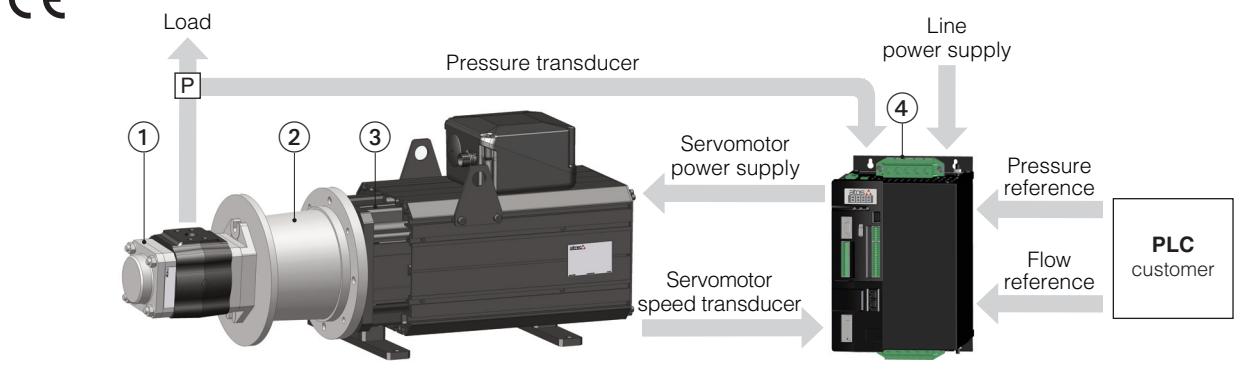
Basics for Smart Servopumps - SSP

The SSP servopumps represent a considerable step forward in the generation and control of hydraulic power, combining the typical advantages of fluid dynamics with the ease of control and adjustment of an electric drive.



① Internal gear pumps
② Bell with high precision joint
③ Permanent magnet servomotor
④ Vector control drive

1 GENERAL DESCRIPTION

The SSP servopumps are electro-hydraulic units designed to efficiently and accurately generate and regulate the flow rate and pressure through the continuous modulation of the pump rotational speed.
They guarantee high power density, high dynamics and precision, significant reduction in energy consumption and noise level, reliability and construction robustness.
The SSP servopumps are composed by a fixed displacement internal gear pump, driven by a permanent magnet synchronous servomotor, controlled by an electronic drive. The latter controls the speed of the servomotor and therefore of the pump, to adjust the flow rate or pressure of the system in closed loop based on the reference signals Q and P received from the machine PLC.

An angular position transducer, integrated in the servomotor, provides information on the instantaneous rotational speed of the pump and therefore the flow rate generated, while a pressure transducer, installed on the pump delivery, provides information about the actual pressure of the line.
Atos has developed specific Smart Functions that offer flexibility of use and simplified commissioning, with significant advantages for the user.

Benefits of Smart Pumps - SSP

- **Energy savings** up to 80%
- **Simplification of the hydraulic circuit and reduction of overall dimensions**
- **Noise reduction** up to 20 db less
- **Integrated P/Q control** developed for hydraulics by industrial electrohydraulic specialists
- **Smart Start-up** for quick and easy commissioning
- **Smart Tuning** to select the optimal pressure control among the 3 dynamics levels available
- **Multiple axis** for the optimization of the parameters for each axis of movement of the machine
- **Smart maintenance** for minimizing machine downtime and maximizing productivity
- **S-SW-SETUP,** dedicated software with a simple and easy to use graphic interface
- **S-SW-SIZING,** for quick sizing of the SSP servopump

2 MAIN ADVANTAGES OF SERVOPUMPS

Servopumps offer general advantages over "traditional" systems equipped with fixed or variable displacement pump, operated by asynchronous motor:

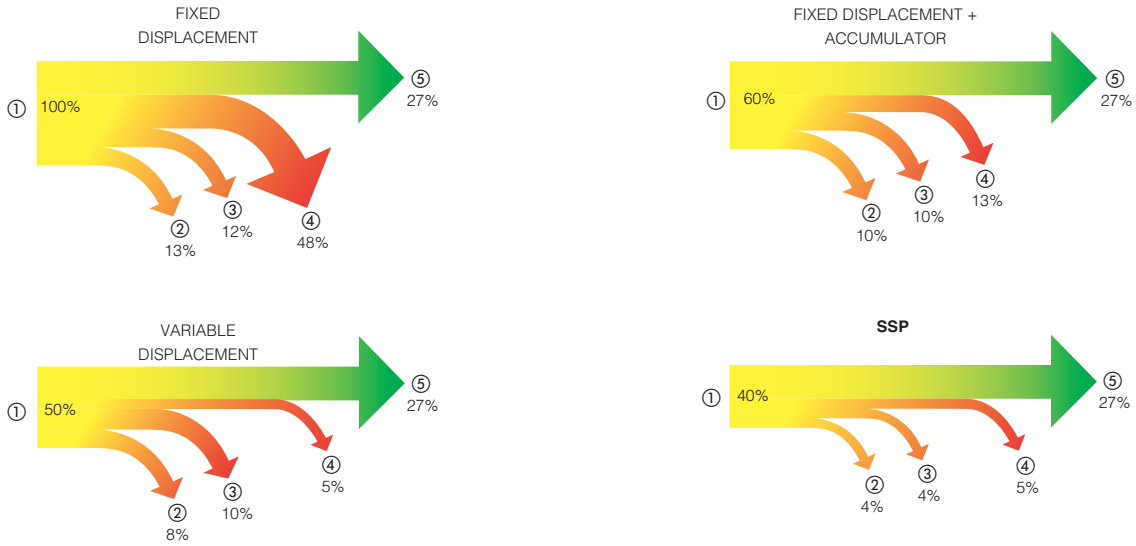
Efficiency

In traditional systems the pumps operate at constant speed regardless of the flow actually required at the different stages of the machine cycle, generating excessive power, which is then dissipated as heat.
In SSP servo pumps the flow rate is modulated through the change in the rotational speed, up to values close to zero when no flow is required, with a substantial advantage in terms of energy savings.

