly automated agricultural machinery compared to front-wheel steered tractors. Common tractors with four-wheel steering have equal large tire diameters on the front and rear axles. In comparison, this study uses a standard tractor, which means that the tires of the rear axle have a larger diameter than the tires of the front axle, thus significantly affecting the rear-axle steer control. An off-the-shelf front-wheel steering system is used, while the rear-wheel steering control is built from scratch. Steady-state accuracy and fast convergence are the control objectives. A double-acting differential cylinder is used as a steering actuator, supplied by a current controlled proportional directional valve with feedback from an angle sensor. The tractor's load sensing variable displacement pump provides hydraulic power. A SIL2 functional safety variant electric control unit with redundancy is used for the rear-axle controller. In-vehicle network communication is via CAN bus based on SAE J1939. System identification and modelling of the steering system are carried out, followed by controller setup and tuning using first order lag plus integrator plus delay rules while considering dead-zone and valve saturation. Further on, this paper introduces two novel controller designs, utilizing gain scheduling and model-based state space control techniques, which lead to enhanced performance.

AUTOMATED SYSTEM SYNTHESIS FOR ELECTRIFIED MOBILE MACHINERY

Presenter: Bernhard Sender, RWTH Aachen University, Germany



The electrification of mobile machines leads to new drive solutions. Not only the electric drive components are newly deployed, but also the mechanical and hydraulic drive components can be utilized in a new or different way. This allows more efficient systems to be built and new advantages to be exploited. Conventional development processes require the developer to select a specific drive concept to be investigated at an early stage. The drive concept is then examined by means of simulations and/or experimental tests. The suitability of the drive system for the application is only evaluated after its detailed investigation and an iterative process. The overall process leads to a high effort and requires a large amount of time. Thus, it is economically not possible to evaluate many different system combinations with conventional methods. This paper proposes a tool to improve the development process. A methodology for an automated drive system evaluation is presented both structurally and in terms of how individual components are modelled. The methodology aims to deduce functioning system topologies based on load cycles. An analysis on the influence of different load cycles is therefore conducted.

PUMPS 1:05 - 2:25 p.m.

PREDICTIVE MAINTENANCE FOR AXIAL PISTON PUMPS: A NOVEL METHOD FOR REAL-TIME HEALTH MONITORING AND REMAINING USEFUL LIFE ESTIMATION

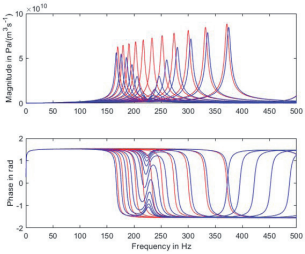
Presenter: Anik Kumar Samanta & Shrinivas Kulkarni, Danfoss Technologies Private Limited, India

In this paper, a novel method to estimate and predict the condition of an open circuit piston pump is presented. We introduce the concept of the 'Pump health index' which can assess the health of the pump in real time and use it to estimate the remaining useful life of the pump. The solution is agnostic to pump size, make, and application duty cycle. The solution has been tested with different levels of degradation that were simulated on the physical pump. The algorithms were implemented on multiple embedded platforms to illustrate the agnostic nature of the developed technology.

A NOVEL PULSATION COMPENSATOR FOR DISPLACEMENT MACHINES

Presenter: Gudrun Mikota, Johannes Kepler Universität Linz, Austria

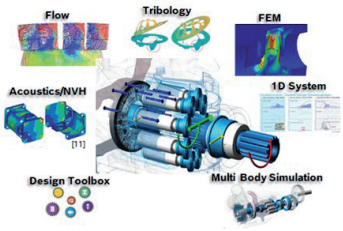
This paper presents a mechanical compensator for hydraulic pressure pulsations induced by a pump or motor. The compensator is based on the combination of pump or motor mass moment of inertia and the torsional compliance of the adjacent coupling. According to the displacement volume, angular deflections of the resulting oscillator correspond to volumes which can compensate for geometric or dynamic pulsations at the natural frequency of the oscillator. Two design concepts are suggested for the coupling. Three models are set up for various configurations of the overall system, accounting for limited inertia of an electric motor and the influence of an outlet pipeline. Model parameters are determined for a 32 ccm radial piston pump and a 250 ccm axial piston pump. Torsional damping from viscous friction is roughly estimated and considered by different levels. At the pump outlet, frequency response functions between flow rate excitation and pressure response are calculated. The results show that the compensation effect is relevant for both pumps and particularly robust with respect to resonances in the hydraulic system.



PUMPS 1:05 - 2:25 p.m.

PRACTICAL REVIEW OF RELIABILITY METHODS COMBINED WITH VIRTUAL VALIDATION TECHNIQUES TO SHIFT LIMITS OF TODAY'S HYDROSTATS

Presenter: Stefan Haug, Bosch Rexroth AG, Gemany



Ensuring sufficient technical reliability is a key factor in the market success of industrial products. However, for the off-highway industry, especially for battery-powered vehicles, the constant trend towards higher power densities of fluid-mechatronic components means an increase in component loads and a reduction in the necessary reliability reserves. To improve key performance indicators such as speed range and pressure limits, while considering the required performance level, deep technical understanding must be systematically transferred into new designs and software.

Innovative hydraulic pumps with modern electronic controls increase mobile machine productivity and reduce energy consumption simultaneously. By utilizing high-end multiphysics simulation within a design for reliability (dfr) approach, it is possible to achieve a robust design for stability at high dynamics using only electronic feedback from a swivel angle sensor signal, without mechanical feedback. Additionally, it is possible to achieve much smoother operation, especially at the beginning of the actuator movement.

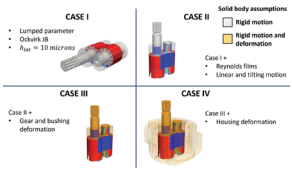
Ensuring the benefits of variable pumps and meeting new system requirements, such as high speed and low speed levels with high torque, is becoming increasingly relevant, especially for electrically driven machines. By employing leading-edge simulation of flow fields, cavitation, and thermo-elastohydrodynamics, it is possible to meet these challenging demands.

The overall goal is to make the best possible use of the machine-specific operating limits by ensuring reliability and considering the load/stress on the hydraulic components. This holistic approach has been proven through the first serial system validations.

PUMPS 1:05 - 2:25 p.m.

A STUDY ON THE EFFECTS OF BODY DEFORMATION ON THE PERFORMANCE OF EXTERNAL GEAR MACHINES

Presenter: Ajinkya Pawar, Purdue University, USA



The energy efficiency of external gear pumps (EGPs), similar to all positive displacement machines used for high-pressure applications, is significantly influenced by the power losses occurring in the lubricating interfaces that seal the internal displacement chambers. Therefore, it is crucial to account for these interfaces accurately, when developing predictive simulation tools. However, the literature has suggested various modelling approaches for EGPs, with different assumptions regarding the analysis of these interfaces. This makes it challenging for a designer or a researcher to determine what are the essential physical domains needed for properly modelling the lubricating interfaces and assess the EGP performance.

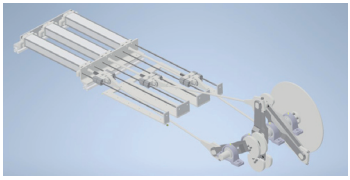
This paper addresses the above research question by leveraging a comprehensive simulation tool (Multics-HYGESim) developed by the authors' research team to compare the effect of different modelling assumptions. HYGESim includes tribological considerations pertaining to the meshing of the gears, the lubricating films at the tooth tip interfaces, at the journal bearings, and at the lateral interfaces. It also considers realistic fluid properties, including the effects of cavitation and aeration, mixed lubrication effects, as well as material deformation effects for the gears, lateral bushings and the EGP housing. Deformation of the internal parts of an EGP is related to the internal balancing features and it is strongly coupled with the instantaneous pressurization of the pumping volumes. For this reason, a realistic quantification of these effects is difficult in simulation.

Using a commercial EGP design as a reference, with known experimental volumetric and hydro-mechanical efficiency, this paper demonstrates how predictions can vary based on different simulation assumptions regarding body and lubricating film behaviours. Results are discussed starting from a basic rigid-body assumption that considers only body motion and analytical formulations of lubricating interfaces, to simulation model cases of progressively increasing in complexity to account for deformations of gears, bushings and housing. The results show that consideration of deformation effects allow more accurate prediction of power losses and efficiencies of the pump while simulations carried out without deformation considerations approximate the leakages and the power losses at the lateral lubricating interface though can predict the fluid dynamic performance. These findings will offer valuable insights to EGP designers, enabling them to understand the strengths and limitations of different modeling assumptions on the prediction of EGP behavior, especially regarding the effects of body deformation.

NEW AND SPECIAL APPLICATIONS 1:05 - 2:25 p.m.

DEVELOPMENT OF RECIPROCATING AIR EXPANDER FOR μ -CAES TECHNOLOGY

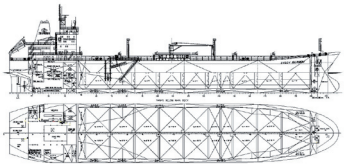
Presenter: Jan Markowski, AGH University of Science and Technology, Poland



As renewable energy sources (RES), such as solar and wind, continue to grow in the energy mix, it becomes crucial to address their inflexibility and daily demand-production gap. Energy storage is vital, allowing storage during low demand and supplying power when needed. The authors investigated compressed air energy storage (CAES) as a mechanical solution, focusing on micro-CAES (μ-CAES) for smaller industries or housing estates. This research aimed at optimizing μ-CAES efficiency through modifications to the air expander's construction (piston parameters) and process parameters (air pressure, temperature). Initial results with a 3-cylinder expander showed an average power of 2.2 kW and 0.45 efficiency. Further enhancements, such as compressed air supply control and waste heat utilization during expansion expects to affect on increase of efficiency to 0.8.

SHIP BALLASTING PROCESS TIME CALCULATION WITH USE OF SUBMERGED BALLAST PUMPS WITH HYDRAULIC DRIVE SUPPLIED FROM CONSTANT PRESSURE HYDRAULIC CENTRAL LOADING SYSTEM ON MODERN PRODUCT AND CHEMICAL TANKERS

Presenter: Andrzej Banaszek, West Pomeranian University of Technology Szczecin, Poland

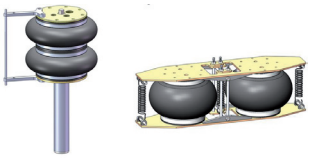


Ballast systems are among one of the most important installations installed on board modern product and chemical tankers. They have a significant impact on the safety of the ship by determining its stability on the sea wave and the strength of the hull. Logistically, the efficiency of these systems is crucial in planning the loading and unloading times of a given tanker. Due to the explosion-hazardous zone, ballast pumps of the submersible type are often equipped with hydraulic drive. The purpose of the article is to present a methodology for calculating the time of ballasting process of a modern chemical tanker and the flow control of submerged ballast pumps with hydraulic drive, supplied from the hydraulic constant-pressure central loading system. The results of the calculations are important for the correct determination of the liquid cargo loading time of a tanker at the fuel terminal, the organization of the logistics and service system for the ship and for the entire loading port. In addition, the paper presents the construction of a submersible ballast pump with hydraulic drive with a description of the hydraulic system installed on board a modern tanker. The methods of controlling the flow of submerged ballast pumps are described, along with a new concept of using constant torque regulators to control the pump flow. Experimental results and theoretical calculations are presented.

