Abstracts

Group 5: Industrial Hydraulics

5-0 Achievements and Potentials of Hydraulic Drive Technology demonstrated on plastic injection moulding machinery

G. P. Holzinger, R. Schiffers

This general lecture will give an introduction to the Group 5 on Industrial Hydraulics at the 8th International Fluid Power Conference in Dresden in Germany. Introductory market-relevant existing injection moulding machines concepts will be presented with respect to the different areas of application. In addition to standard injection moulding machines more complex systems with high level of integrated functions as can be found in automotive applications will be shown. This is followed by a summary of the demands for the different drive axles of injection moulding machines. The focus here is force, speed, reproducibility and energy consumption. For the purpose of comparison electro-mechanical drives are also listed with. Furthermore, the competitive situation of electro-hydraulic and electro-mechanical drive technologies in injection moulding machines is illustrated and a prognosis for future development will be presented. Finally, trends and requirements for the hydraulic drives are formulated from the perspective of an injection moulding machine manufacturer.

5-1 Analysis of the Energy Efficiency of Hydraulic Deep Drawing Presses

H. Lohse, J. Weber, D. Klug, T. Klusmeier, K.-H. Petzold

Hydraulic deep drawing presses are widely used for industrial sheet metal forming today. Small manufacturers of drawn parts and suppliers of the automotive industry especially appreciate these machines because of their flexibility in process design.
Despite their high energy consumption, the energy efficiency of modern hydraulic presses is nearly unknown due to a lack of experimental investigations as well as suited simulation models.
The authors' objective is to reduce this gap by analyzing the energy efficiency using measurement and simulation. This is the prerequisite for systematic technical improvement.

5-2 Variable-Speed Pump Drive System for a 5000 kN Ring Expander

E. Siemer

In cooperation with Bosch Rexroth and MAE Maschinen- und Apparatebau Götzen, a new hydraulic drive system has been designed using the example of a ring expander. Ring expanders are part of a process chain for the manufacture of high-precision rolled rings in particular for high-alloy steels. In this application a large differential cylinder acts on an expanding cone. This in turn acts via 9 or 12 segments, so-called expanding shoes, on a rolled ring to calibrate the inside diameter. Here, similar to a bending process, the ring is expanded beyond its yield point and brought to the required dimension.
The concept is based on a frequency-controlled servo-asynchronous motor with a drive power of 65 kW. An axial piston pump rotating clockwise and a second axial piston pump rotating anti-clockwise are mounted on a common drive shaft. Both pumps are designed as variable pumps with a mechanical torque controller. The swash plates are designed for two-quadrant operation. The reliable reduced set-up speed is attained without additional valve control by means of the reliable limitation of the servo-motor speed according to Cat. 3 via a module in the frequency converter.
"With the variable-speed pump drives, Rexroth now offers pump control in a highly dynamic intelligent electrical drive which only generates the volume flow actually required. Reduced speed during breaks in the cycle or when not running at full power mean a significant drop in the energy required, in noise emissions and in hydraulic power losses. The pump drive increases the speed of the highly dynamic motors as required as soon as the hydraulic system needs more power. All components come from the standard Rexroth product portfolio." /1/

5-3 Energy Efficiency of Various Hydraulic Drives used in Injection Moulding Machines

R. Schiffers, G. P. Holzinger

The presentation starts with an introduction of the injection moulding process. The basic process steps of the injection moulding cycle as well as the relevant machine functions are illustrated.
Besides the performance and productivity of injection moulding machines in recent years the subject of "energy efficiency" has moved more and more into focus and can be demonstrated by an increased marked demand in the plastics processing industry. Driven by the need of an improved systems efficiency several new developments have been introduced in the hydraulic drives technology of injection moulding machines. One approach for example is the use of frequency converter controlled variable speed servomotors in the power pack of injection moulding machines. Compared to the current standard drive, the mains-powered asynchronous motor with variable displacement pump, they have very low power losses at low flow rates or in idling phases. Depending on the mould that is installed and the corresponding process settings, the savings in terms of energy can be as high as 50% of the total energy required by the machine. The presentation will offer an overview on the different drives that are used in injection moulding machines and will give a classification by means of energy efficiency in different fields of application.
Since the hydraulically driven injection moulding machines have to compete with electromechanically driven ones at the market, these are also taken into account.