Compared to traditional systems, SSP is able to reduce energy consumption by up to 60/80%.

The lower figures represent a comparison between the consumption of a generic industrial machine equipped with traditional systems and the same machine with an SSP servopump system.

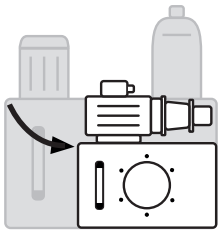
① Absorbed electrical power
② Energy losses due to electric motor performance (and drive)
③ Energy losses due to hydraulic pump efficiency
④ Energy losses by rolling through control valves
⑤ Useful hydraulic power



Smart ServoPump is in line with all climate protection initiatives and the European Green Deal, which invites machine manufacturers to use energy-efficient solutions.

Reduction of tank size and heat exchanger

The high efficiency of SSP results in less heating of the oil thanks to the reduction of the heat-dissipated power. This allows to contain the size of the tank and heat exchangers with the possibility, in some cases, even to avoid them.



Pump displacement reduction

The possibility of reaching maximum rotational speeds of up to 3000 rpm allows to reduce the displacement of the pump compared to traditional systems with asynchronous motor.

Simplification of the hydraulic circuit

Thanks to the high dynamic response and dedicated algorithms, SSP allows to directly control the speed of movement and the strength of hydraulic actuators with optimal levels of precision and repeatability allowing the use of simple ON/OFF directional valves.

Noise reduction

The internal gear pump that equips the SSP allows a general reduction of noise compared to other types of pumps. This, combined with the rotational speed modulation, especially in the static phases of the machine cycle, allows a reduction of up to 20 db compared to traditional systems and allows the user a lower investment to meet noise protection measures.

3 INTEGRATED P/Q CONTROL P/Q CONTROL

Atos has exploited its unique know-how in electro-hydraulic systems to develop a specific P/Q control algorithm entirely dedicated to SSP servopumps and capable of satisfying the needs of any industrial machine.
SSP's P/Q control is specifically designed for hydraulic axes and is able to automatically manage the hydraulic properties of the working fluid.

The algorithm automatically selects which pressure-to-flow control is activated at each phase of the cycle according to the load conditions, always ensuring optimal management, free from sudden passages from P to Q and vice versa, pressure peaks and vibrations.

In this way the customer will be lightened by the construction of his own control algorithm and will only have to send to the D-MP drive the pressure and flow rate reference signals required at each phase of the machine cycle.

Q CONTROL PHASE

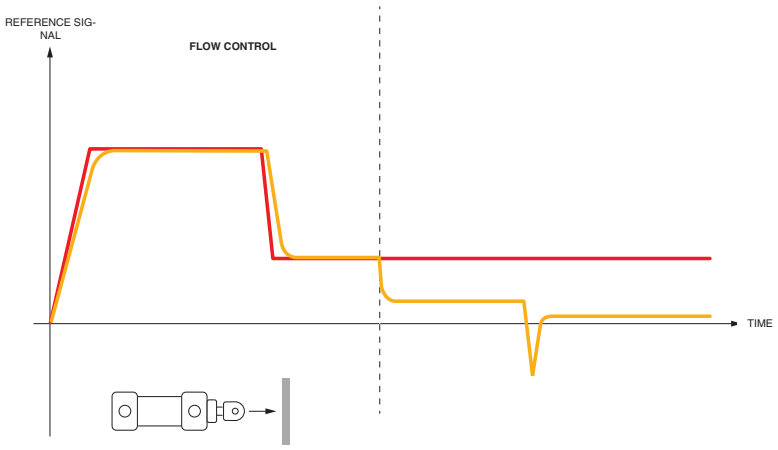
These phases are characterized by hydraulic axis translation with a normally low applied load, such as the translation of a mold before arriving in mechanical stop.

The SSP servopump will then follow the flow reference by adjusting the speed of the motor in such a way that the pump will deliver the required flow rate according to the below equation:

$$Q = \frac{cc_{pump}\, n_{engine}}{1000}$$

Where:

Q	[l/min]	= flow rate
cc_{pump}	[cm^3/rev]	= pump displacement
n_{engine}	[rpm]	= servo motor rpm

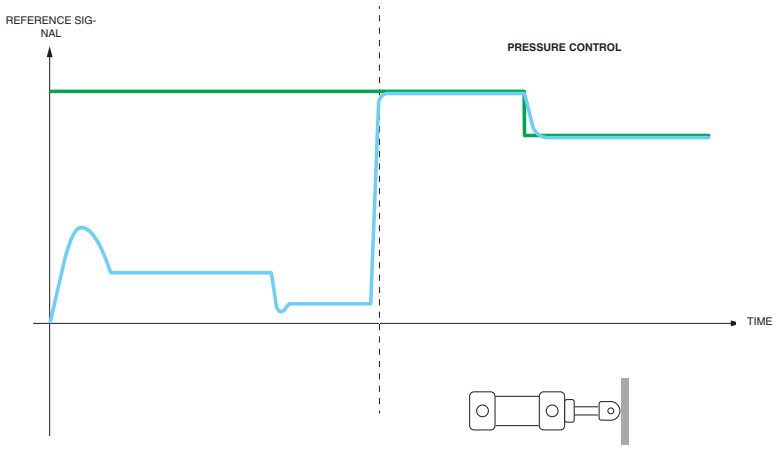


During the flow control phases the pressure reference signal is still present and has the function of limiting the maximum pressure of the system and therefore the force applied by the hydraulic actuator ensuring the safety of the machine.