NEW AND SPECIAL APPLICATIONS 1:05 - 2:25 p.m.

COMPARATIVE ANALYSIS OF PERFORMANCES OF NON-METAL PRESSURIZED RESERVOIRS WITH VARIABLE VOLUME

Presenter: Dingyu Wang, Yanshan University, China

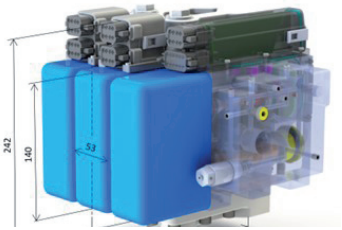


The lighter weight of hydraulic reservoirs can improve the power-to-weight ratio of hydraulic equipment and reduce power consumption, achieving energy conservation and emission reduction. In this study, three types of non-metal pressurized reservoirs with variable volume (VVPR) are designed and manufactured. Among them, a single-layer configuration is the basic functional prototype. Firstly, the structure of VVPR is designed to meet the differential volume compensation by its variable volume in an asymmetric hydraulic cylinder system. Then, series and parallel configurations are proposed based on the basic prototype. Finally, a test bench is built to test the step and sine response performances of the VVPR. The response time of the reservoir is not affected by the step amplitude of the hydraulic cylinder changes, with an average response time of 0.028 s. In addition, the lag time of the single-layer reservoir is the smallest in the sine test, which is 0.11 s. Through comparative analysis, the configuration of the series reservoir is more compact and can get more pressure. Parallel reservoir can get greater variable volume with the same displacement change. It provides an alternative solution for lightweight hydraulic systems in the future.

INDEPENDENT METERING IN MOBILE APPLICATIONS 2:50 - 4:00 p.m.

COMPACT FLUID POWER CONTROL UNIT WITH INDEPENDENT METERING

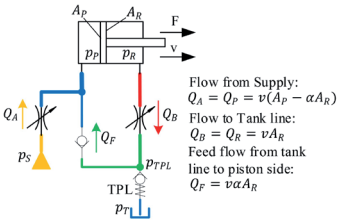
Presenter: Mathias Niebergall, University of Applied Science Ulm, Germany



Various requirements on fluid control applications, such as increasing power, energy efficiency, system safety and installation space restrictions, require new customized technological solutions on a system level. Independent meter-in and meter-out control edge arrangements with aligned electronic network and software solutions provide the freedom for the design of intelligent overall fluid control systems. The focus of the paper presented is the development of a new fluid control unit, that meets the following requirements: high power based on a maximum pressure level > 500 bar and a flow rate of up to 200 l/min, an appropriate valve stroke, valve speed, and installation space according to the specification. The fluid control unit presented has independent control edges actuated by a step motor, and a compact pilot control solution. On system level the modelling and simulation of an excavator implement drive has been carried out by means of a typical operating cycle. Firstly for a throttle system with conventional linked control edges and already with a customized load sensing pump control. Secondly for an optimized throttle system with independent metering, hydromechanical flow sharing, a customized load sensing pump control, and with an electronic control of the regeneration circuit. The comparison of the simulation results of both system variants shows already an excellent reduction of the energy consumption of 20% for the optimized implement drive system.

COMPARISON OF STRATEGIES FOR UNNOTICEABLE MODE SHIFTING IN MOBILE INDEPENDENT METERING SYSTEMS

Presenter: Jan Lübbert, TUD Dresden University of Technology, Germany

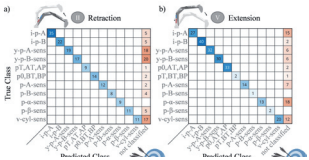


Independent Metering (IM) offers great potential to improve the energy efficiency of hydraulic systems. This is especially important in mobile applications due to the limited capacities of electric accumulators, which will probably become the primary energy source in many applications in future. One energy saving mechanism of IM are regenerative operation modes. In many applications, the load direction changes during an ongoing movement. In these cases, regenerative modes are feasible only if there is a way to shift unperceivably between the modes while moving. In this paper, four different mode-shifting techniques are described and compared on an excavator-arm test rig. These are continuous shifting with three active valves (CSA) or with two active valves and a passive path (CSP), and discrete shifting with a pressure compensator (DSMR) and without one (DS). It will be shown, that unnoticeable mode shifting is possible using serial production mobile hydraulic components – either continuously with a low-pressure regenerating valve layout comprising simple check-valves, or fast and discrete using a pressure compensator.

INDEPENDENT METERING IN MOBILE APPLICATIONS 2:50 - 4:00 p.m.

FAULT LOCALIZATION FOR INDEPENDENT METERING SYSTEMS BY MODEL-BASED FAULT DETECTION

Presenter: Eric Fischer, TUD Dresden University of Technology, Germany

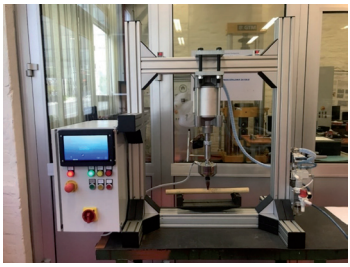


This paper deals with fault localization for a mobile hydraulic system with independent metering, but it is also applicable to other hydraulic systems. The basis for this contribution is a model-based fault detection, which generates multiple symptom patterns for various component failures using a set of parity equations (see previous publications from the authors). The symptom patterns are evaluated through different classification methods such as geometric, statistical, and artificial intelligence methods. The evaluation focuses on simple approaches that are applicable in practice. Taking into account the limitations of mobile systems, different operating points, and a variety of fault scenarios, a correct fault localization of up to 92% of detected faults is possible. After locating faults correctly, IM systems enable a range of reconfiguration modes to keep the machine's functionality and therefore rise the availability. Laboratory demonstrator tests confirm the simulation-based outcomes.

SUSTAINABLE PNEUMATICS 2:50 - 4:00 p.m.

CONTROL OF A PNEUMATIC SYSTEM FOR MATERIAL STRENGTH TESTING

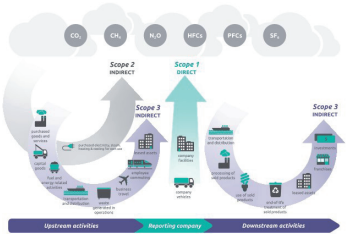
Presenter: Željko Šitum, University of Zagreb, Croatia



The article describes a prototype device for testing the dynamic stress of materials with the intention of analysing the fatigue behaviour of the materials. A pneumatic cylinder controlled by a proportional pressure regulator is used to achieve the required force. The experimental set-up consists of structural elements with pneumatic components, then a control system with a Controllino device and HMI interface, and the measuring system composed of a dynamometer with an amplifier characterized by high accuracy and sampling frequency characteristics. With this system, it is possible to work in both compression and tension ranges. The basic parameters of the process were identified, then the control-oriented dynamic model of the system was derived, and the synthesis of the PID controller was made for more precise following of the sinusoidal reference signal. Compared to hydraulic solutions that are used to achieve large forces, this pneumatic fatigue testing machine has a compact design, the desired reference is simply set via the HMI interface, it is portable, and it can be used to test materials with lower tensile strength.

PRODUCT CARBON FOOTPRINT OF HYDRAULIC AND PNEUMATIC COMPONENTS – CHALLENGES IN ACCOUNTING AND COMPARABILITY

Presenter: Johannes Sprink, RWTH Aachen University, Germany

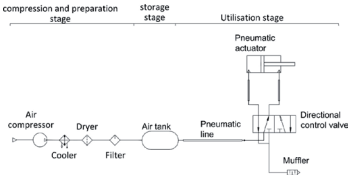


To achieve global climate protection goals, a reduction of greenhouse gas emissions is necessary. Accordingly, emissions from technical products such as fluid power components must be known over the entire Product Life Cycle. The Product Carbon Footprint (PCF) is used to systematically record the greenhouse gas emissions of a product.
For the calculation of a PCF, for each step in the life cycle, the inputs of material and energy have to be identified and analyzed. Within the context of a cradle-to-gate analysis, the focus is on the production phase and upstream processes. In a previous study carried out by the authors, a variety of fluid powered components were evaluated in regards of their greenhouse gas emissions during the production. Challenges that can arise in such accountings are presented in this paper. For example, in many cases the use of database factors is unavoidable due to the lack of primary data. However, determining of exact factors poses a problem that cannot be neglected. It is shown that even with similar preconditions extreme deviations in the results can occur. Examples for such results will be presented and explained.
Conclusions are drawn that may also be helpful when accounting products. Furthermore, recommendations are presented on how to deal with the calculation results of third parties.

SUSTAINABLE PNEUMATICS 2:50 - 4:00 p.m.

EXERGY ANALYSIS FOR THE INTERMITTENT AIR SUPPLY IN PNEUMATIC MACHINES

Presenter: Dominik Gryboś, AGH University of Krakow, Poland

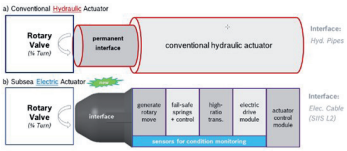


Pneumatic systems are widely used to automate production lines in manufactured plants. Their big disadvantage is their low energy efficiency, 10-20%. It is mainly due to the overconsumption of compressed air by the oversized pneumatic actuator and other components. Reducing air consumption at the utilisation stage can result in significant exergy savings. This can be done by lowering the supply pressure, introducing back pressure, or using expansion energy in the actuator. The most promising is the last method that can be implemented using the intermittent air supply in the pneumatic actuator. The literature lacks an exergy analysis of the utilisation stage of pneumatic and intermittent air supply systems. There is also no optimisation of the control algorithm of intermittent air supply control algorithm in terms of minimising exergy consumption. In this paper, we demonstrate a mathematical model and exergy analysis as a tool for assessing the efficiency of the utilisation of pneumatic system and conduct computer simulation. Exergy analysis showed that for intermittent air supply the reduction in exergy consumption decreased by more than 60% compared to the classic oversized system. The results of the computer simulation give the opportunity to optimise the operation of the utilisation stage in pneumatic systems. Furthermore, exergy analysis can be a useful tool for energy analysis and assessment of pneumatic systems, as well as providing information on the desired direction of changes in the installation.

NEW AND SPECIAL APPLICATIONS 2:50 - 4:00 p.m.

