REVIEWED

Electro-Hydrostatic Drive Concept for the Ring Rolling Process

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Rising electricity costs are forcing machine builders and plant operators to find solutions for how energy-intensive machines can be operated and produce more efficiently. Large potentials lie in the drive technology used. The example of the electro-hydrostatic drive concept for the ring rolling process demonstrates how a higher productivity with minimized power consumption and at the same time simplified and cost-effective installation brings competitive advantages. Together with Moog GmbH, SMS group GmbH has developed a new generation of ring rolling machine, the RAW ecompact, with a modern electro-hydrostatic drive concept.

Keywords: Power on demand, speed-controlled electro-hydrostatic drive, radial piston pump, ring rolling
Target audience: Industrial hydraulics, design process, metal forming industry

1 Motivation

“The most eco-friendly and cheapest kilowatt-hour is the one we don’t consume in the first place. And the more consciously and efficiently we use heat and electricity, the less we have to generate. That saves money, at the same time increasing the security of the supplies and contributing to us achieving our climate targets.” /1/

With this in mind, the German Federal government implemented the European Community’s ECO Design Directive 2009/32/EC with the act governing the ecodesign of energy-related products (Energy-related Products Act - EVPG). Whereas initially the primary goal was to reduce the energy consumption of hand-held tools such as circular saws, vacuum cleaners, lighting, etc., further product groups such as the ENTR5, machine tools, have now been added.

The SMS group’s answer to these demands from the market is EcoPlant Design. Criteria for an EcoPlant solution are the following four requirements:

- Significant reduction in the use of energy and process media
- Significant reduction in the use of raw materials
- Significant reduction in emissions
- Significant improvement in the recycling quota

As long ago as 1987, studies were conducted at the IFAS Aachen into reducing the energy losses of a conventional hydraulic system (throttle control) through the use of a direct pump drive (hydrostatic drive) (Figure 1). With the current pressure to save energy and the reduced costs of variable-speed drives, various suppliers have now come onto the market offering such components.

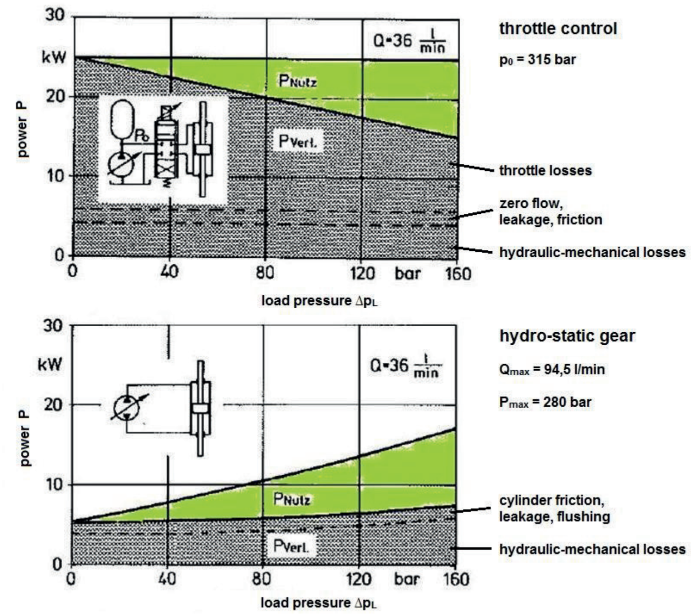

Figure 1: Performance of hydrostatic drives at constant volumetric flow /2/

2 R&D Goals

The goal was to develop a new series for a **RAW ecompact** radial-axial ring rolling machine that meets the SMS group criteria for an EcoPlant machine.

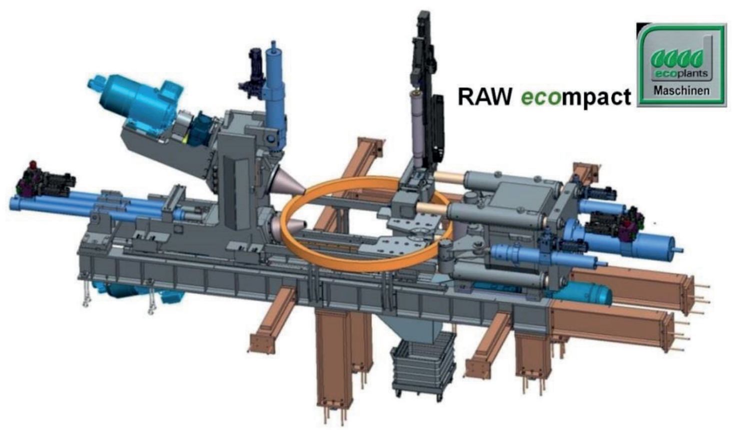

Figure 2: 3D View of the RAW ecompact machine series

The main objectives of this new development were

- Increased energy efficiency with process-related widely differing working points
- Drastically reduced central hydraulics and pipework in the field
- Cost optimisation through reduced erection and commissioning times
- Built-in condition monitoring