P CONTROL PHASE

When, during translation, the axis encounters a strong load and the line pressure increases to a value close to the reference signal, pressure control is automatically activated. The D-MP drive controls the speed of the servo motor to limit and maintain the pressure exerted on the load to the value imposed by the reference signal.

These pressure stage can occur for example during the tonnage phase of a press or during the deformation of the metal material of a bending machine.



If, during the pressure control phases, a line depressurization is required, the PGI/PGIL pump is able to rotate in the opposite direction for a short period of time.
Simply reduce the pressure reference and D-MP drive will temporarily reverse the pump's rotation direction to discharge oil from the hydraulic circuit. During the pressure control phases, however, the flow rate reference signal is present and represents a limitation of the speed imposed on the load if the line pressure suddenly drops below the reference.

4 SSP SMART FUNCTIONS

Smart features allow to exploit the most of the potential of SSP, making the system simple to use and at the same time extremely flexible.

4.1 Smart Start-up

The procedure supports the user during the commissioning phases of the SSP system, through a series of guided and intuitive procedures:

• General settings
It allows to choose the communication interface with the system (via Signals Analog or Fieldbus), configure analog signals (Voltage or Current) and set the protection features (see sect. 6).

• Motor connection check
It performs an automatic control of the motor phases, verifying that they match the direction of rotation of the resolver and sending an alarm to the PLC if they are not. It also performs a self-calibration of resolver signals. The function is essential to allow the start-up of SSP, as it allows to verify the correctness of the electrical connections.

• Magnets check
It performs an automatic control of the motor magnets status. The function is essential to enable the algorithm of smart maintenance of PMM motor to function.

• Autotuning
It automatically determines the optimal parameters of the pressure control, to adapt the dynamic response of the SSP and guarantee control precision and stability, regardless of the type of machine or the hydraulic circuit. Once the procedure is started, the servopump is subjected to an automatic cycle of a few seconds at the end of which the hydraulic parameters of the system will be estimated and the various control parameters set, based on the volume of oil controlled and the elasticity of the circuit. If the procedure is not carried out, the SSP servopump will use the factory parameters.
The S-SW-SETUP software can autonomously detect whether the Smart Start-up procedure has been performed or not.
As any Atos products, through the S-SW-SETUP Software it is possible to save the system parameters on the PC and to load them again on the D-MP Drive if necessary.

4.2 Smart tuning

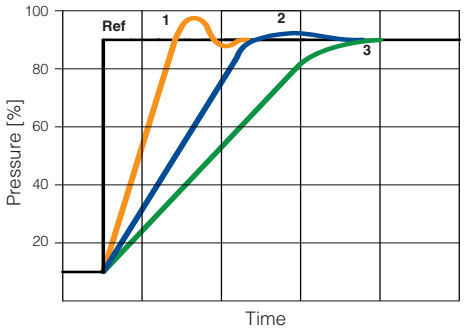
Once the Smart Start-up procedure is complete, the Smart tuning feature allows to further refine the pressure control response by choosing from 3 different levels of performance:

- dynamic, high dynamic and minimized response time (factory setting)

- balanced, for fast response times with limited overshoot/undershoot

- smooth, attenuated response time, for soft adjustment that avoids undershoot/overshoot

The chosen setting can be changed at any time via the S-SW-SETUP Software, or via fielbus or digital inputs of the D-MP Drive.



1 = dynamic
2 = balanced
3 = smooth

In case of necessity, performance can be further customized by directly modifying the individual control parameter via S-SW-SETUP.

4.3 Multiple axis

SSP servo pumps allow to create 4 possible sets of parameters, related to:

- Flow/pressure limits
- Flow/pressure ramps
- Parameters for pressure control and P/Q logics

Since most of industrial machines perform different movements, each driven by specific cylinders/motors of different sizes and with different pressure and flow requirements, the use of a single set of parameters could lead to inaccuracies in P/Q control with the possibility of unwanted vibrations or undesired response times.

The multiple axis setting allows to optimize the different features for the different conditions of the machine cycle ensuring maximum performance at all stages of the cycle.

The active axis can be selected in real time via fieldbuses or digital inputs of the D-MP drive.

4.4 Smart maintenance

This functionality provides information about servopump health conditions, allowing to plan in advance the replacement of worn components to minimize unexpected failures and machine downtime, thus maximizing productivity.