DIGITAL REDUNDANCE FOR COMPACT SUBSEA ELECTRO-HYDROSTATIC ACTUATORS USING SENSOR FUSION

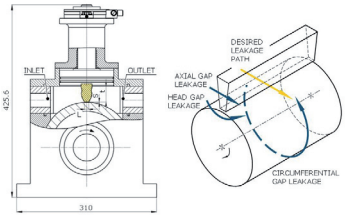
Presenter: Joao Pedro Duarte da Silva, Bosch Rexroth AG, Germany



Compact electro-hydrostatic actuators (EHAs) offer a promising solution for subsea production with their cost-effective and energy-efficient design, combining the benefits of electromechanical and electro-hydraulic systems. However, adapting these compact EHAs to fit within the limited space of traditional subsea systems poses a challenge, particularly in maintaining system reliability. This study introduces a Digital Twin (DT), composed of a physical EHA model and multiple Kalman Filters for parameter estimation, aimed at creating digital redundancies for critical sensors. The effectiveness of this approach was validated using co-simulation with Dymola software, where a simulation model emulated both the Plant (Real Twin), as a Modelica model, And a mathematical model as a software object (Digital Twin). The results demonstrate reliable digital redundancies for position and load measurements, with minor deviations that are within acceptable limits.

DEVELOPMENT OF A GENERIC TEST RIG FOR THE DETERMINATION OF THE INFLUENCE OF NON-NEWTONIAN FLUID PROPERTIES ON THE LEAKAGE CHARACTERISTIC OF ROTATING DISPLACEMENT PUMPS

Presenter: Pascal Moor, Technische Universität Darmstadt, Germany



The efficiency of rotating displacement pumps is mainly influenced by internal leakage. When designing the pumps for Newtonian fluids, the manufacturers report satisfactory quality of predictive models. For the non-Newtonian fluids however, there are no suitable models that allow the manufacturers to predict the pumps behaviour or efficiency. Many of the manufacturers try to estimate the efficiency for non-Newtonian applications with their well-established models, which have however been developed specifically for Newtonian fluids. The efficiency is therefore overestimated by a significant amount. Especially non-Newtonian fluids with pseudoplastic and viscoelastic properties are of interest since the overlap of these properties has not been well researched. The most important blind spots in literature are the impact and interdependency of the moving boundary within the sealing gaps and the contraction flow for this type of fluid. The Chair of Fluid Systems addresses these blind spots with the development of a test rig for generic studies of the gap flow representative of the characteristic sealing gaps within pumps. The test rig is characterised by its modular construction which allows the efficient investigation of geometric gap parameters and fluid properties.

NEW AND SPECIAL APPLICATIONS 2:50 - 4:00 p.m.

SELF-SENSING MICROPUMP WITH GAS BUBBLE DETECTION FOR IMPROVED DOSING RELIABILITY

Presenter: Kristjan Axelsson, Fraunhofer EMFT, Germany

In micro-dosing system gas bubbles are a common source of dosing errors, by adding sensors to detect these the complexity and costs of the system increases. This paper introduces a novel approach for piezoelectric micropumps to detect gas bubbles without the usage of additional sensors like pressure or medium sensors. The proposed approach uses artificial intelligence (AI) methods directly implemented onto the micropump's high voltage driver circuit. The AI-methods are trained on a dedicated testbench, demonstrating successful gas bubble detection without increasing system costs and complexity and without the usage of additional sensors. This technology enhances dosing accuracy to ensure safer and more reliable micro-dosing applications.

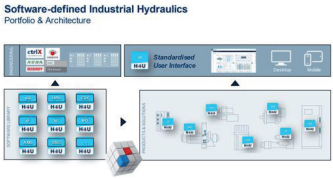
CONFERENCE

WEDNESDAY, 20TH OF MARCH

INDUSTRIAL CONTROL STRATEGIES 11:15 a.m. - 12:45 p.m.

SOFTWARE DEFINED INDUSTRIAL HYDRAULICS

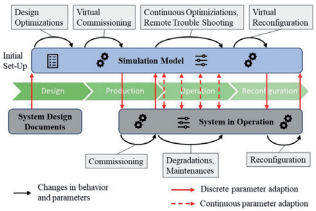
Presenter: Mark Krieg, Bosch Rexroth AG, Germany



While in the past the customer's experience of the hydraulic solution was primarily defined by hardware, software is now taking on a much more important role. This trend of software massively shaping the customer experience and, in some cases, even the specification of the hardware is referred to as the "software-defined industrial hydraulics". This evolution not only affects development and operation, but also makes new business models and types of collaboration possible.
Thus, the next step in digitalization is to decouple software solutions from their hardware and unify them into an open and modular software platform for hydraulics. Using the principles of software development, hydraulics know-how can be encapsulated in hardware-independent software building blocks that can handle the wide variability of hydraulics systems in a compact manner.
In order to shape this transformation towards software-centricity, it is important to proceed incrementally and iteratively. The advantages of this change, such as continuous optimization and the possibility of updating and upgrading machine functions, will be demonstrated using specific examples.

SEAMLESS INTEGRATION OF DEVICE AND FIELD DATA INTO THE SYSTEM SIMULATION OF A HYDRAULIC SERVO-PRESS USING AAS

Presenter: Malte Becker, RWTH Aachen, ifas, Germany



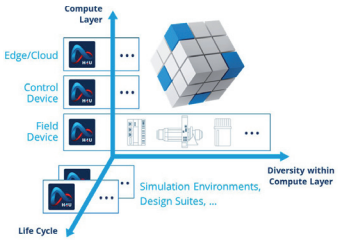
This contribution presents a framework for improving the simulation-based development process relying on seamless data and parameter exchange between general types of components, physical components of a specific system and the respective simulation model. The proposed solution relies on the concept of the Asset Administration Shell (AAS) to leverage the availability and interoperability of the heterogenous assets and to access their proprietary properties. Therefore, three AAS-based solutions are introduced to integrate different asset kinds. They represent component type data and simulation models provided by the component supplier, simulation models of components instantiated in a local simulation environment, and real components in operation with different communication interfaces. The solutions are implemented in a framework and demonstrated successfully through different simulation-based engineering use-cases using a servo-hydraulic press as a reference system.

INDUSTRIAL CONTROL STRATEGIES 11:15 a.m. - 12:45 p.m.

DEVELOPMENT OF AN OPEN AND MODULAR PLATFORM FOR HYDRAULICS TO INCREASE PRODUCTIVITY AND FLEXIBILITY

Presenter: Marco Genise, Bosch Rexroth AG, Germany

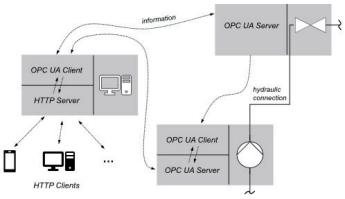
This document describes the challenges and solution strategy for decoupling software solutions that implement hydraulic control functions from their hardware and unifying them into an open and modular software platform for hydraulics. The challenges we identified primarily concern the software engineering domain, which may be surprising since our starting point and even the resulting software building blocks are all about controlling hydraulic systems. Thus, the key solution elements are based on software engineering principles: computer hardware abstraction and model-based software development.



PHYSICAL IMPLEMENTATION OF A DISTRIBUTED, AGENT-BASED CONTROL FOR FLUID SYSTEMS USING OPC UA

Presenter: Tobias C. Meck, Technische Universität Darmstadt, Germany

Conventional control strategies for fluid systems often rely on local control of the system's components, like pumps and valves. Here, communication between the control units is non-existent, which can have a negative impact on the energy efficiency. Distributed control is a promising alternative where so-called agents are assigned to components. These agents are autonomous units with individual goals. They can perceive and influence their environment through sensors and actuators. Furthermore, they are able to share information with each other. This leads to an increased energy efficiency while maintaining the positive aspects of local control, such as a low implementation effort and high robustness. The concrete methods are the subject of current research and are typically only verified in simulations. For a thorough evaluation and broad acceptance in industry, an assessment of the methods when facing real systems is crucial.

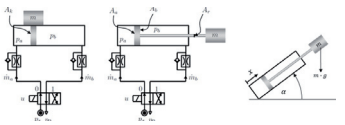


In this work, we therefore focus on the physical implementation of distributed control. We examine a simple fluid system with a centrifugal pump and a valve. A valve agent measures its volumetric flow rate and communicates this information to a pump agent via Wi-Fi and OPC UA. The pump agent has the goal of achieving a target flow by using a PI controller and adjusting the rotational speed. The results are promising and easily scalable to more complex systems and control methods.

PNEUMATICS 11:15 a.m. - 12:45 p.m.

SIZING OF PNEUMATIC DRIVES UNDER ENERGY EFFICIENCY ASPECTS

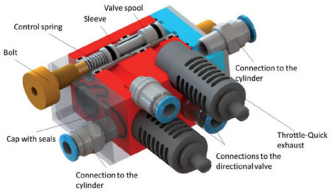
Presenter: Matthias Doll, Festo SE & Co.KG, Germany



The correct sizing of pneumatic drives plays a central role when it comes to energy efficiency. While there are simple design formulas for force-based tasks such as pressing or clamping in order to size the drive efficiently, there is no such easy methodology for motion tasks.
Up to now, the sizing of pneumatic drives has mainly been experience-based or simulation-based. A tool from Festo now enables formula-based sizing without simulation, which directly provides the optimum piston diameter and other components. The approach behind this is based on the natural frequency of the pneumatic drive.
The main drawback of this method is that it is only applicable for horizontal installation positions. Based on more recent findings (which arose in a joint project with the TU Dresden) and based on numerous simulations and measurements, this formula has now been extended so that it can also be used with external forces and thus also for a vertical installation position.

FEASIBILITY STUDY AND EXPERIMENTAL VALIDATION OF A NOVEL COMBINED THROTTLING APPROACH

Presenter: Christian Reese, RWTH Aachen University, Germany

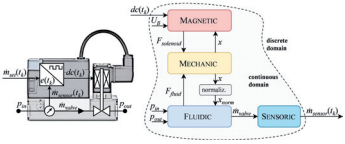


In the field of pneumatic automation, downstream throttled pneumatic drives are commonly used for motion tasks due to their cost-effectiveness, durability, and robustness. However, this type of system is often regarded as being inefficient. Consequently, many researchers have focused on developing more efficient control strategies. This paper presents the results of an experimental investigation of three distinct pneumatic circuits: a novel combined throttling approach, the control by a commercially available downstream throttle with quick exhaust function and conventional downstream throttling. A metric for comparing energy savings adjusted to changes in cycle time is introduced for objective evaluation. The findings highlight a significant reduction in normalized air consumption with the novel circuit compared to both state of the art control schemes.

PNEUMATICS 11:15 a.m. - 12:45 p.m.

REINFORCEMENT LEARNING BASED PID CONTROLLER DESIGN FOR MASS FLOW

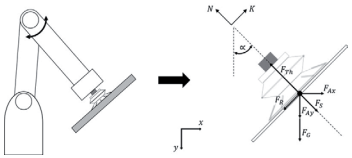
Presenter: Moritz Allmendinger, Bürkert Fluid Control Systems, Germany



This paper demonstrates a model-based control synthesis strategy based on artificial neural networks and reinforcement learning. For this purpose, both the determination of the systems' response as well as the training of the neural network are transferred to a virtual environment. The neural network acting independently but interacting with a conventional PI controller, is optimized in order to achieve the predefined control target. The definition of the control target and the evaluation of the control response are compared with each other in the time domain enabling a flexible integration and adaptation to a wide range of possible requirements. The results illustrate the feasibility of control synthesis based on a virtual trained neural network. Considering variations and uncertainties for the control target and the environment, the neural network should become more robust and suitable for real systems with inherent deviations between each other.