3 Ring Rolling Process

The ring rolling process (Figure 3) for the production of seamless rings is a very complex forming process with two roll gaps (radial and axial forming). By contrast with straight rolling, the infeeds change continuously. After a 360° ring rotation, the run-out geometry enters the roll gap again as the inlet geometry. The radial and axial roll gaps influence one another during rolling by changing the geometry of the rolled product. The very sensitive centering rollers ensure a stable rolling process. Due to the increase in the ring diameter, the axial stand has to be continuously repositioned.

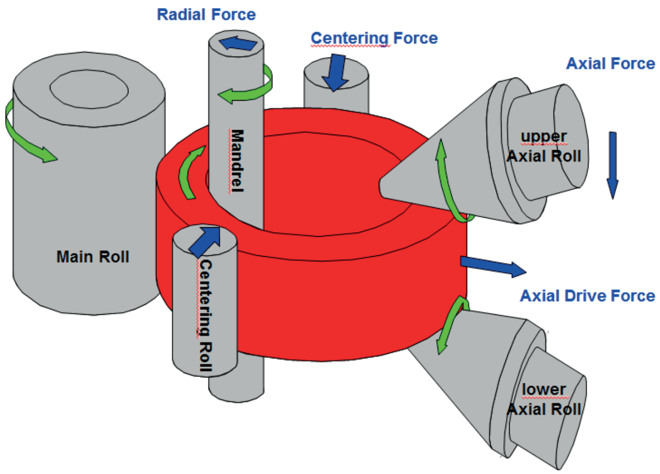

Figure 3: Principle of the ring rolling process

In addition to the main roll drives, there are up to 9 position or force-controlled axes that interact in parallel during the process. Traditionally these axes are designed as cylinder units with control valves that are supplied from a central hydraulic power pack.

4 Electro-Hydrostatic Drive Concept

Development of the new drive concept is based on the Moog electro-hydrostatic pump unit (EPU) product family. This unit consists of a dual-displacement radial piston pump with a maximum working pressure of 350 bar and a servo motor bolted to the pump by means of an adapter flange. These EPUs are available as a modular system, scalable from 19 ccm to 250 ccm (Figure 4).

Pump Vol. [cm³]	Q max [l/min]	p max [bar]
19	85	350
32	118	350
80	216	350
140	322	350
250	450	350

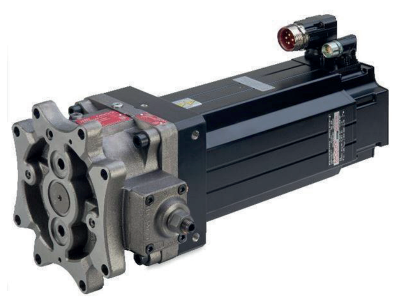

Figure 4: Moog EPU product family

The pump drive is optimised for variable-speed driving in 4-quadrant mode. There are no limitations in pressure-holding mode (high pressure with low volumetric flow). The pump is flanged directly to the servo motor without rubber or plastic coupling, resulting in both a reduction in costs and installation space and in an improvement in the dynamic behaviour. The drive concept selected here is based on a variable-speed pump drive with a douple rod cylinder (Figure 5).

