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Technical article

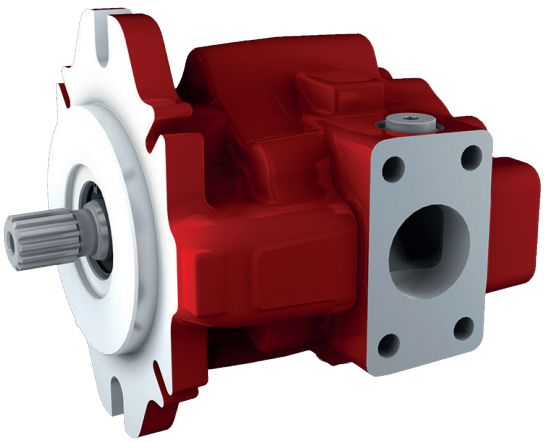
High-Efficiency Pump for Battery-Powered Construction Machines

The newly designed AX from Bucher Hydraulics puts an end to the usual disadvantages of hydraulic pumps

The move to electrical power is also impacting mobile construction machines. When it comes to high forces, however, hydraulics still sets the pace. A novel, high-efficiency pump enables batteries to last longer.

The replacement of hydraulics by electrical systems has often been suggested. The systems proposed are usually based on electrical drive technology in conjunction with mechanical gears, levers, chains or belts – rotary drives, in other words. However, mobile construction machinery requires linear drives with a high force in a very small space. They must also be as robust as possible in the typically harsh environments faced by mobile machines.

With an electromechanical drive, it is usually necessary to convert the rotation into a linear motion by means of threaded spindles or ball screws, for example, and in these environments the drive quickly reaches its limits. Electromechanical drives of this type are quite unsuitable for a construction machine, because the electric motor and gearbox form a heavy and non-separable unit. Each hydraulic cylinder would have to be replaced by such a unit.



The new AX piston pump is available in various sizes with displacements from 18 to 76 cm3/rev, and up to 122 cm³/rev coming soon.

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Ball screws can be fairly compared with ball bearings: they are just as susceptible to impacts. In the event of an overload, even mechanical components can be damaged. Having said that, we should also recognize that shocks, impact loads and overloading are the rule rather than the exception for construction machinery in harsh environments.

The hydraulic cylinder remains vital

In an electromechanical construction machine, every linear drive requires an electric motor with gearbox and spindle. Because we are dealing here with high-power drives, they must be installed directly on the mechanical systems, although it is never the case that all drives require full power at the same time. This leads to unnecessarily high costs. In addition, the rigid arrangement of the e-motor/gearbox/spindle unit is likely to cause considerable space problems on construction machines. On the other hand, electromechanical drives also have clear advantages such as their high energy efficiency and good controllability.

It follows that the hydraulic cylinder is also indispensable for the construction machines of the future. It offers the ideal qualifications for precisely these special operating conditions. Only with a cylinder can high forces be produced in the smallest space. The simple separation between drive and actuator enables flexible configuration in the construction machine. Thanks to its compressibility, the hydraulic system is inherently very tolerant of shocks, impacts, and overloads. Pressure relief valves provide additional protection to the relevant components. Electromechanical drives, in contrast, require shear pins that will shear off if overloaded. This leads to machine standstill and relatively costly repair work.

The power in a hydraulic system can be distributed as required. The total installed power can therefore be lower than the sum of all the cylinder powers together. Compared with electromechanics, this makes hydraulics the more cost-effective technology. As well as that, the prices in €/kW for electromechanical equipment are significantly higher.
On the other hand, we should not conceal the disadvantages of today's normal hydraulic control technology: above all, these are the high losses due to throttling, bypasses, pipes and hoses that are too small and the less-than-ideal efficiencies of the pumps. In addition, the noises from the hydraulic system become dominant in electrical machines because they are no longer being drowned out by the noise of a diesel engine.