A TRAJECTORY-SPECIFIC APPROACH FOR CALCULATING THE REQUIRED HOLDING FORCE FOR SURFACE GRIPPERS

Presenter: Tobias Eberhardt, University of Stuttgart /J. Schmalz GmbH, Germany

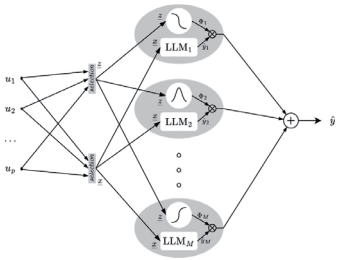


With increasing demands on the productivity and efficiency of manufacturing plants and rising energy costs, manufacturers of components and systems in industrial automation must also ensure that their products are used to their full potential in the intended application. This applies to automated handling with vacuum handling systems too. The energy consumption of such systems is highly dependent on the required holding force. In industrial automation, the required holding force is calculated from a few discrete positions of the surface gripper and the gripping object from the handling process. These positions are called load cases. However, the continuous transition between the kinematic positions of the individual load cases is not observed. The new approach presented in this paper allows an accurate calculation of the holding force required in the transition position when moving along a trajectory. Based on this new approach, the energy consumption of the vacuum handling system can be reduced. A validation with several experiments show good results.

CONTROL 1:45 - 3:05 p.m.

ONLINE LEARNING OF CYLINDER VELOCITY CONTROLLERS FOR EXCAVATOR ASSISTANCE FUNCTIONS USING LOCAL MODEL NETWORKS

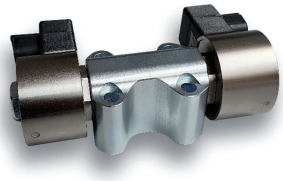
Presenter: Ozan Demir, Robert Bosch GmbH, Germany



This contribution introduces a data-based modeling approach using Local Model Networks for the online learning of cylinder velocity controllers that are applied for the realization of excavator assistance functions like reference tracking of the tool center point (TCP).
Even without any individual machine data, just using available data from a similar machine or expert knowledge, we can design an initial controller that is adapted during operation to improve the controller performance and to allow for automatic controller calibration. This allows for a significant reduction of manual machine commissioning efforts while ensuring the required accuracy of the assistance functions.
In general, changes in the system behavior over machine lifetime could be compensated with our approach.
To show the effectiveness of the proposed strategy, we have applied the proposed machine learning method to a hydraulic excavator. The data-based controllers are adapted online using a rapid-prototyping system and are sufficiently fast to be implemented on a standard control unit. The control performance is comparable to traditional approaches while drastically reducing the time and effort for calibration.

VALIDATION OF A HYDRAULIC PULSE CONTROLLER ON AN OFF-HIGHWAY MACHINE

Presenter: Marvin Schell, Andreas Lupold Hydrotechnik GmbH, Germany

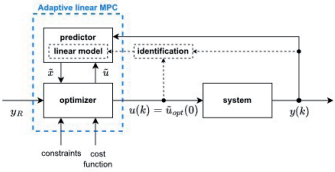


There are different ways of controlling hydraulic variable displacement pumps, mostly the choice of control depends on the application and the respective requirements. With a focus on open circuit off-highway applications, the classic control structures such as pressure cut-off, load sensing, positive or negative flow control or power control are standard. The design of these controllers is usually the responsibility of the pump manufacturer and is often solved purely hydraulically. With the current trends, such as connectivity and increased efficiency of systems, a development into electrically actuated pumps becoming apparent. The preferred technology for this is usually a modified or improved version of the mechanical controller. Using proportional technology for oil flow control of the control system of a pump is one possibility but does not use the entire potential of an intelligent and efficient pump. With the approach of system optimization, a new controller based on two independent digital valves was already presented at the IFK in 2022. This hydraulic pulse controller (HPC) has since been developed further and a system comparison with different pumps has been tested on a modified test rig. In addition, its suitability for controlling an application was tested as part of a proof of concept on a real working machine. Furthermore, the development is now focused on the definition of this as a new smart subsystem and optimal system integration into existing architectures.

CONTROL 1:45 - 3:05 p.m.

MODEL PREDICTIVE CONTROL OF ELECTRO-HYDRAULIC SYSTEMS WITH MULTIPLE DEGREES OF FREEDOM

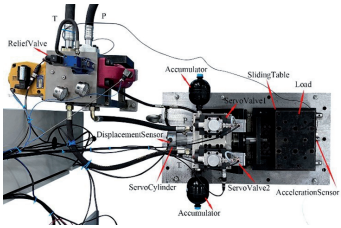
Presenter: Thomas Sendelbach, Bosch Rexroth AG, Germany



Modern hydraulic drives have an ever-increasing power density and robustness, however they become more and more complex in their design and control. In many systems, there is the possibility of using an overdetermination of system control inputs to optimize the operating strategy for energy efficiency or tracking error. Many applications are still largely based on empirical and hard coded rules. More advanced methods are using offline optimization algorithms to calculate an optimized trajectory for more than one manipulated variable for a given command trajectory. However, this approach leads to a lack of robustness and flexibility if model equations are not exact enough, real time control is required or the operating point changes. Traditional algorithms lack in standardisation and scalability which is also crucial for success in the industry. To overcome the disadvantages of rule based or offline optimization methods this paper presents the fundamentals and the application of Model Predictive Control (MPC) with respect to electro-hydraulic drives. Furthermore, possibilities are described to make advanced algorithms economically transferable into series production.

DATA-DRIVEN VIBRATION CONTROL STRATEGY FOR HYPERGRAVITY CENTRIFUGAL SHAKING TABLE

Presenter: Zhu Yang, Zhejiang University, China

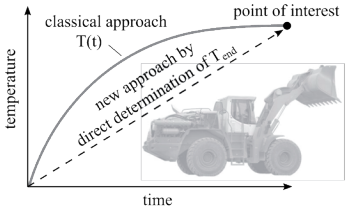


The hypergravity centrifugal shaking table is widely used in the field of civil engineering, which has the scaling effect and is the most effective means of studying the disaster effect of geotechnical earthquake. The compound control of hypergravity centrifugal shaking table is mainly composed of two parts: position servo control and acceleration vibration control. The position servo control is used to ensure that the shaking table works in a safe working area, and the acceleration vibration control is helpful to further improve the seismic wave reproduction ability of the shaking table. Due to the complexity and diversity of the working conditions of the shaking table, it is proved that under the premise of robust position loop control, the vibration control strategy of the acceleration ring of the hypergravity centrifugal shaking table based on the data-driven idea can effectively improve the vibration control accuracy of the hypergravity centrifugal shaking table. At the same time, the vibration control strategy is only based on the current working state of the shaking table. Therefore, It has stronger adaptive control ability.

SYSTEM DESIGN AND ARCHITECTURE 1:45 - 3:05 p.m.

EFFICIENT MODEL-BASED THERMAL SIMULATION METHOD DEMONSTRATED ON A 24-TON WHEEL LOADER

Presenter: Eric Pohl, TUD Dresden University of Technology, Germany



With the ongoing emission reduction and electrification of mobile machinery the efficiency of the hydraulics is becoming increasingly important. Here, the thermal behavior of the entire hydraulic drive system, including all cooling circuits, plays a decisive role. For a comprehensive quantification of the thermal behavior, a model-based analysis method is the most cost- and time-efficient option. In the recent past, thermo-hydraulic network models with lumped parameters have become established for this purpose. Due to their approach of solving coupled time-dependent differential equations, very small time steps and thus very long simulation times can occur for complex systems such as mobile machines. Thus, an efficient design process including parameter studies and optimization is highly uneconomical. In this paper, an efficient computational approach for the determination of local temperatures in thermal equilibrium is presented and used for the simulation of the thermal behavior of a 24 t wheel loader. The results are simulatively validated by a comparison with the classical transient calculation approach with exactly the same parameterization in order to prove the accuracy and the reduction of simulation time. The comparison shows that the presented simulation approach is able to reduce the simulation time by more than 4000 times with almost the same accuracy. This demonstrates the great potential of the simulation method for the design process including economic optimization and parameter studies.

A HYDRO-MECHANIC VIBRATION ABSORBER WITH ADJUSTABLE OPERATING FREQUENCY

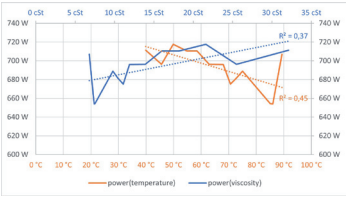
Presenter: Helmut Kogler, Linz Center of Mechatronics GmbH, Austria

Unwanted resonances in industrial plants often result in unpleasant noise or may even end up in a reduced lifetime of mechanical structures and components. Such vibrations are often reduced by wellestablished vibration absorbers, which are designed and precisely tuned to one specific frequency. Furthermore, often the natural frequency of, for instance, a mechanical structure is not accurately known and must be identified by an experimental modal analysis. Another limitation of conventional single-frequency absorbers is that in some applications the frequency of the unwanted vibrations varies over lifetime, which reduces the effectiveness of the initially designed absorber. Moreover, in many cases the frequency of the undesirable vibration changes with the operating point of the plant, which requires the installation of multiple vibration absorbers with different operating frequencies. In this paper a new hydro-mechanical vibration absorber with a continuously adjustable operating frequency is presented, which eliminates the shortcomings mentioned above. In contrast to conventional absorbers the stiffness of the hydro-mechanical spring mass absorber is realized by a gas-loaded hydraulic capacitance, which depends on the mean operating pressure. The concept of the presented absorber is investigated theoretically and validated by simulation experiments. The results are discussed in detail and an outlook on further steps in development is provided.

SYSTEM DESIGN AND ARCHITECTURE 1:45 - 3:05 p.m.

ENERGETIC OPTIMIZATION OF AN EXISTING CLAMPING POWERPACK BY SYSTEM AND CONTROL CONCEPT ANALYSIS AND ADAPTION OF THE HYDRAULIC FLUID VISCOSITY

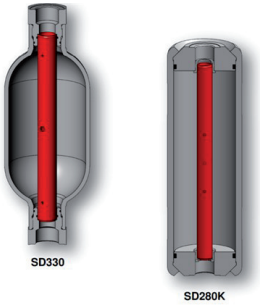
Presenter: Johannes Gattinger, WEBER-HYDRAULIK GMBH, Germany



Many hydraulic systems that have been in operation for several years are planned to be used further on some time. As nowadays the design objectives and possibilities are a lot more focused on energy efficiency than at the time these machines were build, retrofit activities such as energetic optimization are often useful in existing installations.
The clamping powerpack of an automated milling station is examined according to the control strategy of the pump motor by systematic measuring and recording of all relevant system parameters like operating status of the motor, activation status of control valves and pressure switches as well as the different hydraulic pressures in the system.
The system evaluation showed that the motor is driven at constant speed on demand by the controller of the milling station but with a time limited switch-on time, which leads to high losses due to oil flow over the systems relief valve. By improving the hydraulic system design, due to the addition of a pressure accumulator, and changing the control signal of the motor to a separate pressure switch, the energy consumption of the clamping powerpack is reduced by 89 %. In addition, the hydraulic oil viscosity was found to have no significant influence on the efficiency of the powerpack, which was presumed because of the specific application, where pressure, not flow, is the predominant parameter.