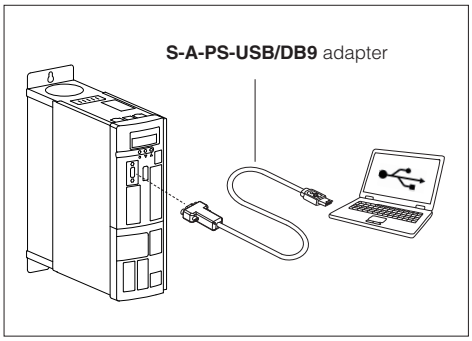
Smart Maintenance has two different algorithms:

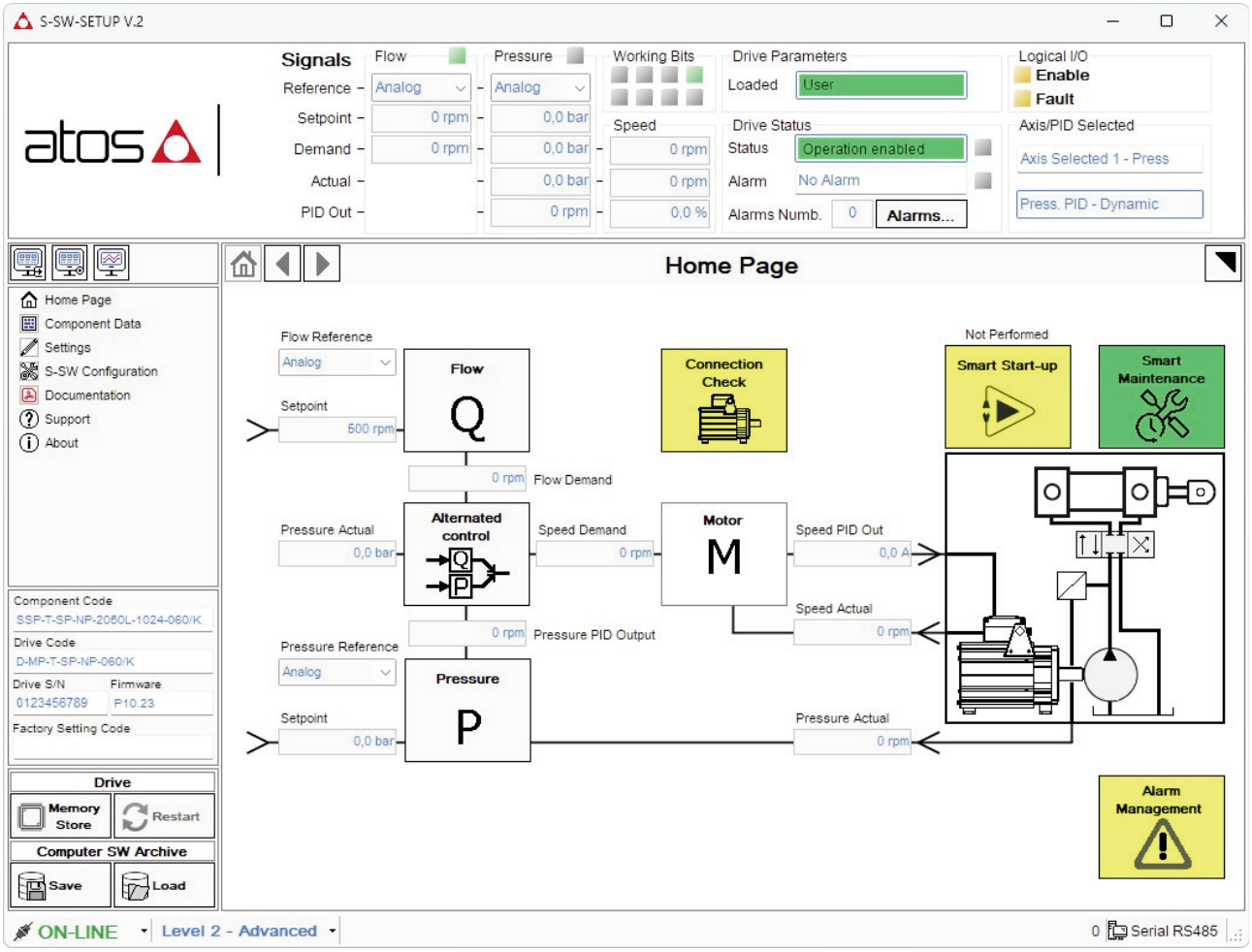
- Pump Remaining Life: this algorithm continuously records the cumulative energy absorbed by PGI* pump and when it gets closer to its statistical end-life, the drive generates an alert to inform the end user. Based on machine cycle, the algorithm also estimates the pump remaining life time so that the user could schedule the replacement of the pump.
- Motor magnets status: this algorithm checks the magnetization status of the PMM motor through a dedicated procedure, which can be started through I/O digital signals, fieldbus or S-SW-SETUP programming software. The drive suggests to perform the test after a certain amount of machine cycles and, if the magnetization status goes below a certain threshold, it generates an alert to inform the end user to schedule the replacement of the motor.
  Pump and motor maintenance informations are easily accessible through I/O digital signals, fieldbus or S-SW-SETUP programming software.

5 PROGRAMMING SOFTWARE

SSP systems can be configured using Atos S-SW-SETUP programming software.
This can be easily used by connecting PC to the D-MP drive via the RS485 port

S-SW-SETUP is specifically developed for servopump systems as opposed to competitive General Purpose Software, which must be customized by the user for the servopump application.
At the first start up, the software will invite the user to follow the Smart Start-up guided procedure (see 4.1) for setting all the parameters needed for the correct start-up and operation of the system.
All the main functions can be reached and modified thanks to a simple and intuitive graphics.
Furthermore, the software allows to monitor in real-time the signals managed by the drive (References, Feedback, Temperatures, Currents, Voltages, etc.) and the status of each individual alarm.
S-SW-SETUP includes an internal oscilloscope to visualize the trend over time of the above signals.