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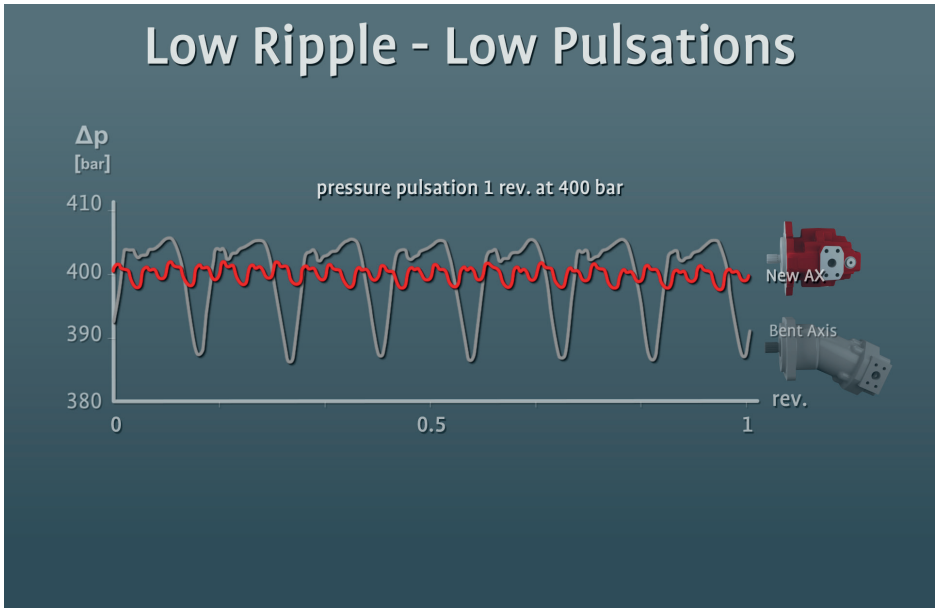
The best of both worlds: electric drives with hydraulics

Two technologies are therefore available, each with very distinct advantages and disadvantages. So why not combine the advantages of electrical drive technology with those of hydraulics to build the optimum electrically powered construction machine? Instead of an electromechanical linear drive, an electrohydrostatic linear drive can be used. It consists of a speed-controlled electric motor, an efficient pump and a cylinder. With the exception of safety functions, energy-hungry valve technology can be dispensed with. Thanks to its low power dissipation, this configuration is very energy-efficient, and it can be controlled just as easily as an electromechanical drive, as trials on the test bench have shown.

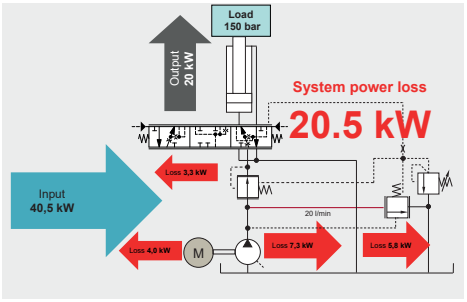
The electrohydraulic linear drive has another advantage in its favor: it makes it particularly easy to recover energy during braking and lowering. In this arrangement, the costs of the drive system – with an electric motor and pump for each cylinder – must be weighed up against the lower battery cost.



The AX reduces pressure pulsations by 80% (graph shows 1 revolution at 400 bar).

Alternatively, optimized valve controls with one electric motor, one pump and several cylinders can be an attractive solution. Combinations of the different systems in one machine are also possible. In any case, an analysis of the power losses over the machine load cycle is always worthwhile.
The performance of electrohydraulic linear drives in a closed circuit is wholly comparable to that of electromechanical drives, without their particular disadvantages. These drives are ideally suited for four-quadrant operation with high power levels and recoverable energy, such as is found in boom or heavy-lifting functions.

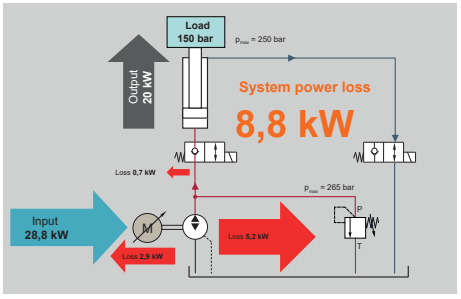
Traditional hydraulic control
Throttle and bypass losses, constant motor speed



Database	
Pump	100 l/min, 175 bar
η Pump	0.8
Cylinder	80 l/min, 150 bar
η e-drive	0.9

- Low invest costs for several simultaneous operations
- High losses for throttle, bypass, pump