USE OF BROADBAND SILENCERS IN HYDRAULIC CIRCUITS TO REDUCE PULSATIONS

Presenter: Peter Kloft, HYDAC Technology GmbH, Germany



New axial piston pumps with fixed displacement volumes, such as the high efficient power package (HEPP) pumps, operate at variable rotational speeds and thus variable flow rates in a wide range. Using intelligent pump control systems, small and light packages are possible. In contrast, the frequency of the fluid pulsations vary due to the rotational speed and have to be controlled avoiding stress or wear in the hydraulic system components (e.g. seals of tubing) and potentially impacting noise emissions.
Especially in mobile machines, the noise of a combustion engine drown out the noise of the hydraulic system. By replacing the combustion engines by electric drives, the fluid born noise (FBN) becomes audible.
Due to the excitation frequencies, a broadband silencer for high-pressure applications is required. This is realized by a Multi-Helmholtz-Resonator (MHR) concept within one cylindrical volume. The design will be adapted for pump-specific frequency characteristics in aircraft hydraulic conditions and fine adjusted during test verification by means of an adjustable tube-inside a pressure shell.

SIMULATION 3:45- 5:00 p.m.

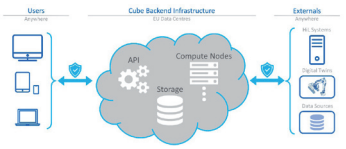
AN APPROACH TO THE EVALUATION OF THE ENERGY EFFICIENCY OF MACHINES BASED ON DIGITAL TWINS AND SIMULATION METHODS

Presenter: Rüdiger Kampfmann, Bosch Rexroth AG, Germany

This paper presents an approach to evaluating the energy efficiency of hydraulic machines using digital twins and simulation methods. It emphasizes the importance of considering the entire life cycle of a product and minimizing power consumption of a hydraulic system during its development. Additionally, sustainability activities at Bosch Rexroth are presented and upcoming legal requirements are discussed. By utilizing digital twins, which contain simulation models, the dynamic and efficiency behavior of the machines can be investigated. Through a visualization of energy flow based on simulation results, opportunities for energy savings are identified. Overall, this contribution showcases the benefits of digital twins in optimizing energy consumption and promoting sustainability in the industrial sector.

A NOVEL SAAS DEVELOPMENT PLATFORM FOR FLUID POWER STANDARD DRIVES

Presenter: Heiko Baum, FLUIDON Gesellschaft für Fluidtechnik mbH, Germany



Today, it is state of the art to use 0D/1D simulations in the development of complex fluid technology drives, as this is the only way to evaluate the dynamic interactions of the system components. However, when modifying existing drives, developers often refrain from simulative validation because they consider the changes to be minor and/or rely on the positive experiences of the past. Consequently, design errors are only discovered in practical use, leading to production disruptions and costly troubleshooting.

A new type of SaaS development platform closes this gap and is aimed at companies with limited capacities and budgets. The platform enables companies to engage engineering service providers in creating customized design workflows. The paper illustrates the platform's application in a mobile hydraulic drive example, detailing the orchestration of pre- and post-processing tasks through a web browser interface. The familiar Excel spreadsheet used for static calculations continues to serve for parameterization source, maintaining the user's established design process while leveraging the precision of 0D/1D simulation. The simulation results are automatically converted into a format familiar to users, either as an Excel spreadsheet or a PowerPoint presentation for documentation and sales support.

SIMULATION 3:45- 5:00 p.m.

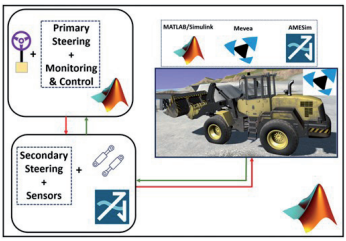
CREDIBLE SIMULATION: EVALUATING THE CREDIBILITY OF SIMULATION MODELS AND SIMULATION MODEL LIBRARIES

Presenter: Simon Leutz, Bosch Rexroth AG, Germany

This paper deals with the evaluation of the credibility of simulation models and simulation model libraries exemplary shown on a model of the Rexroth BRSL Simulation Library.
The topic tackles the questions on how engineers know that they really can trust the results of their simulation models, how exact their simulation models are and if the accuracy of their simulation models is sufficient or not.
In industry, engineers usually validate their simulation model results against real measurement data to examine if the simulation model results match the reality. Usually there is no numerical number describing the accuracy of the simulation model. In the topic of credible simulation, numerical methods of data analysis are used to try to determine a numerical number, the so-called model form error. This then gives an idea of how plausible the simulation model is in terms of uncertainties.
At Bosch Rexroth there is a prototypically developed app that enables users estimating the model form error, performing sensitivity analyses, and simulating variations of parameter uncertainties on key model parameters. Furthermore, there is the possibility to compare the simulation results with real measurement data.
The app may help to certify credible simulation models in the future.

HAZARD-FREE STEER-BY-WIRE IN ARTICULATED HEAVY EARTH MOVING MACHINERY USING CO-SIMULATION MODEL

Presenter: Vinay Partap Singh, Innovative Hydraulics and Automation, Finland



The articulated Heavy Earth Moving Machinery predominantly use hydrostatic steering, because of its reliability and redundancy. In earlier studies an energy efficient Electro-Hydrostatic Steering System was proposed, which works on Steer-by-Wire principle and comply with the safety standards. This paper presents co-simulation of a wheel loader model with hazard-free Steer-by-Wire. A co-simulation model using three software platforms; Mevea for multibody dynamics and mechanics, Simcenter AMESim for hydraulics, and MATLAB/Simulink for hydraulics, control, and data analysis, is created to analyse the hazard-free functionality of the steering. The simulation model of primary steering, which is an electric motor controlled Electro-Hydrostatic Actuator, is validated experimentally. In these heavy machines, as required by the standards there shall always be a secondary steering system for redundancy. The secondary steering, which is through a proportional control valve is modelled using the characteristics of the commercial product. There are five possible hazard scenarios in steering application of such machinery, which have been identified by the authors in earlier publication. These five hazard scenarios are realised in co-simulation model by modelling the respective faults in the primary steering, and the effectiveness of the hazard-free functionality in the steering is analysed. The study demonstrates that the novel Steer-by-Wire for articulated steering can effectively mitigate the potential hazards associated with steering in Heavy Earth Moving Machinery, moreover, co-simulation model provides an effectual mean to analyse the novel solutions.

SYSTEM DESIGN AND ARCHITECTURE 3:35- 5:00 p.m.

GENERAL LECTURE: SUSTAINABLE FLUID POWER

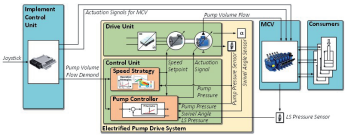
Presenter: Jeff Herrin & Dr. Robert Rahmfeld, Danfoss Power Solutions, Denmark

This lecture will focus on the evolution of Fluid Power technology, products, and systems toward a more climate-friendly future. Changes in legislative and market demands toward decarbonization, require that fluid power consumers and suppliers adjust the approach and the trade-offs that are inevitable in solving the design problem. At the same time, some core industry qualifiers, like reliability, cost, and productivity, cannot be compromised in the commercial realm. So fluid power designers are asked to leverage past experience while at same time test the physical limits for the new, modern specifications. Thus, innovation and an innovative mindset is required to optimize real-world solutions. Furthermore, industry mega-trends are impacting the industries at an accelerating pace, supporting those entities that can move fast, stay flexible, and adapt.

Fluid power technology has both a proud past, but also a bright future for those partners that can adapt design and applications to this new reality. Several modern application and product examples will be highlighted as part of the lecture to bring focus to modern specifications and solutions. Finally, an outlook for decarbonization and its impact on fluid power will be presented.

SOLUTIONS FOR ENERGY-EFFICIENT AND EASY IMPLEMENTABLE ELECTRIFIED VARIABLE-SPEED PUMP DRIVES IN MOBILE APPLICATIONS

Presenter: Steffen Rose, Bosch Rexroth AG, Germany

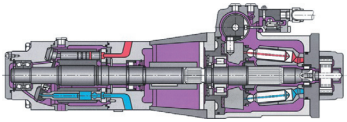


Mobile machinery is currently undergoing a transformation towards an increasingly electrification of its powertrain systems, which is subject to ever-increasing demands in terms of performance, functionality, noise behaviour, integration and – above all – energy efficiency. Especially in the latter case, solutions on a system level appear more and more attractive as the advantages of electric drives can be fully revealed this way – most of all the high torque build-up dynamics and speed variability across a much wider speed range compared to combustion engines that also involves standstill as well as negative speeds. Following this idea, the contribution introduces a model-based and holistic approach to achieve a customer-specific system design that is targeted at a given individual load specification for the energy-efficient supply of the hydraulic implement systems with a demand-oriented volume flow at an optimal speed. Both, the application-optimized dimensioning of the drive components and the use of an operating strategy, lead in combination to significant energy savings during operation. These improvements are presented in this work, which is based on simulations and test bench measurements. Furthermore, this paper concludes with an investigation of the thermal behaviour of the electric drive using different speed operation strategies.

SYSTEM DESIGN AND ARCHITECTURE 3:35- 5:00 p.m.

FUNDAMENTALS OF HYDRAULIC TRANSFORMERS

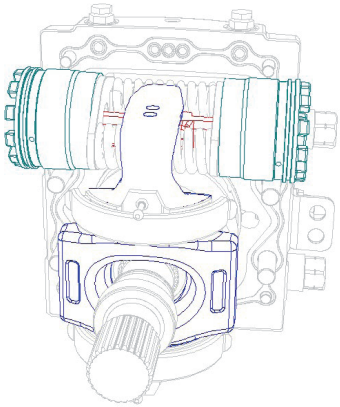
Presenter: Peter Achten, INNAS BV, The Netherlands



In Common Pressure Rail systems (CPR-systems), it is no longer possible to control the loads at the primary side by means of a variable displacement pump. Instead, the loads need to be controlled directly at the load (also referred to as secondary control). Rotating loads could be controlled by variable displacement motors, but hydraulic cylinders need to be controlled by means of hydraulic transformers. The problem is, however, that these transformers are not yet available on the market.
This paper discusses and analyses the principal design options for hydraulic transformers, thereby comparing several combined hydraulic transformers (CHTs), which are combinations of two pump/motors, and the Innas Hydraulic Transformer (IHT). The emphasis is on hydraulic power transformers which can be used as a general hydraulic control component, having a continuously variable control.