All parameters available on the drive can be monitored with S-SW-SETUP or shared with the customer's PLC via fieldbus

6 SIZING SOFTWARE

It is a software developed by Atos to allow the customer to size the servopump that best suits the requirements of their machine cycle.

In the software S-SW-SIZING it is simply required to generate the machine cycle by entering the pressure, flow rate and cycle time data of each phase. It is possible to enter the data manually or load the acquired data recorder from the cycle of an existing machine.
The software shows the different parameters of the cycle and automatically selects the individual components for the SSP system, adapted to the machine cycle introduced.
The complete ordering code is automatically generated by the software.
It is also possible to navigate in detailed pages for each component to view the working conditions with respect to the maximum performance that the component can achieve.

The software also provides an estimate of energy saving compared to traditional systems such as variable displacement pump/fixed displacement pump.

S-SW-SIZING sizing tool software is available for free on the Atos website, you can download it from www.atos.com

7 PROTECTION FEATURES

SSP systems integrate logics specifically developed to prevent stressful working conditions of individual system components, thus avoiding sudden failures and consequent downtime.

7.1 Pump protection systems

The pump is the most stressed element of the SSP system and requires special attention to prevent sudden failures and ensure longer durability. To do so, special safety features have been implemented on the D-MP drive.

Smart cooling

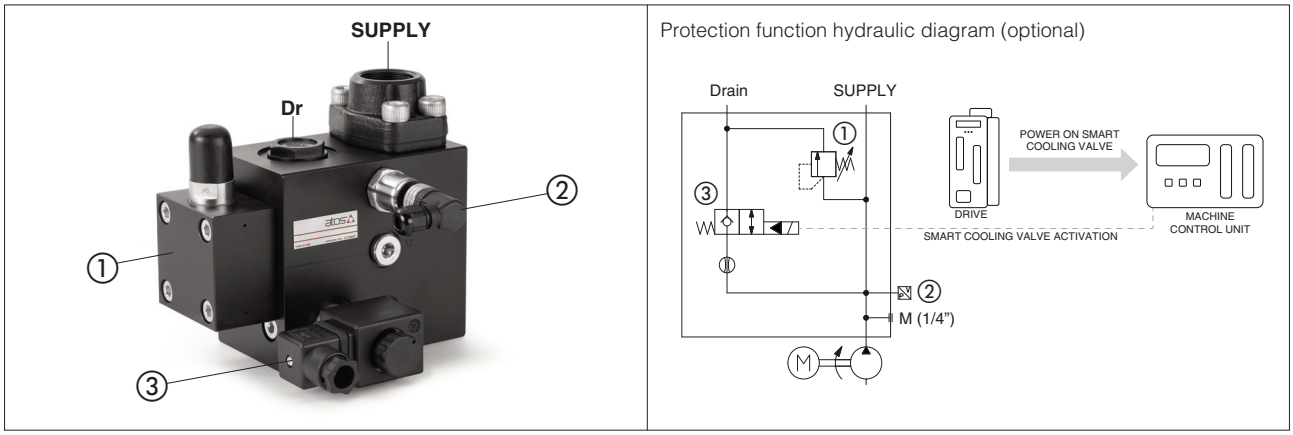
In prolonged pressure control phases, the pump tends to overheat due to internal leakages. An algorithm is implemented in the D-MP Drive to avoid this condition; the drive provides a digital output that indicates when to activate, via PLC of the machine, the dedicated valve that allows a small oil recirculation. This feature is provided in the built-in block available as an option - see tec. table AS300.

This block, flanged directly on the pump, offers a complete and ready-to-use solution. It includes:

① Relief valve, for system protection

② Pressure transducer, to be wired to drive, required for P/Q control

③ Smart Cooling valve, dedicated to pump cooling



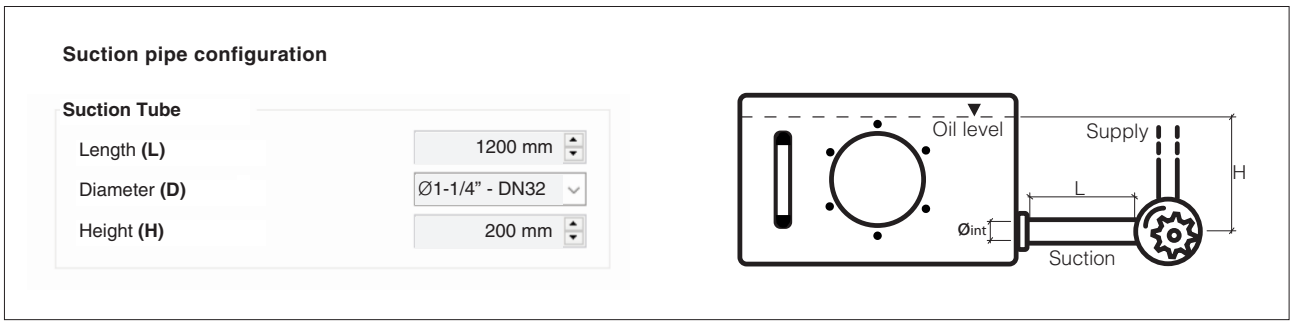
Depending on machine cycle, the Sizing Tool software (see sect. 9) will suggest whether or not the optional manifold is recommended.