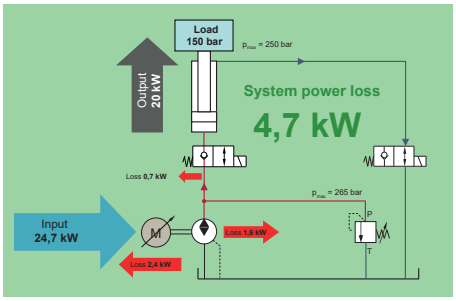
Direct pump control, variable speed e-motor
Standard pump η = 80%



Database	
Pump	80 l/min, 155 bar
η Pump	0.8
Cylinder	80 l/min, 150 bar
η e-drive	0.9

- Improved efficiency
- No losses for throttle, bypass
- High pump loss

Direct pump control, variable speed e-motor
High-efficiency pump η = 93%



Database	
Pump	80 l/min, 155 bar
η Pump	0.8
Cylinder	80 l/min, 150 bar
η e-drive	0.9

- High-efficiency pump – further reduces losses
- **Conclusion:** It is beneficial to analyze the system and all components with regard to losses

The AX pump reduces the system power loss by about half when compared with a conventional pump and comparable performance data.

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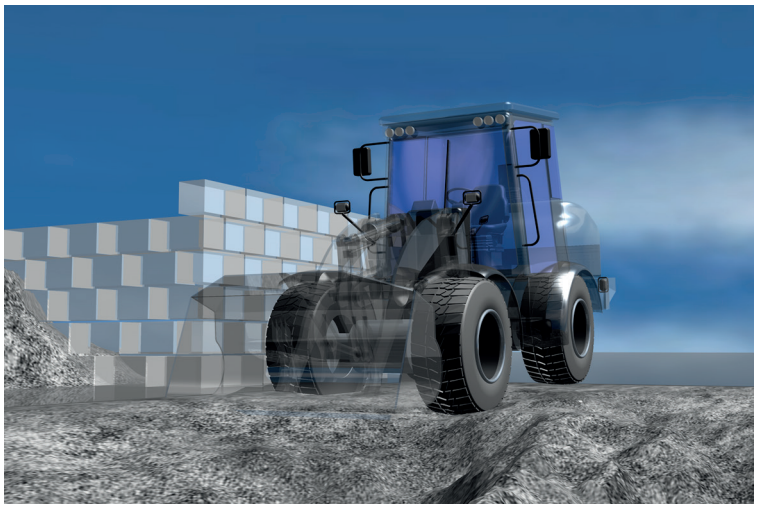
The potential of the move to electrical power

The electrification of construction machinery opens up completely new possibilities that – because of their operating principle – today's hydraulic systems simply cannot offer. For example, all rotary and linear drives can be connected with one another via the DC intermediate circuit, or DC link. The electrical energy in the DC link can be provided by batteries, supercaps, a diesel generator or a fuel cell. From this DC link, the drives draw only the power they need. They can also feed back potential energy recovered from lowering and braking operations.

Depending on their functional characteristics, the cylinders can be operated in open- or closed-loop mode. A battery can serve as an energy buffer so that the diesel engine can always run at its optimum operating point with the lowest specific fuel consumption and optimum combustion. Power peaks during acceleration are covered by the electrical energy storage device. In many mobile machines with typical cyclic load profiles, the diesel engine – once it is decoupled from the work functions in this way – can therefore be considerably smaller.

Overall, electrification offers a mix of different hydraulic drive concepts that can be applied in a flexible combination to meet the requirements of the application and the project budget. For example, the most powerful actuators can be equipped with the new AX pump technology from Bucher Hydraulics while, for drives with lower outputs and shorter 'On' times, conventional load-sensing valve technology may be more economical. But even with these drives, there is plenty of potential for efficiency improvements.



