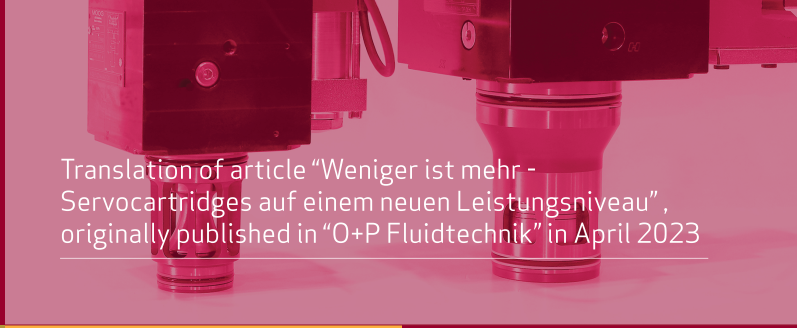
LESS IS MORE - SERVO CARTRIDGE VALVES AT A NEW PERFORMANCE LEVEL



Translation of article “Weniger ist mehr - Servocartridges auf einem neuen Leistungsniveau”, originally published in “O+P Fluidtechnik” in April 2023

2-way cartridge control valves, also known as servo cartridges, are used where high flow rates have to be controlled with precision and with high dynamics. Common applications are, for example, the control of the casting process in die casting machines or the control of force build-up and decompression in forging presses. Moog has designed a complete new series of these valves.

In addition to high dynamics and increased operating pressures (420 bar), the market requirements for 2-way servo cartridge valves are also moving in the direction of higher rated flows in order to be able to save installation space and thus also costs by using smaller nominal sizes. Furthermore, energy efficiency is becoming increasingly important, especially with regard to control oil consumption.

In the development of the new X700 Servo Cartridge Series, the focus was therefore on meeting the above-mentioned requirements in terms of flow, dynamics and energy efficiency as best as possible with innovative design approaches and using modern development tools.

Fig. 1: New X700 Series vs. old DSHR Series Servo Cartridge Valves

Less Control Oil Losses - More Energy Efficiency

The previously used two-stage pilot valves of the Moog D661 series with a ServoJet® jet pipe amplifier as the pilot unit are characterized by high dynamics of the servo cartridges. However, a jet pipe amplifier operates with a constant pilot oil flow rate, which also flows off when the valve is at rest. Especially in applications where the valves are only active for a short part of the overall process due to long auxiliary process times, this constant pilot oil consumption has a negative effect on the overall energy efficiency of the machine.

For this reason, direct drive pilot valves were used for the new series to minimize pilot oil consumption. The optimal choice became the Moog D636 Series with digital power electronics and a linear force motor drive. The valves are part of the Moog Direct Drive Valve (DDV) family and have been used successfully in many applications for years. The bidirectional linear force motor has been further enhanced especially for this application to achieve even higher dynamics.

By using digital onboard electronics, the valves can be equipped with a fieldbus interface and, thanks to the integrated diagnostics and monitoring functions, can also be used in demanding Industry 4.0 scenarios.

Less Pilot Oil Requirement

Since the new size 6 pilot valve has a lower rated flow than the previous size 10 valve, the pilot oil requirement has been significantly reduced. In order to still achieve short actuating times and high dynamics, the control surfaces of the servo cartridge have been optimized.

When designing the control surfaces of a servo cartridge, a conflict of objectives arises: On the one hand, large actuating surfaces lead to high actuating forces and thus to stable control behavior. On the other hand, for a given actuating time, the required control oil flow rate increases with a larger actuating surface. With smaller actuation surfaces, lower control oil flow rates are required, which in turn reduces the actuating forces and consequently higher control pressures are needed for controlling the main stage.

The aim of the development was to achieve stable control behavior with reduced actuation surfaces. To this end, the poppet and sleeve of the main stage were optimized with the aid of CFD simulations to ensure optimum function even with lower actuating forces. Furthermore, compared to the analog controller of the predecessor series, the digital position controller offers extended possibilities that ensure stable position control of the main stage even with lower actuating forces. As a result of these measures, the servo cartridges offer very good dynamics and high stability of position control even at pilot pressures as low as 50% of the main stage pressure.