Protection from cavitation

One of the main causes of excessive wear of pumps is cavitation.
This function allows to set the angular acceleration limits of the servomotor, in accordance to the geometry of the pump intake line, to prevent this phenomenon from occurring.

To do this, simply enter the following parameters during the Smart Start-up procedure that will automatically define the servomotor acceleration limits:

- Suction pipe length
- Diameter of the suction pipe
- Suction port height compared to the oil's free level



Limiting minimum pressure

The drive always guarantees a minimum pressure in the pump supply line (10 bar) that allows to always work in the best conditions.

7.2 Servomotor and drive temperature control

Both the servomotor and D-MP drive temperatures are monitored with dedicated temperature probes in order to protect these components from overheating as a result of incorrect installations or excessively heavy working conditions.
In the event of overheating of the D-MP drive or servomotor, the drive sends an alarm to the central unit and blocks the SSP system to avoid sudden failures.
The servomotor is stopped by means of a deceleration ramp, so to obtain a soft slowdown of the load avoiding system ram blows and pump cavitation.
These features are an additional protection for SSP system although the correct sizing and use prescribed in the user manual allow to exclude problems of overheating of servo motor or drive.

8 COMPONENT DESCRIPTION

The SSP servopumps are composed by following components:

Fixed displacement Internal gears pump - PGI / PGIL

This type of pump is the ideal solution for servopump application as it guarantees reduced pressure pulses and a wide range of rotational speeds with the possibility of going down to a few revolutions per minute, essential characteristics to achieving accurate P/Q control.

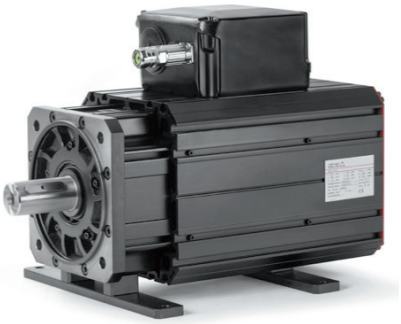
The high efficiency allows to maximize the energy savings of the system, in addition the construction peculiarity allows a reduction in noise emissions up to 20 dB compared to traditional systems.

Two versions are available depending on the required operating pressures:

- **PGI**, cast iron body version, ideal for applications with maximum continuous pressures up to 330 bar – see tec. table **AS300**
- **PGIL**, aluminum body version, for applications with maximum continuous pressures up to 250 bar – see tec. table **AS350**

Both versions cover a wide range of displacements, from 10 cm3/rpm to 125 cm3/rpm, ensuring maximum flow rates up to 350 l/min.

Permanent magnet synchronous servomotor - PMM, tec. table **AS400**



It relies on the most performing technology available on the market for electric motors.

Synchronous servo motors exploits a surface permanent magnet rotor that allows high performance.

They differ from traditional asynchronous motors by:

- high electrical efficiency (up to 94% under nominal conditions)
- smaller footprints
- high control dynamics, due to low rotor inertia combined with a high overload

The servomotor is equipped with an integrated speed transducer (resolver), to control the rotational speed in closed loop.
A temperature transducer allows to monitor any overheating of the servomotor.
PMM servomotors are equipped with a cooling fan, which is activated automatically only under the most demanding conditions of use.
They are available in 8 sizes with rated power from 9 kW to 100 kW and with an overload capacity of 200%.

Servomotor - Pump Coupling

The coupling between servomotor and pump ensures maximum levels of precision in motion transmission, effective vibration damping and mechanical misalignment compensation.
The joint consists of a torsionally rigid lamellar package, which can compensate for axial, angular and radial misalignments.
The peculiar geometry and the materials chosen allow to withstand the torque generated by the servomotor.

Vector control Drive - D-MP, tec. table **AS500**

It represents the "brain" that manages and controls the entire SSP system, taking advantage of the most modern technology used in servo drives.
The Drive electrically powers and adjusts the servomotor speed to obtain flow and pressure values according to the reference signals received from the machine PLC.
It is interfaced with the servomotor angular transducer and the pressure transducer installed on the pump delivery for flow rate and pressure closed loop control.
A dedicated algorithm for P/Q control is implemented on the unit in order to optimally adjust the pressure and flow rate of the hydraulic system.
In accordance with industry 4.0, D-MP drive collects all the hydraulic and electrical parameters of the system in real time, allowing the user a simple monitoring of the status and performance of the machine.
In addition, any error is detected by the drive and returned to the central unit, protecting the system from incorrect conditions of use.

D-MP drives are available in 9 sizes with rated current from 22A to 210A and with 200% overload capacity.

9 FIELDBUS

The Fieldbus interface allows direct communication between the SSP and the machine control unit.
The bus allows the exchange of the following information:

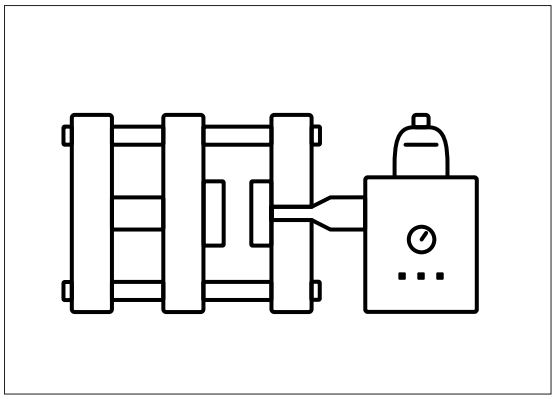
- speed and pressure reference signals and logic inputs (example: enable signal)
- speed and pressure feedbacks
- diagnostic information
- all the configuration parameters of the SSP system

10 APPLICATION EXAMPLES

The following paragraphs examine real machine cases highlighting the advantages that SSP servopumps offer over traditional systems.

