High-pressure plunger pumps in water hydraulics

Dipl.-Ing. Ralf Bukowsky, Dipl.-Ing. Thomas Jockenhöfer and Norbert Leonhardsberger

High-pressure plunger pumps are the core element of modern water hydraulic systems. They are used as press drives, in descaling systems, for hydroforming or in underground mining pump stations – just to name a few. The increasing dynamics of innovations and the demands of the markets for high-performance, efficient high-pressure pumps and water hydraulics systems mean that a high degree of specialist engineering knowledge and competence is required. Continuous further development of pumps and turnkey integration into production processes in the various areas of application are imperative.
The economical use of energy and raw material resources, the benefits of water in new applications, together with current materials and designs, mean that water hydraulics is being used increasingly for industrial applications.

**Differences between oil and water hydraulics**

In oil hydraulics, axial piston pumps have essentially become established; used as fixed displacement pumps and control pumps.

Oil hydraulic components have high-quality demands for the hydraulic fluid with regards to specifications and purity. These demands or similar demands are currently not met in water hydraulics. The reasons for this may be process-related, e.g. in descaling or parts cleaning. Or the users are not yet prepared to dedicate the effort that is common in oil hydraulics for ensuring the quality and purity of the fluid medium. Water is generally readily available, but in varying quality. Therefore, it is also necessary to stipulate specifications for the fluid in water-based hydraulics. The aim should be a comparable level of caution and care in the application of water hydraulics systems as it is already the case in oil hydraulics.

The benefits of water in comparison to oil contribute considerably to the areas of use for water hydraulics. The good viscosity-temperature performance enables an even control accuracy in case of temperature changes. Thermostatic control of the cooling circuit is therefore not required. Compared to mineral oil, and as a result of its up to 50 % higher bulk modulus, water has lower elasticity. As a result, there are minimal switching delays and time delays as well as smooth movements at pressure and load changes. The lower viscosity and higher corrosive aggressiveness represent a challenge for design engineers.

Compared to oil, water can absorb around twice as much heat due to its high level of thermal conductivity. This leads to lower thermal strain in throttling points. The 16 % higher density of water means liquid friction and flow losses are lower. Pressure losses with the same flow rate and pipe diameter are approximately 50 % lower. As a non-combustible liquid with almost unlimited availability, the chemical-physical properties of water have a positive influence on procurement, operating and insurance costs.

Water hydraulic components nowadays are just as stable and reliable as oil hydraulic pumps. Thus, RWTH of Aachen, for example, uses a water hydraulic inline piston pump for stability trials for oil hydraulic valves. The hydraulic water inline piston pump has already outlived generations of oil hydraulic valve components. One disadvantage of the water hydraulic pump is that it is not adjustable. Experts in water hydraulics compensate this disadvantage with innovative system design. A prerequisite is a suitably comprehensive product range with pumps with the appropriate engineering principle to make flexible delivery rates possible.

**Pumps in modern water hydraulics**

Pumps nowadays have to be energy-efficient, robust and engineered for continuous operation in their applications. High quality materials, wear-resistant and corrosion-resistant coatings, innovative technical designs as well as the latest manufacturing and inspection processes guarantee low wear and long service lives. With

**Water hydraulics – a historical digression**

Nowadays, the term “hydraulics” is often used as a synonym for “oil hydraulics”. Historically however, the term “hydraulics” comes from the Greek “hydor”, for water, and “aulos”, for pipe. Water hydraulics is the oldest hydraulic technology in the world.

The origins of industrial technical water hydraulics are marked by the patent registered by Englishman Joseph Bramah in 1795 for a hydraulic press driven by water pressure. The press operates in accordance with Blaise Pascal’s law of hydrostatics in communicating vessels and amplifies the applied force 2034-fold. In Bramah’s press, the water is not used exclusively for force but also for signal transmission.

The first weighted accumulator for large volumetric flow rates was developed by William G. Armstrong in 1851.
a broad portfolio of three-plunger and five-plunger pumps, which cover a range of volumetric flow rates from 50 to 738 l/min with operating pressures of up to 500 bars, a wide range of applications can be covered. Optionally, every pump type can be equipped with an external lubricating oil supply and a variable frequency drive.

Various volumetric flow rate and pressure combinations are possible with every pump type by simply replacing the pump inserts. This way, the units can be adapted flexibly if the conditions and requirements change. Numerous additions and adaptations are available for all pumps. Starting with pump bypass, pressure limiting and safety valves, through pulsation dampers, to custom designs, fully tailored pump units can be manufactured.