Less Pressure Drop - Higher Rated Flow

In the development of the poppet and sleeve, the goal was to increase the operating pressure of the main stage to 420 bar while significantly improving the rated flow. The rule of thumb that high flow rates also require large cross-sections also applies to valve development. However, the valve geometry in the flow area and the design of the connecting holes in the manifold are also decisive factors. For this reason, great importance was attached during development not only to the optimization of the poppet and sleeve, but also to simple but effective optimizations of the port bores.

The use of modern computer-based development and simulation tools opens up numerous possibilities for efficient and detailed valve design for design engineers. For example, FEM strength calculations and CFD flow simulations can be used to optimize the geometries of the valve poppet and valve sleeve on the computer without having to build and measure prototype valves. This is not only cost-effective, but also very time-efficient. In addition, the detailed analysis of the simulation results enables targeted optimization of the components.

Less Material for More Flow

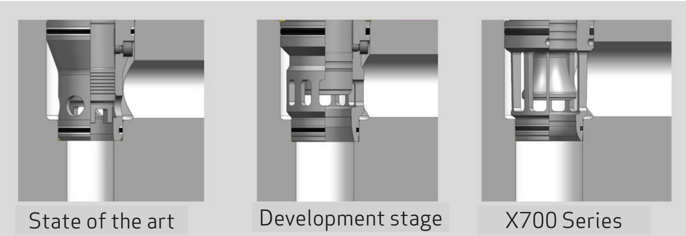


Fig. 2: Development stages of flow optimization

Fig. 2 shows examples of various innovation stages in the poppet and sleeve design of the 2-way servo cartridges: on the left of the picture, the design of the poppet and sleeve of the previous DSHR series with round lateral holes in the valve sleeve and cylindrical valve poppet corresponding to the previous state of the art can be seen. In the first development stage, which is still based on the conventional cartridge design (Fig. 2, center), an increase in flow rate has already been achieved by means of long-hole-shaped windows while the poppet is still cylindrical. However, a significant leap in flow performance was only achieved with the transition to large, rectangular windows with very narrow bars and a waisted poppet design (Fig. 2, right). The sleeve has been optimized to such an extent that even if the bars between the windows were completely eliminated, the flow rate would only increase by about 7%.

Usually, the axial forces occurring in cartridge valves are supported by the sleeve in the installation bore (shown in Fig. 2, left). By fixing the sleeve in the cartridge cover as part of the new design, the forces acting on the sleeve have been reduced to such an extent that it can be made very filigree with large openings and narrow bars. A decisive advantage of the narrow bars is the independence of the flow from the sleeve orientation. This means that it does not matter how the sleeve is aligned with respect to the lateral B-bore. The flow is always approximately the same. This is not the case for sleeves with a few large openings. Here, attention must be paid to the orientation of the sleeve with respect to the B-bore in order to achieve the optimum flow.

New Poppet Geometry Allows Improved Flow in the Inner Valve Area

Together with the sleeve, the poppet geometry was also optimized. The original cylindrical poppet was further developed into a waisted poppet. This new geometry allows improved flow in the inner valve area between the poppet and sleeve. As a result, the flow through the built-in valve is not only between the valve sleeve and the cavity, but also through the newly created space between the valve sleeve and the poppet, which once again significantly reduces the flow resistance.

Less Pressure Drop in the Manifold

During development, not only was the valve flow-optimized, but the installation cavity was also considered in accordance with ISO 7368. The standard specifies the maximum size of the axial A port and a diameter range for the radial B bore.

Investigations during development showed that it is very advantageous to use different bore diameters for the flow directions A to B and B to A, some of which deviate from the standard. For this reason, in addition to the standardized connection diameters, two further sets of bore diameters were defined for the A and B connections (Fig. 3) to enable the user to design a manifold with optimally low flow resistance depending on the direction of flow. The mounting bore of the built-in valve corresponds to the ISO cavity, but has enlarged port diameters.

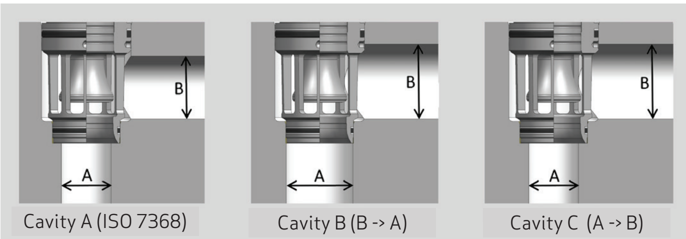


Fig. 3: Overview of optimized port diameters

Bore shape A is the universal bore shape according to ISO 7368. Bore shape B is optimized for flow direction B to A, and bore shape C for flow direction A to B. Fig. 4 shows the influence of bore shape and flow direction using the example of size 40.