DYNAMIC VALVE PLATE DESIGN FOR AN AXIAL PISTON PUMP (SERVO-LESS PUMP)

Presenter: Jaromír Tvarůžek, Danfoss Power Solutions Open Circuit Pumps Engineering, USA



In times with a need to reduce CO2 emissions we are focusing on reducing fuel with improving the power-losses of hydrostatic pumps and motors. Key areas of high losses in typical designs are the cross-port at the valve plate and leakages in the servo system and at control spools. The elimination of just the cross-port is discussed in [1]. The proposed concept is a new solution using an active special valve plate porting to reduce the cross-port losses, which also controls the displacement of hydrostatic unit. The active porting strategy has in fact direct influence on the servo moments of the hydrostatic unit. With special control software, which controls the porting at the valve plate, it is possible to increase the efficiency, influence the noise and control the displacement, respectively.

[1] Ivantysyn J. and Ivantysynova M. 2001. Hydrostatic Pumps and Motors. Academic Books International. New Delhi

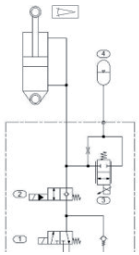
CONFERENCE

THURSDAY 21TH OF MARCH

SYSTEM LAYOUTS IN MOBILE MACHINES 11:20 a.m. - 12:40 p.m.

ELECTRO-HYDRAULIC DAMPING STRATEGIES FOR HYDRO-PNEUMATIC SUSPENSIONS

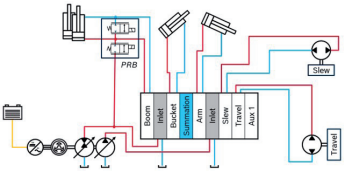
Presenter: Steffen Antoni, ARGO-HYTOS GmbH, Germany



Operators of mobile machines are exposed to high vibration loads while on the machine. To reduce this, seat, cab, axle and wheel suspension systems are used today. In addition to a uniform ground pressure required to steer and brake the machines safely, the main aim is to reduce whole-body vibrations. The driving comfort can be improved and component stress can be reduced. The wide range of applications for such machines means that the suspension systems have to meet special requirements in various driving and working conditions. Due to characteristics suitable for mobile machinery, hydro-pneumatic suspension systems are increasingly being used in such machines. Adjusting the damping - either adaptively, semi-actively or actively - is one way to react quickly to changing conditions. This paper will focus on presenting and evaluating different damping strategies for hydro-pneumatics suspension systems. After a general overview of hydro-pneumatic suspension systems, the various damping strategies are discussed in detail. The effects of three damping strategies are explained in detail using the example of a tractor cab suspension.

A COMPREHENSIVE REVIEW OF ELECTRONICALLY CONTROLLED IMPLEMENT ARCHITECTURES FOR MOBILE MACHINERY USING SECONDARY CONTROL

Presenter: Edwin Heemskerk, Bosch Rexroth AG, Germany

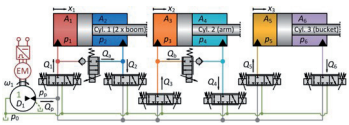


Transmission architectures for drive and implement functions in mobile machinery are currently diverting. On the one hand new market requirements, as alternative energy sources, impact the system design, and so do direct or indirect market drivers as efficiency, controllability, predictability, and driver comfort. On the other hand, the ability to electronically control components in alternative ways enable new architectures as well.
The persons in charge of the machine design must find the balance between considering the new demands and relying on known building blocks to reduce risks and safeguard valuable resources. To help the decision making, an overview of new and promising architectures is presented, utilizing secondary control approaches for drive and work functions. These architectures target to recover kinetic energy, reduce throttling losses, and operate components in their sweet spot.
Decisive criteria for the shown architectures are their maturity, degree of fulfilment of the market demands, minimized risk criteria via proven sub-components and feasibility of handling the transmission variants for varying market demands.

SYSTEM LAYOUTS IN MOBILE MACHINES 11:20 a.m. - 12:40 p.m.

ENERGY EFFICIENT EXCAVATOR FUNCTIONS BASED ON ELECTRO-HYDRAULIC VARIABLE-SPEED DRIVE NETWORK

Presenter: Lasse Schmidt, Aalborg University, Denmark

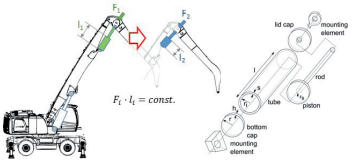


Electrification of mobile working machines is subject to increasing focus in both industry and academia. At this stage, focus has been the replacement of conventional internal combustion engines with cable or battery fed electric motors driving the main pump(s), and the replacement of rotary functions with electro-mechanical drive solutions. However, the linear functions remain controlled by hydraulic control valves resulting in substantial throttle losses, which in turn necessitates large battery sizes and/or low machine uptimes. Alternatively, the valve-controlled hydraulic cylinders may be replaced with electro-mechanical solutions in applications with limited forces, whereas heavy duty working machines such as medium/large excavators may benefit from standalone electro-hydraulic primary controlled drives, i.e., variable-speed standalone drives. The use of such solutions will substantially increase efficiency due to the absent/limited throttle control and the ability to share power through the electric supply/DC-bus. A main drawback is that each axis needs to be designed to meet both the maximum force and maximum speed, hence in the case of using single motor standalone drives, each motor and associated inverter needs to be designed to meet both the maximum force and maximum speed, potentially rendering these somewhat large. Alternatively, dual motor standalone drives can be applied, enabling power distribution via more motors. However, the use of numerous motors requires more extensive system integration and potentially large motor power installations considering industrially available non-specialized components. This paper presents a novel so-called electro-hydraulic variable-speed drive network, applied for actuation of three linear functions of an excavator implement. Cylinder chamber short-circuiting's and electro-hydraulic variable-speed units constitute a drive network allowing both electric and hydraulic power sharing. The drive network is realized with Bosch Rexroth A2 displacement units and eLION electric motors as its core components. Results demonstrate that the proposed drive network is realizable with similar energy efficiency as a standalone dual motor electro-hydraulic drive solution, but with less motor power and with fewer motors, displacement units and integration effort, rendering this a more sustainable and cost-efficient solution. Finally, it is shown that the proposed drive network is superior in terms of installed displacement, electric motor power and energy efficiency, compared to a separate metering valve drive supplied by a battery fed electro-hydraulic pump.

SYSTEM LAYOUTS IN MOBILE MACHINES 11:20 a.m. - 12:40 p.m.

WEIGHT SAVING POTENTIALS OF PRESSURE INCREASE IN CYLINDERS OF MOBILE MACHINES KINEMATICS

Presenter: Tobias Radermacher, TUD Dresden University of Technology, Germany

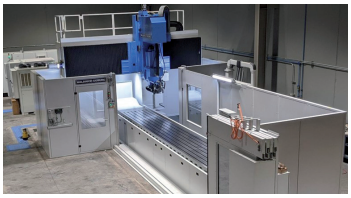


Many mobile machines operate primarily through the use of boom structures, which account for a large share of energy consumption. The purpose of this work is to investigate if and to what extent the selection of the system pressure level in hydraulically driven boom structures can contribute to the reduction of the moving weight and thus to the reduction of the overall energy demand. The paper focusses on the choice of optimal system-pressure with regard to the cylinder-weight. A calculation method is derived that allows for the analytical calculation of cylinder weight with regard to system pressure to profit from the lightermost cylinders taking into account all sizes of differential cylinders, material properties, safety-factors and cylinder-ratio. It is shown that by specifying the load force, cylinder material, safety factor and area ratio as input parameters the system pressure level that allows the lightest cylinders can be determined. Application of the method shows that there are ideal pressure levels for hydraulic cylinders that are almost independent of the cylinder force and therefore machine size. The results show that a proper pairing of cylinder size and system pressure may have big weight-saving potentials. Taking into account high-strength steel (tensile strength σ=500 N/mm^2) enormous weight savings may be achieved with rising system pressures.

DIGITALIZATION 11:20 a.m. - 12:40 p.m.

PRECISE HYDROSTATIC CYLINDER DRIVE WITH INCREASED PRESSURE LEVEL FOR INDUSTRIAL APPLICATIONS

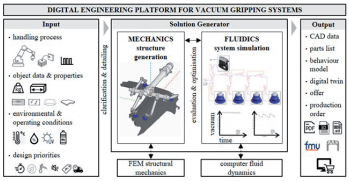
Presenter: Ralf Bonefeld, Bosch Rexroth AG, Germany



Primary controlled hydrostatic drives, mainly based on speed-variable pumps, are increasingly used in various industrial applications, efficiency and controllability being the main advantages. Still, it is an open question, if the simple substitution of a proportional valve by a speed-variable pump leads in general to a qualitatively comparable system behaviour, or if additional measures are necessary.
Especially, for the 4-quadrant control of single rod cylinders, the use of a servo-driven double-pump is advantageous in terms of efficiency. Nevertheless, the sizing of the pump-unit with respect to the cylinder geometry is a non-trivial task. In the following it will be shown that it is essential for a servo-quality performance, to firstly ensure a flow balance matching the cylinder geometry and secondly to achieve an increased pressure level in order to take over load forces without exceeding pressure limits. To this aim, a control of the sum pressure is known to be appropriate [1]. Introducing another controllable motor-pump-unit allows for coping with both aspects at a time with a purely primary controlled architecture. Within the following a generic systematics of corresponding setups is shown and the example of a cylinder drive for a large machine table proves the servo quality of the solution, making it suitable even for precision machining.

NOVEL ENGINEERING AND PRODUCT SOLUTIONS TOWARDS DIGITALIZATION AND SUSTAINABILITY IN VACUUM HANDLING AUTOMATION

Presenter: Maik Fiedler, J. Schmalz GmbH, Germany

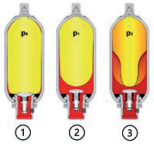


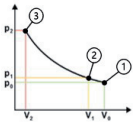
This paper outlines new digital services for vacuum handling automation as well as new fluidic system concepts and products. Due to the large number of applications and different objects to be gripped, as well as the large product portfolio, the design process is heavily based on experience and testing. A digital engineering platform for vacuum gripping systems can help to rapidly provide optimal solutions. With a view to greater sustainability, new or previously little-used fluidic system concepts and innovative components are presented. These include, in particular, system concepts with controllable pumps, grippers with venting function, or the reduction of energy consumption. More efficient cups seal better to the surface of the object being gripped and therefore have less leakage. Simulation and test results are used to demonstrate the potential of the solutions in terms of energy efficiency.

DIGITALIZATION 11:20 a.m. - 12:40 p.m.