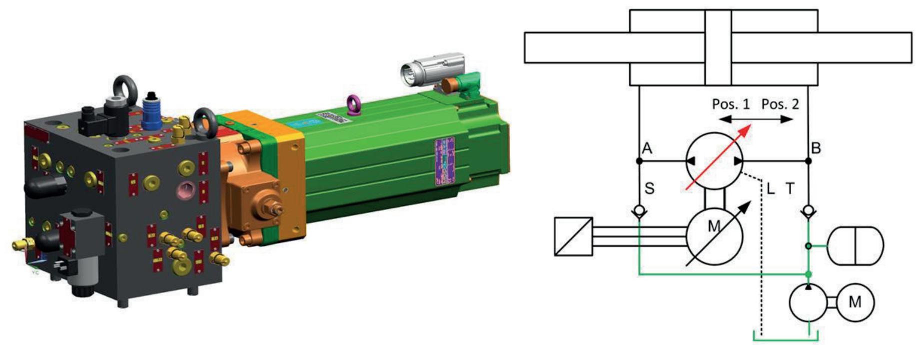

Figure 5: Electro-hydrostatic drive concept

All axes are centrally preloaded with approx. 10 bar (green lines) by a small, central hydraulic power pack. This unit serves at the same time to filter and cool the oil. The dual-displacement pump has two working positions: Position 1 with approx. 5 ccm displacement for rolling (max. 350 bar, 2000 rpm) and position 2 with 19 ccm displacement (max. pump delivery at max. 40 bar, 4400 rpm). The typical working points (torque over speed) are shown in Figure 6 for the "radial rolling force" axis.

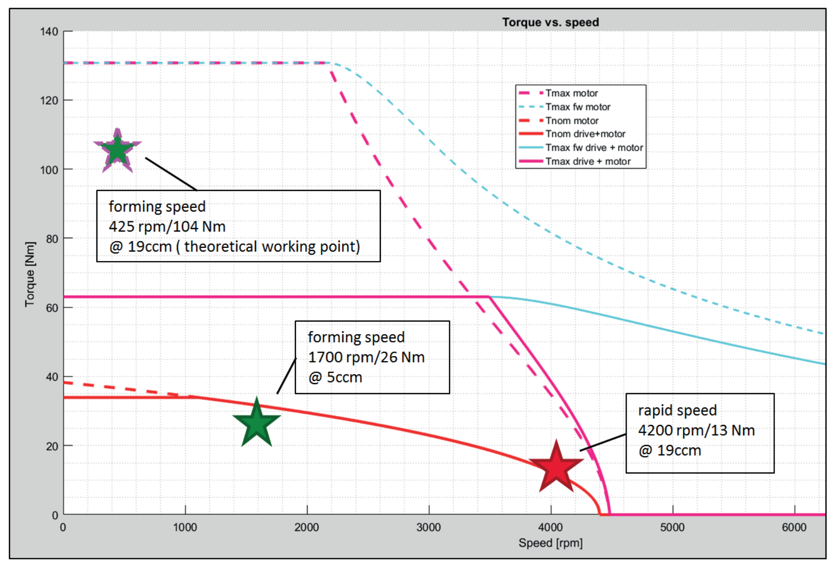

Figure 6: Typical working points of the drive unit

The term “rapid speed” corresponds to the opening and closing of the machine for loading and unloading, i.e. fast movements with low pressure. This point was set in the field weakening area of the motor above the S1 curve for continuous operation. The working point “forming speed” is below the curve for the rated torque (S1 mode for motor and converter), i.e. it can function under continuous load. If the displacement of the pump were not variable (e.g. a constant displacement pump with 19 ccm), this point would lie above the maximum torque curve (S3 intermittent duty, max. 10 sec overload) and would therefore be inadmissible for the rolling process. In this case a more powerful motor and converter would have to be used, leading to higher costs.

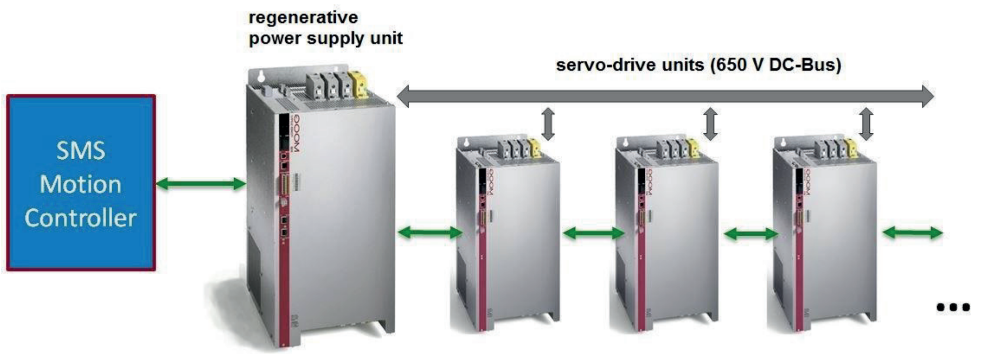

Figure 7: Communication structure of drive system

The servo drives of each EPU are powered by a regenerative power supply unit (PSU) via a 650 V DC bus (Figure 7). Communication is via an EtherCat field bus. The PSU and the drives operate as EtherCat slaves in closed loop. The motion controller as master performs the process control for the position and force control of the axes and transmits the speed settings digitally to the drives (Figure 8). The speed control for the servo motors is realized in the drives. The current process values, such as speed, current, power, temperature, etc. are feed back into the motion controller.