10.1 Example of die casting machines: 65% more energy efficiency

The die casting machines were designed to guarantee extreme speed in the production process and extreme precision in the workpiece. For this reason, reliable and performing components are constantly being sought to increase productivity and reduce cycle times.



In this scenario, SSP systems are the optimal choice.

Hydraulic robustness, high power density and load sealing capacity are the strengths that make servopumps the ideal choice for the harsh environmental conditions of die casting machines.

The high acceleration/deceleration of the servo motor's permanent magnet technology, guarantees an absolute dynamic that allows the reduction of machine cycle times that resulting in a subsequent increase in productivity.

In addition, the use of SSP instead of traditional technologies with constant speed systems allows the simplification of the hydraulic circuit.

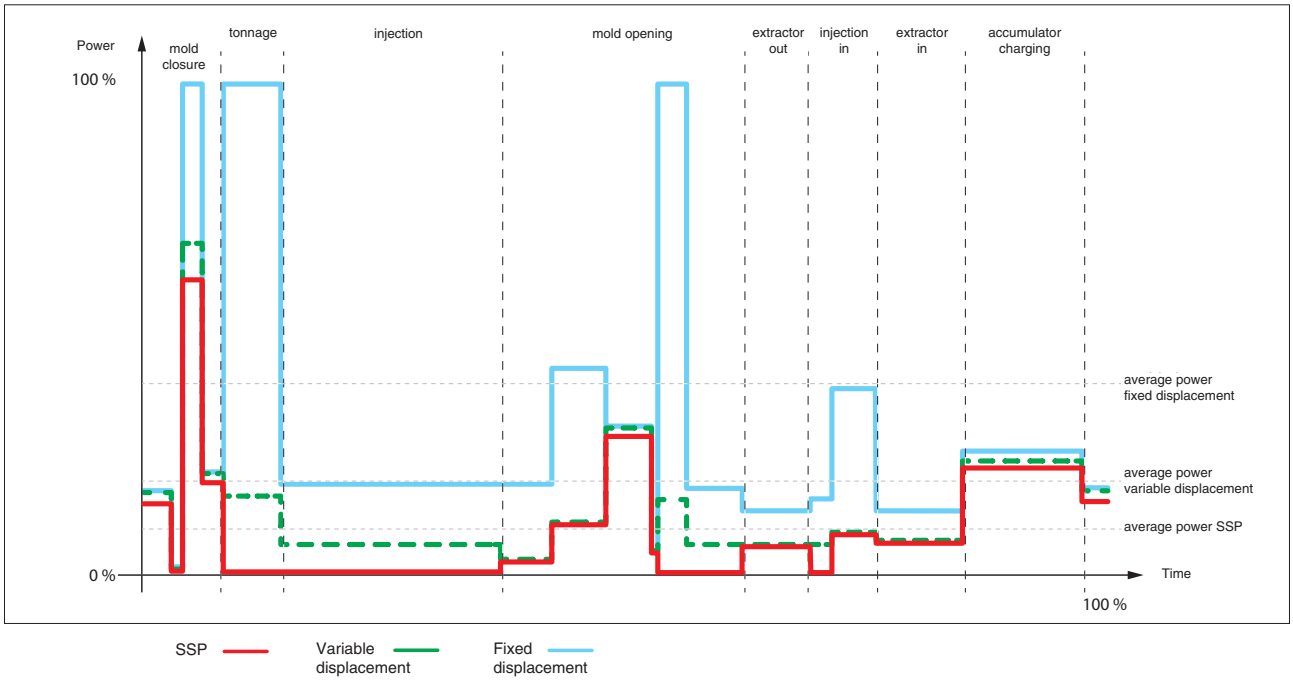
With traditional systems, in fact, it was necessary to have two pumps, one for rapid movements, characterized by very high flow rates, and a second for the slowest movements with high operating pressures.

Now, an SSP system is enough to handle both high-flow and low-flow phases. In addition, thanks to its high dynamics and control precision, it can also allow the replacement of some proportional valves with simple ON/OFF valves.

In die casting machines, the injection phase, which represents one of the most delicate movements, was previously made with accumulator and managed completely by proportional cartridges.

Now it is possible to manage the entire first part of the injection, which requires a very precise cylinder speed control and with very accentuated speed ramps, with the servopump, eliminating the huge energy losses generated by the use of high pressure oil of the accumulator throttled by proportional valves.

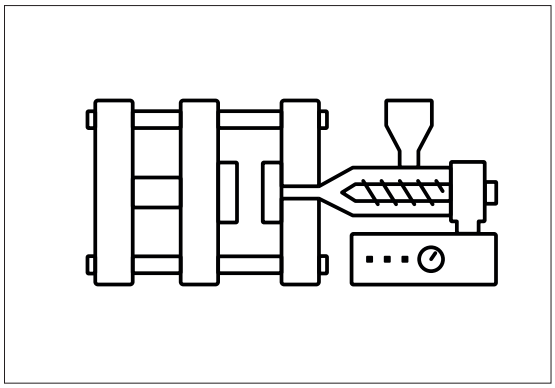
During the second part of the injection, which instead needs very high dynamics and for this reason must be carried out with accumulators, it is possible to stop the pump by bringing the speed reference to values close to 0% and reducing energy consumption and noise.