The range and the configuration options are an important prerequisite of the numerous applications of high-pressure pumps in water hydraulics. Alongside generating pressure, pressure control is also essential for water hydraulic systems. In particular on press systems in the aluminium, copper, steel and stainless steel industry, both press drives and press controls are essential system components which require a high degree of specialist competence.

The following examples for descaling and hydro-forming show two industrial areas of application. A mining application is also assessed in more detail with a high-pressure pump station for underground longwall mining.

Other areas of use for high-pressure plunger pumps can be found in the food industry, energy production, petrochemical and various other industrial processes.

**High-pressure pumps for descaling**

Together with solid forming, hydro-mechanical descaling systems are a classic application for water hydraulic systems. Next to the goal of achieving scale-free surfaces, energy efficiency, minimum water consumption and thus minimum cooling of the workpieces and optimum integration of the descaling system in the production plants, they represent requirements which are no less important or demanding. High-pressure pumps are the heart of every descaling system, regardless of the products being descaled and how the system is engineered.

The removal of the layer of scale from the surface of the workpiece by way of hydro-mechanical descaling can essentially be performed in three ways, whereby the differences between these “types” are minimal to non-existent and their contribution to complete descaling is not shown or cannot be demonstrated precisely.
• **“Breaking”:** The “mechanical impact” of the water jet on the surface of the workpiece creates cracks or breaks in the layer of scale, which may already cause scale to fall off but which also serves to make the processes described in the following more possible.

• **“Removal”:** The water which penetrates between the layer of scale and the surface of the workpiece causes the workpiece to cool locally. Different changes in volume cause the layer of scale to split open.

• Parts of the water also evaporate under the layer of scale and also advance the splitting of the scale.

• **“Washing”:** Loose or less firmly adhered scale is flushed away by the water.

The numerous influential factors during the formation of scale, and also the various effects or descaling, make it difficult to make a precise statement in advance regarding the type, quantity and adhesion of the scale. It is also difficult to determine a processing solution in advance. The intention of this article is not to address the theoretical calculation of the expected layer of scale using the parabolic scale constant. However, two common parameters of the efficiency of the descaling are described:

**Hydro-mechanical descaling systems are a classic application for water hydraulic systems.**

• **Impact:** The impact in N/mm² essentially describes the force with which the water jet meets the surface of the workpiece. It is the combination of pressure and flow which is the result of the nozzle geometry, also decisively influenced by the distance between the nozzle and the surface.

• **Spray energy:** In addition to the parameters listed above, the spray energy also takes into account the water quantity in litres per m².
A system is either a direct descaling design or a high-pressure accumulator system depending on the product and the cycle times or, specifically, the spraying and pause times. The direct descaling method uses high-pressure pumps to deliver directly to the respective nozzle beam. Valves are used if multiple nozzles are activated at staggered intervals. This type of descaling is usually used for long products, such as profiles or wide strip material.

High-pressure accumulator systems cover peaks in demand and are thus designed for products which require short spraying times and longer pause times.

Modern plunger pumps can be used with all system designs for pressure generation. The trend towards higher operating pressures of 400 bars, and more in some cases, represents a proven operating parameter which has been tried and tested over many years for these pumps. This guarantees a high degree of operational reliability and safety. Because of the displacement principle, plunger pumps are suitable for operation with frequency converters and allow a maximum of energy efficiency and the option of infinitely variable adjustment to the current required delivery flows.

Plunger pumps are also used in hydroforming, where they form hollow metal parts into shape.

Hydroforming is the forming of hollow metal parts in a closed mould using high water pressure. The forming is performed using a water-oil emulsion which is pressed into the workpiece at high pressure. During the forming process, the pipe ends are sealed off by sealing punches which are driven by hydraulic cylinders. In the process, the essential processing parameters are the internal pressure, which in series production can usually be up to 4,000 bars, and the pushing into place of material or compression of the ends of the component with the aid of the sealing punches.

The forming process can be broken down into three stages. Whilst the mould tool is being closed, the workpiece is filled, i.e. the air is removed from the workpiece, with a large conveyed volume in the low pressure range. Once the sealing punches have reached the workpiece, the plunger pump is activated. Its task is to remove the remaining air from the workpiece and bring the fluid to a pressure of 200 to 250 bars. The maximum pressure depends on the workpiece. Forming is not yet performed. For this purpose, the downstream pressure intensifier is used. Due to its design, it only has a limited volume. For this reason, it has to be assured that the plunger pump precisely achieves the maximum preliminary pressure, especially in the case of workpieces with large volumes.
In order to fill both small and large workpieces with the same plunger pump, it is equipped with a variable frequency drive. This has the further benefit that during the depressurized circulation, the plunger pump is reduced to a minimum speed and thus energy is saved.