5-4 Dynamic improvement of hydraulic drive trains by trajectory planning and learning algorithms

T. Radermacher, J. Weber, D. Dorner, B. Wagner

The improvement of servo-controlled applications and the disturbance-compensation with good dynamics, little overshooting and minimization of steady state errors is a focus of investigation in electrohydraulic drives. The need for energy-saving solutions with good efficiency leads to the question how the productivity of drive trains can be maximized. The approach proposed in this paper shows a way to maximize the utilization of repetitive processes taking the drive limitations into account. Combining the planning of trajectories according to the systems limitations and an iterative learning controller (ILC) this paper shows a way to achieve good accuracy despite varying drive system parameters and limitations. The iterative approach uses an inversion-based mathematical model of a highly nonlinear plant to minimize the position error on basis of a quadratic next-iteration cost criterion. To show the potential of the ILC it is applied to the displacement-controlled clamping unit of a 1600 kN injection moulding machine. Furthermore the methodology shows a way to recall the
maximum dynamic potential of the displacement-controlled hydraulic drive system without reaching stability limits.

5-5 Pump Actuator Based Control of a Clutch System

C. Junge, F. Budschun

Typically a clutch brake combination (CBC) is actuated by a hydraulic unit consisting of a pump and a valve system. By operating the valves different pressure levels can be generated, which determine the transmittable torque. The rated power of the pump is considerably high, consuming a lot of energy even when no work is done. If a system requires additionally the availability of multiple possible pressure levels, the system gets very complex. Furthermore at the attachment of the system the valveadjustment takes a big manual expenditure of human labor.
A flexible adaptation and the elimination of disturbances would be excellent for modulating the torque. Additionally the reduction of the energy consumption becomes more important today.
Therefore the standard hydraulic pump is replaced by the pump actuator, which essentially consists of a variable speed driven hydraulic pump. This generates superior control possibilities over a standard hydraulic system and allows a great reduction of the energy consumption, better control possibilities for the complete system, as well as new methods of fault diagnostics.

5-6 CLDP - Hybrid Drive using Servo Pump in Closed Loop

B. Brahmer

This paper presents an approach for energy efficient hydraulic drives. A differential pump is directly connected to a differential cylinder. By principle, energy losses and heating of the fluid are very low. Control loop design is surprisingly simple, because given technology and software from electromechanical drives may be applied. Finally, the approach is attractive because of the degree of freedom in mechanical layout and also because from the outside, the drive appears to be “non-hydraulic”. Ease of use and wide technology basis of electromechanical drives is combined with the ruggedness and overload proof of hydraulics.

5-7 Better Braking – Energy Saving Concept for Cylinder Drives with Large Masses

R. Bublitz

Energy saving is currently one of the major trends for drive technology. This applies to the automotive industry as well as to mobile and industrial applications. Intensive research on alternative drive concepts is done not only in the automotive industry but in mobile and stationary hydraulic systems, too.
For hydraulic drive systems enhanced solutions such as variable speed controlled pump drives were developed. These systems provide only the required volume flow and pressure level and avoid throttle losses.
Another approach is only to rethink about the dimensions of the cylinder drives. If a single rod cylinder has to move large masses dynamically the required cylinder diameter is sized by the resulted acceleration and deceleration force.
Within this paper a new drive concept is presented that uses an additional circuit to realise significantly higher deceleration without overloading the cylinder. It allows at the same cycle time the use of cylinders with smaller piston diameters. This reduces the needed pressure level at the same volume flow and the needed hydraulic energy input.