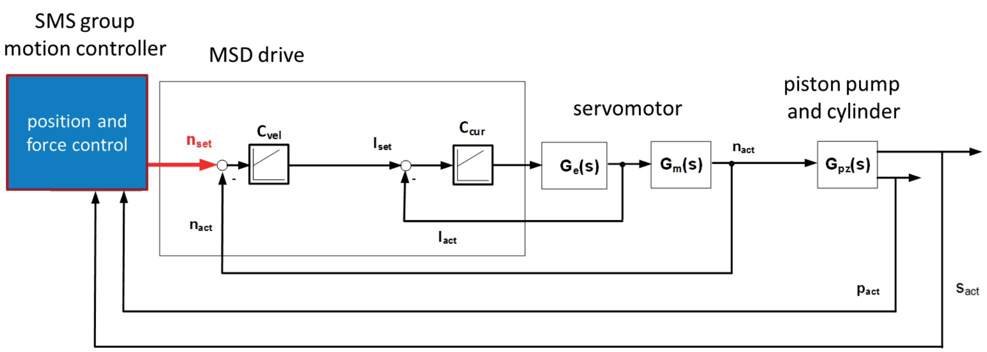

Figure 8: Structure of closed-loop control (simplified)

5 First Results and Feedback

Figure 9 shows a typical production cycle for the ring rolling process. After loading of the ring rolling machine with a pierced blank, the machine is closed to rolling position under no load at rapid traverse speed. The rolling process starts. The rolling forces are then set by the process according to the geometry and weight of the ring. If power or torque limits are reached, the roll feeds are reduced by the process controller so that rolling can be performed continuously in the limit range of the drives (S1 mode). The end of the rolling process is generally followed by a calibration phase in order to reliably achieve the ring dimensional tolerances, such as outside diameter or ovality. All the axes are then retracted to the unloading position at rapid traverse speed. Due to the extremely high pump speeds of up to 4500 rpm (”swirl effect”), the overall efficiency at rapid traverse speed is less than 20%. For the rolling process we achieve an overall efficiency of 40 to 50% even under partial load. This value corresponds to the expectations shown in Figure 1.

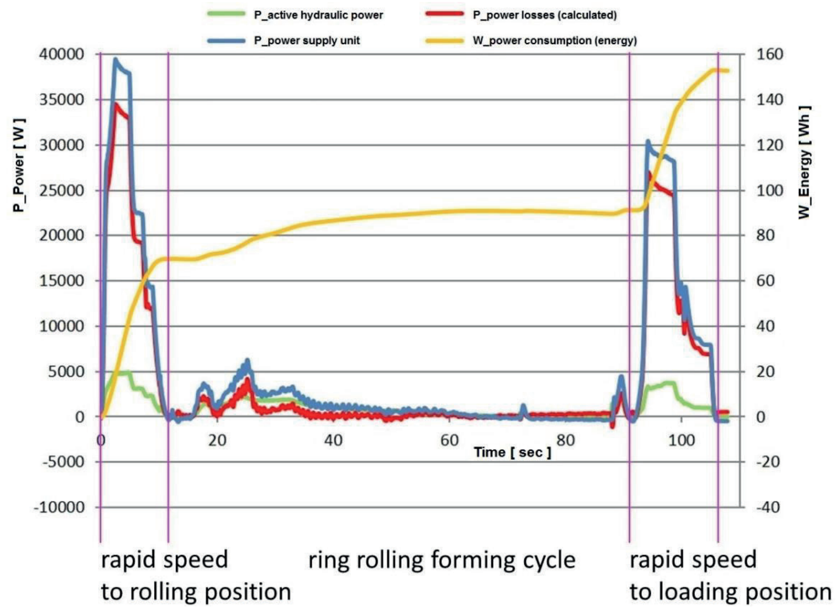

Figure 9: Typical production cycle for the ring rolling process /3/

A further critical point is the influence of pressure pulsation on the control quality of the axes. The pressure pulsation is caused by the physics of the radial piston pump and the speed of the drive (Figure 10).