Ultimately, only the pressure intensifier is responsible for forming the workpiece. It generates the finished form with complex controlling. Hydroforming is principally used in series production for the automobile industry.

High-pressure pumps in high-performance longwall mining

In underground mining, longwall mining with shearers is one of the quickest and most efficient mining methods. For this method, high-pressure and water spray pump stations are used. High-pressure pump stations supply the roof supports (longwall hydraulics) with the necessary power. Water spray pump stations are used for supplying the shearer spraying system or the coal plow water spraying system and for the cooling systems of drive motors. The increasing length and height of the roof supports and the increasing speeds of mining machines mean that the demands for pump stations are also constantly increasing.

The pump stations for two Russian mines have been specially designed for the requirements of the high-performance longwalls on the site. A typical longwall at these mines has a length of approximately 300 m, a seam height of approximately 3 m and a mining progress rate of approximately 20,000 tons a day. An appropriate pressure flow and volumetric flow rate is required to supply it. As well as these high demands which the high-pressure system has to meet, the mine also had special requirements for the water quality in the longwall in order to
Protect the longevity of the longwall equipment and thus the investments. These factors had to be taken into account during development of the pump train. The result is a highly modern, extremely efficient high-pressure pump station: The high-pressure station described here comprises eight interlinked individual stations. The raw water first enters a water treatment system. In this station, the water is directed into a water cyclone in which all solids are separated off. A three-stage filtration process with automatically back-flushing dual filter stages of 100 μm, 50 μm and 25 μm then follows. An HFA-bag return filter with a filter mesh of 50 μm is also stored on this station. It cleans the water-HFA emulsion returning from the face before it is led back to the tank. After the three-stage filtration, the fresh make-up water enters a water treatment system which has been specially developed for underground mining. This station produces
1,000 l of clean, salt-free water in one hour at a water feed pressure of 15 bars. After the treatment process, the water has a conductivity of approximately only 30 µS and is almost completely salt-free.

After the water treatment station, the water is enriched in the automatic emulsion mixing unit with concentrate before it returns to the main tank as a water-HFA emulsion. This stainless steel tank has a total volume of 6,000 l which is broken down into 5,000 l of water-HFA emulsion and 1,000 l of HFA concentrate. As well as the automatic emulsion mixing unit, the tank is also equipped with analogue filling level meters in the HFA and concentrate sections. Both sections are protected from rock falls and other influences by stainless steel tank covers. On the tank, a transmitted light refractometer with double prism is used for monitoring the emulsion. The main tank is connected to an additional 6,000-litre stainless steel tank which is used primarily for increasing the dispensing volume.

A total of three five-plunger high-pressure pumps, each driven by a 400 kW electric motor, have been installed in the pump station and provide the longwall with the necessary power. Each pump delivers a nominal delivery flow of 635 l/min and a maximum operating pressure of 360 bars. The pumps which were developed for mining are designed with flange mountings. Each pump is equipped with its own pressure relief valve, a pump circulation valve DN40 PN 420, an oil gear pressure and temperature monitoring function and integrated oil gear cooler.

The pressure and volumetric flow generated by the pumps is delivered to a manifold block on the accumulator and filter station. The water is directed from the manifold block to two high-pressure double back-flushing filters with automatic back-flushing, and it is filtered one more time. Two hydraulic accumulators with 32 l PN400 are installed in this station for pulsation optimization in order to reduce pressure peaks and switching surges. The water runs through a distribution block and is led to the hydraulic shield supports in the face.

**Water hydraulics – a genuine alternative**

The fields of application described in the examples show the increasing options for modern high-pressure plunger pumps in water hydraulics. New materials and developments will continue to further promote water hydraulics in the future and enable an even wider range of applications. With water as a hydraulic medium, there is thus a genuine alternative to hydraulic oil in many areas.

**Authors:**
Dipl.-Ing. Ralf Bukowsky,
Product Development Manager
Dipl.-Ing. Thomas Jockenhöfer,
Engineering Solutions Manager
Norbert Leonhardsberger,
Business Unit Industry
Hauhinco Maschinenfabrik G. Hausherr,
Jochums GmbH & Co. KG, Sprockhövel