5-8 New Options for a Cost-Saving Wear Monitoring in Fluid Power Systems

C. Krähling, T. Meindorf

In recent years oil condition sensors have been proven as a reliable way to reduce the total cost of ownership. A major application hereby is the cleanliness or wear monitoring. During the operation of hydraulics and gearboxes contamination and wear will cause high costs for the machine owner. The damage by particle contamination results in unexpected downtime, long lead time of spare parts and loss of production. Contamination and wear in gearboxes and hydraulic systems are nowadays monitored with optically operated automatic particle counters and monitors. Alternatively, inductively operating metal particle counter are used to detect metallic particles. However, in certain applications these types of meters are impractical due to the high costs and technical limitations, such as inadequate measurement accuracy or sensitivity to air bubbles. An old fashioned and cost-effective way to detect ferromagnetic wear particles are magnetic plugs, which are still widely used in many applications. Although the sensors are relatively cheap in the production, a costly service is needed to manually inspect and clean the sensor during operation, such as the high-wear situation at the run in of a machine. As part of the contribution a novel sensor concept based on a magnetic debris sensor is presented, which overcomes the shortcomings of known magnetic plugs. The sensor uses a permanent magnet to attract ferromagnetic particles on the sensor surface and accumulate them. The measurement of the accumulated amount of particles is done inductively, which makes a visual inspection unnecessary. Through the sensitivity of the measurement principle even small amounts of wear particles can be measured. The accumulation of wear can be further assessed as sum over time and not as separately occurring events. To enable a repetitive measurement the sensor cleans
itself automatically, using an electromagnet, which produces an opposing field to compensate the permanent magnet. By evaluating the time between two cleaning cycles of the sensor the contamination of the system or the wear of a component can be detected. Long cycle times between indicate small ferromagnetic wear, short times indicate increased wear. The sensor

principle is initially designed for wear monitoring of tribological systems with ferromagnetic materials, e.g. roller bearings. However, it is also possible to detect the wear of non-ferromagnetic materials, through secondary induced abrasion.

5-9 Recirculation of Hydro-Mechanical Power at Stands for Testing Endurance of Hydraulic Cylinders

T. C. Popescu, D. D. I. Guta, R. Radoi

Endurance testing on volumetric machines and hydraulic equipment involves high energy consumption, as it takes a long time to carry them out and they are conducted at rated power. Energy consumption of the test stand can be reduced by a special construction of the pumping group. This includes two hydraulic volumetric machines, a pump and a motor, connected in a closed hydraulic circuit and mechanically coupled to an electric motor. Hydropower produced by the pump is reused in order to drive the pump through the engine. Thus, the power delivered in the system must cover the difference between the power consumed by the pump and the one supplied by the motor, and energy-saving process is called "hydro-mechanical power recirculation".
The material shows the influence of hydro-mechanical power recirculation on energy consumption at stands for testing endurance of hydraulic cylinders, by: comparative analysis of energy consumption for two modes of operation of a mini-stand for testing endurance of hydraulic cylinders, coupled and uncoupled to hydro-mechanical power recirculation; demonstration of energy saving at these stands for testing endurance that operate on the principle of hydro-mechanical power recirculation.

5-10 Experimental Study of Motion Synchronization of Hydraulic Servo Cylinders for Moulds of Continuous Casting Machines Oscillation

T. S. Eldin, S. Kassem

This paper reports the details of a test rig as well as results of experiments conducted to investigate the effect of using a cross coupling controller (CCC) on motion synchronization of two hydraulic servo cylinders. The drive and control system of the two cylinders in the rig is similar to that used frequently nowadays to oscillate the heavy moulds of continuous casting machines. In these systems each of the two cylinders is driven independently in an accurate closed loop control system. The accuracy of position synchronization of the two cylinders is affected in practice by disturbances that have detrimental effects on motion synchronization and may eventually lead to unpredictable production interruptions. A CCC with either a fuzzy logic controller (FLC) or a Proportional (P) controller had been proposed. It showed theoretically to reduce synchronization errors (SE) due to disturbances to practically acceptable values. During experiments each of the two servo cylinders had been loaded with almost constant load by means of two other hydraulic servo cylinders to simulate the mould weight. The experimental results showed that the FLC yields better motion synchronization compared with the P controller .

5-11 Multi Domain Mechatronic Optimization of an Intelligent Electro-Hydraulic Actuator

F. Poltschak, O. Koch, B. Farrokhzad, W. Amrhein, J. Weber

Electro-hydraulic systems combine the advantages of both, the electromagnetic and hydraulic domain and bring together e.g. the good controllability and precision of electrical drives as well as the unbeatable power density and higher robustness of hydraulics. An interesting application in this area is an electro-hydraulic actuator specifically designed for high-speed, high-force, high-precision punching applications. To further optimize the actuator design for the next machine generation the traditional layout process can be enhanced by an optimization step. This starts at the stage of conceptual design, needs a fundamental understanding of the underlying processes and a multi-domain mechatronic model. Therefore the simulation software designed for optimizing electrical machines is enhanced to cover electro-hydraulic and thermal issues too. The advantages of the integrated approach and the principle functionality of the simulation tool are demonstrated in context of the optimization of a newly developed electro-hydraulic actuator which was originally developed for punching machines.