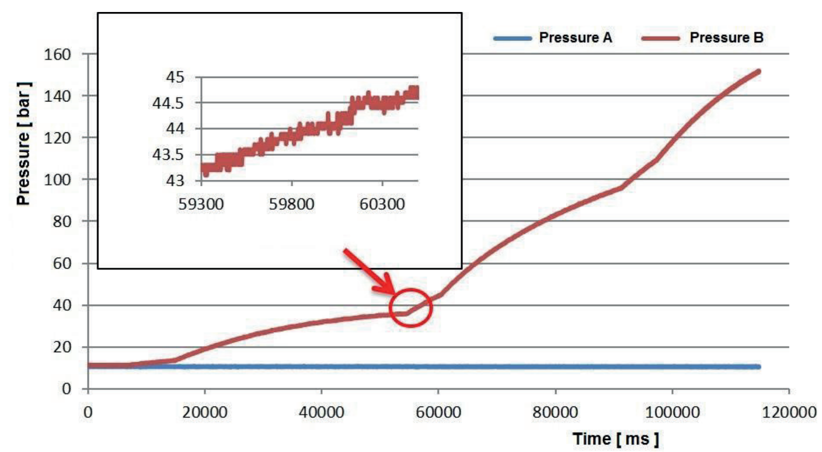

Figure 10: Measurement of the pressure pulsation /3/

Due to the friction in the cylinder and the relatively large oil volume of the cylinder in relation to the pump volume, the damping of the pressure pulsation is sufficient to allow the required positioning accuracy of +/- 0.1 mm at the end of rolling to be achieved (Figure 11). At rapid traverse speed, a positioning accuracy of approx. +/- 0.8 mm was achieved.

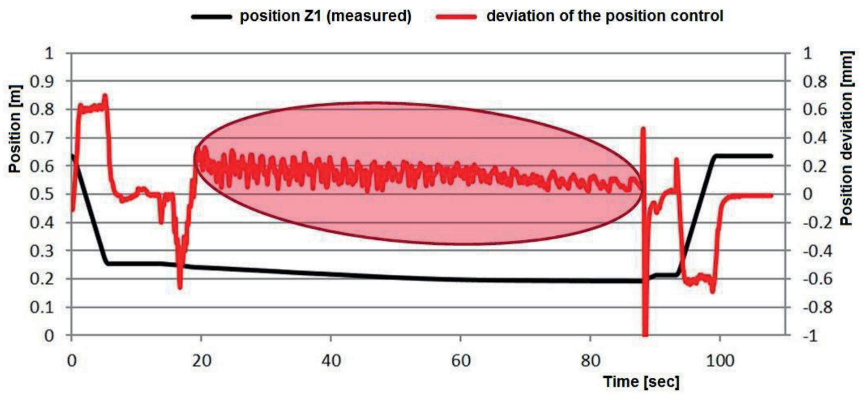

Figure 11: Measurement of the positioning accuracy /3/

The temperature behaviour plays an important role for the selection and dimensioning of the drive motor. The very compact design and the direct connection of the pump to the servo motor make a theoretical calculation of the temperature behaviour very difficult. Furthermore, the temperature of the motor is greatly influenced by the ambient temperature (hot forming) and the working cycle. In order to keep the drive concept as simple as possible, a purely convection-cooled motor was chosen for the design. Figure 12 shows the measured temperature behaviour of the servo motor in pressure holding mode (approx. 80 bar at 220 rpm, 7 Nm). For high-load applications with very short cycle times, water cooling can be used as an option for the motor.