HANDS-ON APPROACH ON DEVELOPING A DEEP LEARNING ALGORITHM FOR STATE CLASSIFICATION OF A HYDRAULIC ACCUMULATOR

Presenter: Oliver Mehl, Hydac Technology GmbH, Germany

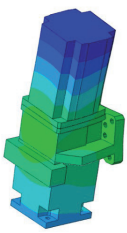




Hydro-pneumatic accumulators are essential components in fluid power systems, serving various purposes like dampening pulsations, stabilizing flow, and ensuring safety. Monitoring their energy state is challenging due to gas leakage, requiring knowledge of gas pressure, temperature, and volume. Real-time measurements of gas temperature and volume are difficult due to transient changes during operation. This paper introduces a novel approach to classify gas mass in bladder pressure accumulators using Deep-Learning, particularly long short-term memory (LSTM) networks. The study aims to classify load situations with minimal sensor data, providing insights into the workflow for classifying multivariate time-series data with deep neural networks. Therefore, a bladder accumulator is equipped with sensors, its dynamic behaviour is recorded and used to train and validate the LSTM network's ability to classify the gas amount inside the accumulator. This method offers a promising way to determine the pre-charge pressure, a crucial parameter for assessing the accumulator's energy state.

ACOUSTIC OPTIMIZATION OF A SERVO-HYDRAULIC PUMP UNIT AND AI EVALUATION OF THE SUBJECTIVE SOUND PERCEPTION

Presenter: Stefan-Georg Backhaus, Bosch Rexroth AG, Germany

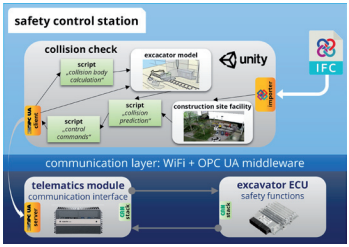


As part of the development of a new type of primary-controlled press drives (direct mounted servo-hydraulic pump unit on the manifold), various concepts were designed and acoustically optimized with the help of the finite element method. In this study, sound measurements were carried out on a hydraulic press. The aim was to analyse the influence of different designs of the pump unit on the sound power of the overall system. In addition to this state-of-the-art procedure, the recorded sounds were played back to participants in listening tests (> 1000) and the subjective perception of the sounds was assessed and evaluated. Psychoacoustic metrics were also analysed. With the aim of replacing time-consuming jury tests in ongoing developments, an artificial intelligence (AI) was developed and trained with the help of the data obtained. This AI helps to accelerate the development process. The results are compared based on the different investigated development stages of the servo-hydraulic pump unit.

DIGITAL CONSTRUCTION 1:40 - 3:10 p.m.

DIGITAL ASSISTED COLLISION AVOIDANCE FOR MOBILE MACHINERY

Presenter: Simon Köhler, TUD Dresden University of Technology, Germany
Manuel Boes, Liebherr Werk Bischofshofen GmbH, Austria



Despite high safety standards and numerous preventive measures, both employees and objects on the construction site are exposed to a high risk of accidents. These scenarios are often caused in the handling of construction machinery, such as excavators or wheel loaders. Today there are different technologies and technological solutions for avoiding such scenarios including mobile machinery, provided by OEMs or third-party developers. This paper presents on the one hand an overview of existing technologies and technological solutions, classifying them into perception sensor, transponder-based and digital twin approaches. Furthermore, various available sensor modalities with their pros and cons for obstacle detection and classification as well as complete solutions are discussed more deeply. On the other hand, this paper introduces a dynamic collision avoidance system for mobile excavators using the cross-platform game engine unity, which combines advantages of digital twin and transponder based approaches. The system collects machine data based on so-called 3D-systems on a construction site and connects them with planning data as well as regulations and guidelines concerning protection zones. By using multiple colliders for static and dynamic objects, a reliable collision prediction on the construction site is realized. The system interacts with the excavator respectively the machine control by limiting actuator speeds, wherefore a certain minimum distance between mobile machinery and objects can always be ensured. For demonstrating the applicability of the solution, different tests on a real construction site environment are presented. The investigated scenarios are oriented towards typical track construction activities.

DIGITAL CONSTRUCTION 1:40 - 3:10 p.m.

CURRENT CHALLENGES AND POSSIBLE SOLUTIONS FOR THE SOFTWARE AND SYSTEM DEVELOPMENT OF MOBILE WORKING MACHINES

Presenter: Sasha Grund, HYDAC Software GmbH, Germany

Currently, manufacturers of mobile work machines are confronted with a multitude of challenges. On the one hand, due to the demographic situation in Germany, approximately 700,000 engineers are expected to retire in the next 5 years, while, on the other hand, developmental topics are becoming increasingly intricate. Additionally, new regulatory frameworks in the form of standards and laws necessitate consideration. Particularly within the realm of system and software development, companies must reposition themselves and formulate strategies to address the shortage of skilled personnel and manage a spectrum of complex developmental topics concurrently.

An analysis of the current labor market situation reveals a notable predicament: The quest for an individual expert seamlessly fitting into a given position, whose profile is augmented by: several years of professional experience in the domain of machine development, expertise in the realms of the Machinery Directive, functional safety, cyber security, software development, encompassing testing procedures, proficiency in agile processes, and adept project management, coupled with additional soft skills, swiftly leads to the realization that either such a candidate does not exist, or competing firms are willing to offer a substantial remuneration for this individual. The terminology „war of talent“ is also invoked in this context. One possible strategy is to rely on young graduates instead of ready-to-use experts. Here it is important to quickly get people ready for the topics so that, for example, machines can be brought onto the market quickly.

The crucial question arises: Is it possible to quickly equip young graduates to tackle complex development problems? With the appropriate resources, this can actually be achieved. The feasibility of such an undertaking depends on the machine architecture and the underlying systems, components and software. Essentially, there are two basic approaches within a machine: pre-developed systems and topic-related ready-to-use software solutions. In professional circles, these solution approaches are more commonly recognized as „No Code“ and „Low Code.“

Pre-developed system and software solutions significantly reduce development and testing efforts. Reusable modules across different vehicles in a fleet minimize additional development work and standardize vehicle functions, irrespective of the technology used. The utilization of certified control units with embedded basic operating systems and the graphic linking of individual certified library elements further reduces development activities, enabling a low-code approach. Additionally, incorporating pre-developed and certified subsystems, like a steering system, leads to a no-code approach. HYDAC offers products suitable for both low-code and no-code approaches, ensuring safe machine development and rapid market entry.

DIGITAL CONSTRUCTION 1:40 - 3:10 p.m.

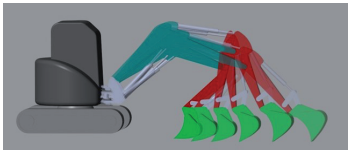
A COMPARISON OF STATE-OF-THE-ART NETWORK ARCHITECTURES FOR INSTANCE-SEGMENTATION IN FOREST ENVIRONMENTS

Presenter: Lukas Michiels, Karlsruhe Institute of Technology, Germany

Research and development have increasingly focused on automating mobile machines to reduce the negative influence of labor shortages and high labor costs. Object detection is a key requirement for the automation of mobile machines. The transfer of the developed methods to the environment of mobile machines, e.g. a forest, a building site, or in mining, is challenging. Objects of the same class can have significantly different phenotypes and the surroundings cannot be controlled, weather as well as lighting conditions can change. Neural networks are the state-of-the-art method for detecting and classifying objects for image sensors. The required datasets as well as network architectures mastering object detection across different forest areas have not yet been presented. We collected two datasets, MobimaWoodlands and MobimaSkidRoads, one with a handheld camera and one captured while driving on skid roads in different areas and in different seasons. Three network architectures for the instance segmentation with two different backbones were trained on the two datasets to segment stems, trees, and stumps. In a subsequent step, the trained networks were evaluated on two public datasets which have not been used in the training process. With an adapted training pipeline, we achieved a similar accuracy with a slight decrease in the AP of 0.1 on one of the unknown datasets with similar tree specimens. On the second unknown dataset, the AP decreased more significantly by 0.3. The findings highlight that generalization over various forest areas is possible, even in demanding outdoor settings. However, the portability to unknown domains cannot be guaranteed especially if different tree species are present, which continues to be an issue in many applications.

ASSISTED DRIVING MIDI-EXCAVATOR FOR AUGMENTED PERFORMANCES AND IMPROVED SAFETY

Presenter: Andrea Cervi, Walvoil SpA, Italy

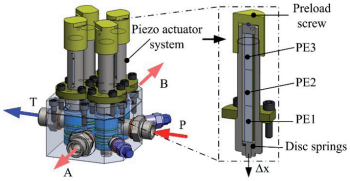


Numerous examples of assisted driving are present in the automotive sector to improve driver comfort and enhance safety. In the Off-Highway vehicles the examples of assisted driving are instead less widespread, although the stresses received by the driver are much higher, due to the more difficult environmental conditions and to the different operations that must be simultaneously controlled.
The purpose of this work is to develop a driving support system, mainly oriented to small-sized excavators, based on a software logic that can support the operator in the execution of predefined functions and paths.
Compared to previous works that dealt with the subject in a theoretical way, the present one starts from a robotic approach, to continue in an extensive simulation activity and conclude with an experimental application.
The case of a 5t Excavator is studied, equipped with 6 degrees of freedom inertial platforms, to dynamically monitor the geometry of the machine.

ACTUATORS AND SENSORS 1:50 - 3:10 p.m.

EXPERIMENTAL ANALYSIS OF ENERGY CONSUMPTION OF PIEZO ACTUATORS USED IN HYDRAULIC SWITCHING VALVE

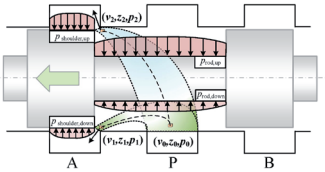
Presenter: Marko Simic, University of Ljubljana, Slovenia



This paper presents a four-way digital piezo valve system (4WDPVS) composed of four high-response switching piezo valves. The main part of the new switching valves introduces the piezo actuator system (PAS) used instead of conventional solenoids. One of the important aspects in digital hydraulic systems is the use of energy-efficient switching hydraulic valves that assure low switching energy and low holding power consumption in the steady-state open valve state. First, the theoretical background of piezo technology is presented. Second, a detailed description of the new piezoelectric actuator system used in switching valves and four-way digital piezo valve system. The main part presents experimental analysis of the electrical energy consumption of the new piezoelectric actuator system. To validate and compare the electrical switching energy and the holding power consumption, several existing switching valves were used as reference. The results show a huge reduction of electrical energy consumption when using the new PAS for hydraulic switching valve actuation. Especially the holding power consumption in the stationary active state is about 6 times lower compared to other existing hydraulic switching valves controlled by solenoids.

