Abstracts

Group 1: Mobile Hydraulics

1-0 Mobile Systems - Requirements and Technology Trends

W. Burget, J. Weber

This paper gives an overview of the current technologies and trends in the mobile machinery market. Several topics will be discussed including economical developments, market trends, state of the art, research being conducted and future directions. The mobile machinery market took a strong hit during the last couple of years due to the financial crisis the western world has experienced. However other markets were still growing, such as the Asian market. The north American and European market are focusing on cleaner and more energy efficient solutions, driven by the emission regulations. This has forced the industry to develop and adapt new solutions in hydraulic systems and components and engine technologies. Some of these technologies have shown their potential for quite some time but have never been incorporated or were only used in very specific applications.
A deeper focus will be taken on advancements in the system architectures and its subsystems such as valve technologies, displacement control, hydraulic transmissions and hybrids in mobile machinery. In conclusion a new joint research project “TEAM” is introduced, which is taking on the challenge to evaluate the newest advancements in the mobile machinery market and finding a way to utilize them in a demonstrator machine.

1-1 Liebherr Pactronic® - Hybrid Power Booster; Energy Recovery and Increased Performance with Hybrid Power

K. Schneider

The world leader in mobile harbour crane technology offers the industry’s first hydraulic hybrid drive for mobile harbour cranes. The new Pactronic® - hybrid drive system addresses two critical issues: increasing handling performance and reducing fuel consumption.
The Liebherr Pactronic® is a revolutionary new hydraulic hybrid drive system and based on an additional energy storage device (accumulator). It is charged by recuperation of reverse power and by the surplus power of the prime mover. The energy, which is stored in the compressed gas, can be released upon demand and provides additional power for the drive system.

1-2 PRB – Regeneration of potential energy while boom-down

J. Amrhein, U. Neumann

This paper introduces the results of a concept study of a hydraulic system called Power Regeneration Boom (PRB). Therein the potential energy of an excavator boom is either regenerated directly or stored in an accumulator and fed back afterwards. Additional costs are kept small by using already existing components for energy recovery. Fuel savings of about 3 l/h and more are feasible and validated by vehicle tests.

1-3 Efficiency Potential of Dry Case Operation for Bent-Axis Motors

R. Rahmfeld, S. Marsch, W. Göllner, et al.

Providing high efficiency hydrostatic units is a key demand for pump/motor manufacturers today, and clearly the need for reducing losses will even grow in the future. Next to providing high efficient rotating groups, a further option to improve hydrostatic unit efficiency is the elimination of churning losses, preferably in hydrostatic bent axis motors due to the high speeds. This technology is known from wide angle (45°) bent axis units in powersplit tractor applications, which achieve the highest series efficiency today. To analyze the reduction of energy consumption by avoiding churning losses for standard hydrostatic drivelines, a bent axis motor has been tested and compared in full and dry case operation according to efficiency and losses. The generated measurement data was then used as base for different churning loss models. In a next step, the selected model was implemented in wheel loader and crawler drivetrain simulation models. Dynamic simulations predicted a noticeable fuel saving potential

depending on the operating conditions when dry case instead of full case operation was used, when the motor is running at higher speeds. The efficiency component measurements and generated models were successfully verified with additional tests on a complete driveline test stand. These additional tests included investigations on tank designs and analyzed the basic abilities to avoid foaming.

1-4 High Pressure Lightweight Hydraulic Fully Composite Piston Accumulators

B. Otte, O. Stelling, C. Müller

High pressure hydraulic products require high strength structural components. High strength steels are traditionally used for common industrial applications, while more expensive lower density alloys are used for lightweight applications. Composites are an ideal reinforcement material for hydraulic products, but reinforced designs are still limited by the strength of the remaining metallic components. Therefore, a better solution would be to remove all metallic components and fully utilise composite materials to support both the hoop and axial loads in the product. Parker has developed a fully composite piston accumulator which offers dramatic weight savings potential and exceptional burst and fatigue strengths.

1-5 Hydro-mechanical Energy Storage System for Hydrostatic Transmissions in Mobile Machinery

F. Straßburger, G. Jacobs

Due to their frequent acceleration and deceleration cycles, industrial trucks and mobile machines offer strong potential for reduction of both fuel consumption and emissions through energy recuperation mechanisms. Simulation results show that fuel savings of up to 14% can be expected as a result of using brake energy recuperation in the field of hydrostatically driven industrial trucks. A hybrid system for hydrostatic drives is currently being developed, constructed and tested at the Institute for Machine Elements and Machine Design (IME). The hybrid system is constructed in the form of a hydromechanical storage system consisting of an adjustable axial piston unit providing input and output and a flywheel for energy storage. This provides an effective recuperation mechanism for hydrostatic drive systems, combining the benefits of high power and high energy density.