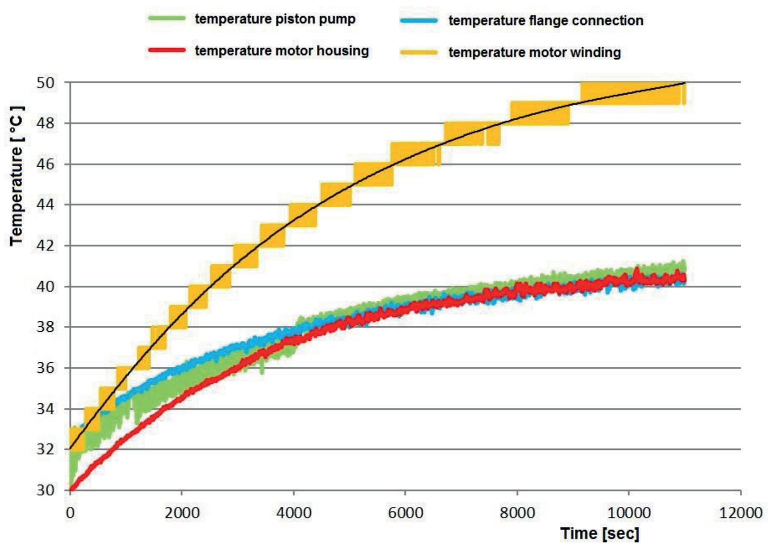

Figure 12: Temperature behaviour during pressure holding mode (80 bar, 220 rpm) /3/

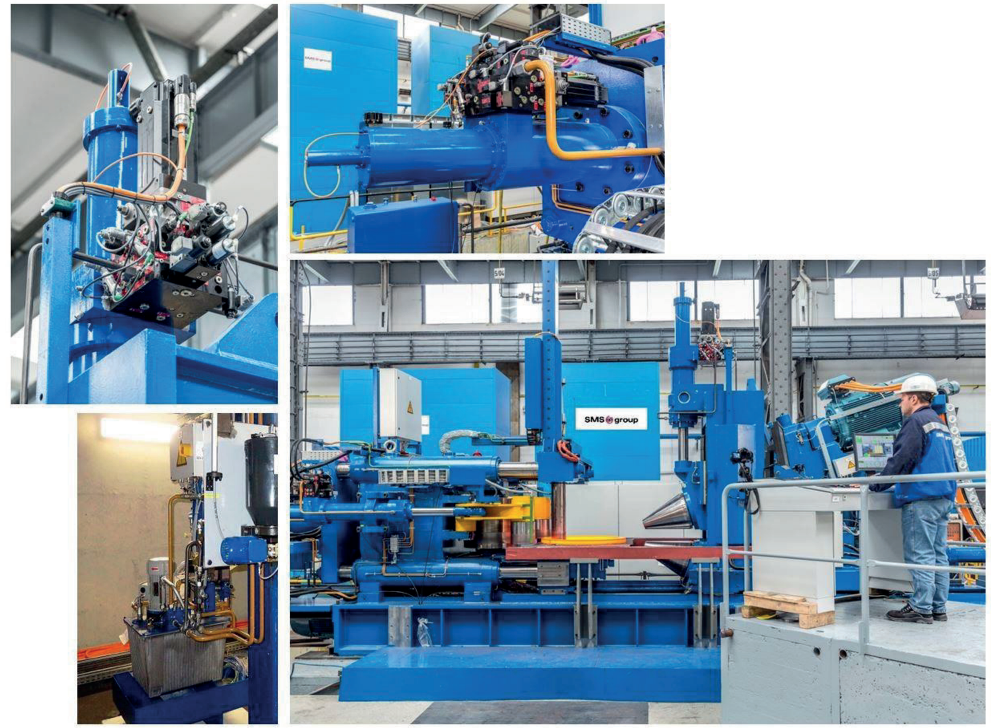

Figure 13: Ring Rolling Mill RAW ecompact, SMS group GmbH

The benefits of the electro-hydrostatic compact drives can therefore be summarised as follows:

- The basic design of the machines can remain unchanged
- Installed power is approx. 60% of the standard hydraulics (230 kW → 137.5 kW)
- Reduced oil volume in the machine (2000 litres → 200 litres)
- Reduced noise level thanks to “power on demand”
- Elimination of the hydraulics room → reduced demands on the foundation
- Significantly reduced piping work → simpler erection
- No flushing necessary at the erection site → commissioning times reduced by approx. 3 days
- Reduced number of components → reduced maintenance work
- Test operation before delivery possible
- Safety: Thanks to the modern converter technologies with SS1 (Safe Stop 1), STO (Safe Torque Off) and SLS (Safely Limited Speed), compliance with the Machinery Directive is easier than with conventional hydraulics.

The first experience with the electro-hydrostatic compact drives shows outstanding controllability (position and force) of the axes. The reduced number of components results in a very sturdy and fault-resistant system. The lowering of the energy consumption by up to 70% and the reduction in the noise emissions by approx. 30% make the machine an environment-friendly EcoPlant.

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