RESEARCH ON FAULT DIAGNOSIS METHOD OF AVIATION DIGITAL HYDRAULIC VALVE BASED ON ENERGY DISSIPATION CHARACTERIZATION

Presenter: Jiesi Ren, Taiyuan University of Technology, China

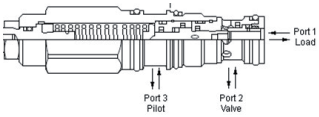


Aviation digital hydraulic valves are often used for high-precision control of aviation hydraulic systems, which determines flight safety, and their reliability cannot be ignored. The prognostic of the valve is an important means to ensure flight safety. At present, there are some key challenges of prognostic methods based on vibration signals, such as the need to attach vibration sensor, the susceptibility of fault characteristics to sensor positions, and the need to damage valve bodies, which result in difficulty in practical application. In this regard, a prognostic method with taking valve spool wear as a typical fault is proposed in this article which dual-driven by a fault mechanism model based on energy loss and data. A mapping mechanism model of energy loss, valve spool wear, and performance degradation is established by calculating the energy loss degree of the valve through existed signals of pressure difference and flow rate and verified through experiments. At the same time, a valve spool wear fault dataset is constructed. Using mechanism modelling and data to drive Deep Extreme Learning Machine (DELM) and Particle Swarm Optimization (PSO) for prognostic and parameter optimization, and verified through random sampling experiments. The results show that the average diagnostic accuracy rate can be increased from 90% to 98%, and the diagnostic time can reach 0.1s by adding energy loss information. The proposed method can provide a reference method for low-cost active operation and maintenance of aviation valves.

ACTUATORS AND SENSORS

LOAD HOLDING VALVES WITH INTEGRATED FLOW SENSORS

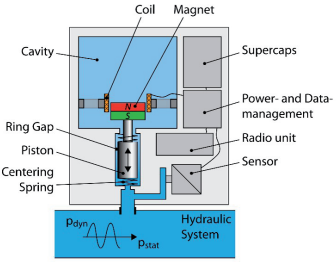
Presenter: Bernd Zähe, Sunhydraulik GmbH, Germany



Counterbalance valves are widely used in mobile hydraulics, they preload the return line of motors and cylinders to ensure the load doesn't move when the proportional control valve is in open center position. They also preload the return line when the cylinder moves to lower a load. In that condition the circuit can be unstable and restrictive counterbalance valves are needed. They stabilize the circuit but require higher inlet pressures. The paper describes a way to stabilize the circuit without adding pressure losses. A flow sensor can be built into the counterbalance. The signal can be used for a closed loop control. A simulation shows that the controller can improve the stability.
An alternative to the flow sensor in the counterbalance valve is a velocity sensor on the cylinder. Again, a controller can use the signal: it closes the loop on the velocity of the cylinder. The paper compares the closed loop controls.

ENERGY HARVESTING FROM HYDRAULIC PRESSURE FLUCTUATIONS USING AN OSCILLATING PISTON

Presenter: Hauke Lerche, TUD Dresden University of Technology, Germany

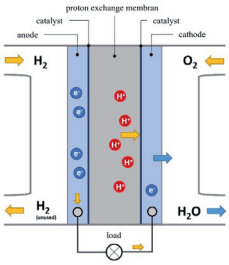


This paper presents an analytical model of a novel energy harvester for use in hydraulic systems. The pressure pulsation caused by the pump is used as the energy source. The harvester can be connected to a hydraulic system's line and is composed of an oil volume that serves as an oil spring, a vibrating piston excited by the pressure pulsation in the hydraulic system, and an electromagnetic linear generator. The harvester is designed to be compatible with a broad static pressure range due to static pressure compensation between the oil volume and the system. The analytical description of the piston motion is derived and validated by measurements. Further, the mechanical harvester parameters are optimized to achieve maximum piston speed. Lastly, the possible performance of the harvester is estimated.

HYDROGEN 3:40 - 4:50 p.m.

HYDROGEN POWERED HYDRAULIC POWERPACK

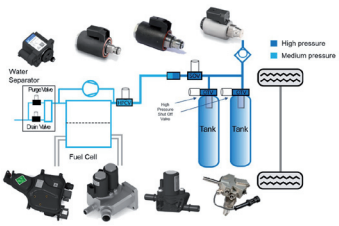
Presenter: Lukas Trommler, TUD Dresden University of Technology, Germany



A general challenge in the construction machinery sector is that 90% of the current fleet of machines uses diesel as fuel. In contrast to the positive developments in the field of particle mass and nitrogen oxide emissions, CO2 emissions are stagnating at a constantly high level. The use of hydrogen fuel cell technology results in CO2 neutral operation and is in line with current CO2 reduction policies. A hydrogen driven powerpack is used to generate hydraulic power, which is then used to drive a stationary concrete pump. This paper deals with the transformation of a conventional drive system to a fuel cell drive system. Furthermore, two different fuel cell operating strategies are discussed. The challenge in using fuel cells is that due to the efficiency and the balance of plant components about 50 % of the electrical power is converted into heat. Furthermore, the volumetric energy density of hydrogen currently limits the unrestricted use of the CO2 neutral fuel. As a result, a sufficiently large cooling system must be kept in place. If the same performance and the same operating time shall be achieved as with a conventional diesel combustion machine, it results an increase of the installation space by a factor up to 8 for a fuel cell drive. For the use of such machines, it is important to ensure that future construction sites have an appropriately prepared H2 infrastructure.

HIGH-PRESSURE SHUT-OFF VALVE SUITABLE FOR HYDROGEN APPLICATIONS

Presenter: Peter Tappe, Magnet-Schultz GmbH & Co. KG, Germany

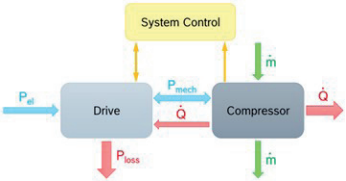


It is well known that the direct or indirect use of hydrogen in mobile applications plays a decisive role in the decarbonisation of this sector. Regardless of the use by means of fuel cell or modified internal combustion engine, various valve functions are required along the functional chain.
In mobile applications, the hydrogen is stored in high-pressure tanks with up to 1050 bar. For dispensed extraction, the shut-off solenoid valve size 32 mm is used as part of an on-tank valve.
The article describes the construction design and explains the design of the sub-functions, in particular the pilot-controlled valve function.

HYDROGEN 3:40 - 4:50 p.m.

HOLISTIC APPROACH TO ELECTRO-HYDRAULIC DRIVE SOLUTIONS FOR HYDROGEN PISTON COMPRESSORS

Presenter: Nicolas Englert, Bosch Rexroth AG, Germany



Compressor drives with hydraulic drive technology are showing good market growth due to the trend towards hydrogen. The application seems very simple at first due to its repetitive cycle, but a closer look reveals some technical challenges. However, with a deep understanding of the end user's point of view as well as the physical principles, it is possible to design a hydraulic system that meets the target cost but also achieves robustness, high flow rate and good energy efficiency. However, no general recommendation can be given for a specific system structure. Though in general, it can be seen that variable displacement pumps should be the favoured solution for motion reversal in a wide target range.

ACTUATORS AND SENSORS 3:40 - 4:50 p.m.

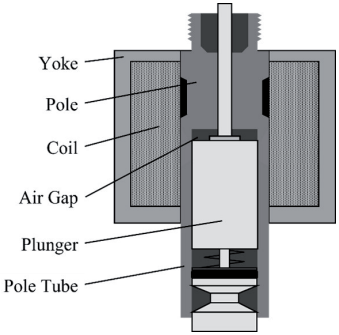
AUTOMATION OF PNEUMATIC THROTTLE CHECK VALVES BY USING NOVEL MULT-STABLE SOLENOIDS

Presenter: Thomas Kramer, TUD Dresden University of Technology, Germany

Multi-stable solenoids are novel energy-efficient actuator structures, which can hold any armature position powerless. Power is only required to change the armature position. They combine the continuous adjustability of proportional solenoid with the energy efficiency of polarised magnetic circuits. Thus, they are well suited for automating pneumatic throttle check valves, in order to set the throttle cross section and thus the cylinder piston velocity to a specific value and hold it for a certain time. This is useful in industry 4.0 context to produce on demand with various required piston velocities or for gradual compensation for increasing frictional forces during cylinder life-time.
The focus of this paper is the application of novel multi-stable solenoids for replacing the today's widely used manual adjustment of throttle check valves. Therefore, two different throttle valves are designed: a spool valve and a poppet valve. They are based on the transfer characteristic of a conventional throttle check valve. The flow behaviour of both valves is investigated to show the principal transfer behaviour and disturbances. The valves are equipped with a multi-stable solenoid for demonstrating the adjustability of the throttle's volume flow rate and on that basis the adjustability of the piston velocity in a pneumatic cylinder drive.

REAL-TIME MODELS OF VALVE SOLENOIDS: AN EVALUATION OF MEASUREMENT AND SIMULATION-BASED PARAMETER IDENTIFICATION

Presenter: Simon Hucko, RWTH Aachen University, Germany

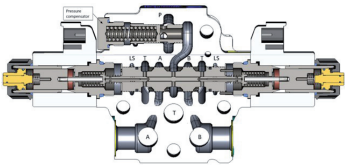


This paper examines the challenges of real-time modeling solenoid valve actuators. Usually, more complex real-time models are executed as lumped parameter models, often simulatively parameterized, using finite element method (FEM) models. The quality of the simulative parameterization heavily depends on the accuracy of the FEM model. The accuracy, in turn, is largely determined by the material parameters used to create the FEM simulation. Variations within the material can render the primary material parameters inaccurate, thereby reducing the accuracy of the FEM model and consequently the derived parameters. The quality of the real-time model thus largely depends on the quality of the material parameters.
To eliminate uncertainties introduced by subpar material parameters and to enable precise real-time models, this work showcases the possibility to reconstruct required material parameters simulatively from flux measurements. The more accurate material data obtained using this new approach could also improve the accuracy when adapting components to new requirements. The paper describes a model with lumped parameters, as well as an FEM simulation model, a test rig, and the process of B(H)/initial magnetization curve calculation, followed by validation with new operating conditions.

ACTUATORS AND SENSORS 3:40 - 4:50 p.m.

LOW ENERGY CONSUMPTION HIGH FLOW CONTROL SYSTEM USING SPOOL-IN-SPOOL DESIGN OF PROPORTIONAL VALVE

Presenter: Jan Koudelka, ARGO-HYTOS s.r.o., Czech Republic



Recently, in many mobile applications, great emphasis has been placed on reducing energy consump-tion, whilst maintaining the high hydraulic performance of the system. At the same time, a small size and, if possible, a low weight must be maintained if the system is used to be used on moving parts of machines.
All these requirements are met by our new high flow control system using the proven spool-in-spool proportional valves principle. This principle has now been enhanced using LS functionality directly on the spool incorporating a brand-new seven chamber design. Our spool-in-spool valve principle enables control of high flow rates and pressures through the valve with a very small solenoid. The large hydraulic power transferred by the valve and low-pressure losses of the solution, enable high dynamics and proportional controllability of the entire system.
The sandwich construction of the control block increases the variability of the entire device whilst space requirements are significantly reduced.
The function of the pressure compensator, together with the LS control of the hydraulic pump, eliminate the pressure drop in individual sections during simultaneous use and increase energetic efficiency of the solution. Everything is included in the individual sections.