1-6 Energy efficient digital hydraulic valve control utilizing pressurized tank line

M. Huova, M. Linjama

Digital hydraulics is a quickly developing alternative for applications requiring cylinder motion control. This paper focuses on digital hydraulic valve system consisting of parallel connected on/off-valves. The energy efficiency of the system relies on distributed valve configuration, electrically load sensing supply pressure and pressurized tank line. Topics of the paper include the analysis of the system dynamics through linear modelling, development of non-linear control mode selection algorithm, steady-state analysis of the energy efficiency and experimental testing of the control performance and the energy efficiency. Measurements show that energy losses can be reduced 53 – 71 % when compared to traditional load sensing proportional valve.

1-7 Towards Resistance-free Hydraulics in Construction Machinery

K. Heybroeck, G. Vael, J.-O. Palmberg

The topic of resistance-free motion control refers to solutions that minimize or completely eliminate the need for proportional valves, hence avoiding the throttling losses associated with metering. Previous research by the authors shows how a secondary control system could be used to improve energy efficiency in construction machines. The proposed solution uses hydraulic transformers, powered by a common pressure rail system driving both the linear work implements and the rotary drives of a propulsion system in a wheel loader.

1-8 Fuel savings of a mini-excavator through a hydraulic hybrid displacement controlled system

R. Hippalgaonkar, M. Ivantysynova, J. Zimmerman

Following system simulations, displacement controlled actuation on a prototype 5-t mini-excavator demonstrated 40% fuel savings in side-by-side testing over the standard mini-excavator for an aggressive truck-loading cycle. Recently, two hydraulic hybrid architectures with DC actuation (including a novel architecture), were investigated in simulation and showed that addition of energy storage capability to the system enables up to 50% engine downsizing and additional fuel savings, without affecting the performance of digging functions. The theoretically optimal power management strategy for the novel architecture predicts 27% fuel savings over the non-hybrid DC architecture. This paper provides an analysis of the optimal control results, and a machine implementable strategy is derived from these. It is observed that atleast one of the pumps connected to the engine shaft, need to be kept at 100% for most of the cycle, implying that the engine needs to be kept at minimum allowable speed, and a high enough throttle.

1-9 Modeling and Hardware-in-the-Loop (HIL) Simulation of an Intelligent Electro-Hydraulic System for a Wheel loader

Q. Yuan, M. Oehrlein, M. Rannov, V. V. Thota

Wheel loaders are versatile earth moving construction equipments. In addition to the drive train, a significant portion of the power generated by a diesel engine is distributed through hydraulics. Emission regulation and high cost of fuel have driven OEMs to develop the next generation hydraulic system with the same performance but with improved fuel efficiency.
In this paper, an intelligent electro-hydraulic valve system used in wheel loaders is presented. The uniqueness of the valve system is Valvistor technology. The pilot operated proportional poppet valve has the large flow rating and automatically reduce the throttling loss. Four Valvistors connect to each work port of a hydraulic cylinder to pressure and tank separately. The decoupling of the meter-in and meter-out flow for tilt and lift work functions significantly improves operational efficiency and control flexibility.
This is in particular important for mid to large size wheel loaders. Moreover, the sensors and the microcontrollers are embedded in each function and integrated via the network. Such modular design eases not only mechanical integration, but also software development and validation. The distributed sensors also enable electronically controlled load sensing technology that intelligently manages power based on the transmitted pressure sensor signals. All of these features are integrated together for improving efficiency.
For such a complex system that can only function with all the controllers in place, it is quite difficult and costly to develop and validate the software on the actual vehicle platform. Hardware-in-the-loop (HIL) platform would be very useful to serve as a virtual system in a wheel loader interacting with electronics and ECU. Development, assessment and validation of control and diagnostic algorithms being conducted on such a platform would save time, man power, and cost. In this paper, modeling approaches for the above hydraulic components and system are presented. The HIL platform that enables hardware in the loop validation for the wheel loader intelligent hydraulic system is presented in detail.

1-10 Development of the independent swing system for a fuel efficient hydraulic excavator

K. Kim, H. Ahn, D.-S. Jang

This paper presents an improvement of fuel efficiency and power control for independent swing system. The swing pump and swing motor comprise a closed hydraulic circuit. Not only does this system remove pressure loss, but it can also regenerate swing kinetic energy. The developed independent swing system is installed into the Doosan Infracore 48ton class excavator and evaluated with 12.3% improvement of the pump power compared to current system in the excavating test mode. Through the feed forward logic, engine speed is controlled to stay within 4% from the reference RPM.

1-11 Power-split transmissions for construction machinery

T. Anderl, J. Winkelhake, M. Scherer

Actual requirements and future challenges of travel drives are demonstrated based on wheel loader applications. Potential to raise productivity, to improve efficiency and automation versus established hydrodynamic and hydrostatic travel drives will be shown.
Dana Rexroth Transmission Systems – a Joint Venture of Bosch Rexroth AG and Dana Holding Corp. – offers a new hydro-mechanical variable power-split transmission (HVT) for construction machinery. Design and functionality of the HVT and applied development methods for endurance dimensioning and model based software design are presented. Potential of the transmissions tractive-, ratio- and power-management capabilities will be demonstrated with measured values. For this, results from drive and working operations on a 4-wheel-drive roller test bench and field operation will be presented.