The larger bore diameters also ensure lower pressure losses in the continuing bores in the manifold.

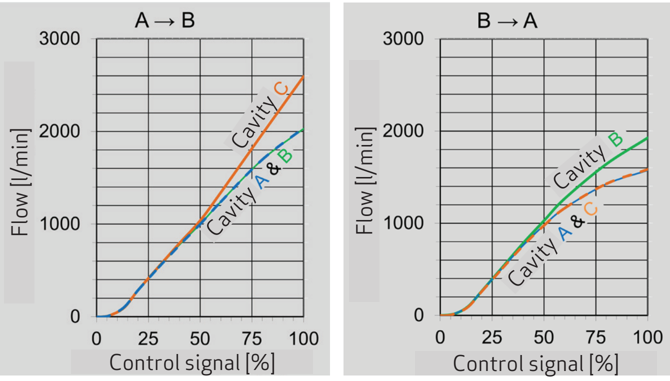


Fig. 4: Rated flows with optimized port diameters

Lower Costs due to Smaller Size

The result of the innovative new design is significantly improved valve flow characteristics, allowing users to select valves one to two sizes smaller in the future while maintaining the same rated flow.

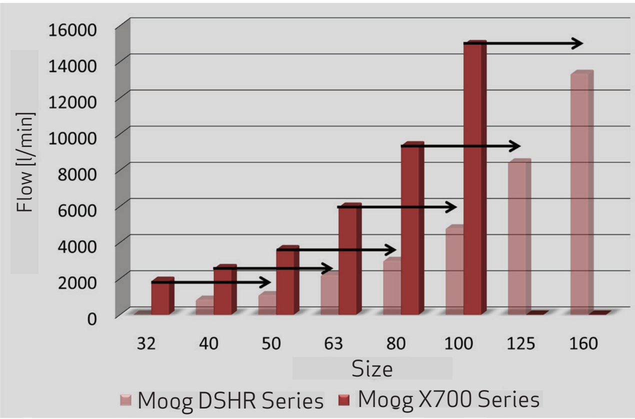


Fig. 5: Rated flows of the DSHR and X700 Series (flow direction A-B)

The significant increase in rated flows with virtually unchanged actuating times has significantly improved the application performance of the servo cartridges: In dynamically demanding applications, the most important parameter is the time in which a cylinder can be accelerated to a certain speed and decelerated again. This time has been significantly reduced by the substantially improved flow performance, as shown in Fig. 5. This shows a comparison of the flow rates achievable within a given time: The DSHR requires 14 ms to reach the maximum flow. The corresponding valve of the X700 series, however, only needs to be opened 65 % for this flow rate and therefore reaches it after only 9 ms, i.e. 35 % faster.

This means that users can either achieve a significantly higher performance from their system while retaining the size, or can achieve better performance even if a smaller size is selected.

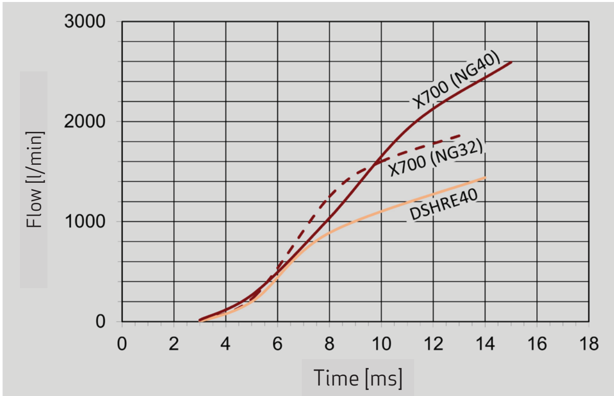


Fig. 6: Rated flow over actuating time of DSHR and X700 Series (flow direction A-B)

Conclusion: Less is More

With the development of the new X700 Series, Moog is taking servo cartridge valve performance to a new level. Both the rated flow and the actuation time to achieve a given flow rate significantly outperform previous technology. The advantages for the users are obvious: They can use smaller sizes and still benefit from higher rated flows and shorter actuation times.

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