In the cycle shown in the graph, the SSP pump ensures energy savings of up to 65% compared to traditional systems.
The phases that benefit the most from an energy point of view are those characterized by low flow rate and high pressure, such as the tonnage phase and some phases of opening and closing molds, in which the servopump delivers exactly the required flow rate.

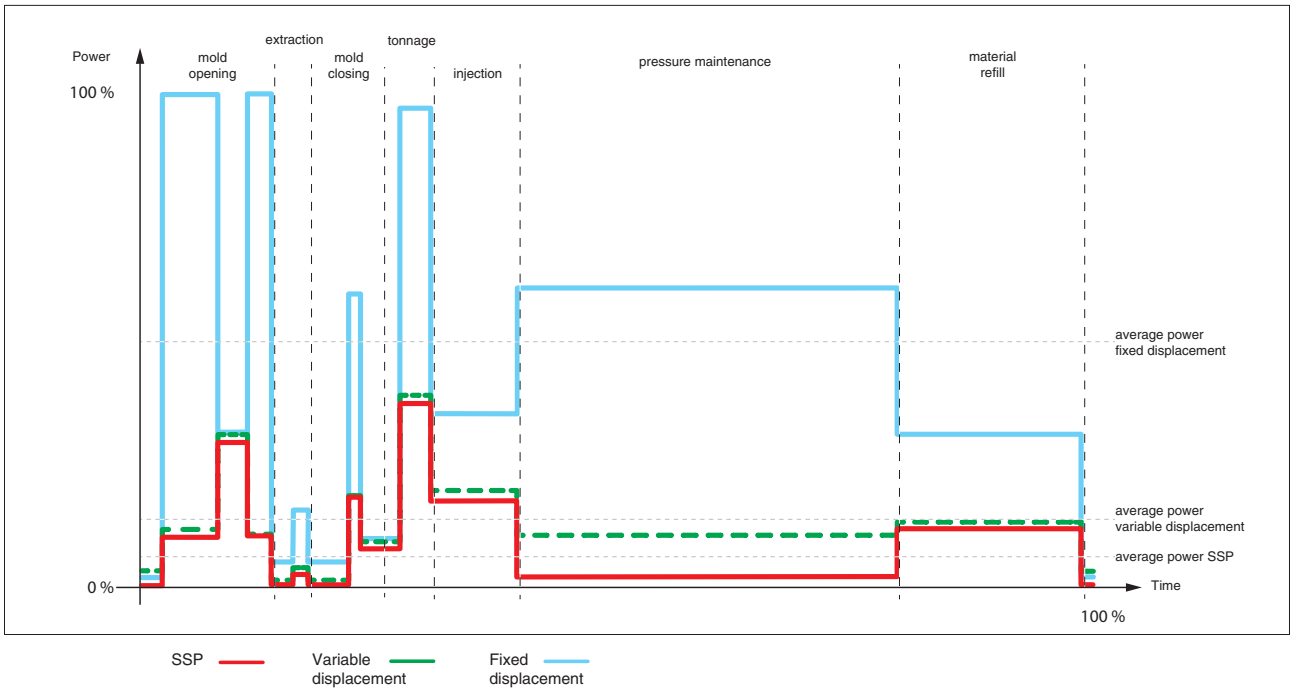
10.2 Example of plastic/rubber injection machines: 65% to 80% energy saving

Plastic/rubber injection presses require high dynamics, precision and maximum repeatability at every stage of the machine cycle together with the reliability of the entire system.



SSP servo pumps ensure high dynamics with engine speed step response times of 0-100% 50 ms for optimal control during all phases of the machine cycle.
The wide speed range allows to manage both the fast mold movement phase and the clamp saving phase, during which it is necessary to maintain a very low speed.

The various phases of the machine cycle usually rely on actuators with different areas and strokes with the consequence of having very different oil volumes to be controlled. With the multi-axis function it will be possible to use different set of parameters and always optimized for every movement, obtaining the optimal control for both larger cylinders that require high dynamics, as the injection cylinders, and with smaller actuators that need softer movements, as the extraction cylinders of the piece from the mold.



In the graph it is possible to detect in detail the great advantages of SSP in term of energy saving compared to other traditional systems.
It is especially during the holding pressure phase, that you have the greatest benefits in terms of energy saving are achieved.
During this phase the pump rotation speed is almost 0 as it has just to compensate for the oil leakage losses of the system (of the pump itself or of other hydraulic components), keeping the line pressure constant.
Depending on the duration of this phase, SSP can achieve energy savings of 65% to 80% per machine cycle.

11 RELATED DOCUMENTATION

AS100	SSP Smart Servopumps	**AS800**	Programming tools for pumps & servopumps
AS200	Sizing criteria for servopumps	**AS810**	Accessories for servopumps
AS300	PGI cast iron internal gear pumps, high pressure	**AS910**	Operating and maintenance information for servopumps
AS350	PGIL aluminium internal gear pumps	**GS510**	Fieldbus
AS400	PMM high performance synchronous servomotors	**S-MAN-HW**	Servopumps installation manual
AS500	D-MP electronic drives	**S-MAN-SW**	Servopumps programming software manual