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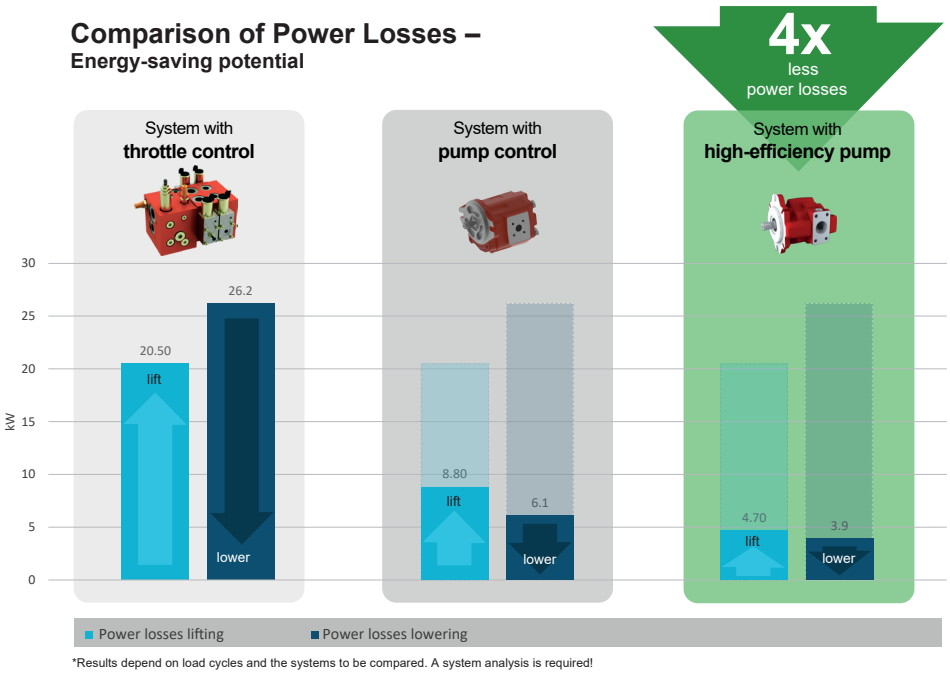
The optimum hydraulic pump for electrification

The high efficiencies of modern electric motors over a wide operating range, together with their low power losses, are in sharp contrast to conventional hydraulic pumps with their lower efficiency and correspondingly higher power loss. This was the starting point for Bucher Hydraulics' development of a new type of pump that systematically eliminates friction losses. Bucher Hydraulics presented the new AX pump at Bauma 2019. It attracted a lot of attention and promptly became one of the finalists for the "Bauma Innovation Award". It is available with displacements from 18 to 76 cm^3/rev, and units with up to 122 cm^3/rev will be available in future. The pump is suitable for continuous pressures up to 450 bar, the usual maximum pressure for construction machines.

Featuring high efficiencies over a wide operating range, it is the ideal partner for efficient electric drives. Looking at some numbers: While a conventional pump may exhibit a power loss of 5.2 kW, it is only 1.6 kW with the new Bucher Hydraulics AX pump. This saves a lot of kilowatt hours, a fact that is particularly noticeable with battery operation. The battery can either be made smaller and cheaper, or its running time can be extended, as modeling calculations (and initial experience) have shown. The extremely low friction not only reduces the power loss, it also decreases wear to almost zero. This makes it possible to achieve a long and reliable service life.

The new AX pump also solves the previously mentioned problem of many electrification projects: the high noise level of the hydraulic components. End users expect electrical machines to have a low noise level that today's axial piston pumps cannot match. Gear pumps are quieter, but they are not designed for the pressure range required for construction machines. Additional sound insulation is difficult to implement due to the cramped conditions, and costly. The AX pump eliminates the causes of noise emission. Even at high power levels, it operates at a comfortable noise level that is comparable with that of electrical machines.

A typical lifting/lowering function for construction machines gives a good illustration of the energy-savings potential of the AX when compared with a valve-controlled system and with an electrohydraulic linear drive using a conventional pump. The power loss from the high-efficiency AX pump can be as much as 50 % less. This also reduces the CO2 emissions. The new operating principle also removes the minimum speed limit that would otherwise have to be observed. This makes it possible to achieve precise cylinder movements without any additional measures. This considerably simplifies and extends the application scope for variable-speed pumps. The AX pump from Bucher Hydraulics therefore meets all the requirements for battery-electric drives for mobile machines.



For lifting and lowering, the new AX pump (right) from Bucher Hydraulics requires less than a quarter of the energy of a classic valve-controlled system.

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